APPLIED CROP PROTECTION 2014

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AARHUS
UNIVERSITY
DCA - DANISH CENTRE FOR FOOD AND AGRICULTURE

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Supplementary information and clarifications (October 2019)

In an effort to ensure that this report complies with Aarhus University's guidelines for transparency and open declaration of external cooperation, the following supplementary information and clarifications are provided, som er udarbejdet i samarbejde mellem forsker(e) og AU/STs dekanat:

The Publication Applied Crop Protection is a yearly report providing output to farmers, advisors, industry and researchers in the area of crop protection. The publication typically summarizes data, which is regarded to be of relevance for practical farming and advice. It covers information on the efficacy profiles of new pesticides, effects of implementation of IPM principles (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 pesticides resistance to ensure that only effective strategies are used by the farmers to minimize build-up of resistance.

The report was initiated in 1991, when 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 EU's rules for efficacy data. Efficacy testing of pesticides was opened up to all trial units, which had obtained a GEP approval (Good Efficacy 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 bigger out-reach. The choice of topics, the writing and publishing of the report is entirely done by staff from Aarhus University 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 is 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 have supplied pesticides and advice on their use for the trials and plant breeders have provided the cultivars included in specific trials. Trials have been located either on AU's research stations or in fields owned by private trial hosts. AU has collaborated with local advisory centres and SEGES on several of the projects e.g. when assistance is needed regarding sampling for resistance or when looking for specific localities with specific targets. Several of the results have also been published in shared newsletters with SEGES to ensure a fast and direct communication with farmers.

Chapter 1: Climate data for the growing season 2013/2014 and specific information on disease attack 2014
Information collected by AU.

Chapter 2: Disease control in cereals
Trials in this chapter have been financed by ADAMA, Dow, Dupont, Bayer Crop Science, BASF, Syngenta, Nordic seed, KWS and Sejet Plantbreeding, but also certain elements have been based on AU's own funding and from The Danish Environmental Protection Agency's research funding (Miljøstyrelsens forskningsmidler) (septoria project).

Chapter 3: Control strategies in different cultivars
Trials in this chapter have been financed by income from selling the DSS system Crop Protection Online, as well as input from Bayer Crop Science and BASF. Certain elements have been based on AU's own funding.

Chapter 4: Disease control in grain maize
Trials in this chapter have been financed by Bayer Crop Science.

Chapter 5: Fungicide resistance-related investigations
Testing for fungicide resistance is carried out based on a shared cost covered by projects and the industry. In 2014 ADAMA, Bayer, BASF and Syngenta were involved from the industry. The Swedish part is financed by Swedish Board of Agriculture (Jordbruksverket) and also AU-agro have been included.

Chapter 6: Disease control in sugar beet
Trials in this chapter have been financed by Dupont, Bayer and BASF.

Chapter 7: Interactions between nitrogen and diseases in wheat
The results presented in this chapter is part of a project financed by GUDP.

Chapter 8: Control of late blight (Phytophthora infestans) and early blight (Alternaria solani & A. alternata) in potatoes
Trials in this chapter have been financed by income from Nordisk Alkali, Dupont, Bayer, BASF, Syngenta. Certain elements have been based on AU's own funding. Several of the trial plans have been carried out in collaboration with SEGES, which include the testing of DSS.

Chapter 9: Influence of application technique on control of potato early blight (Alternaria solani)
The project was financed by GUDP.

Chapter 10: Innovative IPM solutions for winter wheat based rotations: Cropping systems assessed in Denmark
The trials presented was financed by the EU project PURE.

Chapter 11. Desiccation of potatoes – influence of maturity /green biomass
Projects described in this chapter has been financed by GUDP.

Chapter 12. Integrated control of blackgrass – long term effects
Internal AU project

Chapter 13. Screening for new adjuvants for herbicides
Projects described in this chapter has been financed by the agricultural tax funds (promilleafgiftsmidler) via SEGES

Chapter 14: Results from testing of herbicides, growth regulators and desiccants in agricultural crops in 2014
No data has been presented.

Chapter 15: Insecticide resistance experiments
Projects described in this chapter has been financed by Innovation Fund Denmark.

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Preface

This publication contains results from crop protection trials in agricultural crops and focuses to a major extent on results with different pesticides. To a great extent the results are presented through graphics and in the form of tables. Trial results from specific IPM-related activities which are not specifically related to pesticides are also included.

The present publication also gives a description of the climate as well as the pest incidence in the crops. The publication is a summary of the publicly available results generated every year by the Department of Agroecology.

The results concerning new products and marketed pesticides will moreover be included in the annual updating of the advisory programme "Crop Protection Online". Many of the results in this year's publication are results from single trials or trial series. Trials from several years are also summarised in several cases.

The publication has been compiled and edited by Lise Nistrup Jørgensen, Department of Agroecology, Aarhus University, Flakkebjerg, Denmark in collaboration with other scientists in the team at Flakkebjerg.

Thanks are due to all who have contributed to generating the results described in this book. Specifically acknowledged are both the chemical companies selling pesticides, private trial hosts, staff at local advisory centres, SEGES and staff at the Department of Agroecology.

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I Climate data for the growing season 2013/2014

Lise Nistrup Jørgensen & Helene Saltoft Kristjansen

For the country in general the climate during the growing season (September 2013–August 2014) was characterised by an autumn close to average (a surplus of precipitation and little sunshine) and average temperatures of 9.9°C. The first frost came in late September, which was rather early. The country was hit by a storm with record high wind speeds on 28 October. The dull weather continued during the winter, and the average temperature was 3.7°C, which was 3.2°C above normal and 1.8°C above the average of 2001-10. 24 consecutive hours with frost occurred only 20 times during the winter 2013-14, which are 33 times less than average. The precipitation was above normal in all the three months of December/January/February. But the spring was dry with precipitation 4% below average. The temperature was 2.5°C above normal, and the spring was sunny, especially in March. The summer of 2014 was the eighth hottest summer since 1874 with a lot of sunshine. The precipitation was just above average (219 mm), but it was unevenly distributed across the country; hence the growing conditions differed from area to area. At Flakkebjerg the **autumn and winter** (September–February) were generally warm with average precipitation. There was only one night with frost in October and only a few frosty nights during November and December. The only period with frost and snow came in late January. The **spring** (March–May) was generally warm (2.5°C above normal) with a lot of sunshine. Hence the winter crops started growing very early. It was very dry in March and April, which to some extent affected the crops and the weed germination. The water balance was -22 in March and -40 in April; the normal is +3.9 and -27.6. The **summer** (June–August) was hot with temperatures above average, and the precipitation in June and July was far below average. Most of the trials were irrigated during the growing season. The harvesting started early and passed off easily and smoothly due to the dry weather. All cereal trials at Flakkebjerg were harvested by 1 August. 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 thirty years (1973-2003).

Figures 1, 2, 3 show climate data from the climate station at Flakkebjerg. This station covers cropping conditions for most trials. The normal temperature is the average of data from 30 years (1973-2003).

Figure 4 shows the water balance for the months April to August.

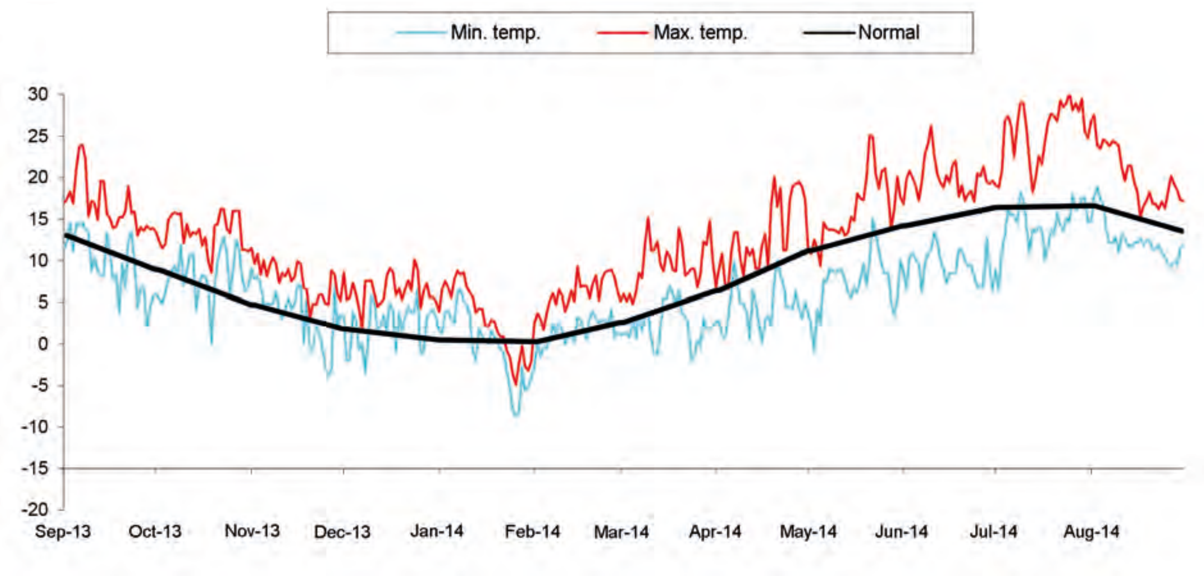


Figure 1. Temperatures in the cropping season 2013/2014 Flakkebjerg.

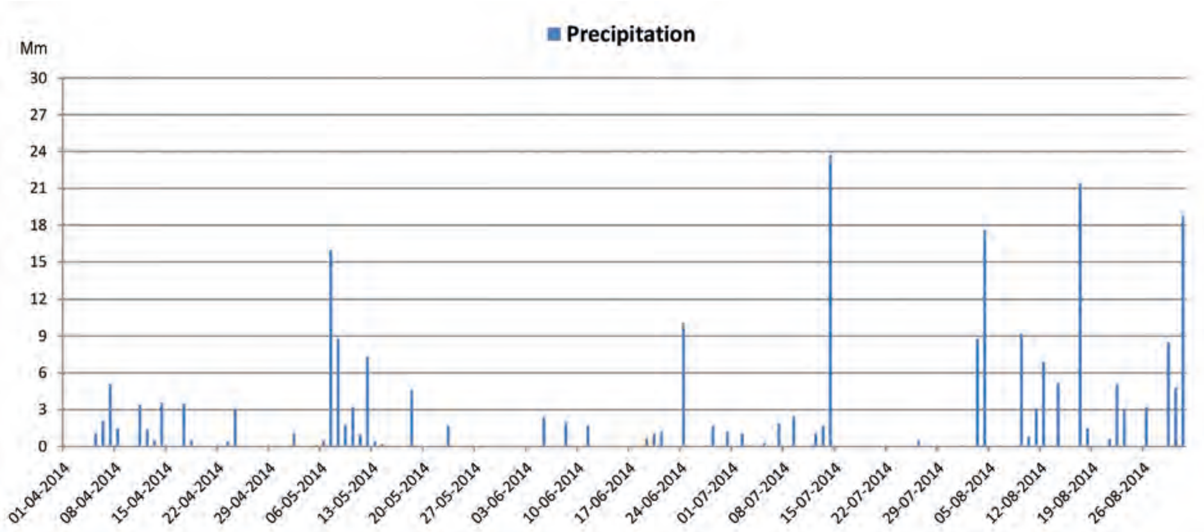


Figure 2. Precipitation in the growing season 2014 – Flakkebjerg.

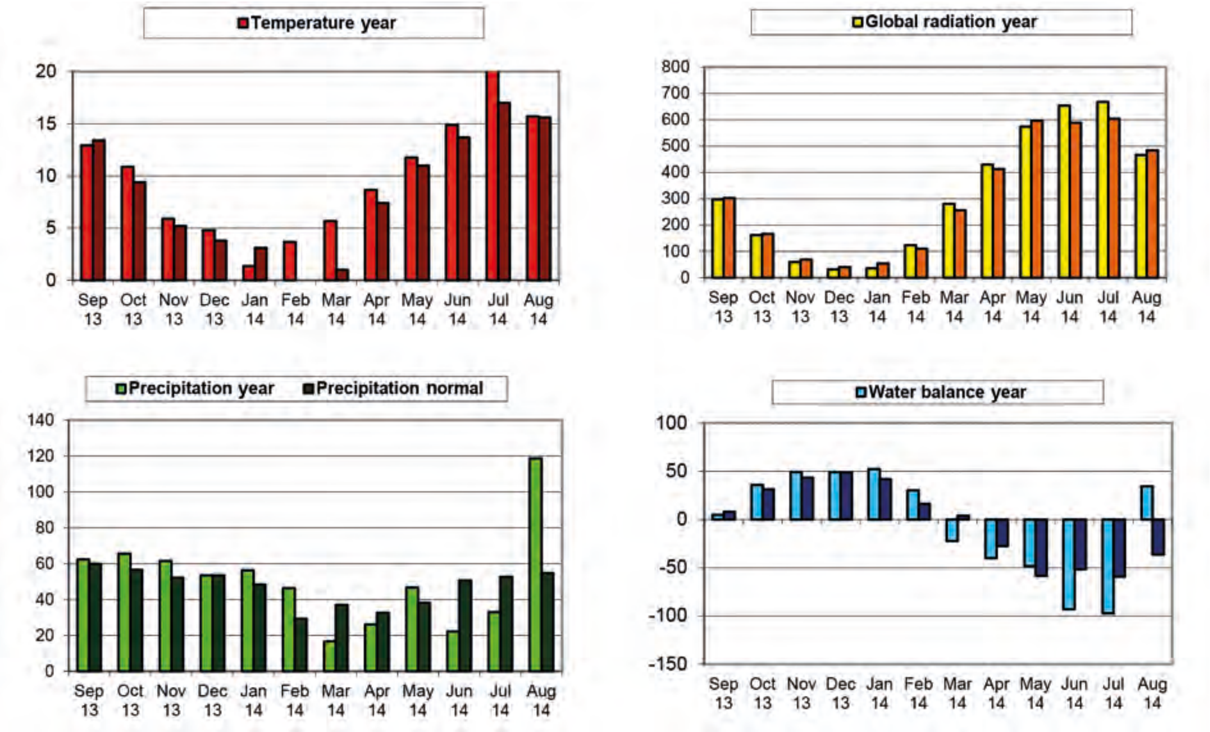
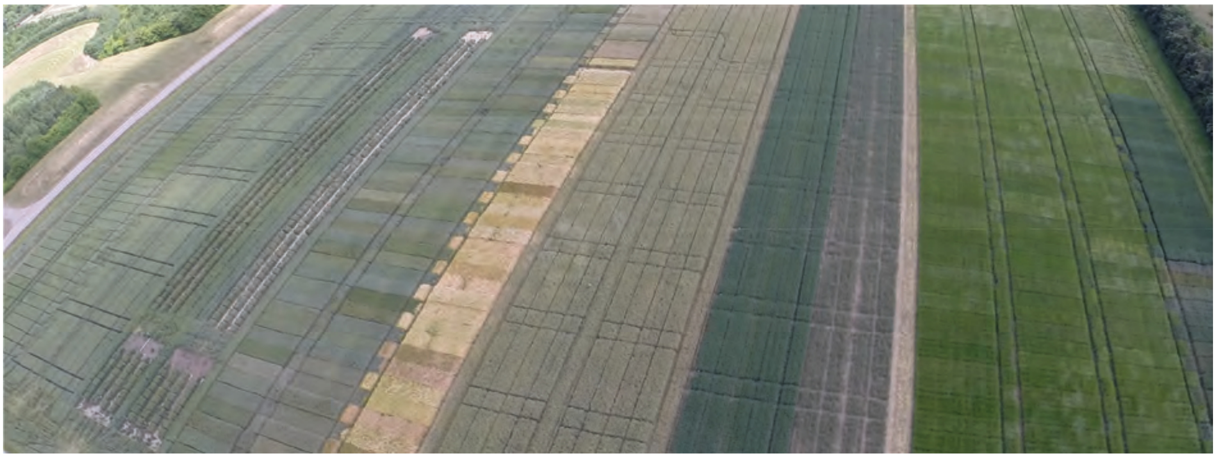


Figure 3. Climate data from Research Centre Flakkebjerg, growing season 2014.

Table 1. Overview of temperatures and precipitation in Denmark for the whole season 2013-2014.

	Average temperature °C		Average precipitation mm	
	2013/2014	Normal 1961-1990	2013/2014	Normal 1961-1990
September	12.9	12.7	62.4	73
October	10.9	9.1	65.6	76
November	5.9	4.7	61.5	79
December	4.8	1.6	53.5	66
January	1.4	0.0	56.3	57
February	3.7	0.0	46.4	38
March	5.7	2.1	16.7	46
April	8.7	5.7	26.1	41
May	11.8	10.8	46.7	48
June	14.9	14.3	22.2	55
July	20.7	15.6	33	66
August	15.7	15.7	118.7	67
September		12.7		73



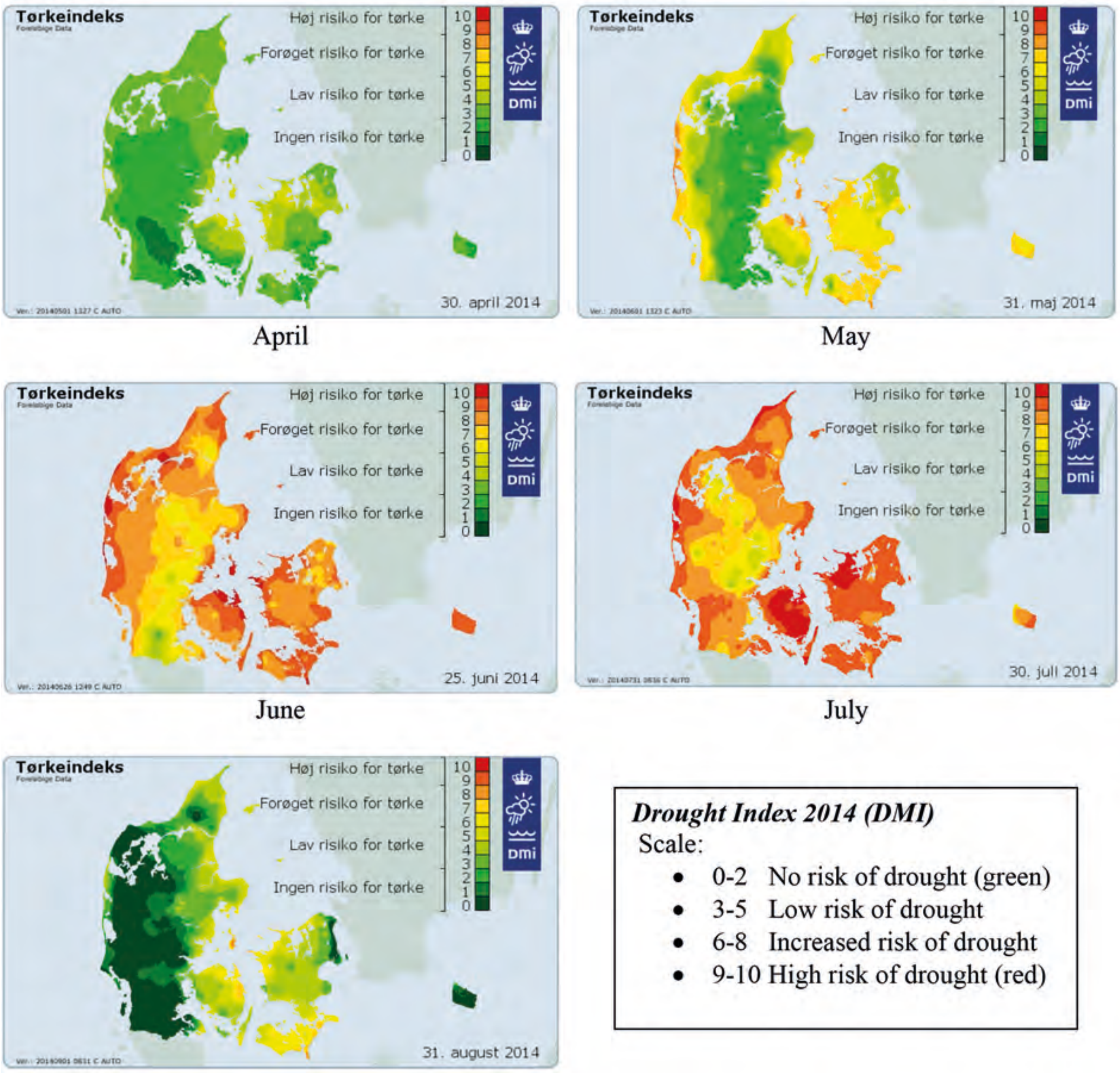


Figure 4. Drought index for the season 2014.

1. Disease attacks in 2014

Lise Nistrup Jørgensen, Bent J. Nielsen, Helene Saltoft Kristjansen, Hans-Peter Madsen & Hans Hansen

In this chapter information is given about the diseases occurring in the trials carried out in 2014. This makes it possible to evaluate if the target diseases were present at a significant level and whether or not the trials gave representative results. Yield levels in cereal trials were also ranked and compared with the previous year's responses.

Wheat

Powdery mildew (*Blumeria graminis*). The attack in 2014 was generally a minor one and almost insignificant at most localities with the exception of sandy soils. The specific mildew trials in wheat were carried out at Jyndevad trial station, which is well known for its severe attack of powdery mildew. Recordings carried out by the advisors in the national monitoring system organised by SEGES showed only minor attacks.

Septoria leaf blotch (*Zymoseptoria tritici*). The attack of *Septoria* was very severe right from the early start of the season. The mild winter gave good conditions for inoculum to survive the winter. Particularly early sown fields were in part of the country seen to give increased levels of attack. Humid conditions in both April and May during elongation of the crop gave rise to severe attack. An attack was seen on the flag leaf as early as 1 June, which is highly unusual for Danish conditions. In the trials the attack on the flag leaf reached a level of 45% at GS 75, which was significantly higher in comparison with previous years (8% in 2012, 32% in 2013). Data from SEGES show the high level of attack in 2014 (Figure 1).

Yellow rust (*Puccinia striiformis*). The attack in susceptible cultivars was generally severe, again following the mild winter. Particularly cultivars like JB Asano and Substance had very severe attacks in variety trials. In the cultivars Baltimor and Ambitions, which were used for fungicide trials, inoculation took place in April, which guaranteed that an attack would develop.

Brown rust (*Puccinia triticina*). Despite the mild winter, which gave some overwintering of this disease only a minor attack was seen during the growing season. Specific trials in the cultivar Hereford were inoculated with brown rust, but even so only a minor attack developed late in the season. This was slightly surprising as the warm weather in June was regarded as conducive for the development of this disease. In trials the level of attack never increased beyond a few per cent.

Tan spot (*Drechslera tritici repentis*). The attack developed from early April in fields which had winter wheat as previous crop and minimal tillage. The attack developed significantly in these fields. Trials carried out at two localities gave rise to significant attack, which gave good options for efficacy evaluations. Fields which had second year wheat but which had been ploughed before sowing only showed a minor attack of tan spot.

Fusarium head blight (*Fusarium* spp.). Only a minor attack of fusarium head blight was seen in fields this year as the weather was mostly dry during flowering. In several trials carried out at Flakkebjerg artificial inoculation with a spore solution of *Fusarium graminearum* and *Fusarium culmorum* took place. These trials developed significant attacks following irrigations, which were also part of the treatments. Good conditions for distinguishing differences between fungicide and cultivar susceptibility were given.

Eye spot (*Tapesia herpotrichoides*). An attack was assessed in a few trials following development of white heads. The activity with this disease has been very low for many years but the level in this year's trials showed that the disease may still play a role and should not be forgotten.

Take-all (*Gaeumannomyces graminis*). An attack was seen in second and third year fields in 2014. No specific trials included control of this disease. Approximately 5% of the wheat area is treated with Latitude and seeds are imported from mainly Germany as Latitude is not approved in Denmark.

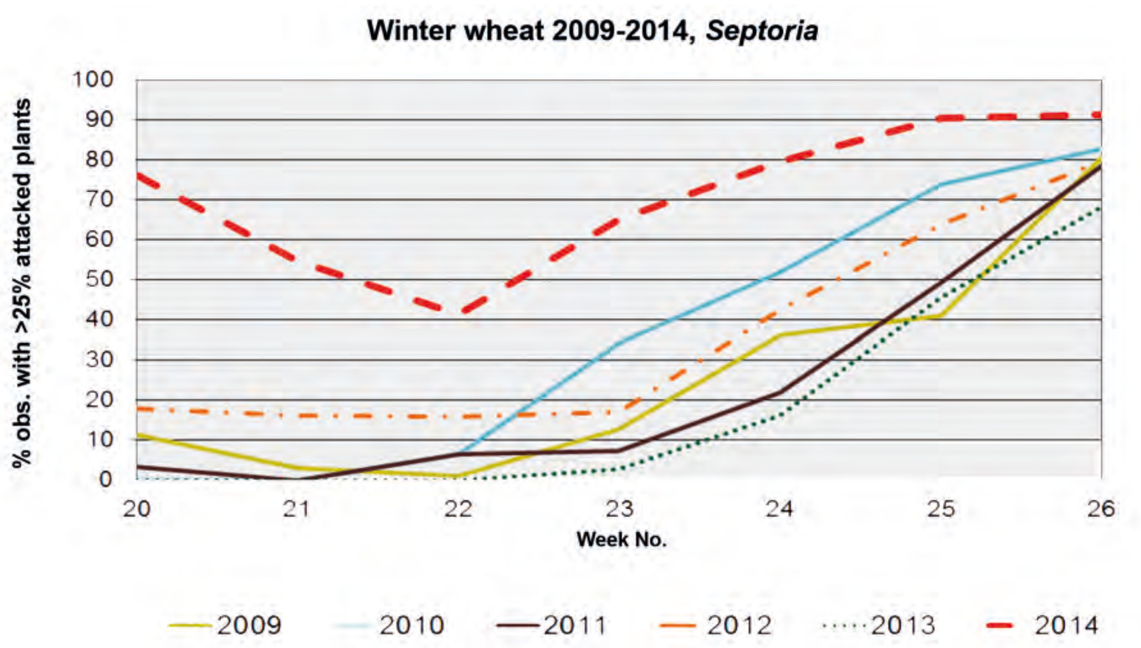


Figure 1. Development of *Septoria* in the national monitoring system led by SEGES.

Figure 2. Attack of *Septoria* on flag leaves at GS 53-55 at Ultang in KWS Dacanto sown in the first week of September.

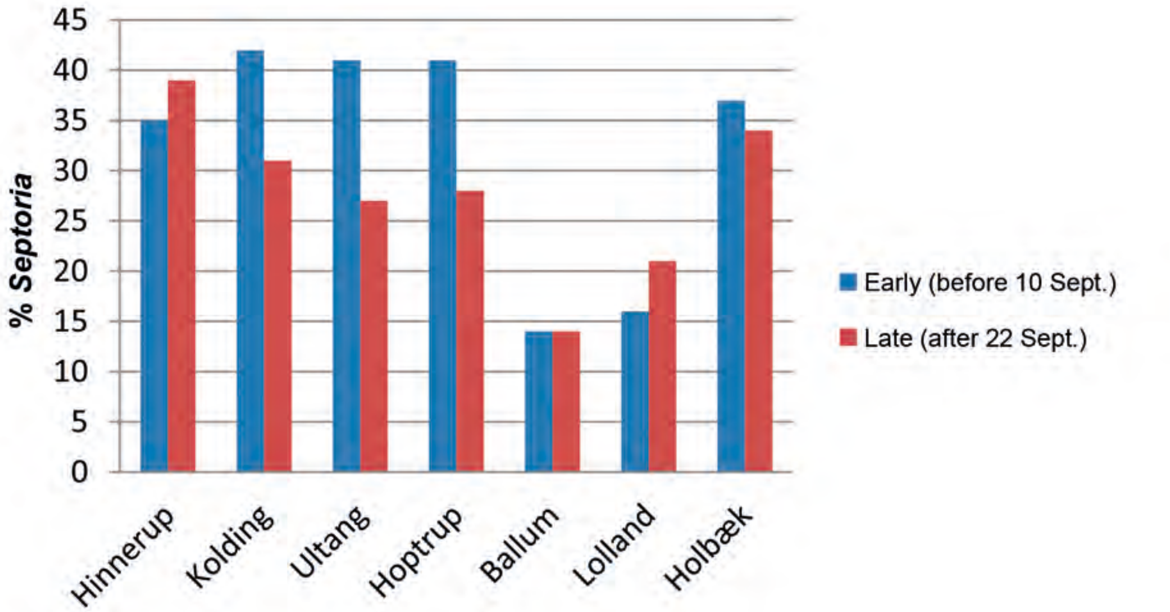


Figure 3. Attack of *Septoria* at 7 Danish localities with different sowing dates**.** At 4 sites the early sowing led to increased levels of *Septoria* attack.

White heads in winter wheat crops caused by a mixture of eyespot and take-all.

Healthy stems to the right and diseased stems to the left.

Triticale and rye

Yellow rust (*Puccinia striiformis*). In 2014 a severe attack of yellow rust developed following good conditions for surviving the winter. The triticale trials were severely infected with attack and gave good conditions for distinguishing the performances of the products. A severe attack in the heads was also seen causing significant yield reductions.

Septoria nodorum blotch (*Stagonospora nodorum*). Only very insignificant attacks developed in the trials as these were entirely dominated by yellow rust.

***Rhynchosporium* (*Rhynchosporium secalis*)** developed a significant attack in rye. This gave rise to good assessments in the trials providing data with differences between fungicide performances.

Brown rust (*Puccinia recondita*) developed late in the season with a significant attack. This disease is known to reduce yields and most products were seen to provide good control if applied after heading.

Stem rust (*Puccinia graminis*) and **yellow rust (*Puccinia striiformis*)** both developed very minor attacks in the rye crop. Due to high disease pressure in nearby triticale crops an attack of yellow rust was also seen to a minor extent in rye. Both stem rust and yellow rust attacks were, however, too insignificant to provide ranking of the efficacy of the products.

Winter barley

Powdery mildew (*Blumeria graminis*). The attack in 2014 was generally slight, which only gave minor possibilities for ranking the performances of the products. Also, in the national monitoring system run by SEGES only a minor attack was recorded. In field trials assessed between GS 65 and 57 attacks were only about 1%.

Brown rust (*Puccinia hordei*) occurred with only a very minor attack in 2014 despite a mild and early spring. Since 2011 the attacks of brown rust in trials have been minor. In the 2014 trials the average attack around GS 75 was only between 1 and 2%.

***Rhynchosporium* (*Rhynchosporium commune*).** The dominant disease in winter barley trials in 2014 was *Rhynchosporium*, giving a moderate attack in several cultivars. Good opportunities to distinguish between the performances of the products were given in the season. Around GS 65-73 the average attack in the trials on upper leaves varied between 5 and 10%.

Net blotch (*Drechslera teres*) occurred with only a minor to moderate attack in 2014. In the cultivar Pelican a considerable attack occurred from GS 65 giving good possibilities for ranking the efficacy of the products. In trials with net blotch the average attack in the susceptible cultivars reached a level of 10% at GS 75.

Ramularia leaf spot (*Ramularia collo-cygni*). The trials developed a relatively late but significant attack of this disease in 2014. This was seen in most cultivars. Good possibilities for ranking the efficacy of the products were given. In the specific trials the average attack of Ramularia leaf spot reached a level of 30% by GS 75-81.

Spring barley

Powdery mildew (*Blumeria graminis*). The attack in 2014 was moderate and limited to the cultivar Milford, which does not carry mlo resistance. This cultivar again provided good possibilities for ranking the performances of the product. Attack of powdery mildew reached a level between 10 and 20% at GS 75.

Net blotch (*Drechslera teres*) appeared in some fields with very considerable attack mainly in Jutland in fields with second year barley and minimal tillage. The attack in the trials carried out at Flakkebjerg stayed at a low level, 1 to 5% at GS 71-73.

***Rhynchosporium* (*Rhynchosporium secalis*)** appeared in some fields with a very significant attack mainly in Jutland in fields with second year barley and minimal tillage. Attacks in our specific field trials were low with the exception of the trials carried out in Jutland.

Brown rust (*Puccinia hordei*) appeared with a very minor attack in 2014 even in the commonly grown and very susceptible cultivar Quench. The attack at Flakkebjerg stayed at a very low level during the whole season.

Ramularia leaf spot (*Ramularia collo-cygni*). The attack of this disease dominated the spring barley trials during the 2014 season. The attack appeared already from GS 55-65 and attack in the most susceptible cultivars reached a level varying from 10 to 20%.

Yield increases in fungicide trials in cereals

Yields in 2014 were generally very high, particularly in winter wheat. In the trials the yields in winter wheat were typically in the range of 90-110 dt/ha and in winter barley around 60-80 dt/ha. In spring barley the level was also relatively high for this crop around 65-75 dt/ha. The crop stands were influenced by the mild winter and the early start of the growing season. The fast ripening period following a very warm late June and July gave rise to less impact from fungicide treatments seen in relation to the diseases which appeared. This was most clear for spring and winter barley. Some drought was seen particularly in the spring barley fields where yield responses in most cases never were significant and where high LSD values were seen.

Yield increases following fungicide treatments in wheat were higher compared with previous years, mainly caused by the high level of *Septoria*. On average the response was 12 dt/ha. Figure 4 shows the variation in responses from standard treatments. The level of responses in winter and spring barley was low to moderate in 2014 (see Table 1).

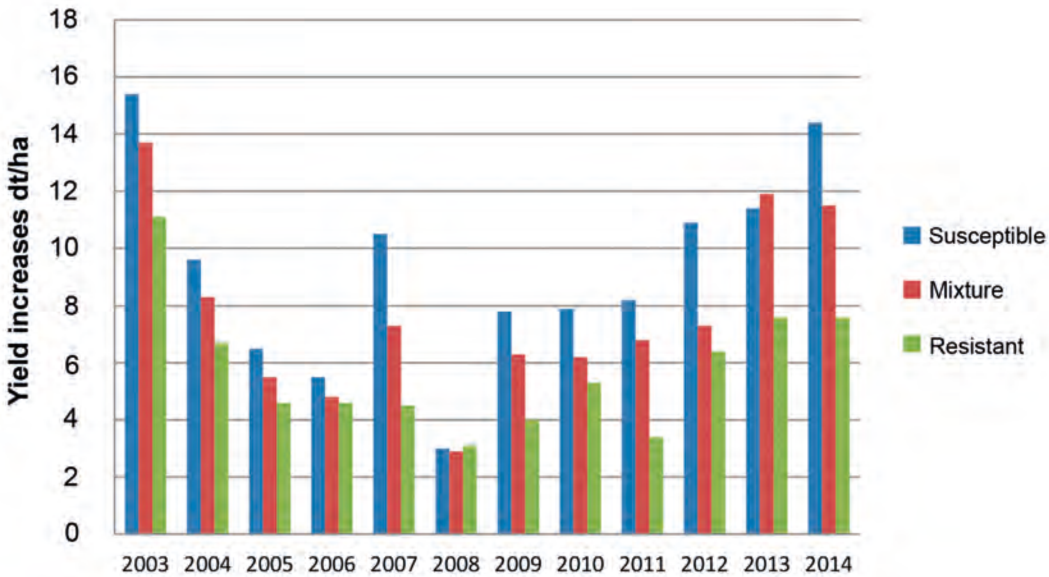


Figure 4. Variation in yearly responses in winter wheat from 2003 to 2014. Large variations are seen between years but also between the level of susceptibility in the cultivars.

Maize

Eye spot (*Kabatielle zeae*). The attack of this disease stayed low during most of the season. The wet weather in the beginning of May was too early to cause a significant impact on attack in maize. The limited attack during summer did not develop further on to late September when differences between treatments became apparent.

Northern leaf blight (*Setospharia turcica*) also developed late and never caused more than a minor to moderate attack.

Fusarium ear blight (*Fusarium* spp.). A significant attack of *Fusarium* in the cobs developed partly driven by an attack by the European corn borer (*Ostrinia nubilalis*). These attacks started early in the season and caused top lodging of the plants.

Grass seed - ryegrass

A severe attack of leaf rust developed in the trials from early spring. Initially, the attack was also mixed with a mildew attack. The attack looked like crown rust, but a specific analysis showed that the teliospores did not have the crown, and a DNA test revealed that it was not crown rust, but possibly a less known leaf rust called *Puccinia holcina*. The trial at Flakkebjerg was inoculated in April with stem rust (*Pucccinia graminis*) to ensure attack of this disease. Stem rust developed and gave a significant attack particularly in the cultivar Calibra.

Stem rust on ryegrass leaves

Stem rust on ryegrass heads

Table 1. Yield increases (dt/ha) for control of diseases using fungicides in trials. The responses are picked from standard treatments typically using 2 treatments per season. Numbers in brackets give the number of trials behind the figures. Data originate from SEGES and AU-Flakkebjerg's trials.

Year	Winter wheat	Spring barley	Winter barley
1992	3.5 (162)	0.8 (121)	2.2 (62)
1993	4.3 (142)	5.7 (112)	5.4 (62)
1994	4.0 (178)	2.3 (97)	2.3 (73)
1995	4.7 (122)	2.3 (98)	4.0 (61)
1996	5.9 (141)	1.5 (110)	3.1 (62)
1997	7.6 (149)	2.7 (91)	3.8 (69)
1998	16.4 (346)	5.9 (89)	6.2 (70)
1999	13.5 (441)	5.8 (178)	6.6 (45)
2000	9.9 (329)	6.3 (223)	7.8 (143)
2001	8.4 (150)	5.1 (106)	6.5 (58)
2002	17.9 (240)	7.0 (200)	7.4 (119)
2003	14.1 (377)	6.1 (244)	4.4 (303)
2004	12.2 (284)	4.4 (351)	5.6 (218)
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)

Potato

Potato early blight (*Alternari solani & A. alternata*)

The trials at Flakkebjerg were artificially infected on 27 June 2014 with autoclaved barley seeds inoculated with *A. solani* and *A. alternata* (seeds were placed in the furrow between the plants). The first attacks on the lower leaves were detected on 7 July, 10 days after inoculation. However, the weather conditions were very dry in July and it was not until the beginning of August that there was a development in the attack. In August and September there was a severe development in the trial at Flakkebjerg with 90%-100% of the leaves attacked in untreated plots at the last assessments in September. The development in early blight in 2014 was similar to the development in 2013 when the weather conditions in July also were dry.

Potato late blight (*Phytophthora infestans*)

The trials at Flakkebjerg were artificially inoculated on 1 July 2014 by spraying with a sporangial suspension of *Phytophthora infestans* (1000 sporangia/ml) over spreader rows between the blocks. The first symptoms were detected in the spreader rows on 8 July and in the untreated trial plots in mid-July. Due to dry weather in July and low infection pressure of late blight there was no disease development until the beginning of August with a severe epidemic development in untreated plots in the last half of August and in the beginning of September. In mid-September almost all untreated plots were destroyed by late blight. The weather conditions were very wet at the lifting of the potatoes in the beginning of October and moderate attacks of tuber blight were seen in several plots.

Oil seed rape

Sclerotinia (S. sclerotiorum)

Sclerotia of *S. sclerotiorum* were placed in the soil in the autumn 2013, and in the spring mycelia suspension was sprayed over the plant at early blooming. However, the weather conditions were dry and not favourable to disease development and only a minor to moderate attack of *Sclerotinia* was observed in the trial plots at Flakkebjerg

II Disease control in cereals

Lise Nistrup Jørgensen, Helene Saltoft Kristjansen, Sidsel Kirkegaard & Anders Almskou-Dahlgaard

Introduction

In this chapter field trials in cereals carried out with fungicides in 2014 are described in brief and results are summarised. In graphs or tables are also included results from several years if the trial plan concerns several years. Included are main results on major diseases from both protocols with new fungicides and protocols in which products applied at different dose rates and timings are compared. Part of the trial results are used as 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.

Apart from the tables and figures providing main data, a few comments are given along with some concluding remarks.

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. But some trials are also sited in farmers' fields, at Jyndevad Field Station or near Horsens in collaboration with a GEP trial unit at the advisory group LMO. Trials are carried out as block trials with randomised plots and 4 replicates. Plot size varies from 14 to 35 m^2, depending on the individual unit's equipment. The trials are sited 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. Spraying is carried out using 150 or 200 l water per ha and a nozzle pressure of 1.7-2.2 bar.

Attacks of diseases in the trials are assessed at approximately 10-day intervals during the season. Per cent leaf area attacked by the individual diseases are assessed on specific leaf layers. At the individual assessments the leaf layer which provides the best differentiation of the performances of the fungicides is chosen. In most cases this is the 2 upper leaves. In this publication only some assessments are included - mainly the ones giving the best differentiation of the efficacy of the products.

Nearly all trials are carried through to harvest and yield is adjusted to 15% moisture content. Quality parameters like specific weight, % protein, % starch and % gluten content are measured using NIT instruments (Foss) and thousand grain weight is calculated based on 250 grains counted. In spring barley, which can potentially be used for malting grain, size fractions are also measured. For each trial LSD_{95} values are included or specific letters are included. Treatments with different letters are significantly different, using the Student-Newman-Keuls model.

When a net yield is calculated, it is based on deducting the cost of used chemicals and the cost of driving. The cost of driving has been fixed to 70 DKK and the cost of chemicals - extracted from the database at SEGES. The grain price used is 105 DKK/dt.

1. Control of powdery mildew (*Blumeria graminis*)

Several trials were carried out at Jyndevad trial station, which is located on sandy soil close to the German border in Jutland and known for being a good locality for investigation of mildew trials. The cultivar Ambition was used for the trials. This cultivar is also very susceptible to yellow rust – the new aggressive Warrior race is known to attack this cultivar.

In Denmark only few mildew products are available. Tern (fenpropidin) is no longer authorised. Talius is still waiting for a new authorisation, so currently only Flexity (metrafenon) is available for specific mildew control. Azoles like tebuconazole and prothioconazole have also over the years been seen to provide good control, if used at an early timing.

Talius showed again in this year's trials a good and persistent control of mildew. Very little difference in control was seen between full or half rate of the product. As expected the product did not have any effect on yellow rust, which in this year's trial was also reflected in the yield result (Table 1). Talius mixed with Proline EC 250 gave good control of both mildew and rust diseases. Talius gave superior control of mildew compared with Flexity. Flexity and Proline EC 250 gave good control of both mildew and yellow rust - in line with the mixture Talius + Proline EC 250. Best yield responses were obtained from treatment providing good control of both mildew and yellow rust. A max. increase of 26.9 hkg/ha was obtained for the mixture Talius + Proline EC 250.

Untreated plot: In this year's mildew trial attacks of both mildew and yellow rust were common. The coformulation DPX N6F84 528EC (proquinazid + tebuconazole + prochloraz) gave good control of both mildew and yellow rust. Clear dose response was seen, although this was only reflected to a minor extent in the yield responses (Table 1).

Table 1. Effects of different fungicides on powdery mildew and yield responses following 2 applications in wheat. 1 trial (14353).

Treatments and l/ha			% powdery mildew			% yellow rust		Yield and increase	Net increase
GS 32-33		GS 51-55	GS 39 L 4-5	GS 55 L 3-4	GS 65 L 2-3	GS 65 L 2-3	GS 73 L 2-3	hkg/ha	hkg/ha
1.	Talius 0.125	Talius 0.125	0.6	3.0	5.5	16.3	46.3	2.2	-1.1
2.	Talius 0.25	Talius 0.25	0.7	1.4	4.3	16.3	48.8	4.5	-0.7
3.	Talius + Tern 0.125 + 0.25	Talius + Tern 0.125 + 0.25	0.1	2.0	1.9	12.5	33.8	7.7	2.6
4.	Talius + Proline EC 250 0.125 + 0.4	Talius + Proline EC 250 0.125 + 0.4	0.1	1.1	1.1	1.5	3.8	26.9	20.0
5.	Talius + Proline EC 250 0.25 + 0.4	Talius + Proline EC 250 0.25 + 0.4	0.1	0.5	2.3	1.1	3.0	25.2	16.4
6.	DPX N6F84 528EC 0.5	DPX N6F84 528EC 0.5	0.3	2.0	4.0	3.5	8.8	24.2	-
7.	DPX N6F84 528EC 0.75	DPX N6F84 528EC 0.75	0.2	0.9	1.4	0.1	6.8	25.5	-
8.	DPX N6F84 528EC 1.0	DPX N6F84 528EC 1.0	0.1	0.4	0.4	0.6	10.0	26.7	-
9.	Flexity 0.25	Flexity 0.25	4.5	9.3	8.8	11.3	45.0	4.6	-0.3
10.	Proline EC 250 0.4	Proline EC 250 0.4	4.8	8.0	5.5	2.3	8.3	19.5	14.6
11.	Untreated	Untreated	28.8	16.3	13.8	13.8	43.8	84.3	-
LSD_{95}			28.8	16.3	13.8	4.8	10.9	6.5	

Data for re-evaluation of Flexity

Another trial (14323) tested 3 dose rates of Flexity with the aim of providing support for the re-registration of the product. At the first assessments Talius and Flexity provided similar control (Table 2). At later assessments Talius showed superior persistent control. Ceando provided control of mildew in line with Flexity, but Ceando was superior for control of yellow rust at the early assessments. Later cover sprays with Bell made the control of yellow rust similar for all treatments. As a curiosity Coca-Cola (5%) was applied to evaluate the efficacy against mildew. Moderate but still significant control was found at the early assessments. However, the effect was clearly inferior to more traditional fungicides. Yield increases from the first treatment applied in this trial were generally limited. Only Ceando increased yields significantly compared to untreated.

Table 2. Effects of different fungicides on powdery mildew and yield responses following 2 applications in wheat. 1 trial (14323). Net yield only relates to treatments at GS 31.

Treatments l/ha			% powdery mildew			% yellow rust	Yield and increases	Net increases
GS 31	GS 37-39	GS 55-61	GS 32 L 5-6	GS 45 L 3-4	GS 55 L 4-5	GS 45	hkg/ha	hkg/ha
1. Untreated	Bell 0.5	Bell 0.5	15.0	8.5	21.3	4.0	97.7	
2. Flexity 0.25	Bell 0.5	Bell 0.5	6.3	2.8	4.3	1.8	1.4	-1.1
3. Flexity 0.25	Bell 0.5	Bell 0.5	4.8	3.3	4.0	2.1	1.6	-0.9
4. Flexity 0.5	Bell 0.5	Bell 0.5	4.0	4.8	4.5	4.3	2.0	-2.2
5. Talius 0.25	Bell 0.5	Bell 0.5	4.3	0.1	1.6	2.1	7.5	4.9
6. Ceando 0.75	Bell 0.5	Bell 0.5	4.3	5.5	3.5	0.4	2.1	-1.6
7. Coca-Cola 5% W/W	Bell 0.5	Bell 0.5	10.5	6.8	12.0	4.5	0	-
LSD_{95}			4.2	3.7	3.8	1.8	2.8	-

Monitoring for resistance to metrafenon has been carried out by BASF over the years and two levels of resistance have been identified: moderate and complete resistance. Approximately 30% of the populations have moderate levels of resistance and only 1-2% have high levels of resistance. Only the latter group is known to substantially influence the performance of Flexity.

Proline EC 250 as a mildewicide

In the 3rd mildew trial different timings and combinations of products were tested for control of powdery mildew (Table 3, Figure 1). Talius used as a single early treatment as well as split mildew control (Treatment 11) provided the best control. Proline EC 250 used alone at half rate gave superior control compared with Flexity. Folpan or Folpan used in mixture with Proline EC 250 (0.2 l/ha) was also inferior to most other treatments. Folicur Xpert provided better control used alone compared to a cocktail of Folicur EW 250 + Flexity.

The two cover sprays using Prosaro and Bell gave an yield increase of 13.7 hkg/ha, ensuring against severe rust and *Septoria* attack. A split mildew treatment using Proline EC 250 + Flexity followed by Folicur Xpert yielded a further 10 hkg/ha. The better of the single mildew treatments (Treatment 1, Treatment 4) gave yield increases between 7 and 8 hkg/ha beyond the level of the cover spray. The results from these trials led to adjustment of the official ranking of mildew fungicides; Proline EC 250 was upgraded and Flexity was downgraded.

Table 3. Effects of different fungicides on powdery mildew and yield responses following different applications in wheat. 1 trial (14330).

Treatments l/ha				% powdery mildew			% yellow rust	Yield and increases hkg/ha	Net increases hkg/ha
GS 31	GS 33	GS 39	GS 55-61	GS 32 Lower leaves	GS 37 L 4-5	GS 55 L 3-4	GS 73		
1. Talius 0.25	-	Prosaro 0.33	Bell 0.5	10.0	0.1	0.9	3.0	20.6	13.4
2. Flexity 0.25	-	Prosaro 0.33	Bell 0.5	9.3	3.3	8.8	2.1	15.4	8.3
3. Flexity 0.125	-	Prosaro 0.33	Bell 0.5	11.3	3.3	11.3	2.1	14.5	8.3
4. Proline 0.4	-	Prosaro 0.33	Bell 0.5	7.5	1.1	6.0	2.8	21.1	14.0
5. Proline + Flexity 0.2 + 0.125	-	Prosaro 0.33	Bell 0.5	6.8	2.0	8.5	1.4	16.9	9.8
6. Proline + Folpan 0.2 + 0.75	-	Prosaro 0.33	Bell 0.5	11.8	7.0	12.5	1.6	14.8	7.4
7. Folpan 1.5	-	Prosaro 0.33	Bell 0.5	13.8	13.8	13.8	4.0	13.6	5.9
8. Ceando 0.375	-	Prosaro 0.33	Bell 0.5	4.8	2.8	9.3	1.0	19.4	12.6
9. -	Folicur Xpert 0.375	Prosaro 0.33	Bell 0.5	13.8	4.5	4.0	2.0	14.8	8.3
10. -	Folicur EW 250 + Flexity 0.25 + 0.125	Prosaro 0.33	Bell 0.5	16.3	10.0	10.5	2.6	15.2	8.6
11. Proline + Flexity 0.2 + 0.125	Folicur Xpert 0.375	Prosaro 0.33	Bell 0.5	8.0	0.3	3.8	1.0	23.4	14.6
12. -	-	Prosaro 0.33	Bell 0.5	15.0	18.8	14.3	1.8	13.7	9.1
13. Untreated	-	-	-	17.5	21.3	15.0	21.3	84.5	-
LSD_{95}				3.6	3.4	4.6	8.3	6.3	-

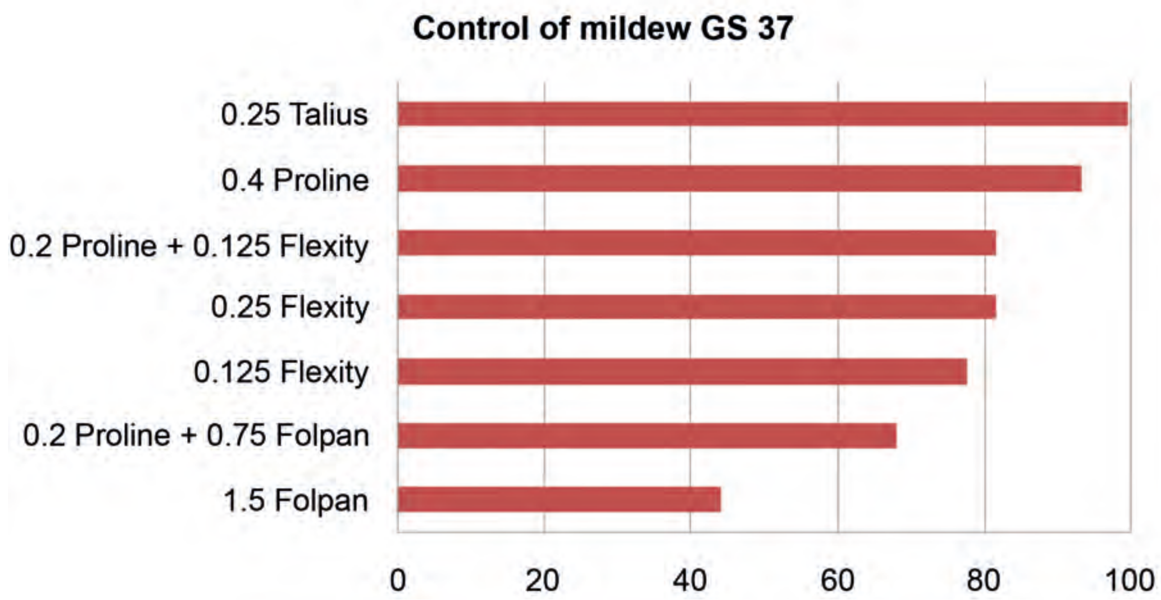


Figure 1. Per cent control of powdery mildew in winter wheat, following an application at GS 31. Assessments were made on leaf 3 at GS 37 with 12.5% attack in untreated.

Treatment 1
0.25 Talius. Good control of mildew, but still attack of yellow rust.

Treatment 11
0.2 Proline EC 250 + 0.125 Flexity/ 0.375 Folicur Xpert. Good control of both mildew and yellow rust.

2. Control of tan spot (*Drechslera tritici repentis*)

3 trials were carried out in 2014 testing the efficacy of different fungicides regarding control of tan spot. Straw infected with tan spot was spread in the autumn at the trial site, which is a method known to provide good attack of this disease. In early April the first clear symptoms of tan spot were recognised at the site. The trial developed attacks of both *Septoria* and tan spot although tan spot was found to be the faster of the two diseases to develop on newly developed leaves.

In one trial different timings and combinations of treatments were tested (Table 4). As tan spot has a very short latent period (less than a week), it is important to keep on controlling this disease also during flowering. This is in contrast to *Septoria*, which due to its long latent period will stop creating a yield reducing attack at an earlier stage. Late timing improved the control at the last assessments, which was also reflected in higher yields. Both Bumper and Proline EC 250 provided good control of tan spot. 2 x 0.5 Bumper was giving control similar to 2 x 0.8 Proline EC 250. All treatments increased yields significantly. The treatments providing the broadest and longest control gave the best yields.

Table 4. Effects of different fungicides on tan spot and yield responses following 2-4 applications in wheat. 1 trial (14326).

Treatments l/ha				% tan spot			% *Septoria*	Yield and increases hkg/ha	Net increases hkg/ha
GS 32	GS 37	GS 51-55	GS 61-65	GS 37 L 1	GS 71 L 2	GS 73 L 1	GS 73		
1. Bumper 0.5	Proline 0.4	Bumper 0.5	Proline 0.4	0.4	2.3	1.6	21.3	14.7	6.6
2. Bumper 0.5	Proline 0.4	Bumper 0.5	-	0.2	5.3	4.0	17.0	10.0	4.4
3.	Proline 0.4	Bumper 0.5	Proline 0.4	1.0	4.8	2.3	24.3	14.6	8.1
4.	Proline 0.4	Bumper 0.5		0.9	5.8	8.3	23.0	11.0	7.0
5.	Proline 0.4	Proline 0.4		1.0	7.0	9.5	27.5	7.2	2.3
6.	Bumper 0.5	Bumper 0.5		0.8	6.3	6.0	38.8	9.2	6.1
7.	Bell + Proline 0.38 + 0.2	Bell + Proline 0.38 + 0.2		1.3	12.5	10.0	33.8	12.0	8.2
8.	Bell + Proline + Comet 0.75 + 0.2 + 0.2	Bell + Proline + Comet 0.75 + 0.2 + 0.2		0.5	7.8	6.3	15.0	14.4	3.3
9.	Viverda 0.5	Proline 0.4		0.7	10.8	7.5	26.3	11.9	6.7
10.	Propulse 1.0	Propulse 1.0		0.8	8.5	5.5	17.3	10.9	-
11.	Proline 0.8	Proline 0.8		0.3	6.0	6.8	11.3	11.5	3.0
12.	Siltra + Proline 0.5 + 0.4	Siltra + Proline 0.5 + 0.4		0.8	15.0	13.5	18.8	9.6	-
13.	Untreated			2.5	23.8	32.5	62.5	75.9	-
LSD_{95}				0.6	4.4	2.9	8.6	3.9	-

In two trials different products were compared using a 2-spray strategy (Table 5). Again Bumper and Proline EC 250 provided very similar control of tan spot but Proline EC 250 was – as expected – superior in control of *Septoria* and yield response. Opus was inferior to both products for control of tan spot.

Table 5. Effects of different fungicides on tan spot and yield responses following 2 applications in wheat. 1 trial (14320).

Treatments and l/ha		% tan spot			% *Septoria* hkg/ha	% GLA	Yield and increase hkg/ha	Net increases hkg/ha
GS 32-33	GS 51-55	GS 39 L 4	GS 71 L 2	GS 75 L 1		GS 73 L 2-3		
1. Untreated		25.4	43.8	28.1	11.3	17.3	827	-
2. Opus 1.0	Opus 1.0	11.5	29.8	11.5	3.5	40	+6.3	-2.8
3. Proline 0.8	Proline 0.8	4.5	7.8	5.1	1.9	70	+10.6	2.1
4. Bumper 0.5	Bumper 0.5	6.5	11.7	3.9	8.0	61	+5.8	2.7
No. of trials		2	2	2	1	2	2	
LSD_{95}							3.0	

Clear symptoms of tan spot with brown lesions, dark brown spot at the centre and yellow chlorotic halo.

3. Control of Fusarium head blight (*Fusarium* spp.)

In 2014 3 trials were carried out testing the efficacy of different fungicides for control of Fusarium head blight (Table 6). The trials were inoculated during flowering with a spore mixture of *Fusarium culmorum* and *Fusarium graminearum*. Treatments were applied either 1 day before or 1 day after inoculation. Two weeks after inoculation the first symptoms were seen. Proline EC 250 and Prosaro were used as references. They both provided significant control of the disease. Level of control varied between 45 and 73% control. Proline EC 250 proved to be slightly more effective in control of *Fusarium* than Prosaro. Only moderate yield responses were measured for the control.

Table 6. Control of *Fusarium* in wheat following treatments during flowering. Treatments are carried out the day before or the day after inoculation with a spore solution. 3 trials from 2014. The trial was sprayed with cover sprays before heading.

Treatments	*Fusarium* GS 77 No. of attacked head per 4 metres				*Fusarium* GS 77 No. of attacked head per plot				Yield and yield increase
GS 65	14356	14331-1	14331-2	Average	14356	14331-1	13331-2	Average	hkg/ha
Untreated	11.5	3.2	7.3	7.3	47.1	54.5	24.5	42.0	97.0
Prosaro 1.0	8	-			20.7	-	-	-	
Proline 0.8	6.4	2.1	3.4	4.0	16.7	9.0	7.8	11.2	+3.8
No. of trials	1	1		3	1	1	1		3

Untreated plot with *Fusarium*.

Plot treated with Proline.

4. Control of *Septoria* (*Zymoseptoria tritici*)

New political taxes on pesticides

A new pesticide tax was introduced in the summer of 2013 to stimulate the use of less toxic and more expensive products in Denmark replacing the old pesticide tax based on the cost of the pesticides.

Treatment Frequency Index has been the main indicator of pesticide use in Denmark since 1985 reflecting the intensity of use. The newly developed Pesticide Load (PL) per ha is seen as a better indicator for the potential adverse impacts of pesticides on the environment and human health. Based on the use pattern of pesticides in 2011, it is foreseen that the PL per ha will be reduced significantly in future as the farmers are expected to select the cheaper product solutions and thus the least harmful pesticides. The new politically agreed pesticide strategy sets a goal of a 40% reduction in PL per ha by the end of 2015.

Several different combinations of fungicides with different pesticide loads have been tested to clarify how solutions with low pesticide load will perform compared with solutions with higher pesticide load. Focus has been to evaluate the performance on particularly *Septoria* and yield. The testing has been carried out over two seasons. The expected cost differences are listed in Table 7. In several cases the expected cost changes have not been fulfilled as the companies have had means of adjusting the price to partly compensate for the higher tax.

Table 7. List of fungicides, their pesticide load (PL), tax per standard dose, cost per standard dose and per cent change in price since introduction of the new tax.

Products and standard dose	PL/standard dose	Tax per standard dose	New price (DKK/standard dose)	% change in price
Viverda 2.5	3.4	400	1090	9
Ceando 1.5	2.95	312	638	46
Bell 1.5	3.1	357	675	18
Opera 1.5	2.76	209	810	24
Dithane 2.0	1.04	188	258	169
Rubric 1.0	1.99	220	380	8
Osiris Star 1.34	2.2	245	409	-
Tern 0.8	1.12	150	310	46
Folicur 1.0	0.77	95	210	7
Juventus 1.0	0.45	53	320	2
Prosaro 1.0	0.54	71	362	-7
Aproach 0.5	0.41	50	175	-14
Comet 1.0	0.79	97	414	-4
Flexity 0.5	0.38	49	375	3
Amistar 1.0	0.26	41	322	-20
Armure 0.8	0.48	63	-	-
Bumper 0.5	0.27	36	95	0
Proline 0.8	0.37	50	378	-12
Folpet 1.5	0.54	125	250	-

Results from two trials carried out in 2014 are given in Table 8 and the summary of the 4 trials from two seasons is included. A summary is also shown in Figure 2. Most treatments gave comparable levels of disease control - in the range of 60-70% control on the 2nd leaf and 80-90% control on the flag leaf. Treatments which included Viverda were slightly superior to other treatments. The reference treatment with 2 x 0.5 Rubric was inferior to most other treatments, which mainly consisted of combinations of treatments. Yield increases in the two trials from 2014 were significantly improved and varied from 13.6 to 21.9 hkg/ha. The combination which included Proline EC 250 followed by the mixture of Armure and Bell improved yields most, but also Proline EC 250 followed by Viverda improved yield very much.

The political goal has been to reduce the pesticide load by 40% by the end of 2015. Specifically for wheat fungicides this means a reduction from 1.67 in the reference period to approximately 1.0 by 2016. By choosing solutions which consist of combinations with a dominance of Proline EC 250, Prosaro and Armure this target could be within reach. However, in control strategies it is still desirable to use solutions which include Viverda or Bell, in particular as they have been seen to improve control levels slightly compared with triazoles used alone and these mixtures are the only means of applying the SDHI fungicide boscalid, which provides an alternative mode of action to the triazoles for control of *Septoria* diseases.

If the choice of fungicides becomes too narrow, it is believed that the risk of developing further resistance to azoles will increase. So it is highly recommended to spray max 3 times with azoles per season and not to use the same azole more than twice per season and preferable only once.

The season 2014 was dominated by severe attack of Septoria leaf blotch.

Table 8. Control of *Septoria* following two applications and yield increases from use of different fungicide combinations for control of diseases in winter wheat. Summary of 2 trials from 2014 (14328) and 4 trials from 2013 and 2014 (13318 & 14328).

Treatments growth stage (GS) and l/ha		Pesticide load/ treatment		% *Septoria*	Yield and yield increase hkg/ha	% *Septoria*	% *Septoria*	Yield and yield increase hkg/ha	Net yield hkg/ha
			2014			Summary of 4 trials from 2013 and 2014			
GS 33-37	GS 55		GS 71-73 leaf 2	GS 75 leaf 1		GS 71- 75 leaf 2	GS 75-77 leaf 1		
1. Rubric 0.5	Rubric 0.5	2.0	60.9	14.9	13.6	36.7	8.2	11.5	6.5
2. Bell 0.75	Proline EC 250 0.4	1.73	49.7	10.9	14.9	29.9	5.7	14.7	8.4
3. Viverda 1.25	Viverda 1.25	3.42	36.5	5.4	20.3	19.8	2.8	18.0	6.3
4. Viverda 0.75	Armure 0.4	1.27	47.0	11.5	16.9	27.5	6.2	13.9	8.4
5. Viverda 0.75	Proline EC 250 0.4	1.22	44.3	9.8	17.0	26.7	5.2	14.5	8.3
6. Viverda 0.75	Osiris Star 0.67	2.13	45.7	6.2	18.6	26.4	3.3	15.2	8.2
7. Proline EC 250 0.4	Viverda 0.75	1.21	48.4	6.2	20.6	28.9	3.3	18.1	11.9
8. Proline EC 250 0.4	Prosaro 0.5	0.46	44.5	6.8	18.3	32.1	4.6	14.0	9.2
9. Proline EC 250 0.4	Armure 0.2 + Bell 0.375	1.09	45.8	5.9	21.9				
10. Bell 0.375 + Proline EC 250 0.2	Proline EC 250 0.4	1.06	46.4	9.3	17.7	28.5	5.2	15.3	9.7
11. Proline EC 250 0.32 + Rubric 0.1	Proline EC 250 0.32 + Rubric 0.1	0.68	43.4	7.2	17.3	29.2	3.9	14.0	9.1
12. Proline EC 250 0.2 + Rubric 0.25	Proline EC 250 0.2 + Rubric 0.25	1.18	48.9	9.4	16.5	28.3	4.9	14.0	9.1
13. Untreated	Untreated	-	87.0	36.9	88.2	69.5	28.8	85.1	-
No. of trials		-	2	2	2	4	4	4	4
LSD_{95}					3.5			3.9	-

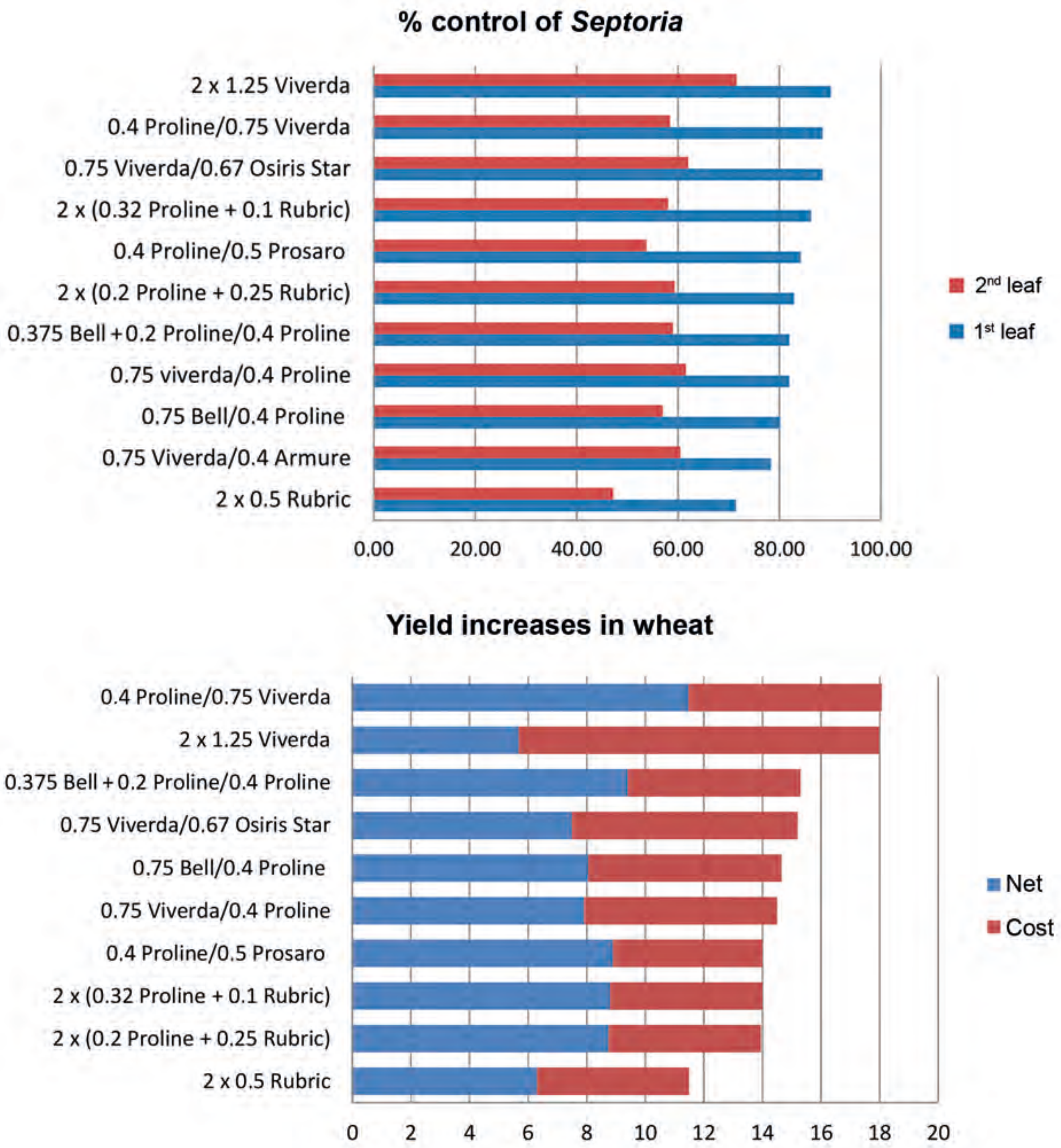


Figure 2. Effect from different treatments with different pesticide loads for control of *Septoria* on the flag leaf and impact on yield. 4 trials from 2013 and 2014.

Changes in sensitivity to triazoles

During several seasons the field performances of azoles have been tested in order to keep a check on possible changes over time. In 2 trials from 2014 (14329) both solo azoles and combinations of azoles in tank mixes or co-formulations have been tested in a two-treatment strategy. The efficacy from the trials have been compared and ranked using a dose rate equivalent to 2 x half rates (Table 10). Treatments were applied at GS 33 and 51-55. Bumper 25 EC and Folicur EW 250 showed as in the previous year that the performance regarding control of *Septoria* was very low (Figures 3 and 4).

Compared with previous years this year's trials showed a reduced control from epoxiconazole compared with previous years' trials. In the previous season the tendency was that epoxiconazole gave better control than prothioconazole, but in 2014 the ranking showed a noticeable difference. The trials represent results from two localities – Flakkebjerg and LMO. Proline EC 250 followed by Armure gave also a good level of control in line with Proline EC 250 applied twice. See Figure 3. The two co-formulations Prosaro EC 250 and Osiris Star (0.67 l/ha) performed very similarly with respect to control. The lower rate of Osiris Star (0.56 l/ha) performed as expected less well compared with the higher rate. Juventus used alone performed in line with the tank mix of 0.25 Maredo + 0.25 Bumper 25 EC. Figure 4 shows the results from trials carried out in 2012 and 2013; here it can be seen that the ranking of azole performances was quite different compared with results obtained in 2014 (Figure 3).

The yield responses from the two trials reflected to some extent the control of *Septoria*; however, a few exceptions were seen. Bumper 25 EC, Folicur EW 250 and Juventus yielded as expected least, at the other end Proline EC 250 and Armure gave the best yield results. The solutions with Rubric and Osiris Star did not differ significantly from each other.

Ten further trials had Proline EC 250 and Opus/Opus Max included as reference products for new testings (Table 9). With the exception of one trial, all these 10 trials showed that Proline EC 250 performed better than Opus or Opus Max on flag leaf control, which were in line with the results from the split treatments with the two products (Figure 7).

Looking at the performance of azoles during a longer time spell, the drop in performance seen in 2014 was quite noticeable (Figure 5). The drop in performance can partly be linked to the high levels of attack seen in 2014, but this can not entirely explain the drop and shift in performances. The drop in efficacy from tebuconazole has been known since about 2000 and has been quite stable (Figure 6). In Figure 7 the graph shows that the performances of prothioconazole and epoxiconazole have changed their ranking. Similarly a drop in performances was seen for mixtures of SDHI and epoxiconazole (Figure 8). The drop in performance for epoxiconazole is worrying and the reason for the change is being investigated; see also chapter V (Fungicide resistance-related investigations). Similar drops in performances have been seen in Ireland and the UK.

Table 9. % attack of *Septoria* in 10 trials from 2014 with application carried out at GS 37-39.

2nd leaf	1	2	3	4	5	6	7	8	9	10	Average
Untreated	38.8	62.5	85.0	83.0	75.0	13.3	60.0	11.8	31.3	33.8	49.45
Proline	6.3	18.8	28.3	40.0	25.5	3.8	32.5	2.3	20.0	5.8	18.33
Opus	10.0	19.3	36.3	49.0	40.0	2.5	28.8	1.5	18.0	11.8	21.72

Flag leaf	1	2	3	4	5	6	7	8	9	10	Average
Untreated	50.0	35.0	34.5	15.0	95.0	15.0	66.6	15.8	51.3	50.0	42.8
Proline	21.3	11.0	5.8	10.0	27.5	4.8	38.8	3.3	28.8	8.8	16.0
Opus	28.8	13.0	10.8	13.0	70.0	6.0	36.3	7.8	32.5	28.8	24.7

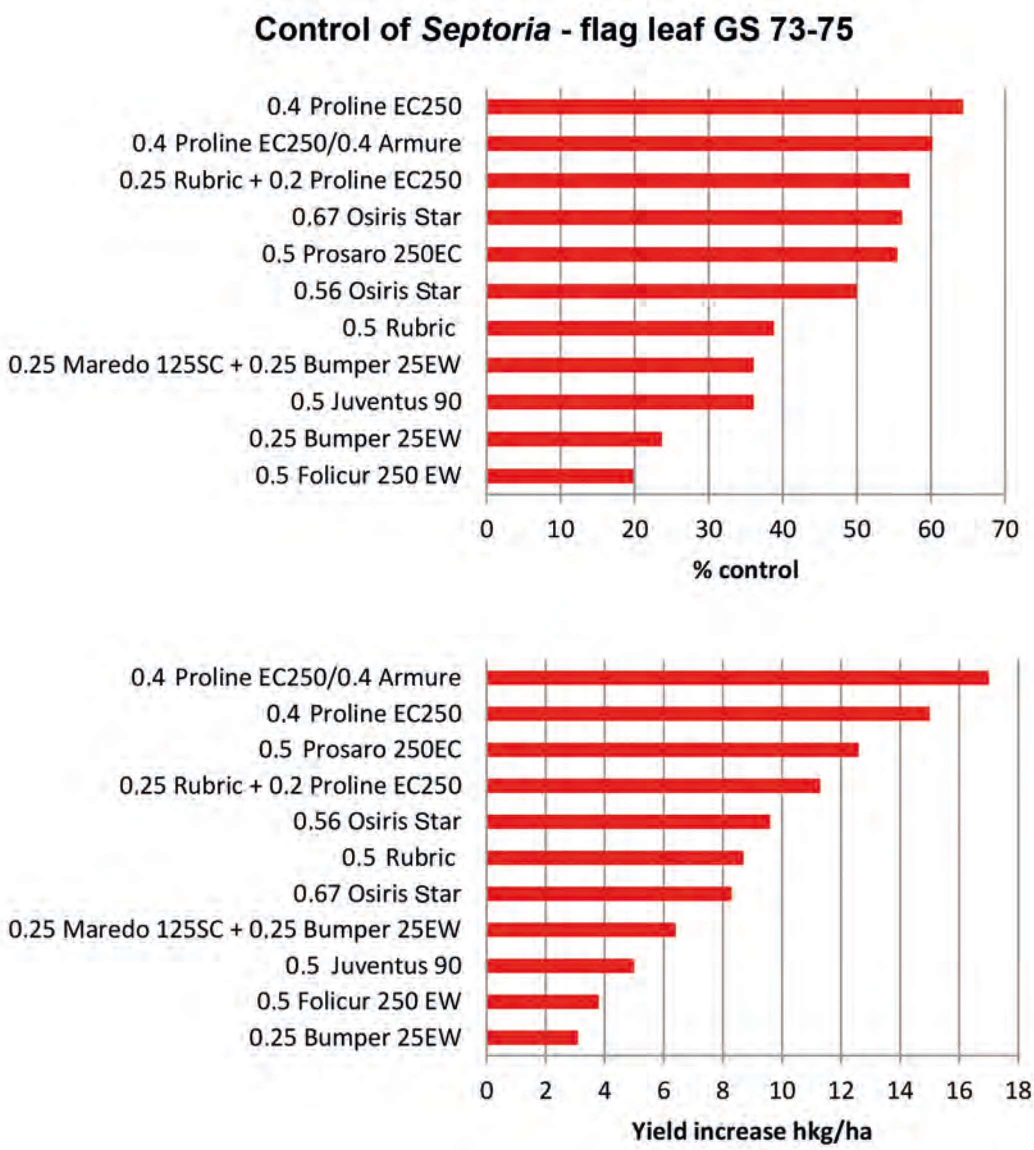


Figure 3. Control of *Septoria* and yield increases from treatments with azoles. Average from 2 trials from 2014 (14329). Untreated with 45% *Septoria* attack on 1st leaf, yield in untreated = 85.5 hkg/ha LSD_{95} = 3.7. Treatments were applied at GS 33 and 51-55.

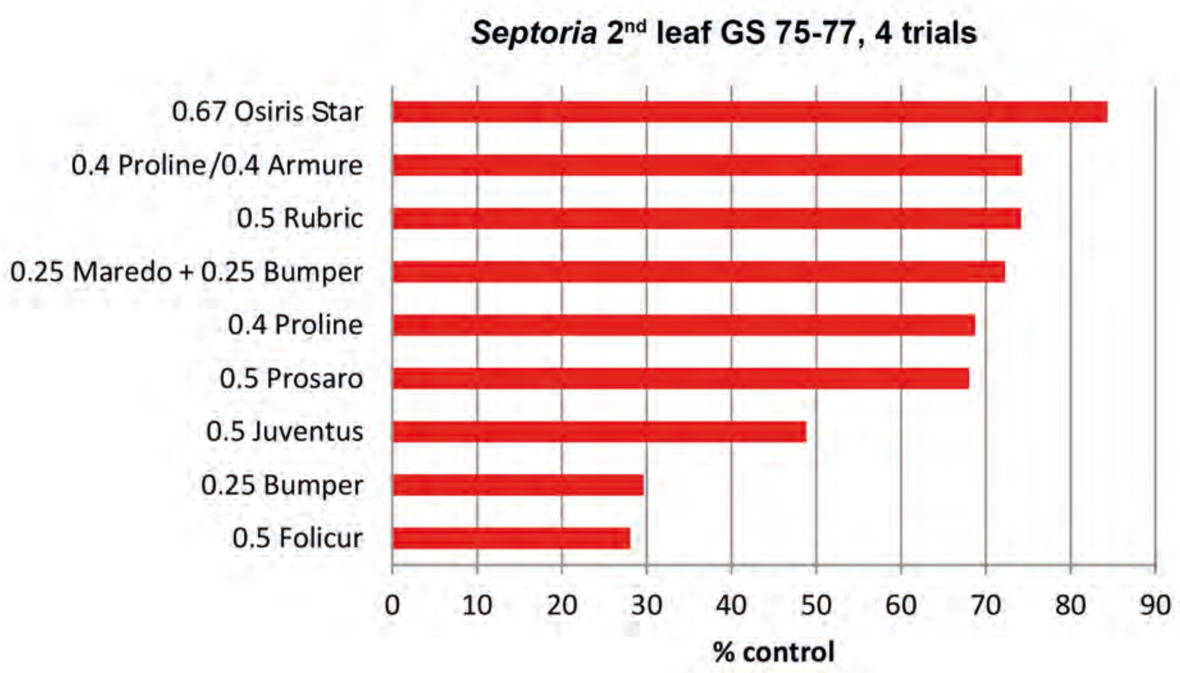


Figure 4. Control of *Septoria* following treatments with different triazoles. Average of 4 trials 2012-2013. Untreated 60% *Septoria* attack. Treatments were applied at GS 33 and 51-55.

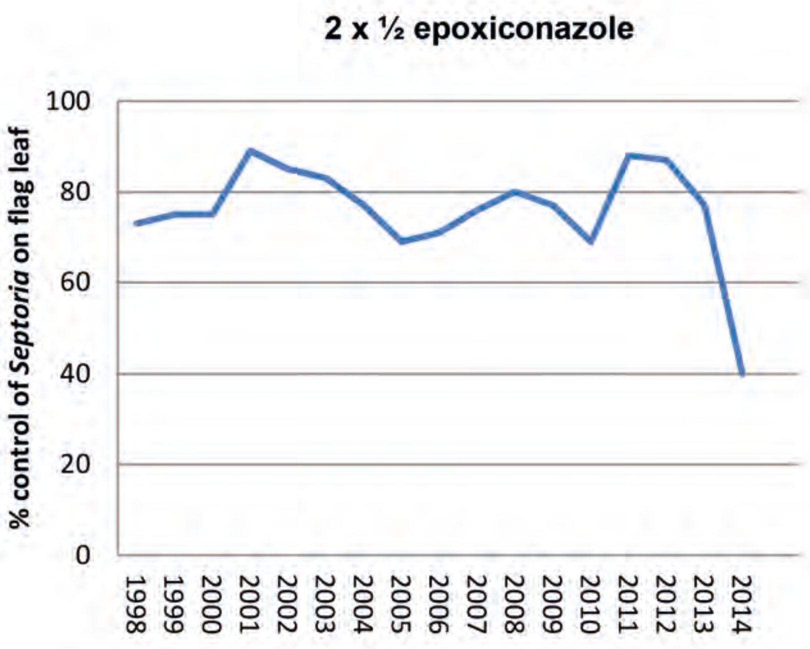


Figure 5. Per cent control of *Septoria* using 2 x half rates of Opus/Rubric. Average of two applications applied at GS 33-37 and 51-55. In the individual year the number of trials varies from 2 to 6 trials.

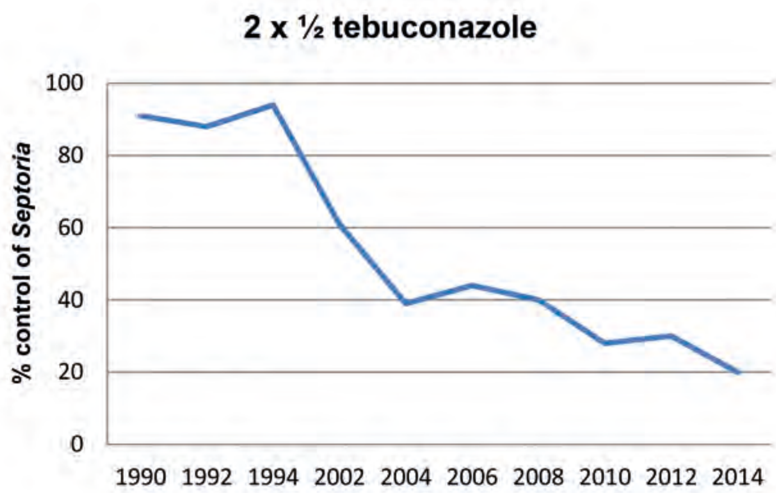


Figure 6. Per cent control of *Septoria* using 2 half rates of Folicur (tebuconazole). Average of two applications applied at GS 33-37 and 51-55. Folicur was not tested in each year.

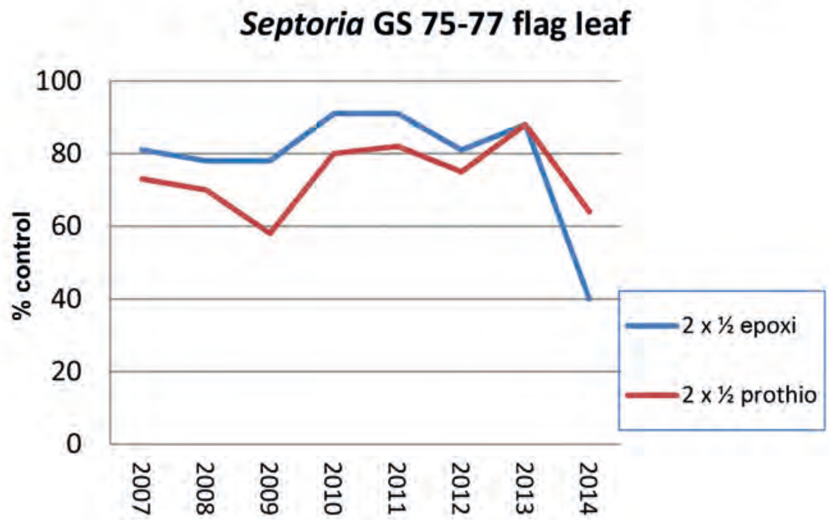


Figure 7. Per cent control of *Septoria* using 2 half rates of Proline and Rubric/Opus. Average of two applications applied at GS 33-37 and 51-55.

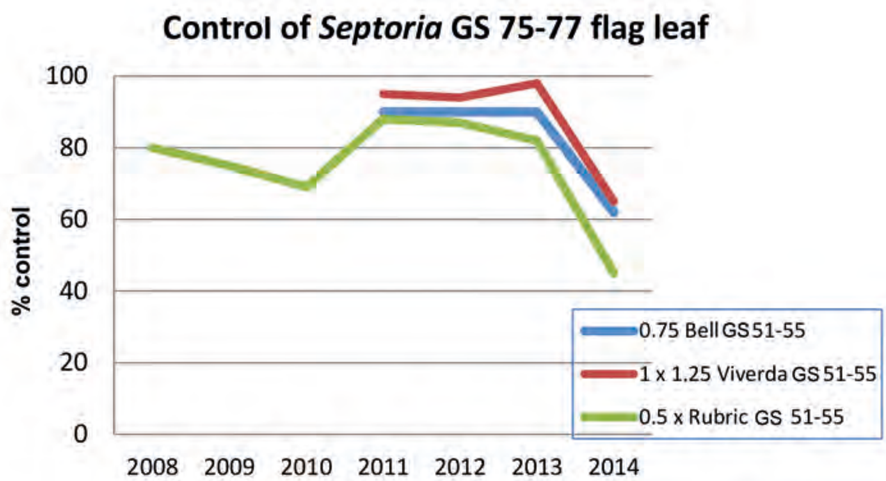
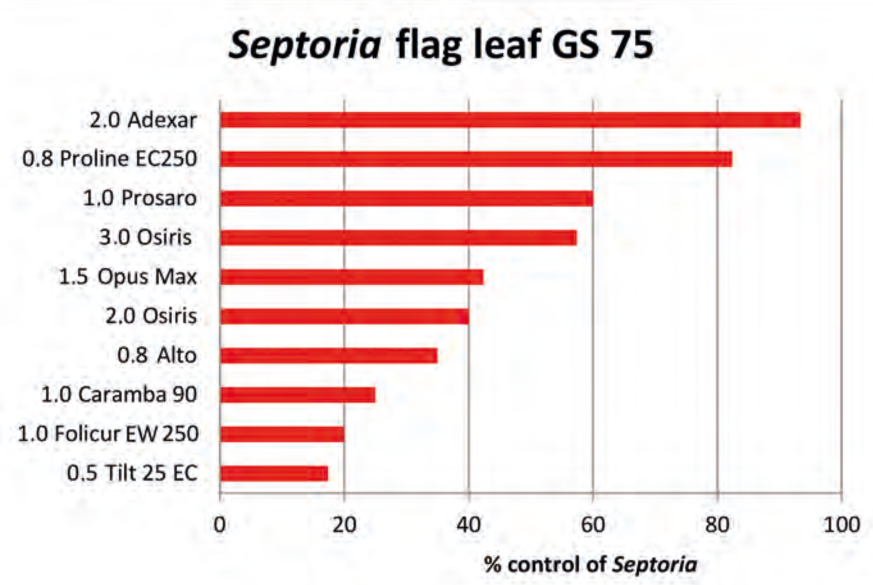


Figure 8. Control of *Septoria* with solutions including SDHI.

Table 10. Effects of triazoles on *Septoria* and yield responses following 2 applications in wheat. 2 trials (14329).

Treatments and l/ha		% *Septoria*			% GLA	Yield and in-crease hkg/ha	Net yield hkg/ha
GS 33	GS 51-55	GS 39 F3	GS 73-75 F2	GS 73-77 F1	GS 77 F1		
1. Rubric 0.5	Rubric 0.5	9.1	45	9.5	24	8.7	3.8
2. Proline EC 250 0.4	Proline EC 250 0.4	8.8	33,8	12.3	21	15.0	10.1
3. Juventus 90 0.5	Juventus 90 0.5	8.5	48.1	10.8	19	5.0	0.6
4. Bumper 25 EC 0.25	Bumper 25 EC 0.25	9.5	63.8	12.3	16	3.1	0.9
5. Folicur 250 EW 0.5	Folicur 250 EW 0.5	13.5	64.4	14.3	15	3.8	0.7
6. Proline EC 250 0.4	Armure 300 EC 0.4	7.5	36.3	10.0	24	17.0	-
7. Prosaro EC 250 0.5	Prosaro 0.5	7.0	36.3	9.5	22	12.6	7.8
8. Osiris Star 0.67	Osiris Star 0.67	8.4	37.5	7.8	24	8.3	3.3
9. Osiris Star 0.56	Osiris Star 0.56	8.9	39.4	8.3	25	9.6	5.2
10. Maredo + Bumper 0.25 + 0.25	Maredo + Bumper 0.25 + 0.25	8.3	52.5	9.5	22	6.4	2.3
11. Rubric + Proline 250EC 0.25 + 0.2	Rubric + Proline EC 250 0.25 + 0.2	8.2	40.6	10.5	22	11.3	6.4
10. Untreated	Untreated	13.9	75.6	25.0	12	-	-
No. of trials		2	2	2	2	2	2
LSD_{95}						3.7	-

One further trial (14321) was carried out using different triazole solutions. This trial showed to a great extent the same responses as 14329. Treatments in this trial were applied at GS 37-39 in the cultivar Hereford, which was seen as very susceptible. This trial also included a few other products as well as higher dose rates (Figure 9). Adexar (epoxiconazole + fluxapyroxad) was also included and clearly gave the best control. Green leaf area was assessed in the trial at the last assessment and these data reflected both the level of *Septoria* control but also a very high correlation with the yield increases harvested in the trial.



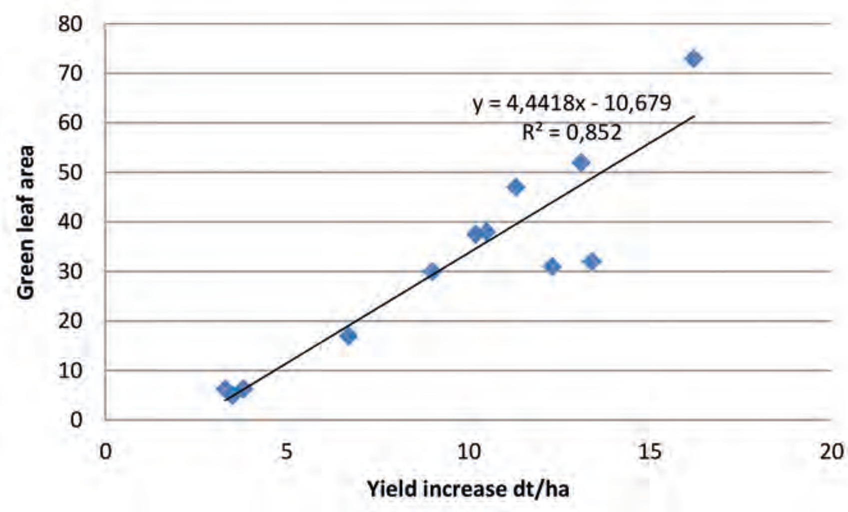


Figure 9. Per cent control of *Septoria* on the flag leaf from treatments with different azoles applied at GS 37-39. Results from 1 trial from 2014 (14321). Untreated had 50% *Septoria* attack on the 1st leaf assessed at GS 75. The lower figure shows data from the same trial, in which per cent green leaf area correlated well with the harvest yield increases.

Summarising effects of reference products

In different trial series Opus, Proline EC 250 and Comet were used as reference products. These trials showed that Opus and Proline EC 250 provided significant control of both *Septoria* and yellow rust (Tables 11 and 12). Opus provided approximately 50% control of *Septoria* and Proline EC 250 60-65% control. As expected, Comet provided very low control of *Septoria* due to the high level of strobilurin resistance. Compared with Opus Proline EC 250 was clearly inferior with respect to control of yellow rust. Comet provided control of yellow rust in line with the effect seen from Proline EC 250.

Table 11. Results from 5 trials comparing 2 azoles applied at GS 37-39.

Treatments GS 37-39	% *Septoria* GS 75 leaf 2	% *Septoria* GS 75-77 leaf 1	% yellow rust GS 65-71 leaf 2	% yellow rust GS 65-71 leaf 1	Yield and yield increases hkg/ha	Net increase hkg/ha
Untreated	78.5	40.6	22.6	22.6	96.8	-
Opus 1.0	35.8	18.9	0.2	0.8	+14.0	9.4
Proline EC 250 0.8	29.5	14.6	0.5	3.2	+17.1	12.7
Proline EC 250 0.4	48.8	29.6	1.0	4.4	+10.8	8.3
No. of trials	5	5	2	2	5	
LSD_{95}					2.6	

Table 12. Results from 5 trials comparing 2 azoles and the strobilurin Comet applied at GS 37-39.

Treatments GS 37-39	% *Septoria* GS 75 leaf 2	% *Septoria* GS 75-77 leaf 1	% yellow rust GS 65-71 leaf 2	% yellow rust GS 65-71 leaf 1	Yield and yield increases hkg/ha	Net increase hkg/ha
Untreated	59.6	30.7	8.6	17.9	87.7	-
Opus 1.0	30.6	14.5	0.2	1.0	12.0	7.4
Proline EC 250 0.8	30.5	11.4	0.8	5.8	15.6	11.3
Comet 1.0	46.8 (4)	22.8 (4)	0.7 (2)	6.0 (2)	3.8 (4)	-0.8
No. of trials	5	5	3	3	5	
LSD_{95}					4.3	

Comparison of available solutions for ear treatments

In line with trials from previous years treatments with different fungicides were tested when applied during heading (GS 51-55) (Table 13). A cover spray was applied at GS 32 using a low dose of Ceando (0.375 l/ha). This year the ear application was late seen in relation to the disease epidemic, which started very early and which gave a high risk of *Septoria* development at the time of 2^{nd} leaf emergence. This resulted in generally very low levels of *Septoria* control on the 2^{nd} leaf.

Yield increases in all 3 single trials were significant although LSD values were quite high, indicating variability in the trials partly following a fast ripening. The best yield increases gave approximately 10 hkg/ha in increase and were measured from solutions like 0.375 Bell + 0.2 Proline EC 250, 1.0 Folpan + 0.2 Proline EC 250, 0.4 Proline EC 250, 0.4 Armure or 0.75 Viverda (Figure 10). Ceando (0.375) used at the early timing as a single treatment provided an insufficient control but did still contribute approx. 4 hkg/ha to the yield increases. The best net yield result was obtained from Bell + Proline EC 250, Proline EC 250 and Armure. The highest rate of Viverda suffers from too high a cost, which leads to a low net return. In Figure 11 results from 3 years' trials have been summarised, and the ranking of the solutions is clear. Again Viverda and Bell + Proline EC 250 have given the best result.

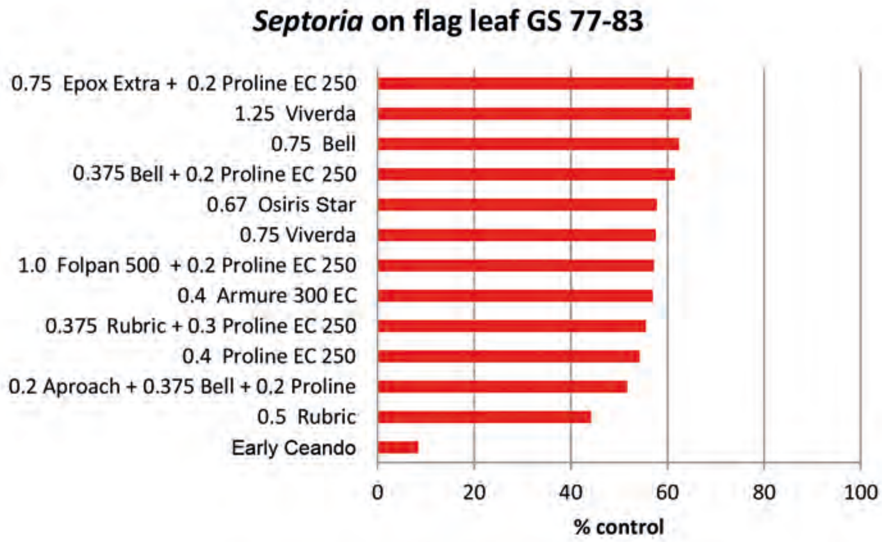
Untreated - Hereford.

0.8 Proline EC 250 applied at GS 39.

2.0 Adexar applied at GS 39.

Table 13. Effect of ear applications for control of *Septoria* in wheat. 3 trials (14325) and summary of 9 trials from 3 seasons.

Treatments and l/ha		Results from 2014				Results from 2012-2014			
		% *Septoria*		% GLA	Yield and yield increase	% *Septoria*		Yield and yield increase	Net yield hkg/ha
GS 31-32	GS.51-55	GS 73 leaf 2	GS 75 leaf 1	GS 75 leaf 2	hkg/ha	GS 77 leaf 1	GS 77 leaf 2	hkg/ha	
1. Ceando 0.375	Rubric 0.5	69.6	46.3	6.0	8.5	17.9	36.9	10.1	5.4
2. Ceando 0.375	Proline 250EC 0.4	66.3	38.0	6.7	11.3	15.6	36.0	11.8	7.2
3. Ceando 0.375	Bell 0.75	62.5	31.2	10.1	10.0	11.8	32.2	11.6	5.5
4. Ceando 0.375	Osiris Star 0.67	63.3	35.0	12.5	9.7	13.0	34.8	12.1	6.6
5. Ceando 0.375	Armure 300 EC 0.4	65.4	35.7	7.5	10.9	15.3	37.4	11.7	7.3
6. Ceando 0.375	Viverda 0.75	65.0	35.2	11.6	8.2				
7. Ceando 0.375	Viverda 1.25	57.1	29.1	14.5	10.8	10.2	27.6	15.3	7.3
8. Ceando 0.375	Rubric + Proline EC 250 0.25 + 0.2	64.2	36.9	6.5	8.9	14.5	33.0	11.6	7.0
9. Ceando 0.375	Bell + Proline EC 250 0.375 + 0.2	65.8	31.9	8.6	11.8	14.0	37.9	13.6	8.3
10. Ceando 0.375	Folpan + Proline EC 250 1.0 + 0.2	67.1	35.5	4.0	11.4				
11. Ceando 0.375	Epox Extra + Proline EC 250 0.75 + 0.2	64.2	28.7	8.5	8.8				
12. Ceando 0.375	Aproach + Bell + Proline 0.2 + 0.5 + 0.2	65.8	40.1	8.6	10.7				
13. Ceando 0.375	Untreated	78.8	76.0	0.5	4.3	29.4	43.9	7.9	5.7
14. Untreated	Untreated	80.0	83.0	1.0	0.0	43.9	66.0	84.1	-
No. of trials		3	3	3	3	9	9	9	9
LSD_{95}					2.7			3.6	-



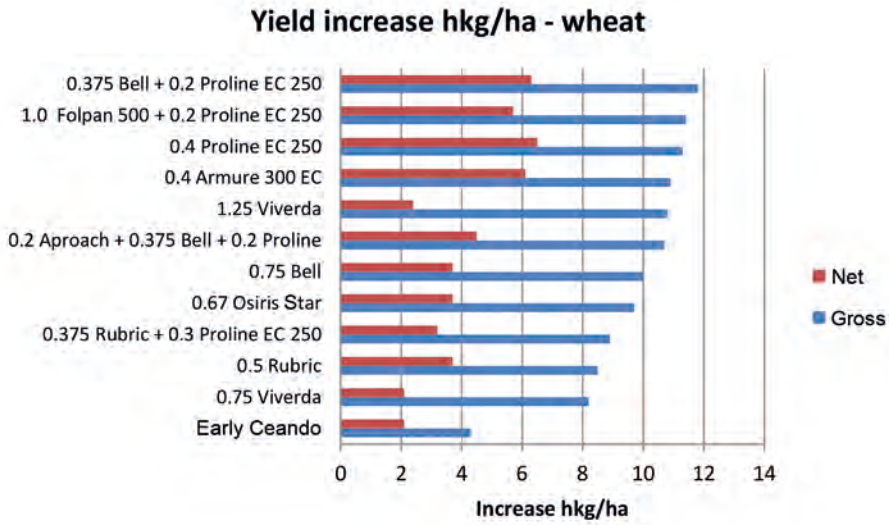


Figure 10. Control of *Septoria* and yield increases from treatments with different ear treatments. Average from 3 trials carried out in 2014 (14325). Untreated with 83% *Septoria* attack on 1st leaf, yield in untreated = 90.6 hkg/ha LSD_{95} = 2.7.

SDHIs

Denmark has so far only approved one SDHI – boscalid. However, several of the newer ones have been tested over the years. In Denmark in previous years, Adexar gave control and yield responses similar to Viverda. Imtrex (fluxapyroxad) was tested in 2014 and compared with Proline EC 250 in one trial for its preventive and curative effects. Imtrex was seen to be much more curative than Proline EC 250 – as shown in Figure 12. The trial was artificially inoculated with *Septoria* at GS 37-39 and treatments were applied 5 and 9 days after inoculation. The curative effect of Proline EC 250 was reduced significantly when applications were delayed by 4 days, whereas this was not the case for Imtrex. These effects were also reflected in the yields harvested from the trial as seen in Figure 12.

Five trials included among other treatments a comparison of Proline EC 250, Comet and Aviator Xpro (a mixture of a bixafen (SDHI) + prothioconazole). Aviator Xpro proved to be superior in control of both *Septoria* and yellow rust and also gave the best yield increase (Table 14).

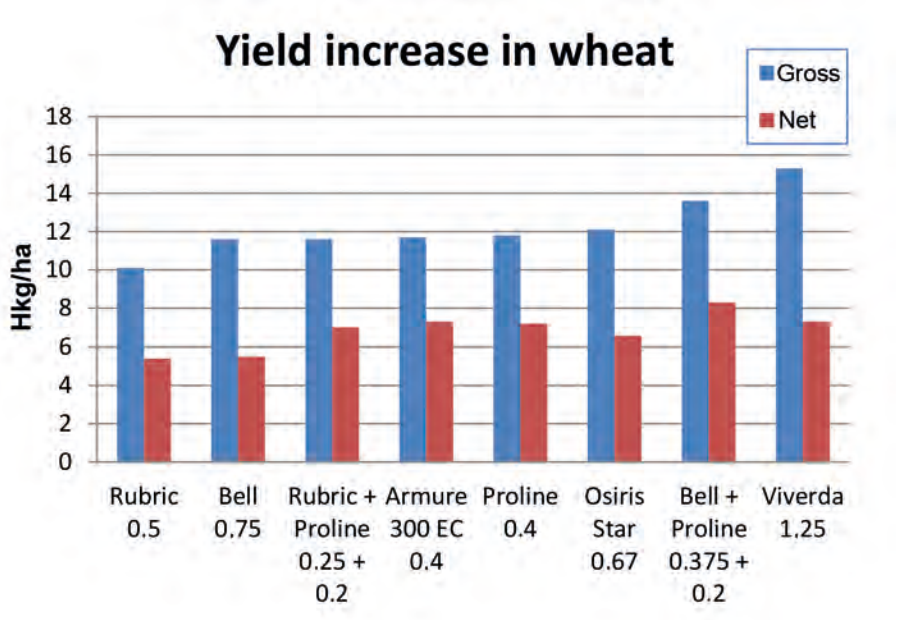


Figure 11. Yield increases from different ear treatments for control of *Septoria* applied at GS 51-55. Average of 9 trials (12325, 13325, 14325). LSD_{95}= 3.6.

Table 14. Results from 5 trials comparing azoles, strobilurins and the mixture product Aviator Xpro.

Products	GS 32 & 45	% *Septoria* GS 75 leaf 1	% *Septoria* GS 75 leaf 2	% yellow rust GS 75 leaf 2	Yield and yield increases hkg/ha
Proline 250 EC	2 x 0.8	7.6	20.6	2.5	+17.3
Comet 200	2 x 1.0	40.5	69.8	13.4	+2.9
Aviator XPro	2 x 1.25	3.4	7.5	0.7	+20.6
Untreated		46.0	70.8	34.8	83.8

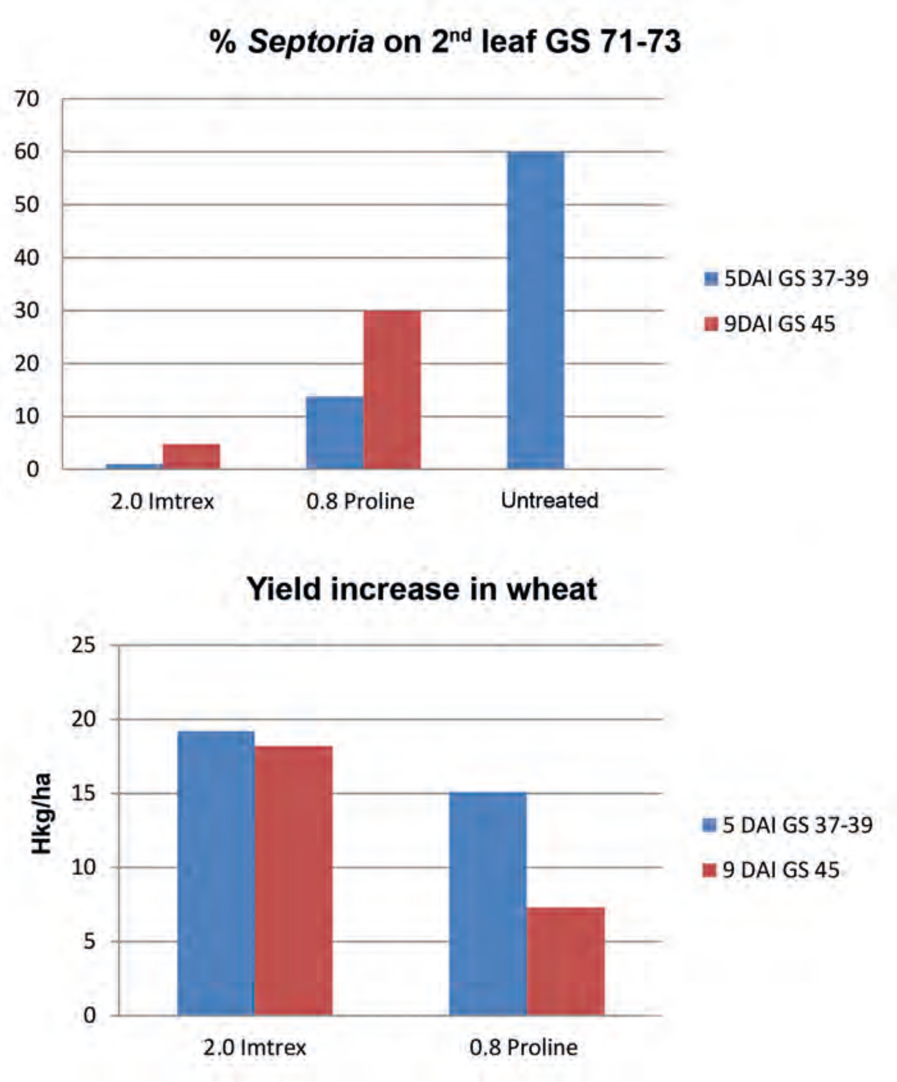


Figure 12. Per cent attack of *Septoria* following artificial inoculation with *Septoria* at GS 37 and applications 5 and 9 days later with Proline EC 250 and Imtrex. 1 trial (14356).

Benefit from use of strobilurins

Comet

Despite high levels of strobilurin resistance in the *Septoria* population, slight benefits from adding Comet to standard products have still been seen over the years. In two trials from 2014 and 1 trial from 2013 the benefits from adding Comet to Ceando/Bell were investigated (Table 15). Three different timings were tested and in 2014 double applications of Comet were also tested using two rates (0.15 and 0.3 l/ha). Both in 2013 and again in 2014 a clear benefit was seen from adding Comet (Figure 13). In 2013 the best responses in control were seen from the treatment at GS 37-39 and in 2014 the best responses were seen at the two early timings (GS 32 and GS 37-39). The trial from 2013 showed both an improved control and a significant yield benefit from adding Comet. The two trials from 2014 showed a similar positive response.

Table 15. Control of *Septoria* and yield increases from different treatments in wheat with and without adding of the strobilurin Comet. 3 trials (13382-1, 14327).

Treatments l/ha			% *Septoria* 2014		% *Septoria* 2013+2014	Yield and increases 2014	Yield and increases 2013+2014	Net increases hkg/ha
GS 31-32	GS 37-39	GS 59-61	GS 73 leaf 1	GS 73 leaf 2	GS 75 leaf 1		hkg/ha	
1. Untreated	Untreated	Untreated	25.7	86.9	61.7	83.1	80.1	-
2. Ceando 0.3	Bell 0.5	Bell 0.5	12.5	61.3	31.3	14.5	13.8	6.3
3. Ceando 0.3 + Comet 0.3	Bell 0.5	Bell 0.5	11.3	47.5	32.0	19.3	19.4	10.7
4. Ceando 0.3	Bell 0.5 + Comet 0.3	Bell 0.5	9.0	48.8	28.8	19.3	19.1	10.6
5. Ceando 0.3	Bell 0.5	Bell 0.5 + Comet 0.3	13.4	55.7	28.8	16.9	17.9	8.2
6. Ceando 0.3 + Comet 0.3	Bell 0.5 + Comet 0.3	Bell 0.5	9.3	42.6	-	22.9	-	13.0
7. Ceando 0.3 + Comet 0.15	Bell 0.5 + Comet 0.15	Bell 0.5	11.0	45.1	-	19.7	-	11.0
No. of trials			2	2	3	2	3	3
LSD_{95}						4.6	3.6	

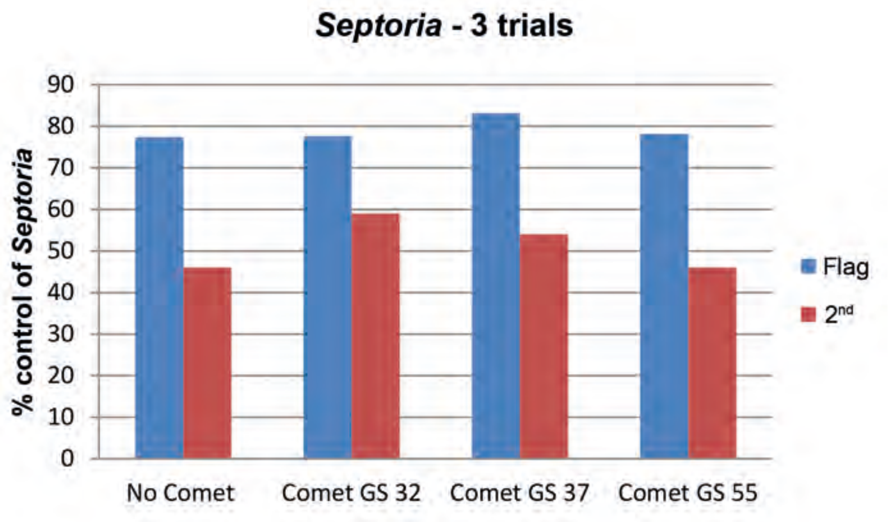
Acanto/Aproach

In one trial Aproach/Acanto was applied in a two-spray strategy using either Acanto alone or Acanto as a mixing partner for Proline EC 250, Prosaro EC 250 or Bell. In this trial Acanto used alone had very little effect on *Septoria* as a result of high levels of strobilurin resistance (Table 16). A very limited dose response could be seen for both *Septoria* control and yields when the dose of Acanto was increased from 0.25 to 1.0 l/ha. Adding Acanto to azoles did not lift the level of *Septoria* control compared with using Proline EC 250 alone at two half rates (Treatment 9). In this trial the mixture of Acanto + Prosaro EC 250 gave the best control, but only still in line with using 2 x 0.4 l/ha Proline EC 250.

Acanto used alone did not significantly increase the yield nor did the sequence of Proline EC 250 followed by Acanto. All other treatments improved yields significantly.

2 x 1.0 l Folpan followed by 0.375 Bell.

2 x (0.375 Bell + 1.0 Folpan) followed by 0.375 Bell.



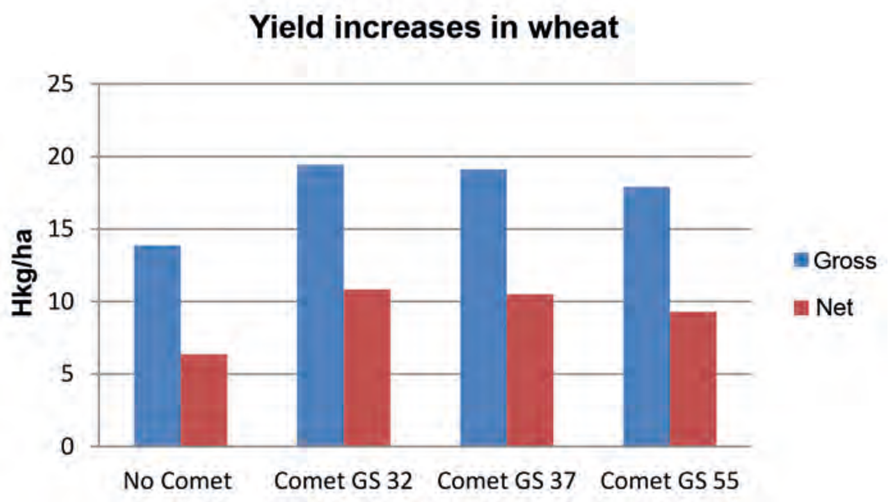


Figure 13. Control of *Septoria* and yield increases from treatments with and without Comet added at different timings. Standard treatment was 0.3 l Ceando (GS 32), 0.5 l Bell (GS 37-39) and 0.5 l Bell (GS 59-61). Average from 3 trials carried out in 2013 and 2014 (13382 + 14327). Yield LSD_{95} = 3.6.

Table 16. Effects of Acanto on *Septoria* and yield responses following 2 applications in wheat. 1 trial (14358).

Treatments and l/ha		% *Septoria*			% GLA	Yield and increase hkg/ha	Net yield hkg/ha
GS 32-33	GS 51-55	GS 47 F4	GS 73 F2	GS 77 F1	GS 77 F1		
1. Acanto 0.25	Acanto 0.25	9.0	5.0	20.0	60	1.7	-1.3
2 Acanto 0.5	Acanto 0.5	11.5	3.5	26.3	63	2.2	-2.5
3. Acanto 1.0	.Acanto 1.0	8.75	2.8	22.5	64	3.1	-4.9
4. Acanto + Proline 0.25 + 0.4	Acanto + Proline 0.25 + 0.4	7.75	1.1	8.3	79	7.5	0.9
5. Acanto + Prosaro 0.25 + 0.5	Acanto + Prosaro 0.25 + 0.5	7.0	1.3	5.0	75	4.9	-1.6
6. Acanto + Bell 0.25 + 0.4	Acanto + Bell 0.25 + 0.4	4.0	2.3	5.3	89	8.6	2.2
7. Acanto + Tilt 250 EC 0.25 + 0.4	Acanto + Proline 0.25 + 0.4	6.0	1.9	6.5	79	4.0	-1.5
8. Proline 0.4	Acanto 0.5	5.5	3.0	13.8	70	2.1	-2.7
9. Proline 0.4	Proline 0.4	1.9	1.3	9.0	79	9.7	4.8
10. Untreated	Untreated	23.8	8.5	45	47	96.3	-
LSD_{95}			1.3			3.9	-

Effects from the use of Folpan

Folpan was authorised for use in cereals in Denmark in 2014. The product has been tested in several trials and shown moderate control of *Septoria*. The main argument behind recommending Folpan is to minimise the risk of developing resistance to more specific fungicides like azoles or SDHIs.

In 2014 Folpan was tested as an input being part of a control strategy using 3 timings. Adding Folpan to a standard programme mixed with Bell or Proline EC 250 increased the level of control noticeably compared to using azoles alone. However, using Folpan alone as the first or as both first and second treatments provided inferior control compared with using azol-based solutions. Folpan was slightly better compared with using Dithane (mancozeb). All treatments increased yield positively and significantly. Although a visual benefit could be seen from adding Folpan, this did not reflect in higher yield increases from the tank mixes. Using either Folpan or Dithane alone at the two early timings gave inferior yield responses compared with treatments in which azoles were included at all timings (Figure 14).

Table 17. Control of *Septoria* and yield increases from different treatments in wheat in which Folpan was part of the control strategy. 2 trials (14332).

Treatments l/ha			% *Septoria*			% GLA	Yield and increases hkg/ha	Net increases hkg/ha
GS 31-32	GS 37-39	GS 59-61	GS 65 leaf 2	GS 75 leaf 2	GS 77 leaf 1	GS 75/77 leaf 1		
1. Bell 0.375	Bell 0.375	Bell 0.375	6.5	33	5.3	30.5	15.0	8.2
2. Bell 0.375	Proline 0.2	Bell 0.375	6.1	41	6.8	27.9	13.1	7.0
3. Proline 0.2	Bell 0.375	Proline 0.2	7.4	45	7.9	20.5	9.9	4.5
4. Folpan 1.0	Bell 0.375	Bell 0.375	7.9	41	6	29.4	8.7	1.9
5. Folpan 1.0	Folpan 1.0	Bell 0.375	10.5	46	6.4	30.1	7.2	0.4
6. Dithane 1.0	Dithane 1,0	Bell 0.375	11.4	51	6.8	17.5	5.1	-1.0
7. Folpan + Proline 1.0 + 0.2	Folpan + Proline 1.0 + 0.2	Bell 0.375	5.0	28	4.4	37.6	11.0	2.4
8. Folpan + Bell 1.0 + 0.375	Folpan + Bell 1.0 + 0.375	Bell 0.375	4.9	23	4.8	39.4	14.7	7.7
9. Bell	Aproach + Bell 0.2 + 0.375	Bell 0.375	6.0	35	5.4	34.6	12.9	5.4
10.Untreated	Untreated	Untreated	22.3	76	27.9	1.4	87.3	-
No. of trials			2	2	2	2	2	2
LSD_{95}						7.5	3.3	-

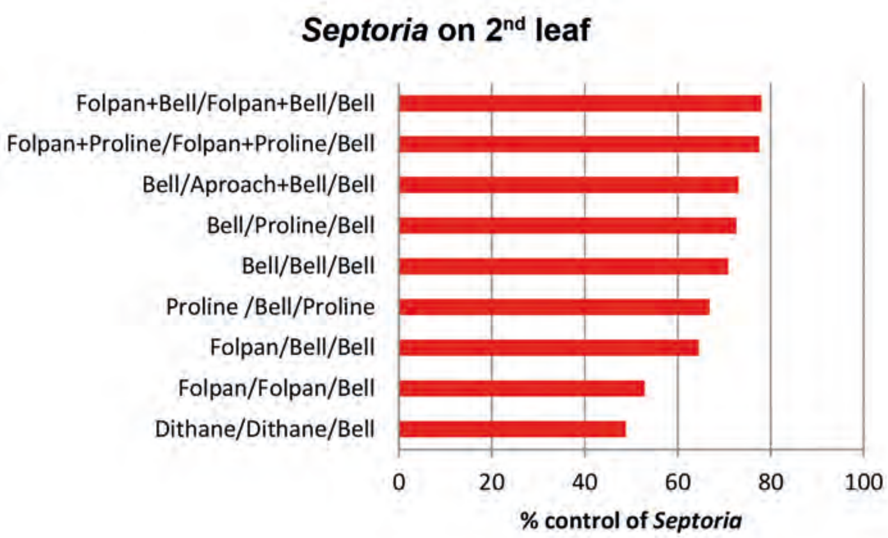


Figure 14. Per cent control of *Septoria* applied at GS 31-32, 37-39 and 51-55. Average of 2 trials (14332). For dose rates – see Table 17.

Adding Ultimate S to Viverda

In 2013 problems with sedimentation and nozzle blocking were experienced in some cases when Viverda was used. This gave rise to an investigation in order to try understanding what caused the problem. Water quality factors like pH and Ca+ content were investigated, but no clear answers were found to be the main cause for the sedimentations occurring in some random cases. For the 2014 season the company recommended that Viverda should be mixed with the spray solution stabiliser Ultimate S, which was believed to remove the risk of sedimentation. Two trials were carried out to investigate if mixing Viverda + Ultimate S would have any effect on the performance of the product. Results are shown in Table 18. The results from the two trials show that adding Ultimate S did not have any negative effect on the performance of Viverda; if anything, a slight improvement was seen both for control of *Septoria* and yield responses. The dose of Ultimate S was recommeded as 1:1.

Table 18. Control of *Septoria* and yield increases from a three-spray programme in wheat with and without adding Ultimate S to Viverda. 2 trials (14322).

Treatments l/ha			% *Septoria*			Yield and increases hkg/ha	Net increases hkg/ha
GS 31-32	GS 37-39	GS 59-61	GS 65 leaf 2	GS 77 leaf 2	GS77 leaf 1		
1. Untreated	Untreated	Untreated	30.4	57.5	52.3	87.0	-
2. Ceando 0.3	Viverda 0.75	Viverda 0.75	13.3	23.5	44.6	15.6	6.2
3. Ceando 0.3	Viverda+Ultimate S 0.75 + 0.75	Viverda+Ultimate S 0.75 + 0.75	13.7	22.4	42.1	18.2	-
LSD_{95}						4.1	

Effect of timing

In a project financed by Miljøstyrelsen (Danish EPA) new models for control of *Septoria* are being developed and tested. The decision support system Crop Protection Online (CPO) has for many years been recommending treatments for control of *Septoria*, based on days with precipitation. Treatments are recommended if 4 days with rain (> 1 mm) have occurred starting at GS 32. If the programme has recommended a treatment, the crop is seen as protected for 10 days before a new risk period is initiated. A new model based on leaf wetness and periods with high relative humidity is being investigated as an alternative to the existing model along with a growth model. In order to test the new models, trials are carried out at Flakkebjerg as well as the National Field Trials. Two cultivars (Mariboss and Hereford) were used for the testing and 4 different timings were included (Table 19, Figure 15). The new models did not release applications and need further adjustments and also CPO gave inferior yield results compared with standard treatments using 3 applications. CPO recommended only two treatments and in the season 2014; three applications were found to be needed. The trials will continue in 2015.

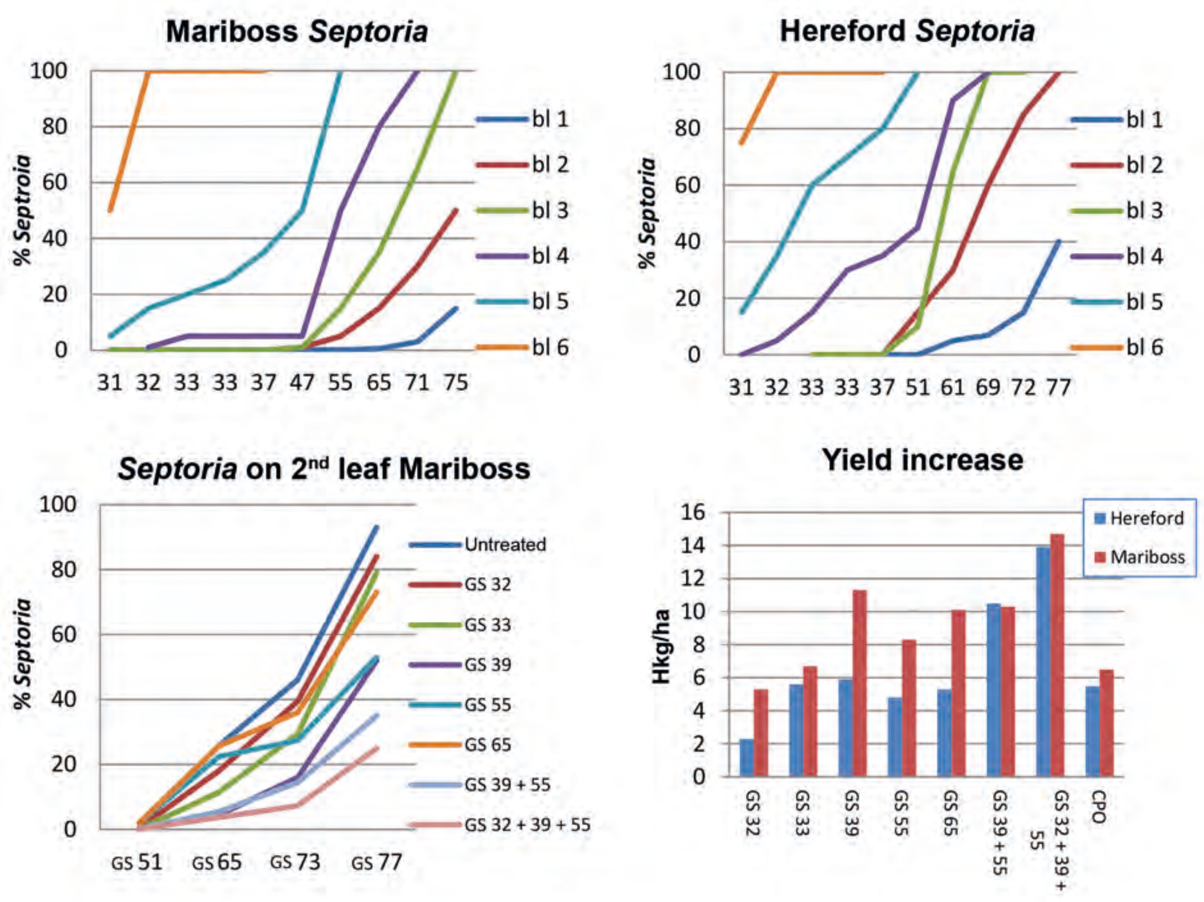


Figure 15. Development of *Septoria* at specific leaf layers in the two cultivars assessed at weekly intervals. The attack in Hereford was at all assessments more advanced than the attack in Mariboss. Disease development following different treatments is shown at the bottom left. The treatments with just a single timing all gave insufficient control. Only double and triple treatments gave significant control. At the bottom right the yield increases from treatments are shown for the two cultivars.

Table 19. Control of *Septoria* and yield increases from different timings in wheat (14300).

Treatments l/ha					% *Septoria*				Yield and yield increase	
GS 30-31	GS 32-33	GS 37-39	GS 45-51	GS 61	GS 65 leaf 2	GS 65 leaf 2	GS 77 leaf 1	GS 77 leaf 1	hkg/ha	hkg/ha
Untreated					Mariboss	Hereford	Mariboss	Hereford	Mariboss	Hereford
1. Bell 05					18.0	32.2	60.1	83.6	8.3	5.3
2	Bell 0.5				11.4	27.2	55.0	70.0	9.7	8.8
3		Bell 0.5			4.4	25.5	43.5	66.6	14.3	8.9
4			Bell 0.5		22.4	42.2	25.1	36.7	11.3	7.8
5				Bell 0.5	25.7	48.9	21.8	40.0	13.1	8.3
6.		Bell 0.5	Bell 0.5		5.4	22.2	15.1	30.0	16.3	16.5
7. Bell 0.5		Bell 0.5	Bell 0.5		3.7	10.6	15.0	16.7	23.7	22.9
8. Model SIM					-	-	-	-	-	-
9. PVO					7.3	25.6	21.8	36.7	12.5	11.7
10. Untreated					25.7	50.5	65.0	93.3	78.7	85.2
LSD_{95}					7.8	7.8	9.8	9.8	6.0	6.0

Measurements from a climate station are included in a project financed by the Danish Environmental Protection Agency for optimisation of the timing of spraying against *Septoria*.

5. Results from fungicide trials in spring barley

In 3 trials in spring barley different fungicide solutions using half dose rates were compared for control of specific diseases. Results from the 3 trials are shown in Table 20. The trial placed in the cultivar Milford developed a severe attack of powdery mildew (*Blumeria graminis*), one trial developed a minor attack of net blotch (*Pyrenophora teres*), two trials had minor attacks of brown rust (*Puccinia hordei*) and two trials developed Ramularia leaf spot (*Ramularia collo-cygni*). As shown in Table 20 most of the tested solutions provided very similar and good control of all assessed diseases.

The attack of Ramularia leaf spot developed relatively late and slight differences were seen between solutions. Good control on Ramularia leaf spot was obtained from several products – least control was obtained from a mixture of Comet with Proline EC 250 or of Aproach with Proline EC 250. Yield responses were very low in this year's trials and treatments were not significantly different from untreated.

Table 20. Disease control using different fungicides at GS 33-37 and 45-51. 3 trials 2014 (14343).

Treatment l/ha	% barley rust	% mildew	% net blotch	% *Ramularia*	Yield and yield increases hkg/ha	Net yield hkg/ha
GS 33-37 & 45-51	GS 75	GS 73	GS 73-75	GS 75		
1. Proline Xpert 0.5	0	0.1	0.1	0.2	1.0	-1.6
2. Prosaro + Comet 0.35 + 0.15	0	0.1	0.1	0.8	1.9	-0.6
3. Bell + Comet 0.375 + 0.25	0	0.5	0.1	0.3	0.5	-2.8
4. Viverda 1.25	0	0.1	0.1	0.1	0.4	-5.5
5. Viverda 0.75	0	0.2	0.1	0.5	3.1	-0.7
6. Comet + Proline 0.25 + 0.2	0	0.1	0.1	1.8	-0.7	-3.3
7. Aproach + Proline 0.25 + 0.2	0	0.1	0.1	1.9	0.5	-1.9
8. Folpan + Proline 1.0 + 0.2	0	0.9	0.4	0.5	0.1	-3.1
9. Untreated	2.4	18.8	3.2	7.4	65.5	-
No. of trials	2	1	3	2	3	3
LSD_{95}	0.6	2.4	2.9	-	2.8	-

Results from trials carried out over several years have been summarised and show that many solutions provide quite similar yield responses (Table 22).

2 trials were carried out using Opus, Proline EC 250 and Comet as reference products (Table 21). The 2 trials showed very good control of all leaf diseases, the only exception being Comet against *Ramularia*, for which strobilurin resistance is known to be widespread. Despite the lower performance from Comet on this disease this product still gave the best yield responses.

Table 21. Yield increases from control of diseases in spring barley with treatments applied at GS 37-39. Average across different years. The dose of Bell + Comet has varied across years between 0.37 + 0.25 and 0.5 + 0.175.

Treatments		Yield increases hkg/ha					
GS 37-39	l/ha	2011-14	2010+11+12	2011+13	2011+12	2012+13	2013-2014
1. Osiris / Osiris Star	1.0 / 0.67			2.7			
2. Bell	0.75		5.6		5.9		
3. Bell + Comet	0.375 + 0.25	3.7	5.2	3.6	5.0		2.0
4. Proline + Comet	0.2 + 0.25	3.5		3.6	5.2	6.0	1.9
5. Viverda	1.25	4.8		4.6	6.5	8.0	3.3
6. Viverda	0.75						5.1
7. Aproach + Proline	0.25+0.2						2.4
8. Proline + Rubric	0.2 + 0.25					6.4	
9. Proline	0.4				3.2		
No. of trials		12	9	6	6	6	6
LSD_{95}		1.9	1.4	1.9	2.3	2.3	1.9

Table 22. Control of leaf diseases in spring barley in 2 trials from 2014 (14342). 1 application at GS 33-37.

Treatment l/ha	% barley rust	% net blotch	% *Ramularia*	% GLA	Yield and yield increases hkg/ha	Net yield hkg/ha
GS 33-37	GS 75	GS 73-75	GS 75	GS 75-77		
1. Untreated	1.6	5.0	6.0	38	73.9	-
2. Opus 1.0	0	0.3	0	94	5.3	0.7
3. Proline 0.8	0	0.3	0	90	5.8	1.5
4. Comet 1.0	0	0.1	3.5	48	11.1	6.5
No. of trials	2	1	2	1	2	2
LSD_{95}	0.4	1.0	1.6	7.8	4.5	-

Severe attack of mildew on barley.

Flexity (metrafenon)

One trial was carried out in the cultivar Milford known for its susceptibility to powdery mildew (Table 23). 3 dose rates of Flexity were tested with the aim of providing support for the re-registration of the product. The attack developed moderately, and good control was achieved from all tested dose rates of Flexity. Similar positive effects were seen from Ceando and Talius. As a curiosity Coca-Cola (5%) was applied to evaluate the efficacy against mildew. Moderate but still significant control was obtained from this product at the early assessments. However, the effect from Coca-Cola was clearly inferior to the effect from more traditional fungicides. No significant yield responses were harvested from the trial, and no impact on quality parameters was measured either.

Table 23. Control of powdery mildew using different concentrations of Flexity applied at GS 30-31. 1 trial 2014 (14341).

Treatment l/ha	% mildew	% mildew	% mildew	% *Ramularia*	Yield and yield increases hkg/ha
GS 30-31 / GS 37-39	GS 51	GS 59	GS 73	GS 83	
1. Untreated / 0.5 Bell	3.0	4.5	5.0	2.5	67.5
2. 0.5 Flexity / 0.5 Bell	0.0	0.1	0.0	0.8	1.2
3. 0.33 Flexity / 0.5 Bell	0.0	0.0	0.0	0.4	-0.8
4. 0.5 Flexity / 0.5 Bell	0.0	0.3	0.0	0.8	-4.6
5. 0.25 Talius / 0.5 Bell	0.0	0.0	0.0	1.8	0.2
6. 0.75 Ceando / 0.5 Bell	0.0	0.0	0.0	0.8	0.6
7. Coca Cola / 0.5 Bell	1.6	3.0	2	1.8	-0.2
LSD_{95}	0.8	0.9	0.5	1.3	ns

Acanto/Aproach

One trial was carried out in the cultivar Quench known for its susceptibility to most barley leaf diseases including brown rust and Ramularia leaf spot. Two dose rates of Acanto alone as well as Acanto in combination with different other fungicides were tested with the aim of providing support for the re-registration of the product (Table 24). The attack of Ramularia leaf spot developed moderately and good control was achieved from all treatments using mixtures of products. Only Acanto applied alone gave poor control as a result of high levels of strobilurin resistance. However, the control of both net blotch and *Rhynchosporium* was good from all treatments, again with a tendency to better control from treatments with more actives. Significant yield responses were harvested from most treatments, but no significant impact on quality parameters was measured.

Table 24. Disease control using different combinations of Acanto applied at GS 33-37. 1 trial 2014 (14346).

Treatment l/ha	% barley rust	% net blotch	% *Ramularia*	% *Ramularia*	% *Rhyncho-sporium*	Yield and yield increases hkg/ha	Net yield hkg/ha
GS 33-37	GS 73	GS 83	GS 73-75	GS 75	GS 83		
1. Acanto 0.25	0.0	0.6	4.8	7.5	0.8	2.4	0.9
2. Acanto 0.5	0.1	0.1	3.5	9.0	0.8	8.8	6.5
3. Acanta 0.25 + Bumper 0.4	0.1	0.4	3.6	8.3	1.3	9.3	7.1
4. Acanto 0.25 + Proline EC 250 0.4	0.1	0.6	0.6	6.5	0.0	11.6	8.3
5. Acanto 0.25 + Prosaro EC 250 0.4	0.0	0.0	0.3	3.3	0.0	7.4	4.5
6. Acanto 0.25 + Bell 0.75	0.0	0.0	0.3	2.0	0.5	11.5	6.8
7. Proline EC 250 0.4	0.3	2.0	1.3	2.5	0.0	9.2	6.7
Untreated	0.2	6.0	6.0	15.0	2.8	55.0	-
LSD_{95}	0.3	2.8	2.1	5.1	2.1	5.6	-

6. Results from fungicide trials in winter barley

In 2014 three trials in winter barley were carried out, testing different combinations of fungicide solutions against specific diseases which were applied at GS 37-39 using half rates, which has typically been seen as economically optimal solutions. Results from the 3 trials are shown i Table 25. The trials in 2014 were dominated by *Rhynchosporium* (*Rhynchosporim commune*) and net blotch (*Pyrenophora teres*) and late in the season attack of Ramularia leaf spot (*Ramularia collo-cygni*). As shown in Table 25 and Figure 16 most of the tested solutions provided very similar and good control of all assessed diseases.

All treatments gave good control of mildew. With the exception of Prosaro EC 250 and the mixture Folpan + Proline EC 250 all treatments gave good control of net blotch. All treatments gave similar control of *Rhynchosporium* although the higher rate of Viverda was seen to give a slight advantage. With the exception of Aproach + Prosaro all gave similar reduction in the late developing attack of Ramularia leaf spot. Yield increases varied between 3.4 and 8.5 hkg/ha. Treatments which combined azoles and strobilurin generally performed best but very few treatments varied significantly from each other.

Table 25. Control of diseases and yield in winter barley. Average of 3 trials from 14335. The trial was treated at GS 39.

Treatments l/ha	% *Rhyncho-sporium*	% net blotch	% mildew	% *Ramularia*	% green leaves	Yield and increases hkg/ha	Net yield hkg/ha
GS 39	GS 65-71 Leaf 2-3	GS 71 Leaf 1-2	GS 65 Leaf 4-5	GS 77 + 83 Leaf 1-2	GS 81-83 Leaf 1-2		
1. Proline EC 250 0.4	3.7	0.4	0.0	37.5	22.0	4.9	2.4
2. Bell 0.375 + Comet 0.25	3.8	0.2	0.0	30.8	25.0	7.5	4.2
3. Viverda 0.75	3.3	0.2	0.0	27.5	27.0	8.5	4.7
4. Viverda 1.25	2.3	0.1	0.0	23.3	28.0	7.0	1.1
5. Prosaro 0.5	3.6	2.0	0.0	34.2	25.0	5.1	2.7
6. Aproach 0.2 + Bell 0.5	4.4	0.1	0.0	28.3	25.	7.7	4.2
7. Aproach 0.2 + Prosaro 0.5	2.4	0.4	0.0	43.3	25.0	7.2	4.1
8. Proline Xpert 0.5	4.3	0.3	0.0	26.7	22.0	6.7	4.1
9. Proline 0.2 + Folpan 1.0	4.1	2.8	0.0	25.8	27.0	3.4	0.2
10. Untreated	11.2	11.3	1.7	49.2	15.0	76.5	-
No. of trials	2	1	1	2	2	3	3
LSD_{95}		1.7	0.3	5.3	18.1	3.7	-

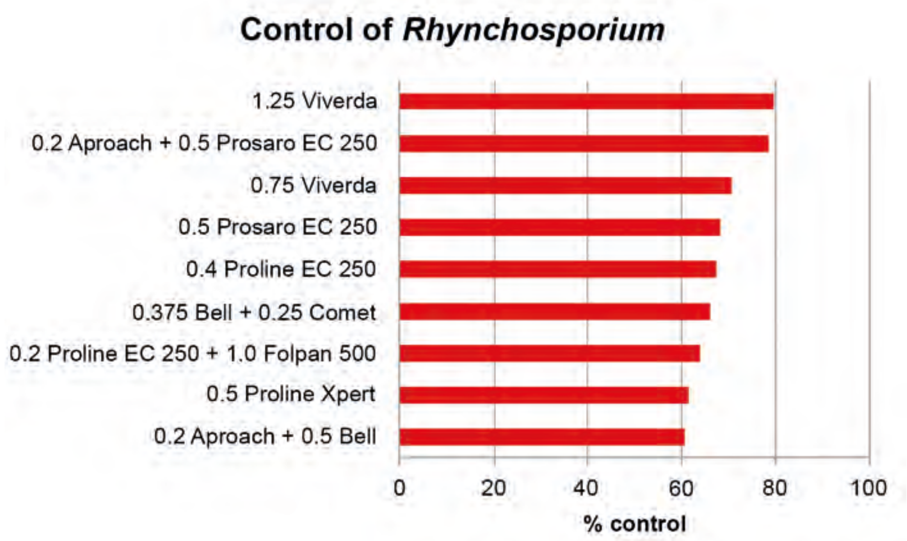


Figure 16. Control of *Rhynchosporium* in winter barley. 2 trials from 2014 treated at GS 37-39.

In Table 26 data from different years are summarised showing responses from control at GS 37-39.

Five trials were carried out using Opus, Proline EC 250 and Comet as reference products. The 5 trials showed very good control of all leaf diseases, the only exception again being inferior control from Comet for control of *Ramularia* (Table 27). Strobilurin resistance is known to be widespread. Proline EC 250 gave slightly better control of all diseases and also the best yield increases.

Table 26. Yield increases from disease control in winter barley using treatments at GS 37-39. Averages from different years.

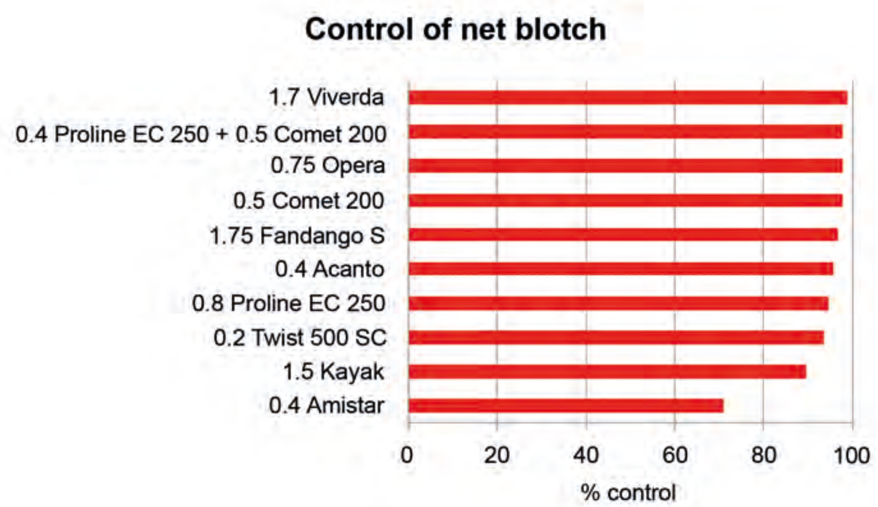
Treatments GS 37-39	l/ha	Yield increases hkg/ha				
		2012+2013	2010+2011	2011+2013	2013-2014	2010-2014
1. Osiris / Osiris Star	1.0 / 0.67	-	6.3	4.2	4.3	-
2. Bell + Comet	0.375 + 0.25	7.9	7.2	6.4	7.4	7.5
3. Viverda	1.25	11.6	-	7.9	8.6	-
4. Viverda	0.75				8.2	
5. Prosaro	0.5	5.8	6.5	5.4	5.8	6.0
6. Proline	0.4				5.0	
7. Proline + Rubric	0.2 + 0.25	3.9	-	-	3.2	-
8. Aproach + Bell	0.2 + 0.5	-	7.1	-	8.1	-
No. of trials		5	6	6	6	14
LSD_{95}		2.8	2.4	2.7	3.0	1.4

Net blotch control

One trial was carried out testing the effect of different products on net blotch using both azoles and strobilurins. The choice was to compare 40% dose rates of strobilurins in various combinations against net blotch (Figure 17). The trial developed a moderate attack of net blotch and all with the exception of Amistar gave very similar control. The trial also developed a significant attack of Ramularia leaf spot at the end of the season, and for control of this disease a clear difference between performances from products was seen (Figure 17). As expected, strobilurins used alone only provided low levels of control.

Table 27. Control of leaf diseases in winter barley in 5 trials from 2014 (14336, 14337, 14334). 1 application at GS 33-37.

Treatment l/ha	% mildew	% net blotch	% *Ramularia*	% *Rhyncho-sporium*	Yield and yield increases hkg/ha	Net yield hkg/ha
GS. 33-37	GS 71-75 Leaf 1-2	GS 75-81 Leaf 1-2	GS 75-81 Leaf 2-3	GS 65-71 Leaf 2-3		
1. Untreated	4.3	5.8	21.2	7.7	79.1	-
2. Opus 1.0	0.2	0.7	10.2	3.8	4.2	-0.4
3. Proline EC 250 0.8	0	0.5	7.9	2.6	8.0	3.7
4. Comet 1.0	0.4	0.3	18.2	3.1	6.5	1.9
No. of trials	3	2	5	4	5	5.0
LSD_{95}	-	-	-	-	3.3	-



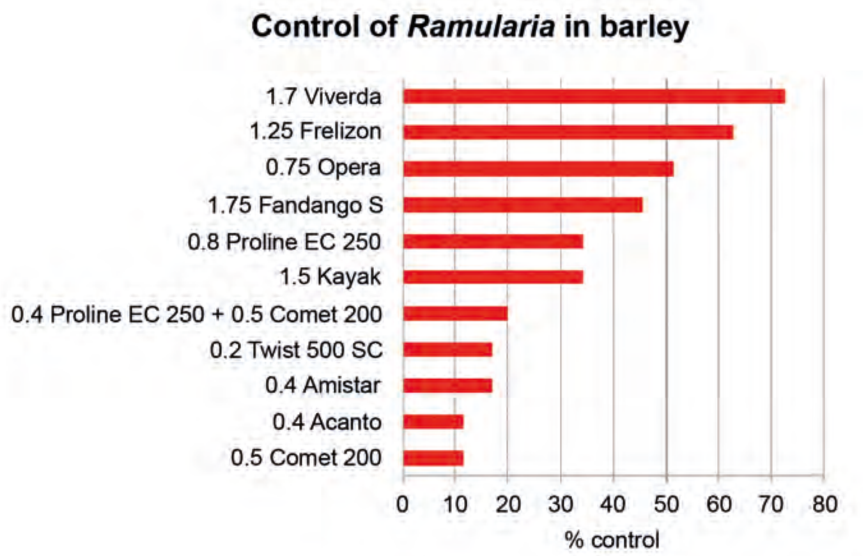


Figure 17. Control of net blotch and Ramularia leaf spot from different fungicides applied at GS 37-39. One trial 2014 (14338).

Table 28. Control of diseases and yield in winter barley. Average of 2 trials (14339). The trial was treated at GS 39.

Treatments l/ha GS 39 (Treatment 2-11)		% net blotch GS 75 Leaf 2-3	% net blotch GS 81 Leaf 2	% *Rhyncho-sporium* GS 61 Leaf 3	% *Ramu-laria* GS 81-83 Leaf 1-3	Yield and increases hkg/ha	Net yield hkg/ha	% strobe resist-ance F129L	% SDHI resistance
1.	0.2 Proline (GS 30-31) 0.25 Comet + 0.2 Proline (GS 45-51)	0.2	0.2	4.5	10.5	7.7	3.6		
2.	0.5 Bumper	3.5	6.3	5.3	28.3	2.8	1.2	-	-
3.	0.75 Viverda	0.3	0.9	4.0	13.9	9.1	5.3	-	-
4.	0.35 Aproach + 0.375 Bell	0.3	0.6	4.0	16.6	10.6	7.2	-	-
5.	0.375 Bell + 0.375 Comet	0.2	1.1	4.5	17.6	9.5	5.8	-	-
6.	1.0 Imtrex + 0.5 Comet	0.1	0.3	4.3	11.1	11.6	-	76	0
7.	1.0 Imtrex	0.6	1.5	3.1	10.8	10.5	-	59	23
8.	0.4 Proline EC 250 + 0.5 Comet	0.2	0.9	4.6	23.0	12.0	7.6	88	0
9.	0.5 Siltra	0.4	0.9	4.3	15.5	9.3	-	70	0
10.	0.5 Siltra + 0.5 Comet	0.2	0.8	3.3	12.3	10.2	-	92	0
11.	0.4 Proline EC 250	2.8	3.3	5.0	22.0	10.2	7.7	65	0
12.	Untreated	11.3	8.8	9.5	33.5	78.9	-	63	10
No. of trials		1	1	1	2	2	2		
LSD_{95}		1.2	1.6	2.6	-	4.6	4.6	-	-

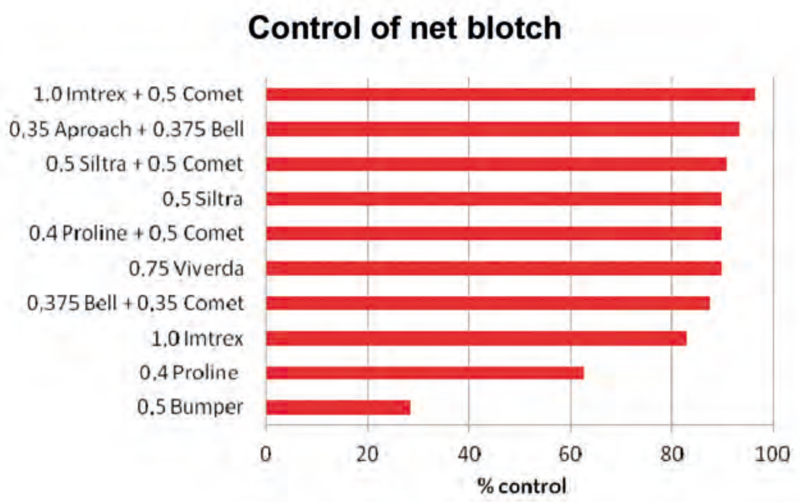


Figure 18. Control of net blotch in one trial with different control strategies, investigating the impact on Strobilurin resistance and SDHI resistance (14339).

Resistance to net blotch

Two trials were carried out as a part of a Norbarag trial (Table 28), testing the effect of different products on net blotch, using azoles, SDHI fungicides and strobilurins. A total of 6 trials were carried out in the Norbarag region. The choice was to compare field performances and then screen for resistance to both strobilruins and SDHI. Only one of the two Danish trials developed a significant attack of net blotch. With the exception of Bumper 25 EC and Proline EC 250 most other treatments gave very good control. The performances from Imtrex notoriously known to be good on net blotch were slightly lower compared with other treatments.

All leaf samples from Flakkebjerg analysed by BASF for resistance showed significant levels of F129 L mutations from all treatments investigated, and for the first time two samples also showed signs of the SDHI mutation C-G79F, which is known to significantly reduce the effect of SDHI. As it is known for azoles and also for the strobilurin mutation F129L, the impact from C-G79F has a variable impact on the performances of different SDHI products. It is too early to say if the control of net blotch from Imtrex has been specificly linked to the finding of C-G79F. Data from the strobilurin resistance monitoring for F129L are shown in Figure 19 and as it can be seen the level of resistance has been relatively stable over the years. F129L is known to be a mutation which only partly influences the field performances of strobilurins.

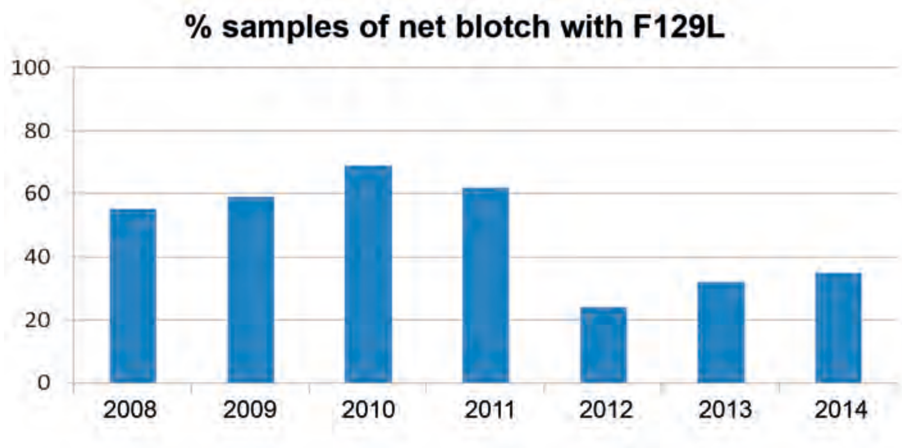


Figure 19. During seven seasons Danish samples with net blotch have been tested for F129L mutations, with help from the chemical companies. Between 16 and 44 samples have been investigated per year. The level seems to be relatively consistent and has not increased as it previously was seen for strobilurin resistance to for example *Septoria*.

Moderate to severe attacks of Ramularia leaf spot developed in both winter barley and spring barley trials in 2014. This disease is in recent years seen as one of the most common leaf diseases.

Acanto/Aproach

One trial was carried out in the cultivar California known for its susceptibility to most barley leaf diseases. Three dose rates of Acanto alone as well as Acanto in combination with different other fungicides were tested with the aim of providing support for the re-registration of the product (Table 29). The attacks of *Rhynchosporium* and Ramularia leaf spot developed moderately. Acanto used alone as well as in combinations gave good control of *Rhynchosporium*. Similarly, all combination treatments gave good control of Ramularia leaf spot. Only Acanto applied alone gave poor control as a result of high levels of strobilurin resistance. Powdery mildew and brown rust was well controlled from all treatments. Significant yield responses were harvested from most treatments but no significant impact on quality parameters was measured although a higher moisture content was measured from the best treatments as a result of the canopy being kept green slightly longer due to less disease.

Table 29. Disease control using different combinations of Acanto applied twice at GS 31-32 and GS 45-51. 1 trial in 2014 (14340).

Treatment l/ha		% brown rust	% *Rhyncho-sporium*	% *Rhyncho-sporium*	% *Rhyncho-sporium*	% *Ramularia*	Yield and yield increases hkg/ha	Net yield hkg/ha
GS 33-37 & 45-51		GS 75 Leaf 2-3	GS 61 Leaf 2	GS 71 Leaf 2	GS 75 Leaf 1-2	GS 75 Leaf 2		
1.	2 x Acanto 0.25	0.1	4.3	2.8	1.3	14.0	3.8	0.8
2.	2 x Acanto 0.5	0.2	2.3	1.8	1.1	12.8	2.4	-2.3
3.	2 x Acanto 1.0	0.1	3.0	2.5	0.5	13.0	4.5	-3.5
4.	2 x Acanto 0.25 + Bell 0.75	0.1	1.3	1.0	0.4	1.5	4.3	-5.1
5.	2 x Acanto 0.25 + Proline EC 250 0.4	0.1	0.1	0.7	0.3	4.8	7.3	0.7
6.	2 x Acanto 0.25 + Prosaro EC 250 0.5	0.1	0.9	1.0	0.5	3.8	5.4	-3.0
7.	Acanto 0.25 + Proline EC 250 0.4/ Acanto 0.25 + Armure 300 EC 0.4	0.2	0.1	1.0	0.7	2.4	3.6	-2.3
8.	Proline EC 250 0.4 / Acanto 0.5	0.1	0.6	2.0	4.5	6.3	6.4	1.6
9.	2 x Proline EC 250 0.4	0.4	1.8	0.9	0.9	3.8	6.2	1.3
10.	Untreated	2.0	7.3	5.8	5.0	17.0	81.6	-
LSD_{95}		0.6	1.7	1.2	0.8	5.4	3.7	3.7

7. Cultivar susceptibility to Fusarium head blight, tan spot and ergot

The Department of Agroecology, Aarhus University, Flakkebjerg has in line with previous years in a project partly financed by the breeders investigated the susceptibility to Fusarium head blight and tan spot of the most commonly grown cultivars in Denmark. In this year's trials 23 cultivars were included. Two parallel trials were conducted, one with inoculum being added during flowering and one with inoculum being added to the soil surface during elongation.

Trial with inoculation during flowering. Two rows of 1 metre were drilled in the autumn per cultivar and four replicates were included. The trial was inoculated 4 times (9 June, 11 June, 14 June and 17 June) using a spore solution consisting of both *Fusarium culmorum* and *Fusarium graminearum*. To stimulate the development of the disease, the trial was irrigated by a mist irrigation system 2 times per day. Wheat is most susceptible during flowering and at the time of inoculation the degree of flowering was assessed to ensure that all cultivars were inoculated during flowering. Approximately 14 days after inoculation the first symptoms of Fusarium head blight were seen.

Trial with inoculum placed at the soil. In this part of the trial grain with attack of *Fusarium* prepared in the lab was placed on the soil together with debris from maize. To stimulate the development of the disease, the trial was irrigated by a mist irrigation system 2 times per day. The attack in this part of the trial is normally less severe compared with attack in the other trial. But this trial is regarded as the best for estimation of the risk of development of mycotoxins.

Both trials were assessed counting the attack on 100 ears per cultivar per replicate. Also the degree of attack was scored as an average of the ears attacked. Results are shown in Figure 20 and Table 31.

In Table 30 the ranking of cultivars to *Fusarium* susceptibily is summarised, including also data from previous years.

The small plots were hand harvested, and grains were investigated from both trials; samples were ground and investigated for content of the mycotoxins – deoxynivalenol (DON), nivalenol (NIV), zealenone (ZEA), HT-2 and T-2. The content of nivalenol, zearalenol, HT2 and T-2 was very low in the trials and therefore not included in the table. Toxins were measured in both trials, and as it is commonly seen the levels were higher in the trials which were inoculated by spore suspensions. Very few samples were below the 1250 ppm maximum limit given for grain for human consumption. Even the most resistant cultivar Skalmeje exceeded the limits. A correlation between per cent attack assessed in the trials and the measured content of DON showed a moderate link with a R^2 value of 0.45 (Figure 21).

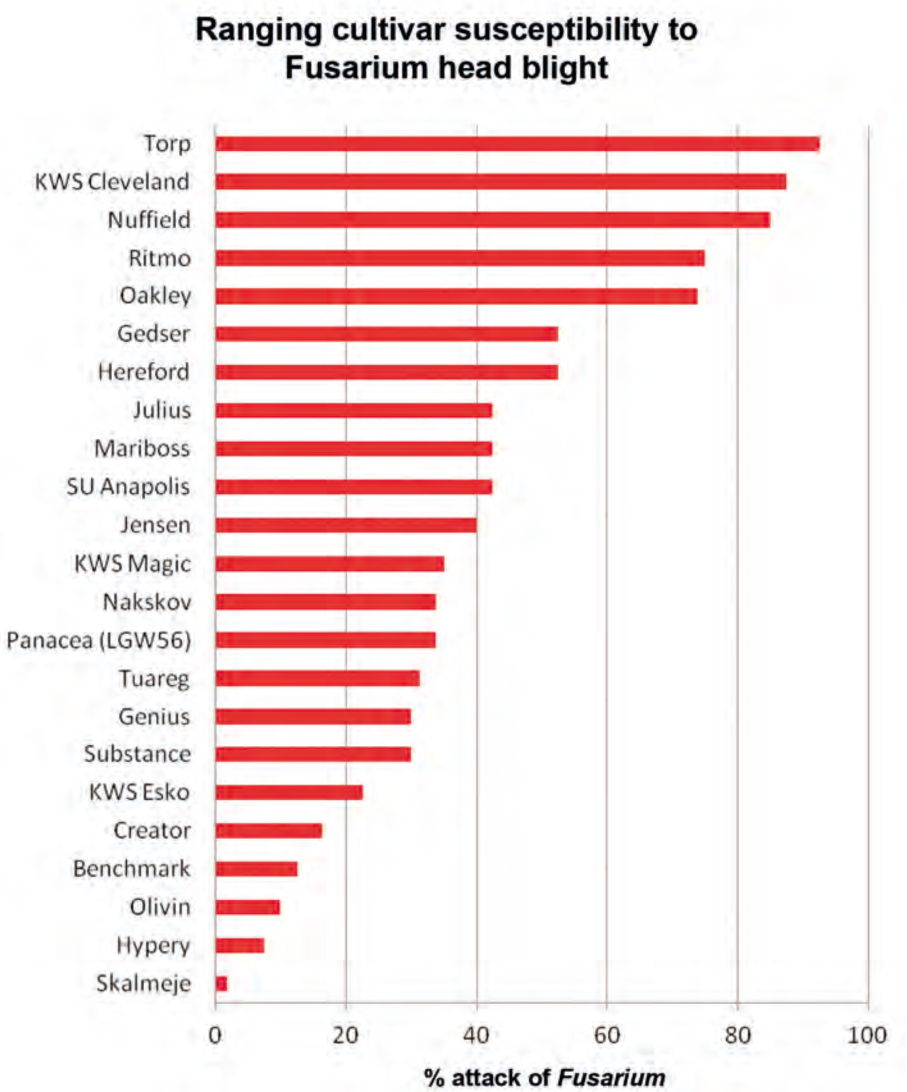


Figure 20. Per cent attack of Fusarium head blight on 5 July. The LSD_{95} value is 22.4.

Table 30. Grouping of cultivars by susceptibility to Fusarium head blight. Based on results from both 2014 and previous years.

Low susceptibility	Moderate to high susceptibility	High susceptibility
Benchmark, Hybery, Skalmeje, Olivin	Creator, Gedser, Hereford, JB Asano, Jensen, Julius, KWS Dacanto, KWS Esko, KWS Magic, Mariboss, Nakskov, Panacea, SU Anapolis, Substance, Tuareg, Genius	Oakley, Ritmo, Torp, KWS Cleveland, Nuffield

Table 31. Results from Fusarium variety trials 2014. Data from 2 different inoculation methods all included.

		14301-1 (spore inoculation)					14301-2 (maize and grain inoculum)			
Disease		*Fusarium*	*Fusarium*	*Fusarium*	*Fusarium*	DON	*Fusarium*	*Fusarium*	DON	Ranking
Date		03-07-2014	03-07-2014	03-07-2014	05-07-2014		03-07-2014	05-07-2014		in CPO and
Assessment		% attack (ears)	% severity	Index	% attack (total score)	ppb	% attack (ears)	% attack (total score)	ppb	Sortinfo
Cultivar		GS 83	GS 83	GS 83	GS 83		GS 83	GS 83		
1	Hereford	11.5	8.8	1.10	47.5	5276	5.8	52.5	2731	2
2	Genius	6.5	10.0	0.43	47.5	1842	5.5	36.3	673	2
3	Tuareg	6.8	6.3	0.40	31.3	3789	2.5	42.5	2341	2
4	Hypery	4.0	5.0	0.20	7.5	1249	6.0	16.3	1017	1
5	Panacea (LGW56)	10.3	6.3	0.71	33.8	7403	5.0	23.8	2542	2
6	SU Anapolis	8.8	7.5	0.73	42.5	1544	8.0	55.0	3835	2
7	Substance	3.5	5.0	0.18	30.0	1005	4.3	27.5	854	2
8	Creator	3.3	12.5	0.54	16.3	2996	1.8	6.3	1139	2
9	Benchmark	4.5	5.0	0.23	12.5	855	2.8	13.8	1891	1
10	Jensen	10.0	5.0	0.50	40.0	5001	3.8	20.0	2453	2
11	Mariboss	12.8	7.5	0.99	42.5	4076	6.8	17.5	3724	2
12	Nuffield	22.5	12.5	3.46	85.0	4076	11.3	65.0	3166	3
13	Torp	30.8	25.0	7.69	92.5	11280	12.5	57.5	4259	3
14	Gedser	13.8	7.5	1.04	52.5	5265	10.0	41.3	1996	2
15	Nakskov	6.8	7.5	0.54	33.8	4671	13.0	52.5	4259	2
16	KWS Cleveland	25.5	10.0	2.55	87.5	6059	24.8	77.5	7648	3
17	KWS Magic	7.0	5.0	0.35	35.0	3767	4.5	73.8	2181	2
18	Julius	10.3	25.0	2.56	42.5	4913	4.3	26.3	1456	2
19	KWS Esko	7.0	6.3	0.49	27.5	2820	6.3	40.0	1394	2
20	Olivin	0.8	2.5	0.04	10.0	1608	4.3	12.5	1291	1
21	Oakley	22.5	13.8	3.15	73.8	8945	19.8	80.0	12085	3
22	Ritmo	21.5	21.3	4.81	75.0	5574	10.3	57.5	2022	3
23	Skalmeje	1.0	2.5	0.05	1.8	1555	2.3	15.0	1703	1
LSD (P=.05)		5,4	6.0	1.5	22.4		8.9	21.9		
Standard Deviation		3,8	4.2	1.1	15.8		6.3	15.5		

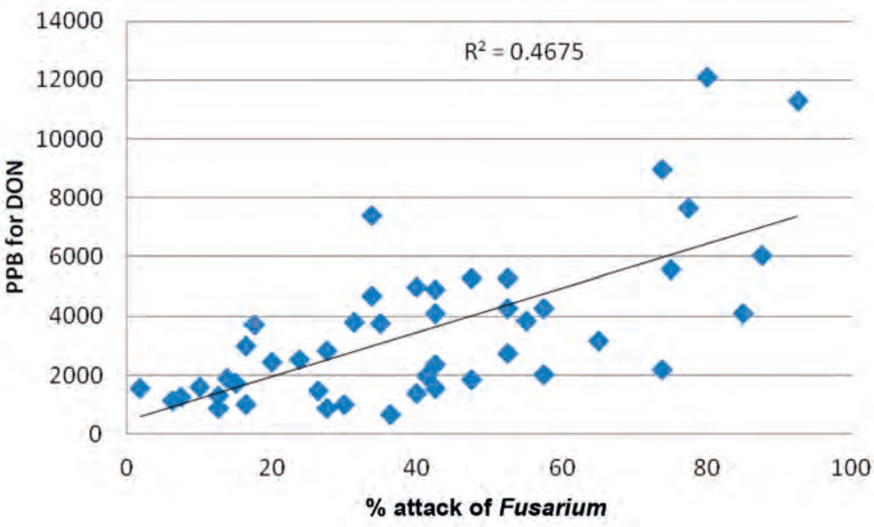


Figure 21. Correlation between % attack of Fusarium head blight and content of the mycotoxin DON. Data from both trials carried out in 2014 are included.

Field trial with different cultivars screened for susceptibility to Fusarium head blight. To the left the very susceptible cultivar – Oakley, and to the right one of the most resistant cultivars - Skalmeje.

Tan spot (DTR) in winter wheat

The same cultivars which were tested for susceptibility to Fusarium head blight were also tested for sensitivity to tan spot. The cultivars were placed in a field with debris of infected straw placed in the field in the autumn 2013. This is known to stimulate the attack of this disease. The trial layout was similar to the *Fusarium* trial using small plots with 2 x 1 metre row and 4 replicates. The trial was assessed 3 times; due to a severe attack of *Septoria* developing also this season, only data from 2 assessments are included (Table 32). Creator, Hypery and KWS Magic showed least attack.

Table 32. Data from the tan spot trial assessing different cultivars' susceptibility.

14302-1			
Disease		Tan spot	
Date of assessment		30-04-2014	02-07-2014
Part assessed		% on leaf 5	% on leaf 3
GS BBCH		33	55
Number	Cultivar		
1	Hereford	2.8	5.0
2	Genius	7.3	4.5
3	Tuareg	5.0	4.3
4	Hypery	2.3	1.5
5	Panacea (LGW56)	7.3	3.3
6	SU Anapolis	6.5	4.5
7	Substance	4.3	2.7
8	Creator	1.3	1.4
9	Benchmark	5.0	2.3
10	Jensen	5.0	5.0
11	Mariboss	4.3	1.8
12	Nuffield	5.8	1.8
13	Torp	5.0	2.0
14	Gedser	2.5	2.3
15	Nakskov	3.5	5.0
16	KWS Cleveland	1.8	3.5
17	KWS Magic	1.3	1.7
18	Julius	3.5	1.8
19	KWS Esko	2.5	3.3
20	Oakley	5.8	2.5
21	Ritmo	5.0	4.8
22	Stakado	1.3	2.8
LSD (P=.05)		2.5	1.3
Standard Deviation		1.7	1.0

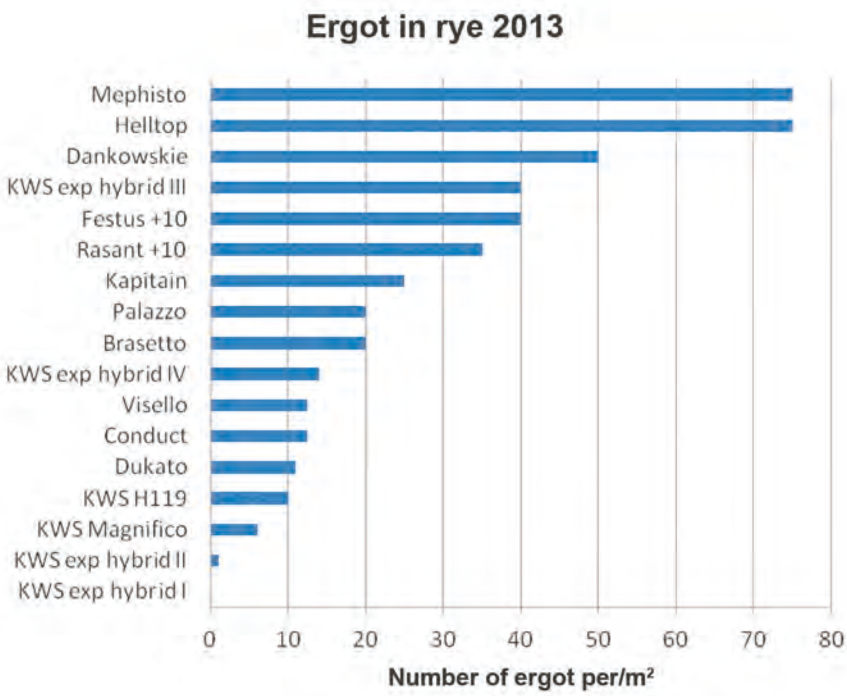
Attack of tan spot on leaves. Attack starts with paper-like small spots, which increase to a larger blotch. The differences in susceptibility are not very great among the commonly grown cultivars.

Ergot in rye

During 2 seasons different rye cultivars were screened for susceptibility to ergot. The project was carried out in collaboration with KWS as part of a Northern Europe project including data from Poland, Germany, Austria and Denmark.

During flowering the trials were inoculated with a spore suspension of ergot (*Claviceps purpurea*). The inoculation took place in the evening when humidity conditions were good. The testing included different of cultivars of which some have increased pollen production (pollen +), which helps to avoid attack; other cultivars contain a mixture of cultivars including one with a high pollen production. The trial in 2014 was inoculated 4 times during flowering and severe attacks of ergot developed in the trials in both 2013 and 2014. Data are summarised in Figure 22. Inoculum from both Germany and Denmark was included and did not show any clear differences in aggressiveness. Cultivars belonging to the pollen + type are commonly grown in Denmark (KWS Magnifico, Palazzo and Brasetto).

Rye with attack of ergot.



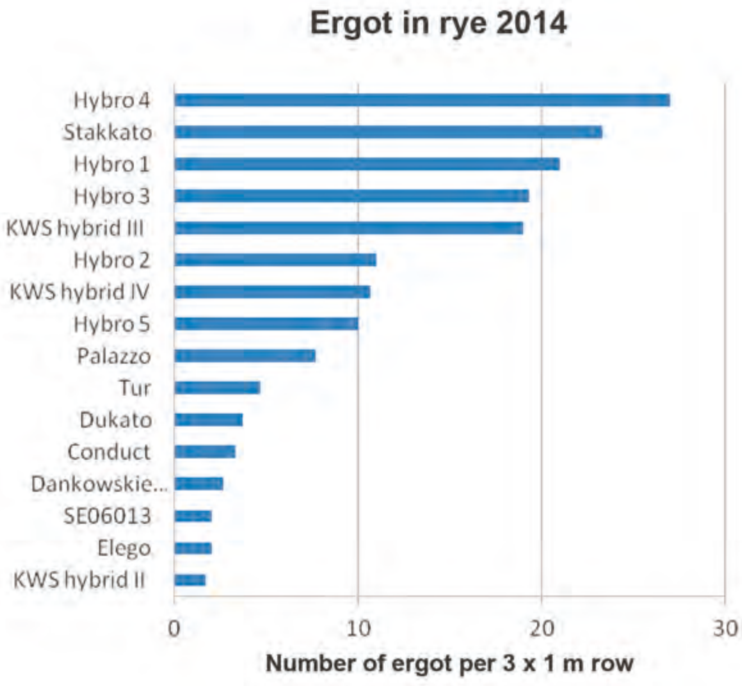


Figure 22. No. of ergot counted per plot in 2013 (1 m^2) in July. In 2014 the numbers were counted in 3 x 1 metre row. The plots were inoculated 3 or 4 times during flowering.

8. Control of diseases in rye and triticale

Control of diseases in rye and triticale

In 2014 3 trials were carried out in triticale and 2 trials in rye. The trials in triticale had yellow rust (*Puccinia striiformis*) as the dominant disease and the attack developed very early. In rye, scald (*Rhynchosporium secalis*) and a late attack of brown rust (*Puccinia recondita*) were the dominant diseases.

Disease control in triticale

In one trial different timings were tested for control of yellow rust. Specific timing gave good control of yellow rust, but 4 treatments were needed to provide full control of the disease through out the season (Table 33). The late application of rust was very important for providing lasting control of rust in the ear. Two treatments were seen to be insufficient and yields were increased by 17 hkg just by adding the last application as well as an early treatment.

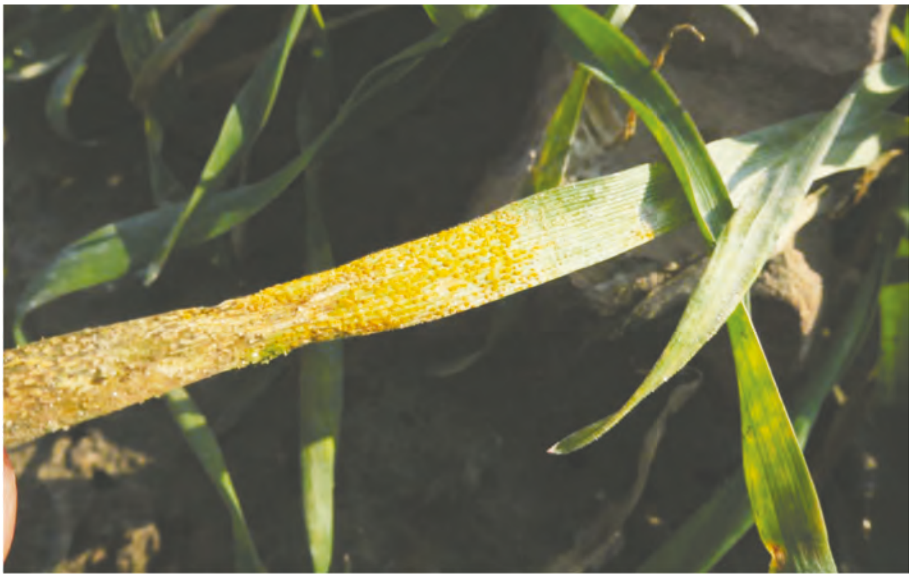
Table 33. Results from control of yellow rust using different timings of Rubric. The trial was carried through to harvest (14366).

Treatments l/ha		Time of treatment	% yellow rust				Yield and increase hkg/ha	Net yield hkg/ha
			Leaf 3 GS 37	Leaf 2 GS 55	Leaf 1 GS 71	Ear GS 77		
1.	Untreated		23.8	25.0	77.5	41	48.7	
2.	0.25 Rubric	GS 30	1.8	18.8	78.8	45	-9.0	-10,6
3.	0.5 Rubric	GS 32	17.5	1.9	60.0	33	15.3	12.8
4.	0.5 Rubric	GS 39	22.5	0	48.8	8	20.6	18.1
5.	0.5 Rubric 0.5 Rubric	GS 32 & 39	10	0	36.3	9	23.5	18.5
6.	0.25 Rubric 0.5 Rubric 0.5 Rubric 0.25 Rubric	GS 30 GS 32 GS 39 GS 61	1.5	0	1.5	1	40.5	32.9
LSD_{95}							6.6	

In another trial different fungicides were applied using one or two timings. The single timing was applied at GS 33-37 and double timing at GS 33-37 and 51-55. The differences between the tested producats were relatively insignificant compared to using one or two timings (Table 34). The mixture 0.25 l/ha of Rubric + 0.2 l/ha of Proline EC 250 performed slightly better compared with the other solutions although the yield increases did not reflect this advantage. Looking at the yield responses Viverda performed better although differences were not significantly different from each other.

Table 34. Control of yellow rust using two different timings. The trial was carried through to harvest (14361).

Treatments and doses applied l/ha	Timings GS	% yellow rust				Yield and increase hkg/ha	Net yield hkg/ha
		Leaf 3 GS 45	Leaf 2 GS 61	Leaf 1 GS 77	Ear GS 77		
1. Untreated		19.0	31.3	32.2	25	61.2	
2. 0.25 Rubric + 0.2 Proline	33-37	0.2	2.0	8.8	4	9.8	7.3
3. 0.75 Viverda	33-37	0.7	4.5	15.0	7	11.7	7.9
4. 0.5 Bumper 25 EC	33-37	0.3	3.3	13.3	6	6.6	5.0
5. 0.8 Proline	33-37	0	1.7	19.3	9	8.5	4.2
6. 1.0 Propulse	33-37	0.2	3.8	12.5	10	10.5	-
7. 0.25 Rubric + 0.2 Proline	33-37 & 51-55	0.1	1.4	0	1	13.8	8.9
8. 0.75 Viverda	33-37 & 51-55	0.7	3.5	0	1	15.6	8.0
9. 0.5 Bumper 25 EC	33-37 & 51-55	0.4	5.8	0	1	10.4	7.3
10. 1.0 Folpan + 0.2 Proline	33-37 & 51-55	4.0	10.5	0	1	12.8	6.5
11. 0.5 Comet	33-37 & 51-55	2.0	12.5	0	1	14.1	8.8
LSD_{95}						5.2	



Attack of yellow rust in triticale in the early spring. The attack was very severe and reduced yields by 4 tonnes per ha.

Disease control in rye

Almost the same trial plan as was carried out in triticale was similarly tested in winter rye. The attack of scald (*Rhynchosporium secalis*) was quite significant in the early part of the season, and late in the season brown rust came in, resulting in a quite severe attack. Viverda and the mixture of Rubric + Proline EC 250 provided very similar control of both diseases although Viverda was seen to be slightly superior (Table 35). Bumper 25 EC was seen to be inferior for control of both diseases. However, if Bumper 25 EC was combined with Prosaro, the performances improved. Despite the severe attack the yield increases from treatments were only moderate. Yield might have improved further if a later timing was included in the trial in order to optimise the control of brown rust.

Table 35. Results from control of *Rhynchosporium* and brown rust in rye using two different timings. The trial was carried through to harvest (14363).

Treatments and doses applied l/ha	Timings GS	% brown rust		% *Rhynchosporium*		Yield and increase hkg/ha	Net yield hkg/ha
		Leaf 1-2 GS 75	Leaf 2 GS 383	Leaf 3 GS 71	Leaf 2 GS 75		
1. Untreated		13.8	50	20.8	37.5	86.0	
2. 0.25 Rubric + 0.2 Proline	33-37	11.5	43	7.8	27.5	6.3	3.8
3. 0.75 Viverda	33-37	7.3	43	7.8	17.5	6.6	2.8
4. 0.5 Bumper 25 EC	33-37	9.5	48	16.8	33.8	-0.1	-1.7
5. 0.25 Rubric + 0.2 Proline	33-37 & 51-55	5.8	30	5.3	17.5	8.2	3.3
6. 0.75 Viverda	33-37 & 51-55	2.3	21	5.8	7.0	9.2	1.6
7. 0.5 Bumper 25 EC	33-37 & 51-55	6.3	40	10.3	18.8	3.1	0
8. 1.0 Folpan + 0.2 Proline	33-37 & 51-55	6.5	34	8.3	11.5	6.4	0.1
9. 0.5 Bumper/0.5 Prosaro	33-37 & 51-55	3.3	30	9.0	18.8	7.0	3.0
LSD_{95}						5.4	

Brown rust in rye. Attacks develop late in most seasons. Severe attacks can be very costly.

Stem rust appeared late in the season in rye, but the attack was too insignificant to give ranking for fungicide efficacy.

III Control of diseases in different cultivars

Lise Nistrup Jørgensen, Helene Saltoft Kristjansen, Sidsel Kirkegaard & Anders Almskou-Dahlgaard

Control strategies in 6 wheat cultivars

Five different control strategies were compared in 6 different wheat cultivars. One of the treatments included the use of the decision support system Crop Protection Online to evaluate the need for treatments. The trials were placed at two localities – one at AU Flakkebjerg and one near Horsens with LMO.

The following strategies were tested:

1. Untreated
2. 0.75 Ceando/0.75 Viverda GS 37-39 & 55
3. 1.25 Viverda GS 39-45
4. 0.5 Proline Xpert/0.4 Proline EC 250 GS 37-39 & 55
5. 1.0 Folpan 500/0.75 Viverda/0.4 Proline EC 250 GS 31-32 & GS 37-39 & 55
6. Crop Protection Online (CPO) (Table 1)

Table 1. Treatments applied following recommendations from Crop Protection Online. 14350-1 and 14350-2.

Cultivars (14350-1)	Date and GS	Products l/ha	TFI	Costs hkg/ha
Mariboss	6/5, GS 33 30/5, GS 51	0.37 Rubric 0.17 Proline + 0.3 Bell	0.87	4.72
KWS Dacanto	6/5, GS 33 30/5, GS 51	0.44 Rubric 0.2 Proline + 0.375 Bell	1.14	5.5
Cultivar mixture	6/5, GS 33 30/5, GS 51	0.37 Rubric 0.17 Proline + 0.3 Bell	0.87	4.72
Hereford	6/5, GS 33 30/5, GS 51	0.44 Rubric 0.2 Proline + 0.375 Bell	1.14	5.5
Jensen	29/4, GS 32-33 6/5, GS 33 21/5, GS 39 7/6, GS 59	0.24 Rubric 0.37 Rubric 0.46 Bell 0.4 Viverda	1.65	8.51
Nakskov	6/5, GS 33 30/5, GS 51	0.37 Rubric 0.17 Proline + 0.3 Bell	0.87	4.72

Cultivars (14350-2)	Date and GS	Products l/ha	TFI	Costs hkg/ha
Mariboss	7/5, GS 33 30/5, GS 49-51	0.37 Rubric 0.49 Bell	0.96	4.77
KWS Dacanto	7/5, GS 33 30/5, GS 49-51	0.44 Rubric 0.49 Bell	1.03	5.03
Cultivar mixture	7/5, GS 33 30/5, GS 49-51	0.37 Rubric 0.49 Bell	0.96	4.8
Hereford	7/5, GS 33 30/5, GS 49-51	0.44 Rubric 0.49 Bell	1.03	5.03
Jensen	7/5, GS 33 30/5, GS 49-51	0.37 Rubric 0.49 Bell	0.96	4.77
Nakskov	7/5, GS 33 30/5, GS 49-51	0.37 Rubric 0.49 Bell	0.96	4.77

The two trials were placed as split plot trials with 3 replicates. Sowing was carried out in mid-September. The cultivars represent the most commonly grown cultivars in Denmark. Cultivar mixture was included as a reference treatment and as an option which aims at optimising IPM control. Most cultivars were susceptible or very susceptible to Septoria leaf blotch. Due to the very mild winter and good conditions for *Septoria* in early spring, the attack was seen to be very severe, particularly on the lower leaves. Several of the cultivars had low to moderate susceptibility to yellow rust early in the season, but all included cultivars showed a high degree of adult plant resistance (Jensen, Hereford, KWS Dacanto).

Control strategies included 1, 2 or 3 applications and were based on strategies given by the companies. Treatment 4 was a treatment aiming at including an anti-resistant strategy. Crop Protection Online recommended 2-3 treatments depending on the cultivars. Specific input from the two localities is listed in Table 1. Total TFI varied in specific cultivars between 0.87 and 1.65. All solutions gave quite similar control of *Septoria*. Early in the season Folpan provided a slightly better control initially – other strategies, which were applied later, gave less control at the earlier assessments. The treatment which only included one treatment of a relatively high rate of Viverda - although applied quite late - still gave good control of *Septoria* on the flag leaf.

Because of lodging only data from one of the two trials are included in Table 2. In the Flakkebjerg trial the gross yield and net yield responses were quite similar for the different treatments. Despite clear differences in disease susceptibility between cultivars the yield responses were also quite similar for the 6 cultivars. In this year's trials CPO gave yield responses in line with standard treatments.

Untreated plot with the cultivar Mariboss with a considerable attack of *Septoria* at GS 75.

0.75 l Ceando applied at GS 37 + 1.25 Viverda GS 55-51.

1.25 Viverda applied at one time GS 39-45.

Table 2. Control of *Septoria* and yield responses, 2 trials - 1 from Flakkebjerg and 1 from LMO with 6 winter wheat cultivars, using 5 different fungicide treatments (14350). (Continues on the next page).

Cultivars	% *Septoria* leaf 2 GS 69-73						% *Septoria* leaf 1 GS 75-81					
	Untr.	0.75 Ceando/ 0.75 Viverda	1.25 Viverda	0.5 Proline Xpert + 0.4 Proline	1.0 Folpan/ 0.75 Viverda/ 0.4 Proline	CPO	Untr.	0.75 Ceando/ 0.75 Viverda	1.25 Viverda	0.5 Proline Xpert + 0.4 Proline	1.0 Folpan/ 0.75 Viverda/ 0.4 Proline	CPO
Mariboss	62.5	40.0	40.8	37.5	35.0	41.7	52.5	18.0	13.9	24.7	22.5	33.5
KWS Dacanto	79.2	50.8	51.7	48.3	45.8	59.2	80.9	37.5	30.0	35.4	31.6	27.5
Cultivar mixture	45.8	28.3	27.8	27.5	24.2	34.2	37.5	9.4	6.9	23.3	17.5	19.2
Hereford	84.2	63.3	59.0	57.5	60.0	66.7	69.2	36.7	19.5	27.5	25.9	35.0
Jensen	48.0	32.5	36.7	33.7	30.8	35.3	26.1	16.4	17.4	15.0	15.2	15.9
Nakskov	83.3	60.0	64.2	55.0	60.0	60.8	75.0	39.2	25.0	45.6	30.8	35.0
Average	67.2	45.8	46.7	43.3	42.6	49.7	56.9	26.2	18.8	28.6	23.9	27.7
No. of trials	2						2					

Cultivars	% green area leaf 1 GS 75-81						TGW (g)					
	Untr.	0.75 Ceando/ 0.75 Viverda	1.25 Viverda	0.5 Proline Xpert + 0.4 Proline	1.0 Folpan/ 0.75 Viverda/ 0.4 Proline	CPO	Untr.	0.75 Ceando/ 0.75 Viverda	1.25 Viverda	0.5 Proline Xpert + 0.4 Proline	1.0 Folpan/ 0.75 Viverda/ 0.4 Proline	CPO
Mariboss	5.0	38.0	36.0	25.0	24.0	14.0	36.5	39.6	39.0	40.1	40.7	40.8
KWS Dacanto	0	17.5	22.5	18.8	22.5	21.3	43.8	45.8	46.1	44.3	45.6	44.9
Cultivar mixture	13.0	47.0	46.0	39.0	41.0	40.0	41.6	40.6	42.1	42.7	43.7	43.9
Hereford	0	8.8	8.8	15.0	8.8	8.8	42.5	43.7	45.0	42.0	43.0	44.3
Jensen	15.0	36.0	34.0	32.0	41.0	42.0	39.6	41.2	41.2	39.6	42.0	42.2
Nakskov	10.0	10.0	11.2	10.0	12.0	11.0	40.1	43.9	43.2	42.6	43.7	43.5
Average	7.2	26.2	26.4	23.3	24.9	22.9	40.7	42.5	42.8	41.9	43.1	43.3
No. of trials	2						2 (LSD_{95} = 2.5)					

Table 2. Control of *Septoria* and yield responses, 2 trials - 1 from Flakkebjerg and 1 from LMO with 6 winter wheat cultivars, using 5 different fungicide treatments (14350) (continued).

Cultivars	Yield and increase hkg/ha						Net increase hkg/ha				
	Untr.	0.75 Ceando/ 0.75 Viverda	1.25 Viverda	0.5 Proline Xpert + 0.4 Proline	1.0 Folpan/ 0.75 Viverda/ 0.4 Proline	CPO	0.75 Ceando/ 0.75 Viverda	1.25 Viverda	0.5 Proline Xpert + 0.4 Proline	1.0 Folpan/ 0.75 Viverda/ 0.4 Proline	CPO
Mariboss	74.4	12.6	5.4	8.2	11.0	6.7	5.1	6.7	3.8	2.5	2.0
KWS Dacanto	93.9	9.6	7.8	11.5	8.1	8.7	2.1	3.7	7.1	-0.4	3.3
Cultivar mixture	99.9	10.5	3.4	4.1	7.1	8.3	3.0	-2.5	-0.3	-1.4	3.6
Hereford	99.5	8.6	9.0	2.9	8.5	6.0	1.1	3.1	-1.5	0.0	0.6
Jensen	98.9	5.9	6.3	3.6	4.7	7.3	-1.6	0.4	-0.8	-3.8	-1.2
Nakskov	95.2	12.9	8.7	9.1	8.2	7.6	5.4	2.8	4.7	-0.3	2.9
LSD_{95}	5.5										
Average	93.6	10.0	6.8	6.6	7.9	7.4	2.5	2.4	2.2	-0.6	1.9
No. of trials	1						1				

Untr. = Untreated; 0.75 Ceando GS 32-33 and 0.75 Viverda GS 55 (costs = 7.48 hkg/ha); 1.25 Viverda GS 39-45 (costs = 5.86 hkg/ha); 0.5 Proline Xpert GS 33-37 and 0.4 Proline GS 55 (costs = 4.37 hkg/ha); 1.0 Folpan GS 31, 0.75 Viverda GS 33-37 and 0.4 Proline GS 55 (costs = 8.5); CPO = Crop Protection Online.

Control strategies in different winter barley cultivars

In 5 winter barley cultivars 5 different control strategies including control and crop protection were tested. One trial was placed at Flakkebjerg and one at LMO - Jutland. The treatments given below were tested in the two trials.

1. Untreated
2. 0.25 Prosaro EC 250/0.5 Viverda (GS 32 + GS 51)
3. 0.75 Viverda (GS 37-39)
4. 0.3 Proline EC 250/0.4 Prosaro EC 250 (GS 32 + GS 51)
5. Crop Protection Online

A considerable attack of *Rhynchosporium* developed in the trials in most cultivars with the exception of Matros. All standard treatments gave a good control of the attack and treatments could not really be distinguished from each other (Table 4). At the end of the season a considerable attack of Ramularia leaf spot developed in all cultivars. Due to the late appearance the control levels were only moderate, but slightly better from double treatments compared with single treatments. The control from CPO was generally lower compared with standard treatments, which partly was due to the choice of products and the early timing (Table 3). Yield increases varied between cultivars. The best increases were harvested in Sy Leoo, California and Sandra. Least responses were seen in Matros, which is regarded as the least susceptible cultivar. Positive net yield responses were harvested in all cultivars. The yield responses from CPO were inferior to standard treatments in most cultivars. Thousand grain weights were increased moderately in all cultivars.

Table 3. Treatments applied following recommendations from Crop Protection Online. 14351-1 and 14351-2.

Cultivars (14351-1)	Date and GS	Products	TFI	Costs hkg/ha
California	25-04-2014 GS 33 14-05-2014 GS 53	0.15 Comet + 0.15 Folicur 0.15 Proline + 0.19 Comet	0.68	3.65
Sy Leoo	25-04-2014 GS 33	0.15 Comet + 0.15 Folicur	0.3	1.56
Apropos	25-04-2014 GS 33	0.15 Comet + 0.15 Folicur	0.3	1.56
Sandra	25-04-2014 GS 33 14-05-2014 GS 53	0.15 Comet + 0.15 Folicur 0.15 Proline + 0.19 Comet	0.68	3.66
Matros	25-04-2014 GS 33 14-05-2014 GS 53	0.13 Comet + 0.13 Folicur 0.15 Proline + 0.19 Comet	0.68	3.54

Cultivars (14351-2)	Date and GS	Products	TFI	Costs hkg/ha
California	07-05-2014 GS 45	0.18 Comet + 0.18 Prosaro	0.38	2.0
Sy Leoo	07-05-2014 GS 45	0.18 Comet + 0.18 Prosaro	0.38	2.0
Apropos	26-04-2014 GS 33	0.18 Comet + 0.1 Proline	0.31	1.8
Sandra	07-05-2014 GS 45	0.18 Comet + 0.18 Prosaro	0.38	2.0
Matros	07-05-2014 GS 45	0.18 Comet + 0.18 Prosaro	0.38	2.0

Table 4. Control of diseases in winter barley and yield responses from 2 trials in 5 winter barley cultivars using 4 different strategies. (Continues on the next page)

Cultivars	% *Rhynchosporium* leaf 2-3, GS 61/65					% *Rhynchosporium* leaf 2, GS 71/73				
	Untr.	0.25 Prosaro EC 250/ 0.5 Viverda l/ha	0.75 Viverda l/ha	0.3 Proline EC 250/ 0.4 Prosaro EC 250 l/ha	CPO	Untr.	0.25 Prosaro EC 250/ 0.5 Viverda l/ha	0.75 Viverda l/ha	0.3 Proline EC 250/ 0.4 Prosaro EC 250 l/ha	CPO
California	5.2	2.2	2.4	2.7	3.5	4.4	1.0	0.7	0.3	3.5
SY Leoo	0.8	0.4	0.4	0.4	0.5	2.0	0.3	0.9	0.9	0.3
Apropos	2.2	0.6	1.3	1.0	1.1	4.2	0.6	1.8	0.2	1.1
Sandra	7.7	2.8	3.0	2.8	5.0	7.7	2.8	3.0	2.8	5.0
Matros	0.5	0.0	0.0	0.0	0.0	0.5	0.0	0.0	0.0	0.0
Average	3.3	3.0	1.4	1.4	2.0	3.8	0.9	1.3	1.2	2.0
No. of trials	2									

Cultivars	% *Rhynchosporium* leaf 1-2, GS 75-83					% brown rust leaf 1-2, GS 71-73				
	Untr.	0.25 Prosaro EC 250/ 0.5 Viverda l/ha	0.75 Viverda l/ha	0.3 Proline EC 250/ 0.4 Prosaro EC 250 l/ha	CPO	Untr.	0.25 Prosaro EC 250/ 0.5 Viverda l/ha	0.75 Viverda l/ha	0.3 Proline EC 250/ 0.4 Prosaro EC 250 l/ha	CPO
California	1.0	0.6	0.5	0.2	0.5	2.7	0.0	0.1	0.1	0.7
SY Leoo	0.8	0.1	0.5	0.2	0.4	2.4	0.1	0.2	0.1	0.4
Apropos	2.7	0.6	0.8	0.3	0.7	1.8	0.0	0.5	0.0	0.1
Sandra	3.5	0.7	0.8	0.4	2.7	4.3	0.1	0.1	0.1	0.2
Matros	0.8	0.4	0.3	0.3	0.4	0.1	0.1	0.1	0.1	0.1
Average	1.8	0.5	0.6	0.3	0.9	2.3	0.1	0.2	0.1	0.3
No. of trials	2									

Cultivars	% *Ramularia* Leaf 1-3, GS 75-83				
	Untr.	0.25 Prosaro EC 250/ 0.5 Viverda l/ha	0.75 Viverda l/ha	0.3 Proline EC 250/ 0.4 Prosaro EC 250 l/ha	CPO
California	45.0	9.0	10.0	14.3	27.5
SY Leoo	43.8	15.0	22.5	16.3	30.8
Apropos	42.5	13.9	13.8	4.3	27.0
Sandra	57.5	26.3	36.3	18.8	38.8
Matros	33.8	5.8	9.8	3.1	18.8
Average	44.5	14.0	18.5	11.4	28.6
No. of trials	2				

Table 4. Control of diseases in winter barley and yield responses from 2 trials in 5 winter barley cultivars using 4 different strategies (continued).

Cultivars	Yield and increase hkg/ha					Net increase hkg/ha				TGW g/1000				
	Untr.	0.25 Prosaro EC 250/ 0.5 Viverda l/ha	0.75 Viverda l/ha	0.3 Proline EC 250/0.4 Prosaro EC 250 l/ha	CPO	0.25 Prosaro EC 250/ 0.5 Viverda l/ha	0.75 Viverda l/ha	0.3 Proline EC 250/0.4 Prosaro EC 250 l/ha	CPO	Untr.	0.25 Prosaro EC 250/0.5 Viverda l/ha	0.75 Viverda l/ha	0.3 Proline EC 250/0.4 Prosaro EC 250 l/ha	CPO
California	83.5	9.4	11.7	10.2	3.9	5.13	7.92	6.13	1.07	46.5	49.9	49.9	50.0	49.5
SY Leoo	84.0	10.1	13.1	16.3	8.4	5.83	9.32	12.23	6.68	36.1	39.5	39.5	41.1	38.7
Apropos	80.6	7.4	4.6	6.0	4.1	3.13	0.82	1.93	0.74	42.6	46.5	46.4	46.9	46.6
Sandra	87.6	9.6	10.0	12.6	9.1	5.33	6.22	8.53	6.27	51.4	54.4	55.7	54.9	54.1
Matros	86.7	2.8	0.0	5.6	1.6	-1.47	-3.78	1.53	-1.17	49.2	49.7	49.3	50.2	47.8
Average	84.5	7.9	7.9	10.1	5.4	3.59	4.66	6.07	2.72	45.2	48.0	48.2	48.6	47.3
LSD_{95}	6.2									2.4				
No. of trials	2													

Untr. = Untreated; 0.25 Prosaro EC 250 GS 32 and 0.5 Viverda GS 51 (costs = 4.27 hkg/ha); 0.75 Viverda GS 37-39 (costs = 3.78 hkg/ha); 0.3 Proline EC 250 GS 32 and 0.4 Prosaro EC 250 GS 51 (costs = 4.07 hkg/ha); CPO = Crop Protection Online.

Control of strategies in different spring barley cultivars

In 5 spring barley cultivars 5 different control strategies including control and crop protection were tested. One trial was placed at Flakkebjerg and one at LMO - Jutland. The treatments given below were tested in the two trials.

1. Untreated
2. 0.2 Proline EC 250/0.5 Viverda (GS 32 + GS 51)
3. 0.75 Viverda (GS 37-39)
4. 0.3 Proline Xpert (GS 37-39)
5. Crop Protection Online (CPO)

A considerable attack of powdery mildew developed in one trial in the cultivar Milford. Most cultivars got moderate attacks of net blotch and *Rhynchosporium*. All standard treatments gave good control of the leaf attack and it was not possible to distinguish between treatments (Table 6). At the end of the season a minor attack of Ramularia leaf spot developed in all cultivars. The control from CPO was generally lower compared with standard treatments, which was partly due to fewer treatments (Table 5).
Yield increases varied between cultivars but were generally low. So were the net yield responses. None of the treatments gave profitable yield responses.

Table 5. Applied treatments in the CPO treatment in the spring barley trials 14352-1 and 14352-2.

Cultivars (14352-1)	Date and GS	Products	TFI	Costs hkg/ha
Milford	-	-	-	-
Tan Tam	-	-	-	-
Evergreen	-	-	-	-
Columbus	12-06-2014 GS 51	0.47 Viverda	0.49	2.62
Quench	12-06-2014 GS 51	0.43 Viverda	0.45	2.45

Cultivars (14352-2)	Date and GS	Products	TFI	Costs hkg/ha
Milford	16-06-2014 GS 55	0.18 Comet + 0.14 Proline	0.35	2.01
Tam Tam	-	-	-	-
Evergreen	-	-	-	-
Columbus	-	-	-	-
Quench	16-06-2014 GS 55	0.12 Comet + 0.1 Proline	0.23	1.59

Table 6. Control of diseases in spring barley and yield responses from 2 trials in 5 different spring barley cultivars using 4 different strategies. Untr. = Untreated; CPO = Crop Protection Online (14352).

Cultivars	% *Rhynchosporium* leaf 2+3, GS 75/77					% powdery mildew leaf 2+3, GS 75/73				
	Untr.	0.2 Proline EC 250/ 0.5 Viverda	0.75 Viverda	0.5 Proline Xpert	CPO	Untr.	0.2 Proline EC 250/ 0.5 Viverda	0.75 Viverda	0.5 Proline Xpert	CPO
Milford	11.7	0.1	0.5	0.8	0.4	11.7	0.2	1.2	0.5	5.3
Tam Tam	6.7	0.4	0.0	1.4	10.0	0.0	0.0	0.0	0.0	0.0
Evergreen	2.7	0.0	0.4	0.4	1.0	0.0	0.0	0.0	0.0	0.0
Columbus	6.7	0.1	0.4	0.5	6.7	0.0	0.0	0.0	0.0	0.0
Quench	1.7	0.7	0.2	0.1	1.3	0.0	0.0	0.0	0.0	0.0
Average	5.9	0.3	0.3	0.6	3.9	2.3	0.0	0.2	0.1	1.1
No. of trials	1					1				

Cultivars	% net blotch Leaf 2+3, gs. 75/73					% *Ramularia* Leaf 2+3, gs. 75/77				
	Untr.	0.2 Proline EC 250/ 0.5 Viverda	0.75 Viverda	0.5 Proline Xpert	CPO	Untr.	0.2 Proline EC 250/ 0.5 Viverda	0.75 Viverda	0.5 Proline Xpert	CPO
Milford	5.5	0.0	0.0	0.1	0.4	1.8	0.0	0.4	0.2	0.7
Tam Tam	8.0	0.1	0.1	0.7	6.0	4.3	0.0	0.3	0.3	4.3
Evergreen	5.3	0.0	0.0	2.0	2.7	5.0	0.0	0.0	1.2	2.3
Columbus	3.3	0.0	0.0	2.0	3.0	3.0	0.7	0.2	0.4	1.0
Quench	15.0	1.2	0.4	2.7	10.0	3.7	0.7	1.0	1.0	0.8
Average	7.4	0.3	0.1	1.5	4.4	3.6	0.3	0.4	0.6	1.8
No. of trials	1					1				

Cultivars	Yield and increase hkg/ha					Net increase hkg/ha			
	Untr.	0.2 Proline EC 250/0.5 Viverda	0.75 Viverda	0.5 Proline Xpert	CPO	0.2 Proline EC 250/0.5 Viverda	0.75 Viverda	0.5 Proline Xpert	CPO
Milford	65.5	1.6	5.2	2.1	2.9	-2.7	1.4	-0.5	1.9
Tam Tam	66.7	5.0	6.4	3.6	-1.1	0.7	2.6	1.0	-
Evergreen	62.8	4.5	3.0	3.0	1.8	0.2	-0.8	0.4	-
Columbus	64.6	6.4	6.3	3.6	-0.5	2.1	2.5	1.0	-1.8
Quench	67.5	4.8	4.3	0.9	2.8	0.5	0.5	-1.7	0.8
Average	65.4	4.5	5.0	2.6	1.2	0.2	1.2	0.0	0.2
LSD_{95}	4.9								
No. of trials	2					2			

Cultivars	TGW g/1000				
	Untr.	0.2 Proline EC 250/ 0.5 Viverda	0.75 Viverda	0.5 Proline Xpert	CPO
Milford	48.9	50.5	50.0	49.9	48.9
Tam Tam	49.0	50.5	50.6	49.4	48.4
Evergreen	48.7	50.0	49.4	49.1	49.5
Columbus	48.7	50.7	50.4	50.0	48.5
Quench	46.7	49.9	49.7	48.8	32.3
Average	48.4	50.3	50.0	49.4	45.5
No. of trials	2				
Costs: 0.2 Proline EC 250 GS 31 and 0.5 Viverda GS 51 = 4.3 hkg/ha; costs: 0.75 Viverda GS 37-39 = 3.8 hkg/ha; costs: 0.5 Proline Xpert GS 37-39 = 2.6 hkg/ha; costs CPO = Crop Protection Online.					

IV Disease control in grain maize

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Control of eyespot (*Kabatiella zeae*) and Northern corn leaf blight (*Setospharia turcica*) in maize

Several trials were carried out in grain maize during 2014, testing the efficacy of different fungicides regarding control of leaf diseases. All trials were located in fields with debris from maize and previous crops being maize for several years.

Depending on the specific trial different timings were tested, varying from GS 33 to GS 61. Despite inoculums from debris the level of diseases was low in the early part of the season, following dry weather.

Propulse (14378)

Propulse has previously been tested and this year it was tested again in two trials. Specifically 4 dose rates (1.0, 0.72, 0.48 and 0.24 l/ha) were tested and compared with the reference product Opera. Double treatments were also tested using 3 dose rates and again compared with double treatments with Opera (1.5 l/ha).

From mid-September a minor attack developed but it was not until late September and early October that clear differences between treatments and untreated could be seen for control of eyespot. No clear differences were seen between specific treatments, only between untreated and treatments although at the very last assessment some indications of dose responses were seen for both double treatments and single treatments at one of the two localities. Assessments for green leaf area also showed differences between untreated and treated plots (Table 1).

Just before harvest 15 cobs were picked from each plot and back in the lab the cobs were measured for weight, length, degree of grain filling and attack of *Fusarium*. A significant attack by the European corn borer (*Ostinia nubilalis*) resulted in an attack in the cobs and led to a more severe attack of *Fusarium*, but none of the treatments had considerable effects on the development of this disease.

The trials were harvested in late October and no significant yield increases were obtained from the treatments in the trials, reflecting the minor attacks and the relatively late development of diseases. Neither did the treatments show any impact on yield parameters like cob weight and TGW.

The trial added to previous year's results, which showed a good effect from Propulse with respect to control of eyespot. Less documentation was provided on northern corn leaf blight as this disease only occurred with a limited attack in the trials.

Table 1. Effects of different fungicides on eyespot in grain maize as well as yield responses following one or two applications. 2 trials (14378).

Treatments and l/ha GS		% eyespot GS 87 L 3-5	% eyespot GS 89 L 3-6	*Fusarium* number of attacks on 15 cobs	Weight of cob g	Yield and increase hkg/ha
1.	Untreated	19.0	37.8	7.8	239.6	96.1
2.	Propulse 1.0 GS 33	2.0	10.0	4.3	232.0	-1.1
3.	Propulse 0.72 GS 33	4.0	11.8	6.3	246.9	2.5
4.	Propulse 0.48 GS 33	3.0	13.4	5.4	233.0	11.0
5.	Propulse 0.24 GS 33	5.0	18.0	6.3	215.2	-8.2
6.	Opera 1.5 GS 33	4.0	10.5	6.4	229.8	3.5
7.	Propulse 1.0 GS 33/51	3.0	11.0	6.5	240.0	5.6
8.	Propulse 0.48 GS 33/51	4.0	13.3	5.9	231.1	-2.6
9.	Propulse 0.24 GS 33/51	5.0	19.3	6.1	237.0	1.6
10.	Opera 1.5 GS 33/51	4.0	12.2	6.2	240.0	3.8
No. of trials		1	2	2	2	2
LSD_{95}				ns	ns	ns

Acanto (14374)

Acanto was tested alone at GS 37-39 and also applied at both timings (GS 37-39 & 55) at the rate of 0.5 l/ha and compared with Opera applied at half rate (0.75 l/ha). Acanto was also tested in a mixture with Bumper as a single treatment applied at GS 37-39. Double treatments compared Acanto used alone or in a sequence with Opera applied either at the early or the late timing. Assessments were carried out at approximately 2-week intervals assessing different leaf sections (Table 2). At both localities disease levels were very low at the time of application. In mid-September a minor attack of eyespot and Northern corn leaf blight developed. Only the late assessments showed clear differences between treatments for eyespot at both sites, whereas this was only the case at one site for Northern corn leaf blight.

The efficacy from treatments applied at GS 37-39 provided less pronounced control compared with treatments which also included a later treatment (GS 55). The mixture of Acanto + Bumper provided superior control compared to Acanto used alone. Opera, as a single treatment, was also superior to Acanto used alone or in mixture. Double treatments which included Opera either at the first or second treatment outperformed Acanto used as a solo product in a split treatment when assessed at the last timings. At the last assessments per cent green area was assessed and major differences could be seen with the double treatments providing most green area.

Fusarium was assessed on 15 cobs per plot. The infection was quite considerable, mainly due to attack from European corn borer (*Ostrinia nubilalis*) in the trials, which so to speak led the way for *Fusarium* to attack. No significant differentiation between treatments could be found for the attack of *Fusarium*.

The trials were harvested in late October with a special plot harvester (Haldrup). No significant yield increases were obtained from the treatments in the trial, reflecting the minor attacks from relatively late occurring diseases. Neither did the treatments show any impact on yield parameters like cob weight and TGW.

Table 2. Effects of different fungicides on eyespot in grain maize as well as yield responses following one or two applications. 2 trials (14377).

Treatments and l/ha GS		% eyespot 2 Oct. L 3-7	% eyespot 9 Oct. L 1-5/L 3-6	% Northern corn leaf blight 9 Oct. L 1-5	% GLA 9 Oct. L 1-6	*Fusarium* number of attacks on 15 cobs	Weight of cob g	Yield and increase hkg/ha
1.	Acanto 0.5 GS 37-39	33.8	16.9	17.5	59.4	7.2	223	-2.1
2.	Acanto + Bumper 0.5 + 0.25 GS 37-39	25.0	10.4	11.3	63.8	6.2	245	+3.9
3.	Opera 0.75 GS 37-39	18.5	6.6	12.5	73.1	4.3	231	-3.1
4.	Acanto 0.5 GS 37-39 Acanto 0. GS 55	2.5	8.9	12.5	68.8	6.3	220	-1.3
5.	Acanto 0.165 37-39 Opera 0.75 GS 55	22.5	4.6	8.8	72.5	7.5	222	+3.6
6.	Opera 0.75 GS 37-39 Acanto 0.33 GS 55	20.5	6.8	7.5	73.8	5.8	224	+3.9
7.	Untreated	26.8	24.4	22.5	50.0	5.8	237	90.9
No. of trials		1	2	1	2	ns	ns	ns

Comet 200 / Opera (14374)

One trial was carried out testing different treatments at GS 53 (Table 3). At the time of application the disease levels were very low. In mid-September minor attacks of eyespot and Northern leaf blight developed slightly. Only at the very last assessment could some significant differences be seen between treated and untreated plots for eyespot and Northern corn leaf blight. At the last assessments per cent green area was assessed and again differences could only be seen between untreated and treated plots.

The trial was harvested in late October. No significant yield increases were obtained from the treatments in the trial reflecting the minor and relatively late coming disease attacks. Neither did the treatments show any impact on yield parameters like cob weight and TGW.

Table 3. Effects of two fungicides on eyespot in grain maize as well as yield responses following one application. 1 trial (14374).

Treatments and l/ha	% eyespot 19 Sept. L 4-6	% eyespot 2 Oct. L 3-7	% eyespot 9 Oct. L 1-5	% Northern corn leaf blight 9 Oct. L 1-5	*Fusarium* number of attacks on 15 cobs	Weight of cob g	Yield and increase hkg/ha
1. Untreated	2.3	23.3	13.8	27.5	3.3	234	119.4
2. Opera 1.5 GS 53	1.6	22.0	5.8	13.8	5.0	246	-3.8
3. Comet 200 1.0 GS 53	1.6	21.3	5.5	17.5	2.8	228	-8.5
LSD_{95}	ns	6.3	3.6	6.8	ns	ns	ns

Comet 200 / Opera (14375)

Comet and Opera were applied at either GS 39 or GS 61. At the time of both 1st and 2nd applications the disease levels were very low. In mid-September minor attacks of eyespot and Northern corn leaf blight developed. Only the late assessments showed clear differences between untreated and treatments for both eyespot and Northern corn leaf blight. The efficacy from both timings provided very similar control and it was difficult to differentiate between specific treatments (Table 4).

No significant yield increases were obtained from the treatments in the trial reflecting the minor and relatively late coming disease attacks. Treatments did not show any impact on yield parameters like cob weight and TGW either. The moisture content in grains was slightly higher following late treatments, also as a result of a slightly improved greening.

Table 4. Effects of different fungicides on eyespot in grain maize as well as yield responses following one application. 1 trial (14375).

Treatments and l/ha		% eyespot			% Northern corn leaf blight	% GLA	*Fusarium* number of attacks on 15 cobs	Weight of cob g	Yield and increase hkg/ha
		23 Sept. L 2-5	2 Oct. L 3-7	9 Oct. L 1-5	9 Oct. L 1-5	9 Oct. L 1-6			
1.	Untreated	12.8	40.0	33.8	33.8	41	4.8	240	108.2
2.	Opera 1.5 GS 39	10.3	24.8	11.3	21.3	66	7.3	255	0.8
3.	Comet 200 1.0 GS 39	8.0	18.3	10.3	17.5	68	3.3	238	-4.1
4.	Opera 1.5 GS 61	7.3	20.3	6.3	11.3	81	4.5	256	1.5
5.	Comet 200 1.0 GS 61	7.3	16.8	5.3	15.0	74	5.8	244	-1.0
	LSD_{95}	4.7	10.2	5.8	6.2	12	ns	ns	ns

In Table 5 data from 6 years' trials have been summarised. The yield responses and eyespot control obtained in grain maize trials with Opera carried out since 2009 are listed. Trials have included different treatments using one or two treatments with either full or half rates. The need for disease control in grain maize varies a lot between seasons. As it can be seen eyespot appeared with considerable attacks in 3 of the 6 years and positive net yield increases were harvested in 2 out of 6 years. Only in 2011 did double treatments give the best net yield responses.

Table 5. Summary of control of eyespot in grain maize and yield responses from treatments with Opera applied once or twice using either full or half rates 2009-2014. Trials were situated in high risk fields with minimal tillage and maize after maize.

	% eyespot top part							
	2009	2010	2011	2012	2013	2014	Average	Average
Untreated	1.1	0	78.0	41.4	6.8	33.1		32.1
1 x 1.5 Opera	0.8	-	15.4	17.2	0.8	15.8		10.6
No. of trials	1	0	4	3	2	5		15
Untreated	-	-	81.1	30.7	8.6	25.9	46.4	44.5
1 x 0.75 Opera	-	-	15.3	-	5.8	12.9		12.4
2 x 0.75 Opera	-	-	6.8	2.3	2.9	-	4.2	
No. of trials	0	0	2	1	1	2	5	5

	Yield hkg/ha							
	2009	2010	2011	2012	2013	2014	Average	Average
Untreated	55.4	47.2	61.6	70.8	107.0	107.0	78.2	-
1 x 1.5 Opera	57.4	52.9	91.5	83.0	114.8	105.9	89.5	
Net yield hkg/ha	-6.0	-2.3	+21.9	+4.2	-0.2	-9.1	+3.3	
No. of trials	1	2	4	3	2	4	16	
Untreated	-	47.2	56.8	75.0	102.4	90.9	70.3	65.8
1 x 0.75 Opera	-	53.2	85.0	-	103.4	87.8	79.3	
Net yield hkg/ha 1 x 0.75		+1.7	+23.9		-3.3	-7.4	+4.7	
2 x 0.75 Opera	-	53.2	93.9	86.8	103.9			81.7
Net yield hkg 2 x 0.75		-2.6	+28.5	+3.2	-7.1			+7.3
No. of trials	0	2	2	2	1	2	7	7

Top: Attack by European corn borer in maize cob.
Bottom: Attack of eyespot on leaves of maize.

Top: Attack by European corn borer in maize cob and following that an attack of *Fusarium* developed.
Bottom: Severe attack of *Fusarium* on maize cob.

V Fungicide resistance-related investigations

Lise Nistrup Jørgensen, Thies Marten Wieczorek, Hanne-Birgitte Christiansen & Birgitte Boyer Olsen

Strobilurin resistance to net blotch

In 2014 20 samples with net blotch were investigated for the distribution of the QoI resistance mutation F129L. The samples were collected from field trials by AU Flakkebjerg, SEGES and The Danish AgriFish Agency and originate mainly from untreated plots in field trials.

Similar to previous years, the investigation for mutations was carried out by BASF and Bayer. The data from 2014 showed that the level of F129L in the population of *Drechslera teres* is quite stable and not changing dramatically. If anything, the level seems to be lowered compared with investigations carried out in previous years. F129L is known to be a mutation which only partly influences the field performances of strobilurins.

Data showed that F129L could be found in 35% of the tested samples. Data from the last 7 years' monitoring are given in Table 1. The localities with resistance have been found on Zealand, Funen, Bornholm, Central Jutland and North Jutland. Field data from Flakkebjerg where the level of F129L is quite high have shown that the different strobilurins perform differently. Amistar has been seen to be more influenced by F129L than Comet and Aproach/Acanto, as seen in Chapter II, Figure 17. 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 1. Summing up of results from the strobilurin resistance investigation, F129L incidence in the net blotch fungus (*Drechslera 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

Norbarag trial with net blotch

Seven trials were carried out as a part of a Norbarag project located in Denmark, Sweden, Finland, Latvia and Lithuania, investigating the performances of different actives. The task was also to compare field performances and then screen for resistance to both strobilurins and SDHI-fungicides. The level of net blotch was very high in most trials and all treatments provided significant and high levels of net blotch control. A tendency to lower control was seen from Proline EC 250 used alone. All combinations using mixtures with strobilurins or SDHIs gave very similar control.

Leaf samples from the trials were analysed by either BASF or Bayer for resistance to net blotch and only the trial from Flakkebjerg showed significant levels of F129 L mutations from all treatments investigated, and for the first time two samples also showed signs of the SDHI mutation C-G79R, which is known to significantly reduce the effect of SDHI. As it is known for azoles and also for the strobilurin mutation F129L, the impact from C-G79R has a variable impact on the performances of different SDHI products.

The performances from Imtrex notoriously known to be good on net blotch were slightly lower compared with other treatments. It is too early to tell if the control of net blotch from Imtrex in this trial can be specifically linked to the finding of C-G79R.

Table 2. Control of net blotch and yield responses in 6 trials with spring or winter barley (14339). The trial was treated at GS 39 and placed in Denmark, Sweden, Finland, Latvia and Lithuaria.

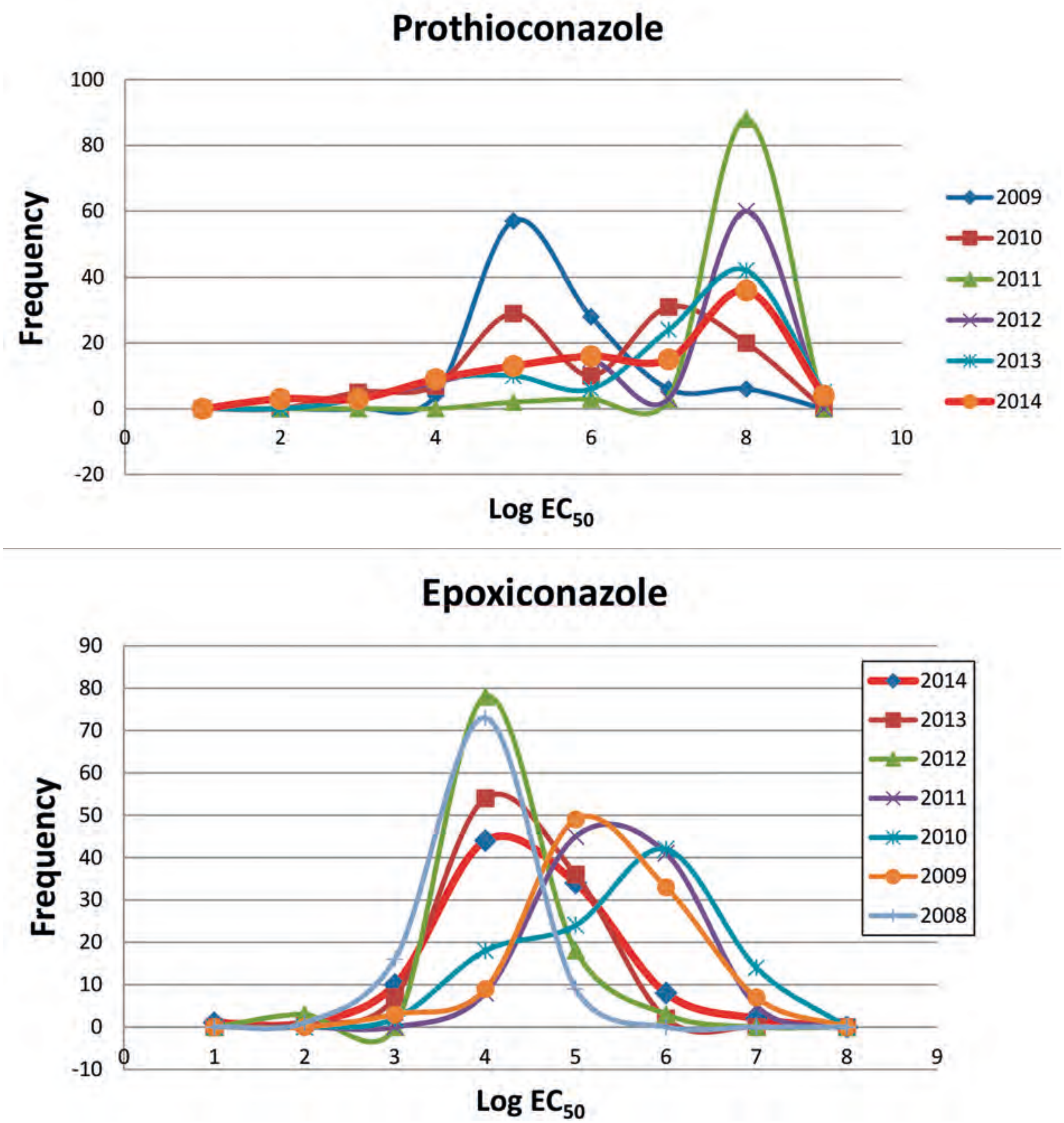
Treatments l/ha GS 39	% net blotch	Green leaf area	Yield and increases	TGW	% strobe resistance	% SDHI Resistance
	GS 75-77	GS 77	hkg/ha	G	F129L	C-G79R
1. Untreated	35.1	36	65.4	41.8	63	10
2. 1.0 Imtrex + 0.5 Comet	0.7	83	+12.2	45.2	76	0
3. 1.0 Imtrex	1.2	84	+11.4	45.4	59	23
8. 0.4 Proline EC 250 + 0.5 Comet	1.5	74	+10.3	45.3	88	0
4. 0.5 Siltra	1.8	79	+10.2	45.5	70	0
5. 0.5 Siltra + 0.5 Comet	0.9	84	+11.1	45.7	92	0
6. 0.4 Proline EC 250	6.1	63	+8.6	43.9	65	0
No. of trials	5	4	6	6	1	1
LSD_{95}	3.1	7.3	2.9	0.8	-	-

Triazole resistance in the population of *Zymoseptoria tritici*

In collaboration between SEGES, local advisors and AU Flakkebjerg leaf samples with *Septoria* are collected and forwarded to Flakkebjerg for sensitivity testing. In total, 27 Danish samples were collected and investigated in 2014. In total, 265 isolates were tested for sensitivity to both epoxiconazole and prothioconazole aiming at 10 isolates per locality. Isolates were tested using the following concentrations.
Epoxiconazole: 0.01, 0.03, 0.1, 0.33, 1.0, 3.3, 10.0 mg/l.
Prothioconazole: 0.01, 0.03, 0.1, 0.33, 1.0, 3.3, 10.0, 30.0, 90 mg/l.

EC_{50} values at a few localities had changed significantly, but overall the sensitivity was close to values seen in previous years. One locality in Southern Jutland had very high EC_{50} values (EC_{50}= 2.3), and this locality was specifically found to give poor control of *Septoria* despite 7 treatments with epoxiconazole during the season. The average resistance factor for all localities where epoxiconazole was tested was 65 and at specific localities varied between 22 and 318. As also seen in previous years the EC_{50} values for prothioconazole were high at most localities. The average resistance factor was 130, varying between 12 and 221.

In field trials from 2014 a significant drop in efficacy was seen for epoxiconazole compared with the performances seen in previous years (see Figure 5, page 33). The low control seen in the field was not reflected in a clear increase in EC_{50} values. With the exception of a few localities the EC_{50} values were not seen to be higher than in previous seasons (Table 4). Results from specific localities are shown in Table 4 and comparisons with previous years' data are shown in Table 3. Figure 1 shows the distribution of EC_{50} values. As it can be seen the overall distributions do not differ from previous years.



Code on X axes	1	2	3	4	5	6	7	8	9
Conc. ppm	<0.01	0.01-0.033	0.033-0.1	0.1-0.33	0.33-1.0	1.0-3.33	3.33-10	10-33.3	>33.3

Figure 1. Frequency of *Septoria* isolates with EC_{50} values grouped into different classes with respect to sensitivity to epoxiconazole and prothioconazole.

Table 3. Summary of measured EC_{50} (ppm) values for epoxiconazole and prothioconazole assessed for *Zymoseptoria tritici* in Denmark. Number in () indicates number of tested isolates.

Year	EC_{50} epoxiconazole	R factor	EC_{50} prothioconazole	R factor
2005	0.12 (47)	2	-	
2006	0.57 (180)	10	-	
2007	0.77 (140)	13	-	
2008	0.17 (88)	3	-	
2009	0.7 (96)	12	0.7	7
2010	1.4 (54)	23	4.4	29
2011	1.33 (85)	22	11.2	74
2012	0.30 (40)	15	10.9	72
2013	0.36 (133)	18	11.7	78
2014	0.51 (265)	69	8.6	130
Wild type IPO323	0.01		0.15	

Table 4. Results from single localities with data from sensitivity testings for *Zymoseptoria tritici* screened on epoxiconazole and prothioconazole using approximately 10 isolates per locality.

	EC50				
	EPO	EPO R factor	PROT	PROT R factor	Number
Årslev, Funen	0.85	100	2.07	31	10
Ultang, South Jutland	0.81	96	2.02	30	10
Ødum, Central Jutland	0.23	27	0.78	12	9
Hostrup, South Jutland	0.59	70	1.58	24	10
Kolding	0.24	28	7.02	106	10
Hinderup, Central Jutland	0.19	22	5.50	83	10
JB Asano field, South Jutland	2.30	318	7.20	117	11
Flakkebjerg	0.45	53	11.91	179	10
Flakkebjerg	0.36	43	8.75	132	10
Flakkebjerg	0.27	32	10.33	156	11
Nykøbing F.	0.62	73	11.91	179	10
Odense SE, 5220	0.39	46	5.77	87	10
Limfjorden	0.39	46	14.52	219	10
Centrovice, Funen	0.46	55	16.64	251	10
Flakkebjerg	0.34	41	13.18	199	9
Sønderborg	0.49	56	12.08	182	10
Ytteborg, Hjerm	0.21	25	16.27	245	9
Følle, Rønde	0.26	31	7.83	118	9
Støvring, Randers	0.25	30	7.29	101	10
Hobro	0.31	38	16.9	187	10
Fjællebro, Ringsted	0.54	40	10.85	163	8
Thisted, Thy	0.29	34	6.61	100	10
Bøgede, Ringsted	0.13	16	3.52	53	7
LMO Horsens	0.45	54	11.32	171	10
Hammelev, Grenaa	0.55	65	14.68	221	9
”Ytteborg”, 7560 Hjerm	1.17	139	13.46	203	9
Hinnerup, Central Jutland	0.25	30	7.42	112	9
Karise, South Zealand	0.61	36	13.94	117	5
Average	0.51	69	8.63	130	265

Strobilurin resistance to *Rhynchosporium* (*Rhynchosporium commune*) in barley

15 leaf samples with rhynchosporium from Denmark (6), Norway (2) and Finland (7) were collected in the summer 2014 and tested for sensitivity to strobilurins. Strobilurin resistance has previously been found in a single case in a French population but has not been commonly found so far. The 15 samples analysed by BASF showed no signs of strobilurin resistance.

Stobilurin resistance to tan spot (*Drechslera tritici-repentis*)

5 samples from the Norbarag region were tested for sensitivity to strobilurins with help from BASF. 2 samples from Denmark confirmed a previous finding, which showed that both F129L and G143A are common. No resistance was found in the Norwegian samples, but in one of two Finnish samples F129L was found. See Table 5.

Table 5. Strobilurin resistance in the *Drechslera tritici-repentis* population.

Country	Locality	% resistance (F129L)	% resistance (G137R)	% resistance (G143A)
Finland	Sarvilahti	**22**	**0**	**0**
Finland	Lieto	**0**	**0**	**0**
Norway	Osorken, Sørøst	**0**	**0**	**x**
Denmark	Flakkebjerg	**36**	**0**	**43**
Denmark	Gerlev, Slagelse	**26**	**0**	**72**

Powdery mildew (*Erysiphe betae*) in sugar beet – sensitivity to strobilurin

In 2014 leaf samples from sugar beet fields with powdery mildew were collected in collaboration with Nordic Beet Research (NBR). Samples were picked from five Danish and five Swedish localities in late August in order to test mildew sensitivity to strobilurins (Table 6). On arrival at AU Flakkebjerg the samples were used to infect symptom free sugar beet plants of the cultivar Julietta (KWS), which is known to be very susceptible to mildew. Diseased leaves were rubbed against the healthy leaves. From each locality 9 plants were inoculated. The day after the inoculation of the plants they were divided into 3 treatments. Three pots were sprayed with 0.5 l Comet (pyraclostrobin) per ha, 3 were sprayed with 0.5 l Opus (epoxiconazole) per ha and 3 were kept untreated. The plants were located at the semi-field area, which is an open area covered with a roof. The plants were followed intensively and the first symptoms could be seen 12-14 days after inoculation (Table 7). Both Comet and Opus provided good control of mildew in the inoculated pots. As it can be seen from the table below there was no clear sign indicating that strobilurin resistance had developed in the populations of *Erysiphe betae*.

Table 6. Localities where powdery mildew was collected.

Danish samples	Swedish samples
1. East Lolland, cultivar: Pasteur; 0.4 l ha^{-1} Opera	6. Lönnstorp; treated
2. South Zealand, cultivar: Doblo; 0.5 l ha^{-1} Opera	7. Gårdsköbing; treated
3. South Falster, cultivar: Doblo; 0.5 l ha^{-1} Opera	8. Gårdsköbing; treated
4. Møn, cultivar: Lombok; 0.5 l ha^{-1} Opera	9. Ö. Sönnarslöv; untreated
5. Zealand, cultivar: Jollina; 0.45 l ha^{-1} Opera	10. Ö. Sönnarslöv; treated

Table 7. Attack of mildew in sugar beet plants which were inoculated with mildew from 10 different localities.

	1	2	3	4	5	6	7	8	9	10
Untreated	+	+	+	+	+++	+++	++	+	++	++
Comet 0.5	-	-	-	-	-	-	-	-	-	-
Opus 0.5	-	-	-	-	-	-	-	-	-	-

VI Disease control in sugar beet

Lise Nistrup Jørgensen, Helene Saltoft Kristjansen, Sidsel Kirkegaard & Anders Almskou-Dahlgaard

Control of powdery mildew (*Erysiphe polygoni*, previously *E. betae*) and rust (*Uromyces betae*)

One trial was carried out in sugar beet testing the efficacy of different fungicides. The trial was sited at Flakkebjerg in the cultivar Smash. Propulse was tested at 5 dose rates and compared with 4 reference products: Opus (epoxiconazole), Opera (epoxiconazole + pyraclostrobin), Sphere (cyproconazole + trifloxystrobin) and Spyrale (difenoconazole + fenpropidin). The crop was treated twice, on 30 July and 21 August. No attack was present at the time of first treatments.

A severe attack of mildew developed from mid-August and a very severe attack of rust developed and ended up almost withering the crop.

All treatments did initially give full control of both mildew and rust (Table 1, Figure 1). A clear dose response was seen for rust in particular. Sphere and Spyrale gave very good and long-lasting control and 1 litre of Propulse gave control in line with 1.0 l Opus.

The treatments which contained strobilurins (Treatments 8 and 9) gave a clear greening effect, which can be seen in the photos on the next pages.

Table 1. Effects of different fungicides on powdery mildew and rust in sugar beet as well as yield responses following 2 applications. 1 trial (143712).

Treatments and l/ha GS		% powdery mildew			% brown rust		Yield and increase hkg/ha	Relative yield
		28 Aug. 29 DAA	19 Sept. 40 DAA	9 Oct. 71 DAA	19 Sept. 40 DAA	9 Oct. 71 DAA		
1.	Untreated	47.5	50	20.0	37.5	58.8	165.1	100
2.	Propulse 1.2	0	0	18.0	4.8	33.8	191.0	116
3.	Propulse 1.0	0	0	14.3	9.5	36.3	189.0	115
4.	Propulse 0.8	0.1	0.3	17.5	13.8	35.0	185.1	112
5.	Propulse 0.6	0.3	2.0	15.0	30.0	38.8	177.6	108
6.	Propulse 0.4	1.5	3.5	12.5	26.3	37.5	175.7	106
7.	Spyrale 1.0	0	0	0	1.5	5.8	200.5	122
8.	Sphere SC 535 0.25	0	0	0	2.5	10.5	196.6	119
9.	Opera 1.0	0	0	10.0	2.1	27.5	201.9	122
10.	Opus	0	0	11.8	10.5	31.3	185.4	112
LSD_{95}		4.6			14	6.1	11.6	-

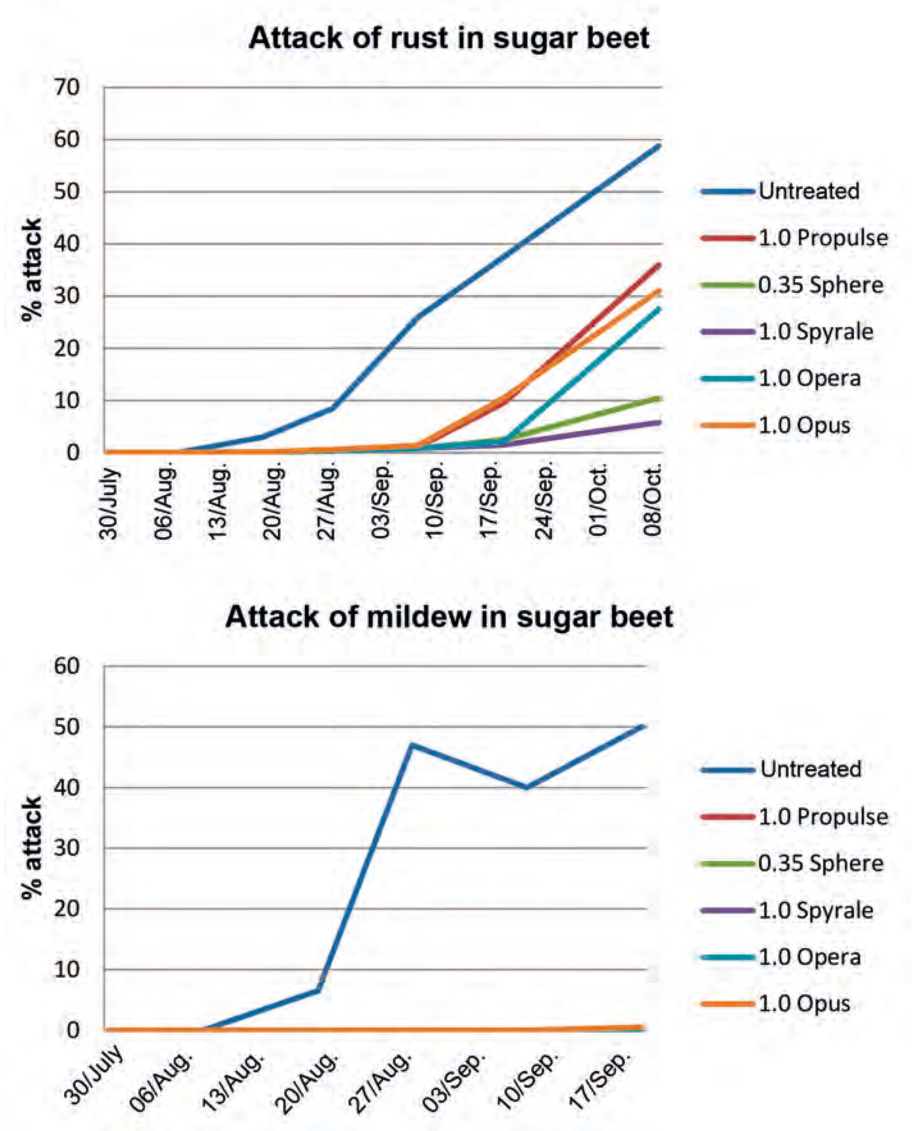
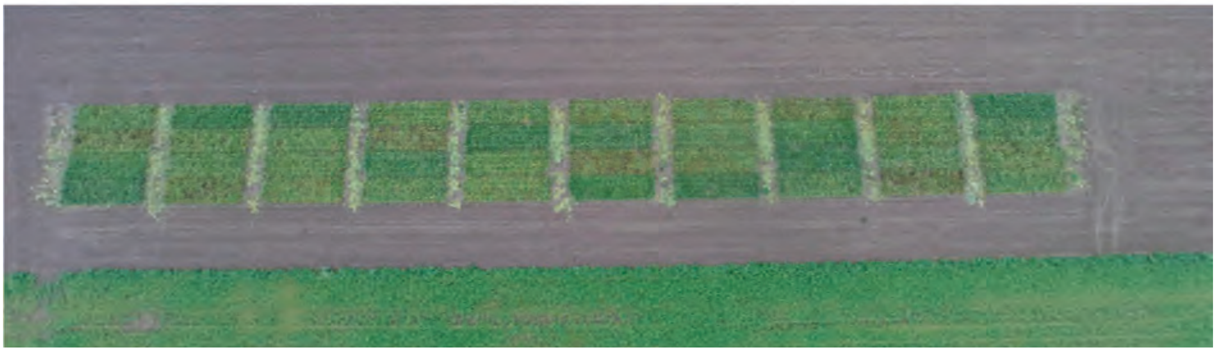


Figure 1. Development of rust and mildew in sugar beet in untreated and selected treatments.

The trial was harvested in November. Kilogram beets harvested per 2 metre row was measured and adjusted for content of soil. Significant yield increases were harvested from all treatments with the exception of the lowest rate of Propulse. Opera, Sphere, Spyrale and the highest rate of Propulse gave the best yield increases. The best yield increase was 23 tonnes/ha providing a very high net return for control. Using EU´s minimum price for sugar (197 DKK/tonne) gives a gross yield increase of 4531 DKK/ha.

Severe attack of mildew developed in the trial in September.

Early (left) and late (right) rust attack.



The picure shows very clear diffences in green colours, depending on the treatments. The most green plots were treated with Opera or Sphere.

Photo from the field with treated and untreated plots next to each other. The yellow colouring of the untreated plot was mainly caused by rust.

VII Interactions between nitrogen and diseases in wheat

Peter Kryger Jensen & Lise Nistrup Jørgensen

In fields with heterogeneous soil types crop development often varies widely due to the different growth conditions. To control diseases, however, a uniform fungicide dose is typically chosen for the entire field. The purpose of this project was to investigate the potential for adapting the fungicide dose rate to the site specific development of the crop. Differences in crop development in the trials were achieved with a combination of variable seed rate and 3 levels of N fertiliser. Three levels of seed rate/nitrogen application created a variation in crop development corresponding to the variation that can be found in heterogeneous fields. In the project it was examined whether the attack of diseases in winter wheat was related to the crop biomass. It was further the aim to examine if there was an interaction between crop biomass and fungicide dose, and hence whether the fungicide dose should be adapted to crop biomass. Crop development was characterised by measuring leaf area index (LAI), vegetation index and taking 3-dimensional photos of the crop in the period in which the fungicide application took place. Leaf area measurements and LAI measurements in the period from fungicide application from the 2014 experiment are shown in Table 1, demonstrating the variation in crop development at the three seed rate/nitrogen levels.

It can be seen that both leaf area of leaves 1 & 2 and LAI were affected by the 3 nitrogen levels. Only minor differences in deposition of spray liquid between the 3 levels were found. However, the 1st leaf (flag leaf) was more upright in the low N treatment and as a consequence had a reduced deposit. Due to the more open canopy, the low N treatment had larger deposits of spray liquid on the 3rd leaf. *Septoria* was by far the most important disease in the 2014 trial. The time of application was relatively late seen with respect to the optimal timing in the 2014 season. In general, this year's trials showed that 3 applications were economically the best. So the one treatment strategy used in this trial should be regarded as suboptimal. The attack developed rapidly in the period following the fungicide application (Table 2). On the 2nd leaf the treatment was regarded as insufficient due to late timing and only on the flag leaf could the treatments be regarded as acceptable. There was a significant influence of the nitrogen level on the *Septoria* attack. In untreated control attacks were much larger at the two high nitrogen levels. At the high fungicide dose insignificant differences in attack between the three nitrogen levels were seen on the 1st leaf. However, at the two lower fungicide rates severe attacks were found at the high nitrogen levels at GS 81 on leaf 1, indicating an interaction between crop biomass and optimal fungicide dose rate. The same appeared in the yield measurement in which no dose response was found at the low nitrogen level, but increasing yield at increasing fungicide rate at the two high nitrogen levels. The yield levels in the trial were relatively high and the nitrogen had a major impact on the protein content in the grain. The protein content was very low at both 80 and 160 kg N/ha. Adjusting the net yield for both cost of fungicides and nitrogen input and also adjusting for the lack in protein, the economic optimum is found for the high input of fungicides at 260 kg N as shown in Figure 1. As seen before - fungicide treatments lower the level of protein as a result of an increase in grain sizes.

Table 1. Leaf area and deposition of spray liquid on the upper 3 leaves at fungicide application. Deposition was measured using a tracer. The fungicide application was carried out 25 May and leaf area index is shown from fungicide application and the following month.

	Leaf area (cm^2) of 10 leaves			Deposited spray liquid (µg/cm^2)			Leaf Area Index (LAI)		
	1st leaf	2nd leaf	3rd leaf	1st leaf	2nd leaf	3rd leaf	23/5	5/6	23/6
80 kg N	180	281	291	0.023	0.073	0.059	GS 47	GS 59	GS 73
1. Control							4.6	3.7	3.8
2. 1.125 Bell							4.5	4.2	4.1
3. 0.75 Bell							4.2	3.9	4.1
4. 0.375 Bell							4.5	4.3	4.2
160 kg N	233	317	298	0.033	0.079	0.048			
1. Control							5.8	5.5	5.7
2. 1.125 Bell							5.6	5.7	5.5
3. 0.75 Bell							5.2	5.3	4.9
4. 0.375 Bell							5.3	5.5	5.5
240 kg N	241	325	284	0.035	0.080	0.043			
1. Control							6.3	6.2	5.8
2. 1.125 Bell							6.3	6.4	6.7
3. 0.75 Bell							6.2	6.1	6.3
4. 0.375 Bell							5.4	5.6	5.7

Table 2. Assessment of *Septoria* attack, yield and protein content in winter wheat cv Hereford.

	Attack of *Septoria* on 1st leaf				*Septoria* on 2nd leaf GS 73	Yield (hkg/ha)	% protein content
	GS 59	GS 69	GS73	GS 81			
80 kg N							
1. Control	0.5	2.5	6.3	57.5	77.5	82.2	8.1
2. 1.125 Bell	0.5	1.3	0.9	23.8	42.5	90.5	7.5
3. 0.75 Bell	0.5	1.8	1.1	23.8	55.0	88.0	7.3
4. 0.375 Bell	0.5	2.3	1.9	40.0	66.3	90.0	7.7
160 kg N							
1. Control	0.5	3.0	11.8	98.3	76.3	88.5	10.1
2. 1.125 Bell	0.5	1.3	0.9	25.0	36.3	105.5	9.1
3. 0.75 Bell	0.9	2.0	1.8	45.0	61.3	102.4	9.2
4. 0.375 Bell	0.5	2.8	2.0	71.3	68.8	98.4	9.5
240 kg N							
1. Control	1.4	2.8	13.8	100.0	90.0	89.2	11.9
2. 1.125 Bell	0.4	1.8	1.0	33.8	42.5	110.8	11.6
3. 0.75 Bell	0.5	1.5	2.0	38.8	56.3	105.0	11.2
4. 0.375 Bell	1.1	2.0	3.3	67.5	62.5	103.1	10.9
LSD_{95}	0.5	1.2	2.0	16.6	8.9	5.5	0.7

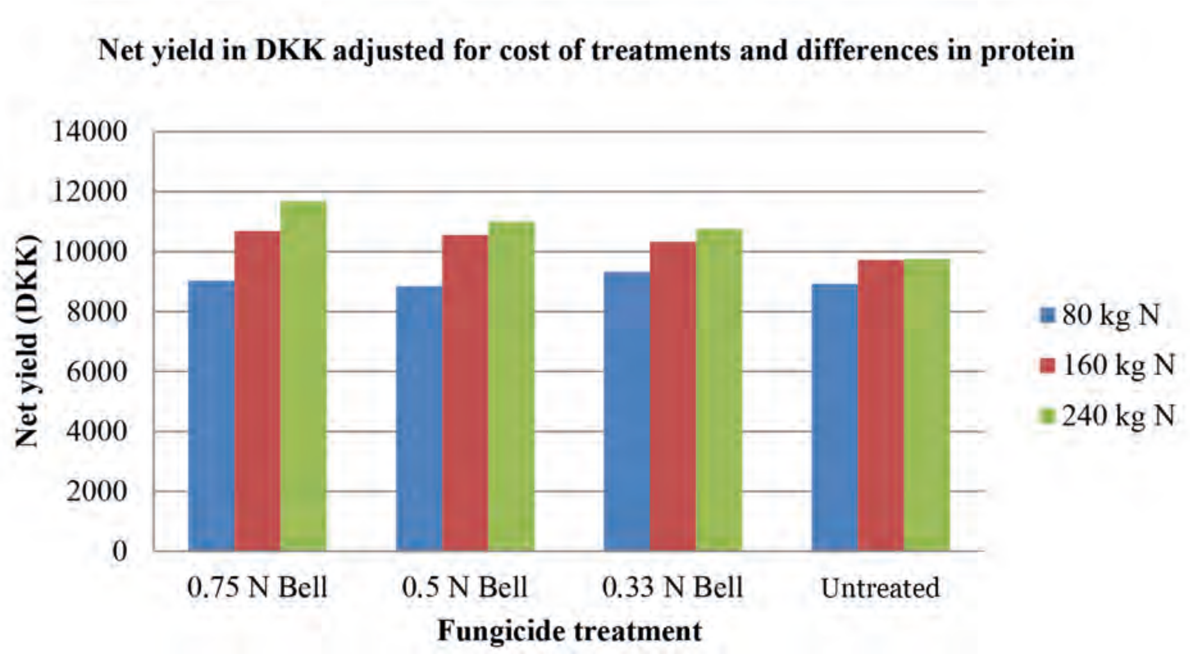


Figure 1. Yield responses adjusted for cost of fungicides and nitrogen as well as for differences in content of protein.

Top: 240 kg N/ha; left: untreated; right: 0.75 Bell. Centre: 160 kg N/ha; left: untreated; right: 0.75 Bell. Bottom: 80 kg N/ha; left: untreated; right: 0.75 Bell.

VIII Control of late blight (*Phytophthora infestans*) and early blight (*Alternaria solani* & *A. alternata*) in potatoes

Bent J. Nielsen

Abstract

In 2014 the decision support system Blight Management (BM) (Skimmelstyring) and different control strategies using the infection pressure calculated in Blight Management were tested at AU Flakkebjerg in co-operation with SEGES, KMC and AKV. The weather conditions in July were not favourable for disease development and it was not until the last part of August that there was a development in the epidemic of late blight. The models were therefore tested under low to moderate disease pressure. It is known that it can be difficult to control sporulating lesions. If spraying was started before approximately 1% attack, it was shown that two times cymoxanil or cymoxanil + propamocarb had enough curative/eradicative effect to stop further development of late blight.

The trials with control of early blight were artificially inoculated with *Alternaria solani* and *A. alternata* at the end of June but due to the dry July development in attack was not seen until the end of August with severe development in September. Although the start was relatively late there was still enough attack to evaluate different spray strategies. Since the development in *Alternaria* attack came relatively late it was the strategies with sprayings late in the season that gave the best results. Different potato varieties were inoculated with *A. solani* and *A. alternata* in order to test the level of resistance. All varieties tested were susceptible to *Alternaria*, but with differences related to the maturity classes and the time needed to reach 50%, attack varied a month between the varieties.

Materials and methods

The potato trials are carried out at AU Flakkebjerg on sandy clay loam (JB 5-6) in co-operation with SEGES (Danish Agricultural Advisory Service) with a randomised complete block design and 4 replicates in the starch varieties Kuras and Dianella. Plot size is 36 m^2 (gross)/21 m^2 (net). The potatoes were planted on 1 May and emerged on 1 June. The late blight trials were artificially inoculated on 1 July with spraying of a sporangial suspension of *P. infestans* (1000 sporangia/ml) over spreader rows between the blocks. The *Alternaria* trials were artificially inoculated on 27 June with autoclaved barley seeds inoculated with *A. solani* and *A. alternata* placed in the furrow between the plants.

Spraying was started according to the protocols and spray technique was 300 l water/ha, Hardi ISO LD 025 nozzle and 3 bar. During the season plots were assessed at weekly intervals for the extent of potato late blight (*P. infestans*) and early blight (*Alternaria solani* & *A. alternata*). Each plot was scored as a whole for % disease severity (percentage coverage of all green leaves; EPPO guideline PP 1/2 (4), 2012). All plots were assessed during the whole season or until 100% disease in the specific plot.

All plots were harvested (4 rows x 7 m from each plot) and starch content measured (weight under water of dry matter. % starch = dry weight – 5.75). Tuber blight was assessed as percentage of tubers affected by tuber blight on minimum 100 tubers per plot after at least 2 weeks and up to 8 weeks of storage under normal conditions.

Potato field trials at Flakkebjerg, 2 September 2014.

The weather in July was dry and the trial site was irrigated by boom 6 times (25 mm water) from mid-June to the end of July.

The trials were performed according to EPPO guidelines PP 1/2(4), PP 1/135(3), PP 1/152(3), PP 1/181(3) and PP 1/263(1). The data were subjected to analysis of variance and treatment means were separated at the 95% probability level using F-test.

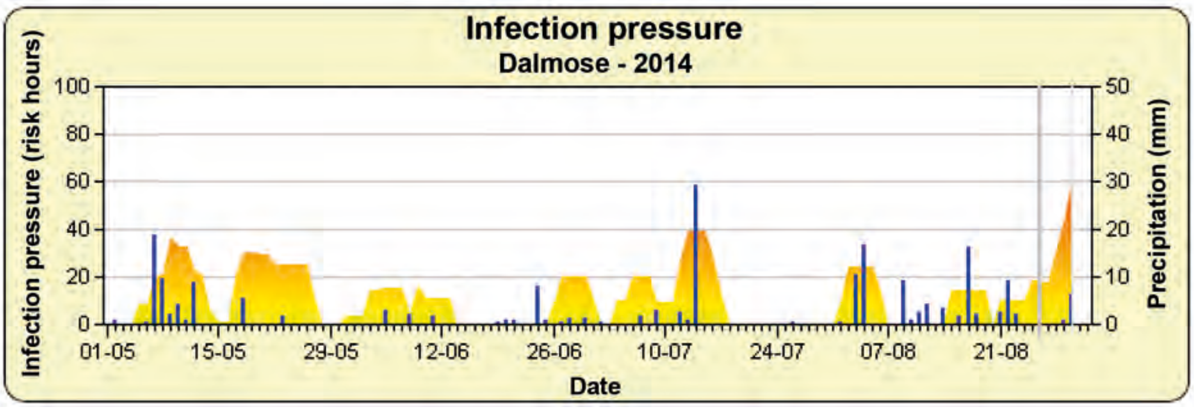


Figure 1. Infection pressure (5 days running mean) for Dalmose 2014 (2 km SE of Flakkebjerg).

Infection pressure for potato late blight (www.euroblight.net)

The infection pressure for late blight is a running sum of sporulation hours during a 5-day window including current date, 2-day weather forecast and two days of historic weather. Sporulation hours for potato late blight (HSPO) is defined as number of hours in periods of 10 or more hours when Rh>88% and temperature at the same time is between 10°C and 24°C. HSPO is 5 if there are 10 consecutive hours of Rh>88% and the temperature in 5 of those humid hours is above 10°C. During a high infection pressure it is expected that there is a risk of both sporulation and infection. Infection pressure: < 20 is regarded as low; 20 - 40 is regarded as moderate risk and > 40 is regarded as high risk.

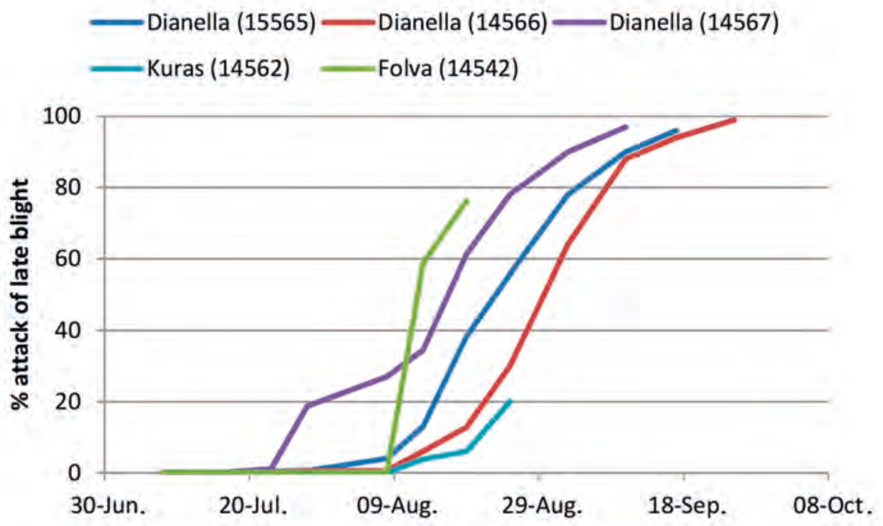


Figure 2. Development of late blight (*Phytophthora infestans*) in untreated plots at Flakkebjerg 2014. Three different trials with variety Dianella and in unsprayed rows of varieties Kuras and Folva. Artificial inoculation on 1 July.

Potato late blight (*Phytophthora infestans*) 2014

The trials at Flakkebjerg were artificially inoculated on 1 July 2014 by spraying a sporangial suspension of *P. infestans* (1000 sporangia/ml) over spreader rows between the blocks. The first symptoms were detected in the spreader rows on 8 July and in the untreated trial plots in mid-July. Due to dry weather in July and low infection pressure of late blight (Figure 1) there was no disease development until the last part of July – start of August with a severe epidemic development in untreated plots in the last half of August and beginning of September. In mid-September almost all untreated plots of the susceptible variety Dianella were destroyed by late blight (Figure 2). Due to the unfavourable conditions for development of late blight the start of the epidemic varied between the different trials as seen in Figure 2 with different trials in the variety Dianella. However, within each trial the attacks were evenly distributed. Compared to previous years, the disease development in 2014 started later than in 2012 but earlier or at the same time as in the dry year 2013 (Figure 3). The first symptoms of late blight were observed in untreated plots at Flakkebjerg on 22 July 2009, 20 July 2010, 15 July 2011, 9 July 2012 and 22 July 2013.

The weather conditions were very wet at the lifting of the potatoes in beginning of October and low to moderate attacks of tuber blight were seen in several plots.

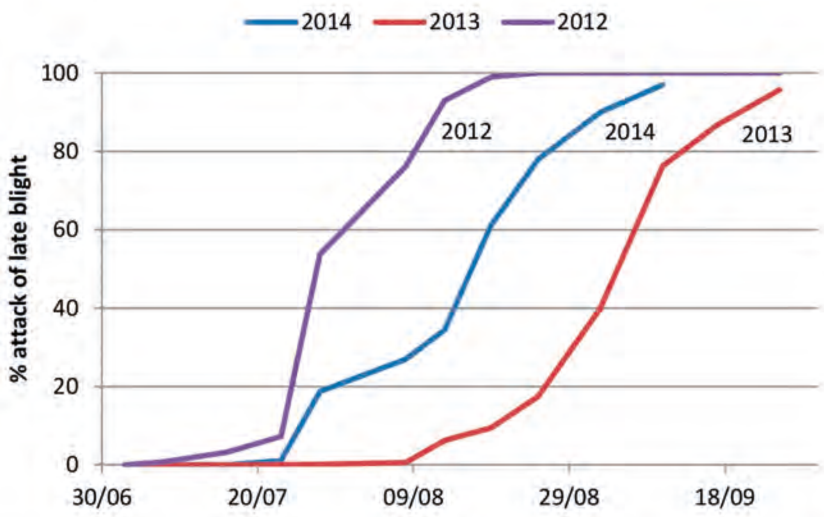


Figure 3. Development of late blight (*Phytophthora infestans*) in untreated plots of variety Dianella at Flakkebjerg 2012-2014. Artificial inoculation first week of July.

Potato early blight (*Alternari solani* & *A. alternata*) 2014

The trials at Flakkebjerg were artificially infected on 27 June 2014 with autoclaved barley seeds inoculated with *A. solani* and *A. alternata*. The first attacks on the lower leaves were detected on 7 July, 10 days after inoculation. However, the weather conditions were very dry in July and it was not until the beginning of August that there was a development in the attack. In August and September there was a severe development in the trial at Flakkebjerg with 90%-100% of the leaves attacked in untreated plots at the last assessments in September (Figure 4). The trials at location Billund in Central Jutland were also artificially inoculated (same seed lot as in Flakkebjerg) and the start of the epidemic was similar to Flakkebjerg, but the trial at the more sandy soils at Billund had a more severe attack later in September (Figure 4). The trial at Sunds in West Jutland was not inoculated, and attacks originated from natural sources (plant debris in the soil). The first attacks came later than at Flakkebjerg, but when first started the development was very quick (Figure 4).

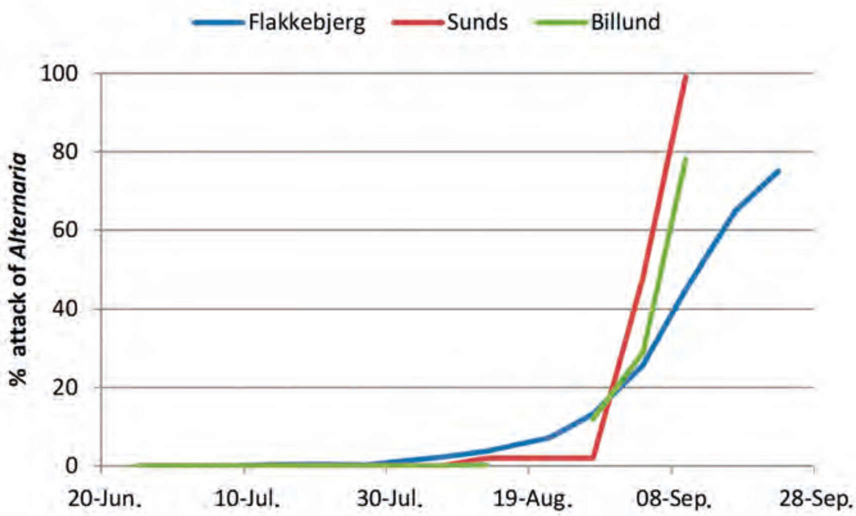


Figure 4. Development of *Alternaria* 2014 in untreated plots at Flakkebjerg, Sunds (West Jutland) and Billund (Central Jutland). Artificial inoculation at Flakkebjerg and Billund, natural infestations at Sunds. Variety Kuras.

The development in early blight at Flakkebjerg in 2014 was similar to the development in 2013 when the weather conditions in July also were dry but later than the development in 2012 (Figure 5). In 2013 the trials were inoculated on 28 June and the first attacks on the lower leaves could be seen from 5 July.

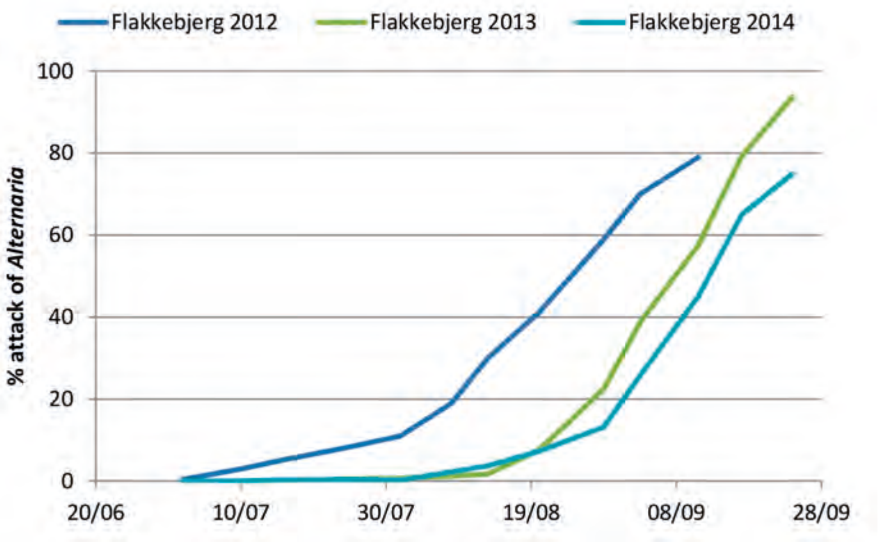


Figure 5. Development of *Alternaria* in untreated plots at Flakkebjerg 2012-2013. Artificial inoculation by inoculated barley seeds at the end of June. Variety Kuras.

The development in attack of *Alternaria* at Sunds (natural infestations) was almost similar in all three years 2012-2014 (Figure 6).

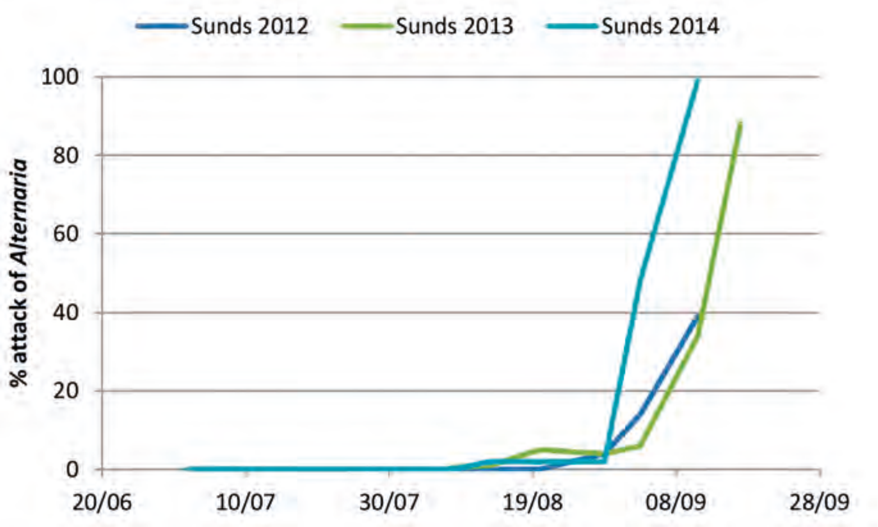


Figure 6. Development of *Alternaria* in untreated plots at Sunds (Jutland) 2012-2013. Natural infestations. Variety Kuras.

Results from field trials 2014

Blight Management

The field trials testing the different dose models in Blight Management were continued in 2014 in co-operation with SEGES (advisory service) and the starch companies KMC and AKV. The project is financed by GUDP (2012-2015). The general set-up was as in previous years with two reference plots with full and half dose of Revus and Ranman Top (treatments 1-2 in Table 1). No untreated plots were included; only disease assessments in unsprayed guard rows close to the trial (variety Kuras in Figure 2).

Table 1. Trial plan for testing of dose models in Blight Management 2014. Actual dates for the sprayings are indicated for the trial at Flakkebjerg. Set-up and the weekly spraying were almost the same in the trials at Dronninglund and Sunds.

	Week	25	26	27	28	29	30	31	32	33	34	35	36
	Spray date	18-Jun	25-Jun	02-July	09-July	16-July	23-July	30-July	06-Aug	13-Aug	20-Aug	27-Aug	03-Sep
		A	B	C	D	E	F	G	H	I	J	K	L
1	Full dose	0.6 RE	0.6 RE	0.5 RanT	0.5 RanT	0.6 RE	0.6 RE	0.5 RanT	0.5 RanT	0.6 RE	0.6 RE	0.5 RanT	0.5 RanT
2	Half dose	0.3 RE	0.3 RE	0.25 RanT	0.25 RanT	0.3 RE	0.3 RE	0.25 RanT	0.25 RanT	0.3 RE	0.3 RE	0.25 RanT	0.25 RanT
3	Model A	RE	RE	RanT	RanT	RE	RE	RanT	RanT	RE	RE	RanT	RanT
4	Model A-UV/LW	RE	RE	RanT	RanT	RE	RE	RanT	RanT	RE	RE	RanT	RanT
5	Model B	RE	RE	RanT	RanT	RE	RE	RanT	RanT	RE	RE	RanT	RanT
6	Model B-UV/LW	RE	RE	RanT	RanT	RE	RE	RanT	RanT	RE	RE	RanT	RanT
7	DACOM (only at Flakkebjerg)												

Plots 1-2: Revus (RE) or Ranman Top (RanT) sprayed at full dose (0.6 l/ha and 0.5 l/ha respectively, plot 1) or half dose, plot 3: Dose model A (see Table 3), plot 4: Dose Model A corrected for UV and leaf wetness (see text for explanation), plot 5: Dose Model B (see Table 3), plot 6: Dose Model B corrected for UV and leaf wetness, plot 7: The commercial program DACOM (see text for explanation).
In order to control attack of *Alternaria* the trials were sprayed with 3 x Signum WG 0.25 kg/ha in all plots.

Dose Model A was the same as in 2013 when the dose of Revus or Ranman Top was adjusted according to the infection pressure, and the occurrence of late blight in the region or area (Table 2). The selection of either Revus or Ranman Top followed the same schedule as in treatments 1-2 (Table 1). If no attacks of late blight were seen in Denmark, spraying would only be recommended according to Model A at infection pressure > 40 and only at half dose (stage 1 in Table 2). Later steps in the model were when attacks were seen somewhere in Denmark (stage 2), in the region (25-50 km from the location, stage 3) or in the field or very close to the field (in the experimental plots in the actual trial, stage 4). If once late blight was seen but then died out (e.g. due to sprayings), the stage could turn back to the previous level (stage 5). The actual dose level was at the end a combination of infection pressure x occurrence of blight and is in Table 2 expressed in per cent of a full dose of either Revus or Ranman Top.

Table 2. Dose models used in Blight Management 2014 in starch variety KURAS. The recommended dose of either Revus or Ranman Top is given in per cent of the standard dose (0.6 l/ha of Revus and 0.5 l/ha of Ranman Top) and depends on the local infection pressure for late blight (www.skimmelstyring.dk) and how close to the location late blight has been recorded (e.g. as noted on www.landbrugsinfo.dk).

Model A *Infection pressure*		Stage 1 No attack in DK	Stage 2 Attack in DK	Stage 3 Attack in region	Stage 4 Attack in **the field**	Stage 5 Late blight not active
> 60	Very high	50	75	100	100	100
40-60	High	50	50	100	100	100
20-39	Moderate	0	50	75	100	75
1-19	Low	0	50	50	75	50
0	No risk	0	50	50	50	50

Model B *Infection pressure*		Stage 1 No attack in DK	Stage 2 Attack in DK	Stage 3 Attack in region	Stage 4 Attack in **the field**	Stage 5 Late blight not active
> 60	Very high	50	50	75	100	75
40-60	High	0	50	75	75	75
20-39	Moderate	0	50	50	75	50
1-19	Low	0	0	**25**	50	25
0	No risk	0	0	**25**	**25**	**25**

Stage 2, attack in the region is within 25-50 km. If active late blight is seen in stage 4 in the field (experimental plot), then curative product is used (Proxanil 2.0 l/ha + half dose of either Revus or Ranman Top), max. two times at 7-day intervals. If late blight is controlled, then shift to stage 5. If blight is still present, stay in stage 4. See text for more explanation. The actual infection pressure is determined by the highest value in the four-day prognosis (www.skimmelstyring.dk) from the current day including the past two days.

In principle **Dose Model B** followed the same rules as Model A, but the actual dose levels were lower (e.g. almost no sprayings at stage 1, Table 2). Dose Model A and Dose Model B were tested in the trial plots 3 and 5 (Table 1). In the trial treatments 4 and 6 were tested Dose Models A and B but the infection pressure was corrected for leaf wetness (LW) and UV light (UV). Prognoses for LW and UV were made in co-operation with the Danish Meteorological Institute, DMI. Under conditions with high UV the infection pressure tended to be corrected to lower values and under conditions with higher humidity (e.g. later in the season) the infection pressure tended to be corrected to slightly higher values. The Dutch commercial system DACOM (former PlantPlus) was tested in the trial treatment 7. The weather data came from a nearby meteorological station.

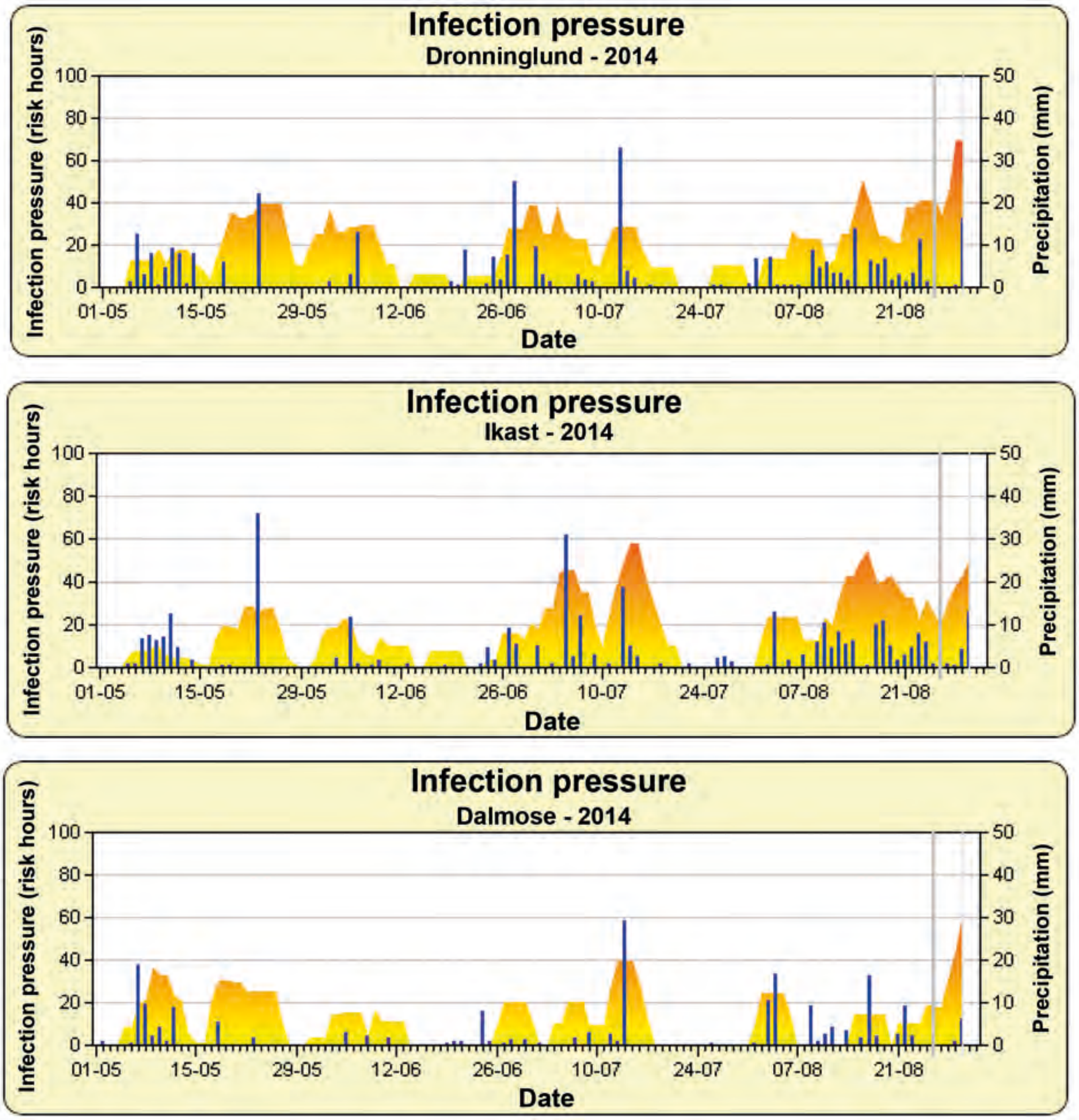


Figure 7. Infection pressure for late blight (5-days running mean) at Dronninglund, Sunds and Flakkebjerg (Dalmose, 2 km SE of Flakkebjerg) 2014. For explanations of the infection pressure, see text under Figure 1.

In both models a curative fungicide Proxanil (2.0 kg/ha) combined with either half dose of Revus or Ranman Top was used when the first active lesions of late blight were seen in the trial plots as explained under Table 2.

In 2014 three trials were carried out according to the plan (Table 1) in the starch variety Kuras at Flakkebjerg (sandy clay loam), Sunds and Dronninglund (sandy soils).

Table 3. Field trials with the dose models in Blight Management 2014 at Flakkebjerg, Dronninglund and Sunds in starch variety Kuras. Spr: Numbers of sprayings, TFI: Treatment frequency index (number of sprayings with standard dose), % LB: per cent leaf attack of late blight mid-September.

		Flakkebjerg			Sunds			Dronninglund			Average		
		Spr.	TFI	% LB	Spr.	TFI	% LB	Spr.	TFI	% LB	Spr.	TFI	% LB
1	Full dose	13	13.0	0.2	14	14	0	13	13.0	0	13.3	13.3	0.06
2	Half dose	13	6.5	0.2	14	7	0	13	6.5	0	11.2	6.7	0.06
3	Model A	13	8.8	0.2	14	10.5	0	13	10.9	0	11.9	10.0	0.06
4	Model A-UV/LW	13	8.0	0.2	14	10	0	13	10.4	0	11.7	9.5	0.06
5	Model B	12	6.0	0.2	14	7	0	13	7.9	0	11.0	7.0	0.06
6	Model B-UV/LW	11	4.8	0.2	14	6.5	0	13	7.9	0	10.6	6.4	0.08
7	DACOM	4	4.0	1.5									

Explanations of the models and trial plan are given in Tables 1-2.
Curative sprayings with Proxanil (2.0 l/ha) were only applied at Dronninglund 14 August.

The infection pressure varied during the season 2014 but was in general low at Flakkebjerg and moderate at Sunds (Ikast) and Dronninglund (Figure 7). There was no attack of late blight recorded in the trials at Sunds or Dronninglund and only very low levels at Flakkebjerg (0.2%, 17 September, Table 3). The trials were sprayed 13–14 times with alternately Revus and Ranman Top. Only one application of Proxanil (2.0 l/ha) was applied at Dronninglund (due to the calculated high infection pressure). The input of fungicides measured as the treatment frequency index was reduced when the models were used in comparison with the standard full dose. At Flakkebjerg the input was reduced from TFI 13 to 8.8-8.0 in Dose Models A and A corrected and to 6.0-4.8 in Dose Models B and B corrected. At Sunds the input was reduced from TFI 14 to 10.5-10 in Dose Models A and A corrected and to 7.0-6.5 in Dose Models B and B corrected. At Dronninglund the input was reduced from TFI 13 to 10.9-10.4 in Dose Models A and A corrected and to 7.9 in Dose Models B and B corrected (Table 3). In average of the three trials the fungicide input was reduced to 71% when Dose Model A corrected was used and to 48% when Dose Model B corrected was used compared to the full standard dose (Figure 8 and Table 3).

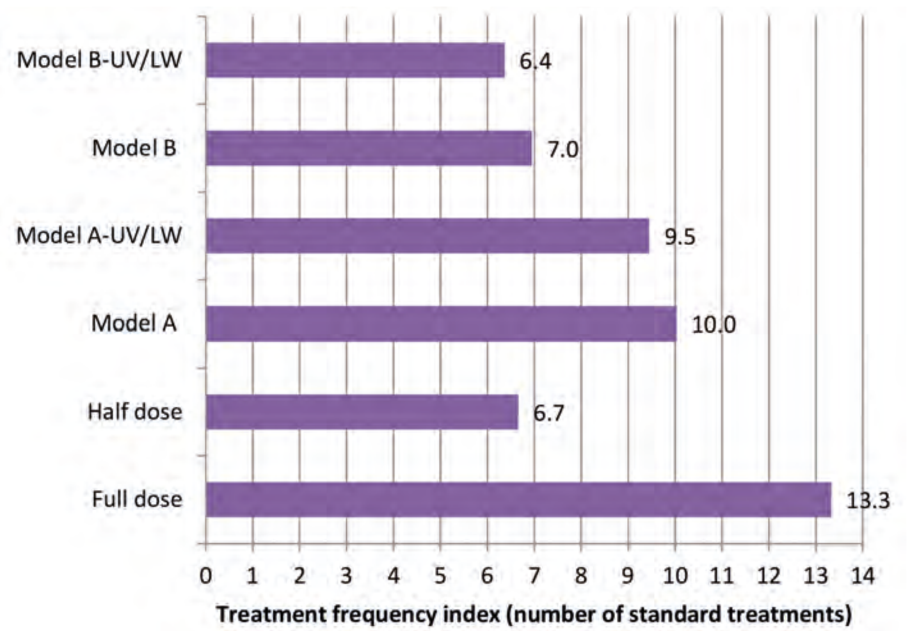


Figure 8. Treatment frequency index (number of standard doses used) in the dose models in average of three trials (Flakkebjerg, Sunds and Dronninglund), 2014. Variety Kuras. Only very low levels of late blight (<0.2% attack). Explanations of models are given in Tables 1-2.

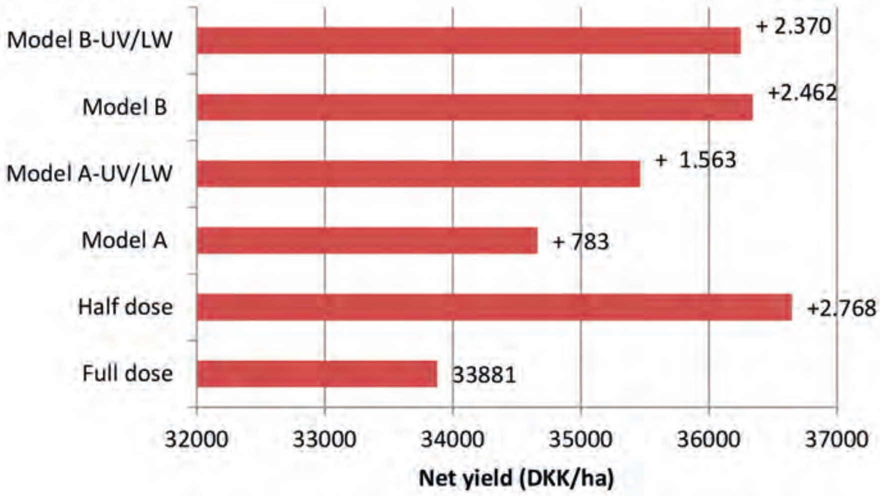


Figure 9. Net yield after using the dose models as an average of three trials (Flakkebjerg, Sunds and Dronninglund), 2014. Variety Kuras. Net yield is calculated by subtracting cost of fungicides (www.middeldatabasen.dk) and cost of sprayings (140 DKK/ha). Only very low levels of late blight (<0.2% attack). Figures above the bars indicate net yield increase relative to full standard dose. Explanations of models are given in Tables 1-2. LSD_{95}: *n.s.*

The commercial program DACOM was tested in the trial at Flakkebjerg. There were some problems measuring the relative humidity correctly in the meteorological weather station connected to the system. However, the program still managed to reduce the sprayings and 4 applications in total were recommended at full dose, which was 31% of full standard input (Table 3).

There were no significant differences in the tuber yield between the models. Using Model A resulted in a net yield increase of 783–1,563 DKK/ha and with Model B a net yield increase of 2,462–2,370 DKK/ha relative to the standard full dose, but lower than for the standard half dose (2,768 DKK/ha; Figure 9).

The same dose models and two new models were also tested at Flakkebjerg in the table variety Folva. The principle for Dose Models A and B is shown in Table 2. The additional Dose Model C and Dose Model D are shown in Table 4. The principle for the dose calculation follows the same rules as mentioned under explanation to Dose Models A and B (and in Table 2). Compared to Dose Models A and B there is a further reduction in the fungicide input in Dose Models C and D. In Dose Model D there is for example no spraying when there is no risk. The trial plan for plots 1-7 was the same as in the trial in the starch variety Kuras (Table 1). Plot 8 was Dose Model C, plot 9 was Dose Model C corrected for UV and leaf wetness and plot 10 was Dose Model C corrected for UV and leaf wetness.

There were no untreated plots in the trial, but in nearby unsprayed guard rows there was a severe development of late blight with 90% of leaves attacked on 26 August (variety Folva in Figure 2).

Routine spraying with full and half dose was 10 times during the season and resulted in a very good disease control (compared to the level in the untreated guard rows, Table 5). A similar level was obtained with Dose Model A (with and without corrections). Slightly more disease was seen in the other models, e.g. approx. 0.2% attack in Models C and D.

Dose models have been tested since 2009 in field trials at three locations every year according to the same set-up as indicated in Table 1 with Revus and Ranman Top in the variety Kuras. Dose levels and details have varied over the year but basically the same principles have been followed as indicated in Table 2 (close to Model A). Figure 10 shows the results of 20 trials 2009-2014. Use of the Blight Management model gave over the years 2009-2014 almost the same level of control as the full standard dose but the fungicide input was 20% lower. Spraying routinely with a half dose during the season resulted in slightly more disease but only 50% fungicide input (Figures 10-11). However, using the dose model gave a better distribution of fungicide during the season with less at the start and higher doses at the end of the season and in this way in general a more safe protection.

Table 4. Dose models used in Blight Management 2014 in table variety FOLVA. The recommended dose of either Revus or Ranman Top is given in per cent of the standard dose (0.6 l/ha of Revus and 0.5 l/ha of Ranman Top) and depends on the local infection pressure for late blight (www.skimmelstyring.dk) and how close to the location late blight has been recorded (e.g. as noted on www.landbrugsinfo.dk).

Model C Infection pressure		Stage 1 No attack in DK	Stage 2 Attack in DK	Stage 3 Attack in region	Stage 4 Attack in **the field**	Stage 5 Late blight not active
> 60	Very high	75	100	100	100	100
40-60	High	50	75	100	100	100
20-39	Moderate	0	**25**	50	100	50
1-19	Low	0	0	**25**	75	**25**
0	No risk	0	0	0	50	0
Model D Infection pressure		**Stage 1 No attack in DK**	**Stage 2 Attack in DK**	**Stage 3 Attack in region**	**Stage 4 Attack in the field**	**Stage 5 Late blight not active**
> 60	Very high	50	50	75	100	75
40-60	High	0	50	75	75	75
20-39	Moderate	0	50	50	75	50
1-19	Low	0	0	**25**	50	**25**
0	No risk	0	0	0	0	0
Stage 2, attack in the region is within 25-50 km. If active late blight is seen in **stage** 4 in the field (experimental plot), then a curative product is used (Proxanil 2.0 l/ha + half dose of either Revus or Ranman Top), max. two times at 7-day intervals. If late blight is controlled, then shift to **stage** 5. If blight is still present, stay in stage 4. See text for more explanation. The actual infection pressure is determined by the highest value in the four-day prognosis (www.skimmelstyring.dk) from the current day including the past two days.						

Table 5. Field trial with the dose models in Blight Management 2014 at Flakkebjerg in table variety FOLVA. Spr: Numbers of sprayings, TFI: Treatment frequency index (number of sprayings with standard dose), % LB: per cent leaf attack of late on 26 August.

		Flakkebjerg		
		Spr.	TFI	% LB
1	Full dose	10	10.0	0.05
2	Half dose	10	5.0	0.08
3	Model A	10	5.8	0.05
4	Model A-UV/LW	10	5.5	0.06
5	Model B	9	3.8	0.10
6	Model B-UV/LW	8	3.0	0.33
7	DACOM	4	5.8	0.22
8	Model C	8	4.3	0.15
9	Model C-UV/LW	7	5.0	0.13
10	Model D-UV/LW	7	3.8	0.18
% late blight in unsprayed guard rows				90
Explanations of the models and trial plan are given in Tables 1-2 and 4. Curative sprayings with Proxanil were applied in treatment 7 (DACOM) on 4 august (2.0 l/ha) and 18 August (2.5 l/ha).				

The cost of spraying in the 20 trials 2009-2014 was reduced by 17% (Figure 11).

Results from the trials can also be seen in "Oversigt over Landsforsøgene 2014" pp. 314-316.

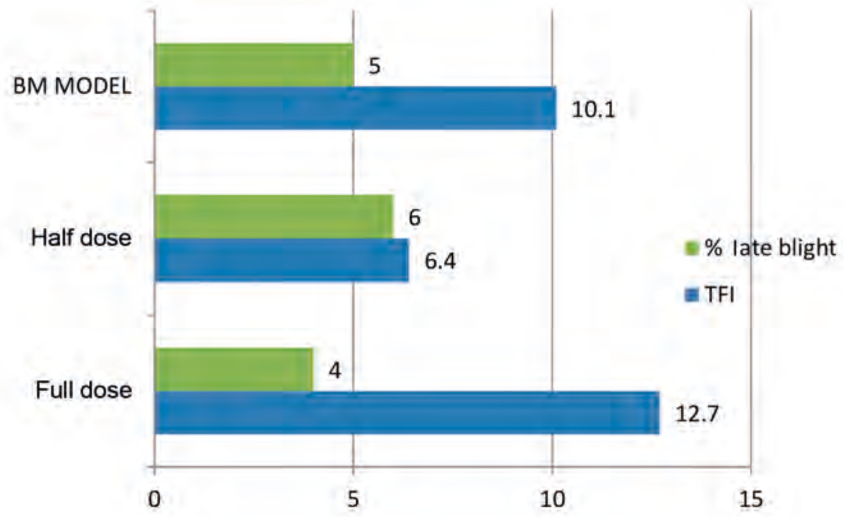


Figure 10. Attack of late blight and treatment frequency index (number of standard doses used with Revus, Ranman or Ranman Top) in average of 20 trials (Flakkebjerg, Sunds and Dronninglund), 2009-2014. Variety Kuras. The dose model used (BM Model) varies over the years but follows the same principle as indicated for Dose Model A in Table 2.

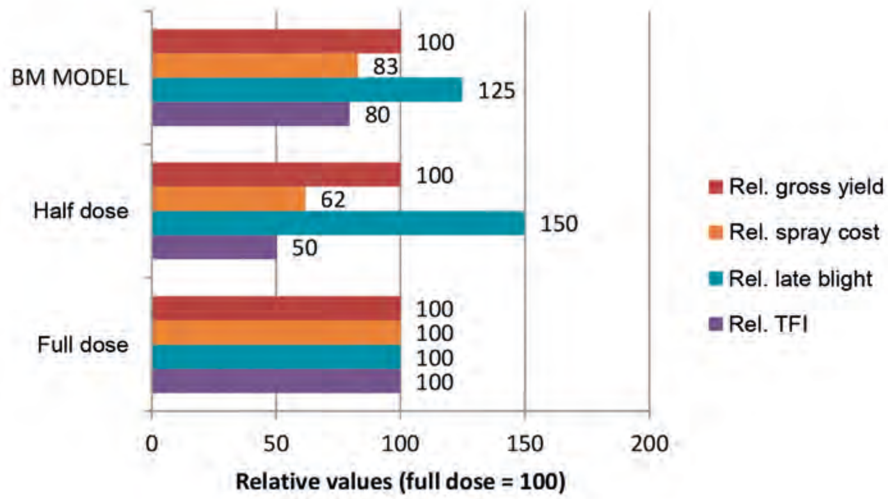


Figure 11. Relative values for gross yield, spray cost, attack of late blight and treatment frequency index in average of 20 trials (Flakkebjerg, Sunds and Dronninglund), 2009- 2014. Variety Kuras. The dose model used (BM Model) varies over the years but follows the same principle as indicated for Dose Model A in Table 2. Full dose of Revus, Ranman or Ranman Top = 100; gross yield 608 hkg/ha, spray cost 3,738 DKK/ha, late blight 4%, TFI 12.7). Late blight and TFI are also shown in Figure 10.

Different control strategies against late blight

In 2014 was tested an experimental plan with different control strategies against late blight. The trials were carried out in cooperation with SEGES on the localities Flakkebjerg, Billund (Mid-West Jutland) and Dronninglund (North Jutland) in the starch variety Kuras. The purpose of the tests was, on the one hand, to highlight the impact of spraying under high infection pressure from late blight, on the other, to test general strategies.

The reference treatment (treatment plot 1 in Table 6) is half dose of alternately spraying with Revus (0.3 l/ha) and Ranman Top (0.5 l/ha). In the treatment plots 2-5 spraying is basically the same as in treatment plot 1, but at high disease pressure (late blight in the region, infection pressure >40 for the past two days and in prognosis for the coming 4 days), products are changed to Revus (0.6 l/ha), Banjo Forte (1.0 l/ha), Proxanil (2.0 l/ha) + half dose of either Revus or Ranman Top, Option (0.2 l/ha) + ¾ dose of either Revus or Ranman Top. Treatment plot 6 is Option (0.15 l/ha) + ½ dose of either Revus or Ranman Top at weekly intervals starting at T3 (Treatment No. 3) but under high disease the pressure dose is changed to the same as in treatment plot 5. Treatment plots 7-8 are routine spraying with Shirlan (S), 0.4 l/ha, Revus Top (RT), 0.6 l/ha, Revus (RE), 0.6 l/ha, Amistar (AM), 0.5 l/ha, or Ranman Top (RanT), 0.5 l/ha. Treatment plots 9-10 are testing effect on tuber blight of Zignal (0.4 l/ha) at the three last sprayings compared with Ranman Top (0.5 l/ha). The general spray plan is shown in Table 6. The exact dates are for the experiment at Flakkebjerg but in principle the same weekly applications were applied at Billund and Dronninglund. However, spraying with the specific fungicides in treatments plot 2-5 varied. At Flakkebjerg the specific fungicides were used three times (Table 6) but at Billund and Dronninglund the specific fungicides were used 7 times (Billund: 26 June, 17 July, 30 July, 14 August, 20 August, 28 August and 3 September. Dronninglund: 30 June, 15 July, 4 August, 18 August, 25 August, 2 September and 9 September).

There were only low levels of attacks of late blight in the trials (<0.4%). Since no untreated was included in the trial, it is difficult to evaluate if all products gave good control. However, at Flakkebjerg there was a relatively large attack in the variety Kuras in unsprayed guard rows and also in the starch variety Dianella (Figure 2). It therefore seems that there must have been good control after spraying with the different strategies at Flakkebjerg under low to medium disease pressure (Table 7) and a trend (not statistically significant) to slightly better control when the specific products were applied in treatment plots 2-6 and in the routine Revus strategy (plots 7-8) compared to reference plot 1 with routine half dose. There were only low levels of tuber blight in the trials (Table 7).

The trials were sprayed with Signum WG (3 x 0.25 kg/ha) in order to control *Alternaria*. However, at the end of the season there was some attack on the leaves. In treatment plots 7-8 Amistar was included in two of the sprayings, which could be seen in the lower attack of *Alternaria*. It could also be seen that fluazinam had some effect (Table 7).

Yield data are shown for the trial at Flakkebjerg in Table 7 and for the trials at Flakkebjerg and Dronninglund in Figure 12.

Results from the trials can also be seen in "Oversigt over Landsforsøgene 2014" pp. 313-314.

Table 6. Trial plan for testing impact of spraying under high infection pressure of late blight and general strategies, 2014. Actual dates for the sprayings are indicated for the trial at Flakkebjerg. Set-up and the weekly spraying were almost the same in the trials at Billund and Dronninglund, see notes under table.

					Inf.pressure>40						Inf.pressure>40	Inf.pressure>40
Week	25	26	27	28	29	30	31	32	33	34	35	36
	17-Jun.	24-Jun.	01-July	09-July	16-July	23-July	30-July	06-Aug.	13-Aug.	20-Aug.	28-Aug.	03-Sep.
	1	2	3	4	5	6	7	8	9	10	11	12
1	0.3 RE	0.3 RE	0.25 RanT	0.25 RanT	0.3 RE	0.3 RE	0.25 RanT	0.25 RanT	0.3 RE	0.3 RE	0.25 RanT	0.25 RanT
2	0.3 RE	0.3 RE	0.25 RanT	0.25 RanT	0.6 Revus	0.3 RE	0.25 RanT	0.25 RanT	0.3 RE	0.3 RE	0.5 RanTop	0.5 RanTop
3	0.3 RE	0.3 RE	0.25 RanT	0.25 RanT	1. 0 BF	0.3 RE	0.25 RanT	0.25 RanT	0.3 RE	0.3 RE	1. 0 BF	1. 0 BF
4	0.3 RE	0.3 RE	0.25 RanT	0.25 RanT	PROX +1/2RE	0.3 RE	0.25 RanT	0.25 RanT	0.3 RE	0.3 RE	PROX+1/2RanT	PROX+1/2RanT
5	0.3 RE	0.3 RE	0.25 RanT	0.25 RanT	Opt+ 3/4RE	0.3 RE	0.25 RanT	0.25 RanT	0.3 RE	0.3 RE	Opt+ 3/4RanT	Opt+ 3/4RanT
6	0.3 RE	0.3 RE	Opt+RanT	Opt+RanT	Opt+ 3/4RE	Opt+ RE	Opt+RanT	Opt+RanT	Opt+ RE	0.3 RE	Opt+ 3/4RanT	Opt+ 3/4RanT
7	S	0.6 RT	0.6 RE	0.6 RT	0.6RE+ 0.5 AM	0.6 RE	0.6RE+ 0.5 AM	S	S	S	S	S
8	S	0.6 RT	0.6 RE	0.6 RT	0.6RE+ 0.5 AM	0.6 RE	0.6RE+ 0.5 AM	S	0.5 RanT	0.5 RanT	0.5 RanT	0.5 RanT
9	0.3 RE	0.3 RE	0.3 RE	0.3 RE	0.3 RE	0.3 RE	0.3 RE	0.3 RE	0.3 RE	Zignal	Zignal	Zignal
10	0.3 RE	0.3 RE	0.3 RE	0.3 RE	0.3 RE	0.3 RE	0.3 RE	0.3 RE	0.3 RE	0.5 RanT	0.5 RanT	0.5 RanT

Plot 1: Half dose of alternating spraying with Revus (RE, 0.3 l/ha) and Ranman Top (RanT, 0.5 l/ha). Plots 2-5: Basically same sprayings with Revus or Ranman Top as in plot 1, but at high disease pressure the products are changed to Revus 0.6 l/ha, Banjo Forte (BF, 1.0 l/ha), Proxanil (PROX, 2.0 l/ha) + half dose of either Revus or Ranman Top, Option (Opt, 0.2 l/ha) + ¾ dose of either Revus or Ranman Top. Plot 6: Option (0.15 l/ha) + ½ dose of either Revus or Ranman Top at weekly intervals starting at T3 but under high disease pressure the dose is changed to the same as in treatment plot 5. Plots 7-8: Routine spraying with Shirlan (S), 0.4 l/ha, Revus Top (RT), 0.6 l/ha, Revus (RE), 0.6 l/ha, Amistar (AM), 0.5 l/ha or Ranman Top (RanT), 0.5 l/ha. Plots 9-10: Zignal (0.4 l/ha) compared with Ranman Top, RanT (0.5 l/ha). High disease pressure is defined as infection pressure (www.skimmelstyring.dk) > 40 past two days, actual day and 4-day prognosis and late blight has been recorded in the region.
In order to control attack of *Alternaria* the trials were sprayed with 3 x Signum WG 0.25 kg/ha in all plots.

Table 7. Field trials testing impact of spraying under high infection pressure of late blight and general strategies in 2014 at Flakkebjerg in starch variety Kuras.

		% late blight	% *Alternaria*		% tuber blight	Yield and yield increase, hkg/ha	
		23-Sep.	15-Sep.	23-Sep.		tubers	starch
1	½ dose Revus & Ranman Top	0.2	2	10	0.5	721.3	134.3
2	+ 0.6 Revus & 2 x 0.5 Ranman Top	0.2	1	7	0.2	44.9	3.2
3	+ 3 x Banjo Forte	0.1	1	6	0	-6.3	-5.8
4	+ 3x 2.0 Proxanil + ½ Revus/RanmanTop	0.07	1	7	0	44.2	11.3
5	+ 3 x 0.2 Option + 3/4 Revus/RanmanTop	0.06	2	8	0	40	2
6	plot 5 + 6 x 0.15 Option + ½ Revus/RanmanTop	0.08	2	6	0	28.3	1.3
7	Shirlan/6xRevus + 2 x Amistar/Shirlan	0.06	0.1	3	0	44.4	5
8	Shirlan/6xRevus + 2 x Amistar/RanmanTop	0.05	0.8	6	0.2	53.5	4.8
9	plot 1 + 3 x Zignal	0.2	0.4	7	0	66	8.3
10	plot 1 + 3 x RanmanTop	0.4	2	6	0.2	58.6	5.8

Details of the spray plan are mentioned in Table 6. Results from the trials at Billund and Dronninglund can be seen in “Oversigt over landsforsøgene 2014”.

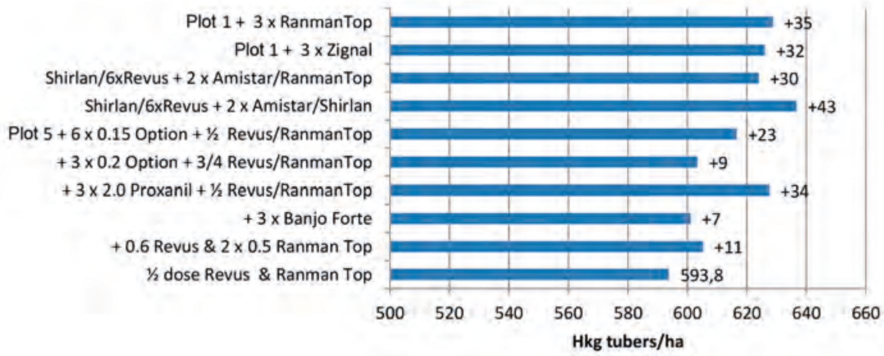


Figure 12. Tuber yield (hkg/ha) in 2 field trials testing impact of spraying under high infection pressure of late blight and general strategies in 2014 at Flakkebjerg and Dronninglund in starch variety Kuras. Figures above the bars indicate the tuber yield increase relative to treatment plot 1 (half dose of Revus or Ranman Top). Explanations of treatment plan are given in Table 6. LSD_{95}: *n.s.*

Curative control under field conditions

Established lesions of late blight can be difficult to control. In order to test the effect of products with curative activity an experiment was carried out as described in Table 8. All plots were sprayed with Revus 0.2 l/ha and later in weeks 31-32 sprayings were stopped to allow late blight to establish. On 10 August there was 0.1-1% attack of late blight in the plots in three of the replicates. In the fourth replicate late blight had developed much faster (5-10%) and these plots were excluded from the analysis. Spraying was started on 12 August and in plot 1 Revus (RE) 0.6 l/ha was followed by Revus after one week. In plot 2 Ranman Top (RanT) 0.5 l/ha was applied after three days and then later the same as in plot 1. In plot 3 the first spraying was Proxanil 2.5 kg/ha + Revus 0.3 l/ha, followed by Ranman Top after three days and then Proxanil 2.5 kg/ha + Revus 0.3 l/ha after three days. In plot 4 the first spraying was Cymbal 0.25 l/ha + Revus 0.6 l/ha, followed by Ranman Top after three days and then Cymbal 0.25 l/ha + Revus 0.6 l/ha after three days. Plot 5 was untreated from week 31 (Table 8).

Table 8. Trial plan for testing effect of curative control on established lesions of late blight under field conditions. Variety Dianella, Flakkebjerg, 2014.

					Within the same week								
	A 1	B 2	C Week 31	D Week 32	E 12-Aug.	F 15-Aug.	G 18-Aug.	H 25-Aug.	I	J	K	L	M
1	0.2 RE	0.2 RE			0.6 RE		0.6 RE	0.5 RanT	0.5 RanT	0.6 RE	0.6 RE	0.5 RanT	0.5 RanT
2	0.2 RE	0.2 RE			0.6 RE	0.5 RanT	0.6 RE	0.5 RanT	0.5 RanT	0.6 RE	0.6 RE	0.5 RanT	0.5 RanT
3	0.2 RE	0.2 RE			2.5 PROX + 0.3 RE	0.5 RanT	2.5 PROX + 0.3 RE	0.5 RanT	0.5 RanT	0.6 RE	0.6 RE	0.5 RanT	0.5 RanT
4	0.2 RE	0.2 RE			0.25 CYMB +0.6 RE	0.5 RanT	0.25 CYMB +0.6 RE	0.5 RanT	0.5 RanT	0.6 RE	0.6 RE	0.5 RanT	0.5 RanT
5	0.2 RE	0.2 RE											

Revus (RE) 0.6 l/ha, Ranman Top (RanT) 0.5 l/ha, Proxanil (PROX) 2.5 kg/ha + Revus (0.3RE) 0.3 l/ha, Cymbal (CYMB) 0.25 l/ha + Revus (0.6 RE) 0.6 l/ha. Dates of spraying are indicated at the top of table.

The results are shown in Figure 13. Spraying with Revus followed by weekly sprayings did control late blight (average 80% control) but could not stop development of the disease (plot 1) and at the end of the season there was 22% attack. Including Ranman Top after three days in plot 2 had an effect on blight (average 85% control) which could be seen for approximately one month, but the development was not stopped. The best effect was obtained with Proxanil 2.5 l/ha + Revus 0.3 l/ha (97% control) or Cymbal 0.25 l/ha + Revus 0.6 l/ha (94% control) at an interval of seven days with Ranman Top in between. Spraying with Proxanil + Revus stopped the development and the attack ranged from 1% after the first week to 2% at the end of season (Figure 13).

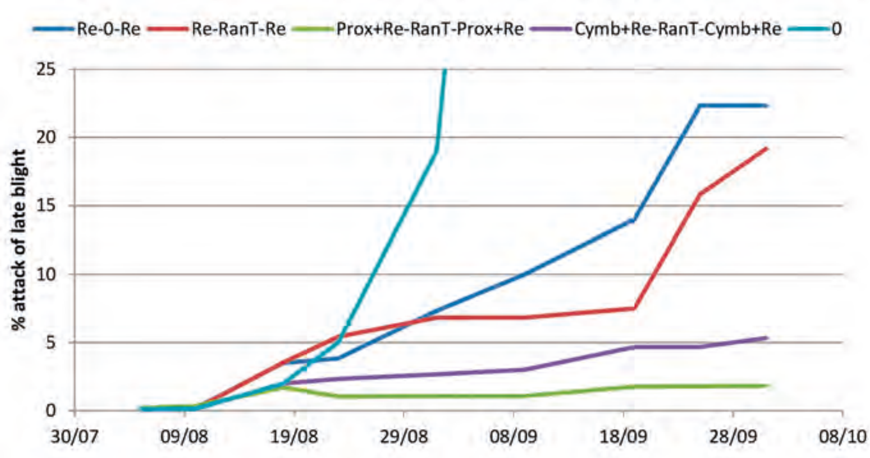


Figure 13. Development of late blight in plots with curative treatments (Proxanil and Cymbal) sprayed on 12 August in plots with 0.1-1% attack of late blight. Y axis is set to max. 25 but the disease development in untreated continued until 99% attack on 25 September. Variety Dianella, Flakkebjerg 2014. For explanations of treatments, see Table 8.

The treatment plots in the trial with curative control. The untreated brown plots can be seen clearly.

Control of early blight (*Alternaria alternata* & *A. solani*)

Field trials with control of early blight were carried out in 2014 in cooperation with SEGES at three locations (Flakkebjerg, Sunds and Billund). The trial at Flakkebjerg and Billund was artificially inoculated on 27 June 2014 with autoclaved barley seeds inoculated with *A. solani* and *A. alternata* (seeds were placed in the furrow between the plants). The first attacks on the lower leaves were detected at Flakkebjerg on 8 July, 11 days after inoculation. However, the weather conditions were very dry in July and it was not until the beginning of August that there was a development in the attack. In August and September there was a severe development in the trial at Flakkebjerg with 84% of the leaves attacked in untreated plots at the last assessments in September (Table 10). The trials were cover sprayed with Revus (0.6 l/ha) and Ranman Top (0.5 l/ha) and only very slight attacks of late blight (*P. infestans*) were observed at Flakkebjerg (< 0.01%). The only pathogen was *Alternaria*.

Table 9. Trial plan for testing different control strategies against early blight (*Alternaria solani* & *A. alternata*). Variety Kuras, 2014. Actual dates for the sprayings are indicated for the trial at Flakkebjerg. Setup and the weekly spraying was almost the same in the trials at Billund and Sunds.

Attack in untreated. Flakkebjerg				0.04	0.3	0.4	0.3	2.3	3.8	7.3	13.3	25.8	45.0
Attack in untreated. Sunds				0	0	0	0.09	0.04	0.2	2	2	48	99
Attack in plots with 4 x Signum. Flakkebjerg				0.03	0.08	0.10	0.09	0.11	0.11	0.11	0.30	1.10	2.80
	17-Jun.	25-Jun.	01-July	08-July	15-July	22-July	29-July	05-Aug.	14-Aug.	21-Aug.	28-Aug.	03-Sep.	09-Sep.
	1	2	3	4	5	6	7	8	9	10	11	12	13
1													
2			0.5 A		0.5 A								
3			0.3 A		0.3 A								
4			0.25 S		0.25 S		0.25 S						
5			0.25 S		0.25 S		0.25 S		0.25 S				
6			0.15S		0.15S		0.15S		0.15S				
7	Tridex	Tridex	0.15S		0.15S		0.15S		0.15S				
8			0.6 RT		0.6 RT		0.5 A		0.5 A				
9	0.6 RT		0.6 RT		0.5 A		0.5 A						
10			0.15S		0.15S		0.3 A		0.3 A				
11			0.15S		0.15S		0.3 A		0.3 A		0.15S		0.15S
12			0.075S		0.075S		0.15A		0.15A		0.075S		0.075S
13				0.15S*		0.15S		0.3 A	0.3 A		0.3 A		
14			0.6 RT	0.6 RT	0.6 RT		0.25 A		0.25 A		0.25 A		
15		DIT	DIT	DIT	0.6 RT	OLY	0.6 RT	OLY	0.6 RT	OLY	0.25 S	DIT	0.25 S
16	DACOM				0.25 S				0.25 S				

Tridex (2.0 kg/ha), RT: Revus Top (0.6 l/ha). 0.5A, 0.3A and 0.15A: Amistar 0.5 l/ha, 0.3 l/ha and 0.15 l/ha. 0.25S, 0.15S and 0.075S: Signum WG 0.25 kg/ha, 0.15 kg/ha and 0.075 kg/ha. DIT: Dithane NT 2.0 kg/ha. OLY: Olympus (1.0 l/ha; 80g/l azoxystrobin and 400 g/l chlorothalonil). DACOM: Commercial Dutch program with the *Alternaria* module. At the top of table is indicated per cent attack of *Alternaria* in the same week in untreated plots at Flakkebjerg and Sunds and plots sprayed with 4 x Signum WG at Flakkebjerg (plot 5). All plots cover sprayed with Revus (0.6 l/ha) or Ranman Top (0.5 l/ha) at weekly intervals.

The trial at Flakkebjerg was inoculated on 29 June. Spores were spread from the inoculated seeds on the soil to the leaves and the first symptoms were seen on 8 July but it was not until the beginning of August that the epidemic phase really started (Table 9, Figure 14). The strategies in which most of the fungicide input was applied in the first part of the season (e.g. 2 x Amistar) had the lowest effect (49-57% control at 2 x 0.3 l/ha or 2 x 0.5 l/ha, Figure 14a). It is interesting to note that the effect of the two early sprayings lasted approximately until the first week of September (6 weeks, Table 10), but could not reduce the late attacks later in September.

Comparing the sprayings with Signum WG there was a clearly better control using 4 sprayings (80-84% control) than 3 sprayings (65% control) and only small differences between 4 x 0.25 kg/ha and 4 x 0.15 kg/ha (84% control and 80% control respectively, Figure 14b). Spraying four times with alternately 2 x Signum WG 0.15 kg/ha + 2 x Amistar 0.3 l/ha (60% dose level, Figure 14c) had a lower effect (71% control) than the corresponding 4 x Signum WG 0.15 kg/ha (84% control). Comparing the strategies using Revus Top, it seems that the first spraying at T1 (plot 9) was placed too early in relation to the actual disease development. No differences between the two strategies 2 x Revus Top 0.6 l/ha + 2 x Amistar 0.5 l/ha could be measured (76% control) and compared to 4 x Signum WG 0.25 kg/ha (84% control) the overall effect was lower (Figure 14d). A similar effect was seen where 2 x Tridex (2.0 kg/ha) were placed early and there were no differences between early Tridex (76% control, plot 7) and 4 x Signum WG 0.15 l/ha alone (80% control, plot 6).

Because of the relatively late start of the epidemic at the beginning of August there was in general a good effect of 6 sprayings. 2 x Signum WG 0.15 kg/ha + 2 x Amistar 0.3 l/ha + 2 x Signum WG 0.15 l/ha (60% dose level) gave 90% control. Reducing this input to 2 x Signum WG 0.075 kg/ha + 2 x Amistar 0.15 l/ha + 2 x Signum WG 0.075 l/ha (30% dose level) had almost a similar high effect (86% control). It is noted that the effect of 6 x reduced dose (30% dose level, 86% control) had a similar effect as full dose 4 x Signum WG 0.25 kg/ha (84% control, Figure 14e). In the trial plan there was also a test of strategies with applications not authorised in Denmark. Spraying six times with 3 x Revus Top 0.6 l/ha + 3 x Amistar 0.25 l/ha resulted in 81% control at the level of 2 x Signum WG 0.075 kg/ha + 2 x Amistar 0.15 l/ha + 2 x Signum WG 0.075 l/ha (86% control). The highest control level was obtained with 4 x Dithane NT 2 kg/ha + 3 x Revus Top 0.6 l/ha + 2 x Olympus + 2 x Signum WG 0.25 kg/ha (95% control) but this included also sprayings at weekly intervals from late June to early September (Figure 14f). The last two sprayings were only tested at Flakkebjerg as part of international testing (in Denmark only 4 x Signum WG and 2 x Amistar are authorised for Alternaria control).

The results are similar to results from 2013 when 2-4 treatments were compared. The best effect in 2013 was achieved with four treatments with either 4 x Signum WG or 2 x Revus Top + 2 x Amistar (83% reduction). Three treatments with either 3 x Signum WG or 2 x Revus Top + 1 x Amistar gave 67% and 64% reduction, respectively, while two treatments (Amistar) gave 62% reduction on average.

Field trial with control of *Alternaria*, 23 September 2014, Flakkebjerg.

Table 10. Field trials testing different control strategies against early blight (*Alternaria solani* & *A. alternata*). Variety Kuras, Flakkebjerg 2014. Details of the spray plan are mentioned in Table 9.

	% attack of *Alternaria*						AUD-PC	Yield and yield increase, hkg/ha	
	07-08	22-08	04-09	17-09	23-09	29-09		tubers	starch
Untreated	2.30	7.3	25.8	65.0	75.0	83.8	1778.7	628.0	108.0
2 x 0.5 Amistar	0.08	0.2	3.8	27.5	50.0	65.0	761.6	99.9	21.0
2 x 0.3 Amistar	0.17	0.2	6.6	32.0	54.5	71.3	903.8	89.4	23.4
3 x 0.25 Signum	0.11	0.1	2.6	22.8	35.0	54.3	614.0	71.1	18.5
4 x 0.25 Signum	0.06	0.1	1.1	7.8	19.0	30.8	286.8	36.5	12.7
4 x 0.15 Signum	0.12	0.2	1.1	7.8	26.3	37.0	355.8	118.0	27.4
2 x Tridex + 4 x 0.15 Signum	0.10	0.1	1.2	11.5	30.8	47.5	433.0	99.8	21.7
2 x Revus Top (T3) + 2 x 0.5 Amistar	0.35	0.3	1.1	11.5	28.5	47.5	428.3	104.3	22.9
2 x Revus Top (T1) + 2 x 0.5 Amistar	0.20	0.4	2.5	12.3	26.3	42.5	429.9	75.2	19.9
2 x 0.15 Signum + 2 x 0.3 Amistar	0.14	0.1	2.4	13.8	35.5	48.3	516.7	107.4	23.9
2 x 0.15 Signum + 2 x 0.3 Amistar + 2 x 0.15 Signum	0.55	0.6	0.8	4.5	10.0	16.5	174.3	112.3	23.6
2 x 0.08 Signum + 2 x 0.15 Amistar + 2 x 0.08 Signum	0.20	0.3	1.8	7.8	14.5	22.5	254.4	97.0	22.8
2 x 0.15 Signum (T4) + 3 x 0.3 Amistar	0.16	0.2	0.4	9.8	23.8	38.8	348.0	99.9	21.1
3 x Revus Top + 3 x 0.25 Amistar	0.28	0.4	1.3	9.8	22.8	31.8	341.8	75.1	15.2
4 x Dithane + 3 x RevusTop + 2 x Olympus+ 2 x 0.25 Signum	0.22	0.3	0.5	1.2	5.0	8.8	82.0	138.7	26.8
2 x 0.25 Signum (T5 + T9) DACOM	0.35	0.3	3.2	18.8	30.0	42.5	526.5	137.5	29.0

There is a good correlation between the assessments at Flakkebjerg, Sunds and Billund (e.g. Flakkebjerg-Sunds R^2=0.80) as seen in Table 11. Average of the assessments at the beginning of September is shown in Figure 15.

The yield obtained in the trial at Flakkebjerg is shown in Table 10 (tuber yield). In average of two trials (Flakkebjerg and Sunds) there was a tuber yield increase of 10%-19% after the different sprayings. In Figure 16 is shown the relationship between *Alternaria* control and % tuber yield increase for the two trials.

The economy in the different spray strategies are shown for two trials (Flakkebjerg and Sunds) in Figure 17. The trial at Billund was not harvested. There was a high net yield increase relative to untreated from 4,473 DKK to 7,380 DKK (15-25% net yield increase).

In 11 trials 2010-2014 there was a tuber yield increase of 6.8% in average of the various treatments. In 2013 it was 6.5% and in 2014 it was 15% on average. The net yield increase was 2,500-4,700 DKK in 2012 and 3,033–5.524 DKK in 2013 by using effective treatment.

Table 11. Attack of *Alternaria* in 3 field trials testing different control strategies against early blight (*Alternaria solani* & *A. alternata*). Variety Kuras at Flakkebjerg (Flak.), Sunds and Billund (Bill.), 2014. Details of the spray plan are mentioned in Table 9.

	% attack of *Alternaria*		
	Flak. 17-09	Sunds 02-09	Bill. 10-09
Untreated	65.0	48.0	78.0
2 x 0.5 Amistar	27.5	21.0	31.0
2 x 0.3 Amistar	32.0	30.0	38.0
3 x 0.25 Signum	22.8	25.0	22.0
4 x 0.25 Signum	7.8	10.0	19.0
4 x 0.15 Signum	7.8	18.0	20.0
2 x Tridex + 4 x 0.15 Signum	11.5	21.0	38.0
2 x Revus Top (T3) + 2 x 0.5 Amistar	11.5	18.0	26.0
2 x Revus Top (T1) + 2 x 0.5 Amistar	12.3	24.0	30.0
2 x 0.15 Signum + 2 x 0.3 Amistar	13.8	15.0	30.0
2 x 0.15 Signum + 2 x 0.3 Amistar + 2 x 0.15 Signum	4.5	9.0	19.0
2 x 0.08 Signum + 2 x 0.15 Amistar + 2 x 0.08 Signum	7.8	24.0	22.0
2 x 0.15 Signum (T4) + 3 x 0.3 Amistar	9.8	19.0	24.0
3 x Revus Top + 3 x 0.25 Amistar	9.8		
4 x Dithane + 3 x RevusTop + 2 x Olympus + 2 x 0.25 Signum	1.2		
2 x 0.25 Signum (T5 + T9) DACOM	18.8		

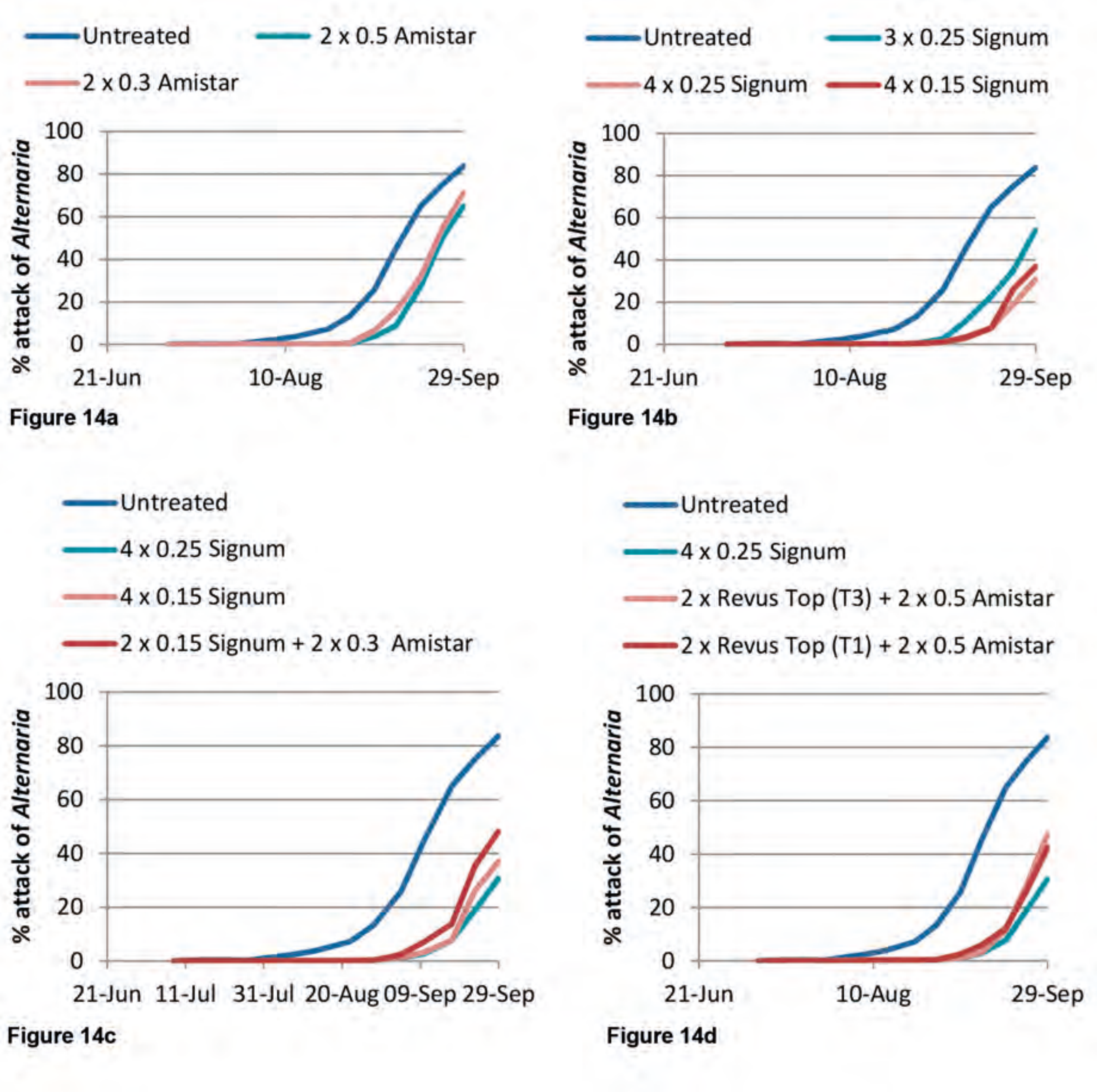


Figure 14. Development of early blight (*A. solani* & *A. alternata*) in field trials at Flakkebjerg 2014. Details of the treatment are given in Table 9. Variety Kuras.

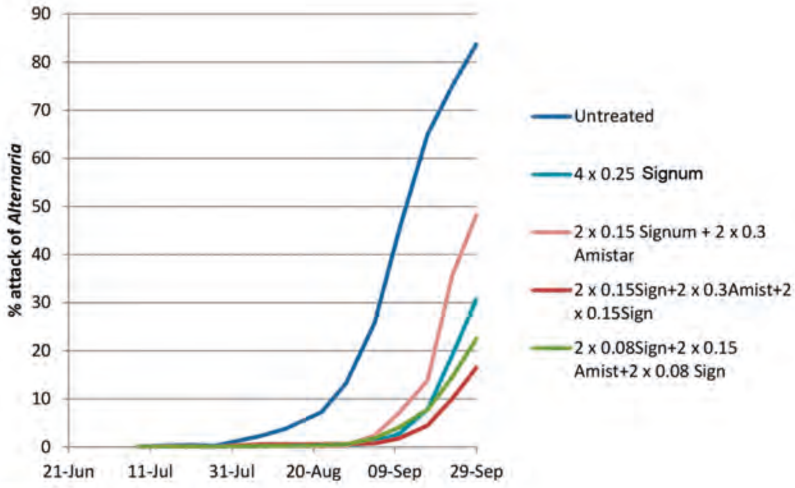


Figure 14e

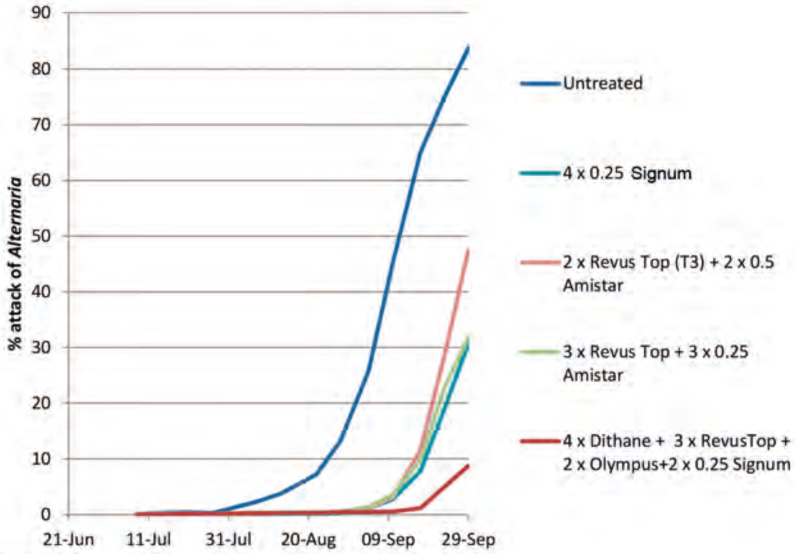


Figure 14f

Figure 14. Development of early blight (*A. solani* & *A. alternata*) in field trials at Flakkebjerg 2014. Details of the treatment are given in Table 9. Variety Kuras.

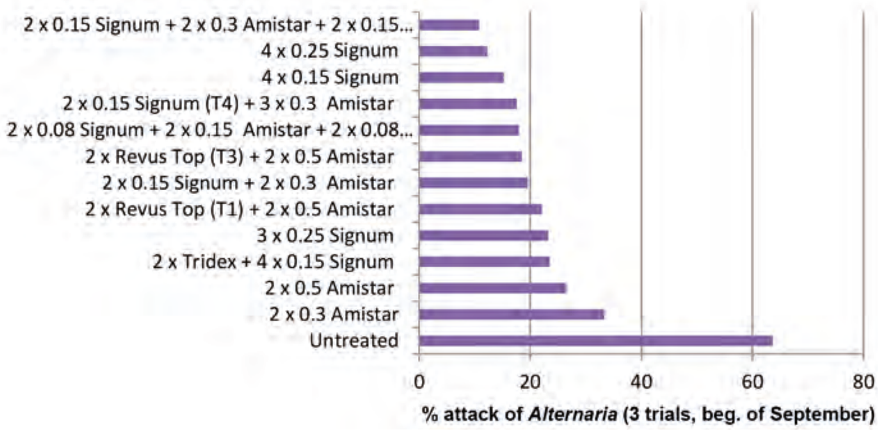


Figure 15. Attack of *Alternaria*. Average of assessments at the beginning of September in 3 trials (Flakkebjerg, Sunds and Billund). Note that the trial treatments have been arranged according to level of control. Variety Kuras, 2014. Details of the treatment are given in Tables 9 and 11.

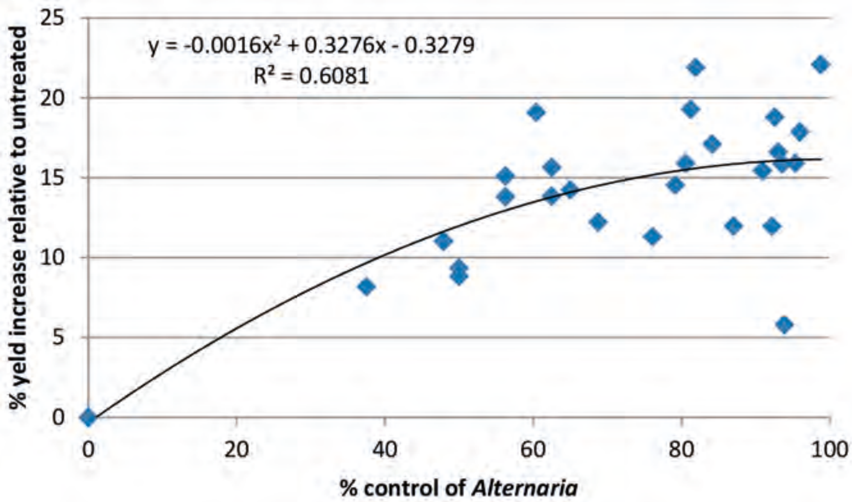


Figure 16. Relationship between *Alternaria* control (% control) and yield increase (% tuber yield increase relative to untreated). Data for two trials in Kuras, 2014 (Flakkebjerg and Sunds).

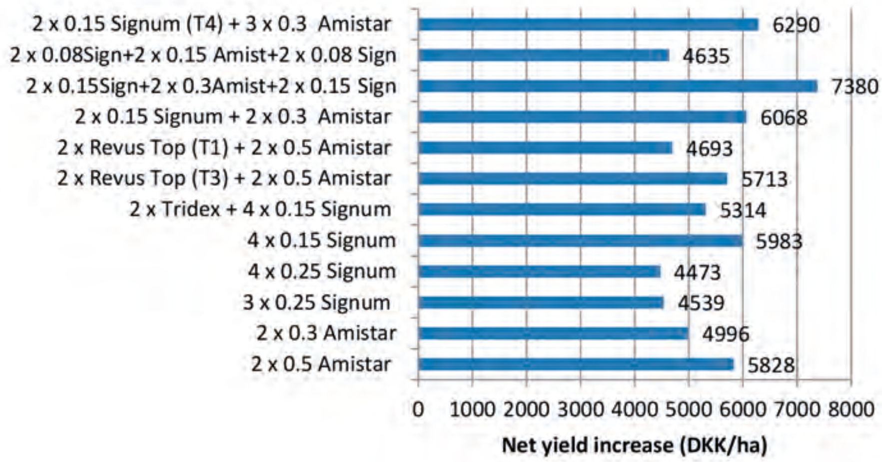
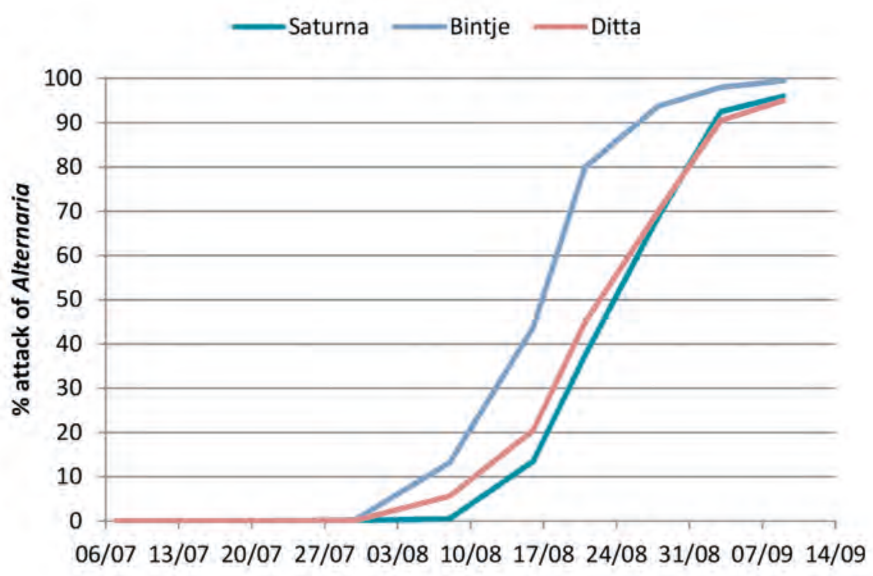


Figure 17. Economy in the different treatments against early blight (*A. solani* & *A. alternata*) in 2 field trials at (Flakkebjerg and Sunds), 2014. Increase in net yield (DKK/ha) relative to untreated (29,109 DKK/ha). Net yield is calculated by subtracting cost of fungicides and labour. Details of the treatment are given in Table 9. Variety Kuras.

Development of *Alternaria* in different varieties

In order to test the development of *Alternaria* in different variety types a trial was carried out with 10 potato varieties in small plots (2 rows x 7 m) and four replicates. The trial was inoculated in the same way as the fungicide trials with autoclaved barley seeds inoculated with *A. solani* and *A. alternata* placed in the furrow between the plants on 27 June 2014. The first symptoms on the lower leaves were detected on 7 July (10 days after inoculation) in all the varieties. Later development in the canopy varied between the varieties (Figure 18). In varieties like Bintje, Ditta and Saturna the attack of *Alternaria* reached 50% on 17–24 August while in varieties like Dianella and Kuras with a long season 50% attack was reached after 5 September. A difference of almost a month in development in *Alternaria* (Figure 19).



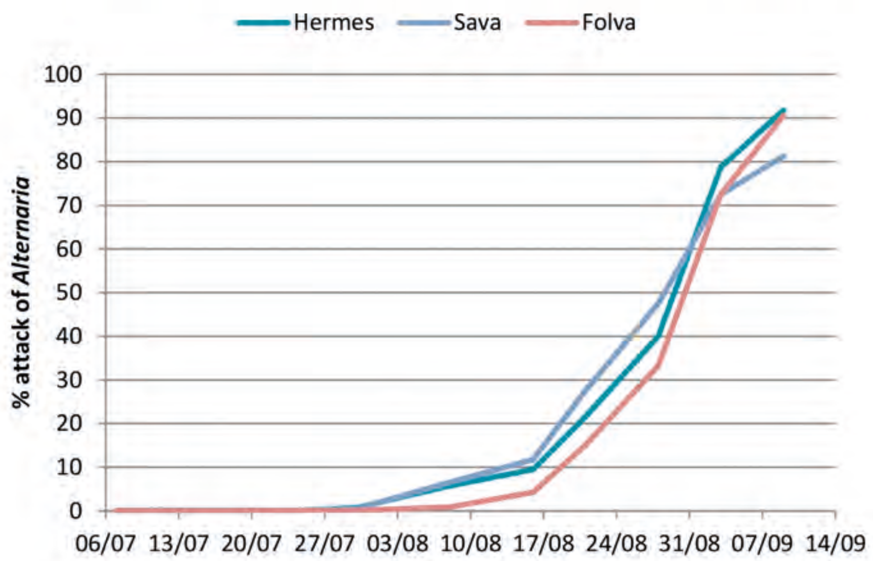


Figure 18. Development of *Alternaria* in different potato varieties. Artificial inoculation with *A. solani* and *A. alternata* on 27 June. The varieties have been divided into maturity groups. Small plot trials (2 m row x 7 m), Flakkebjerg 2014. (This figure is continued on the next page).

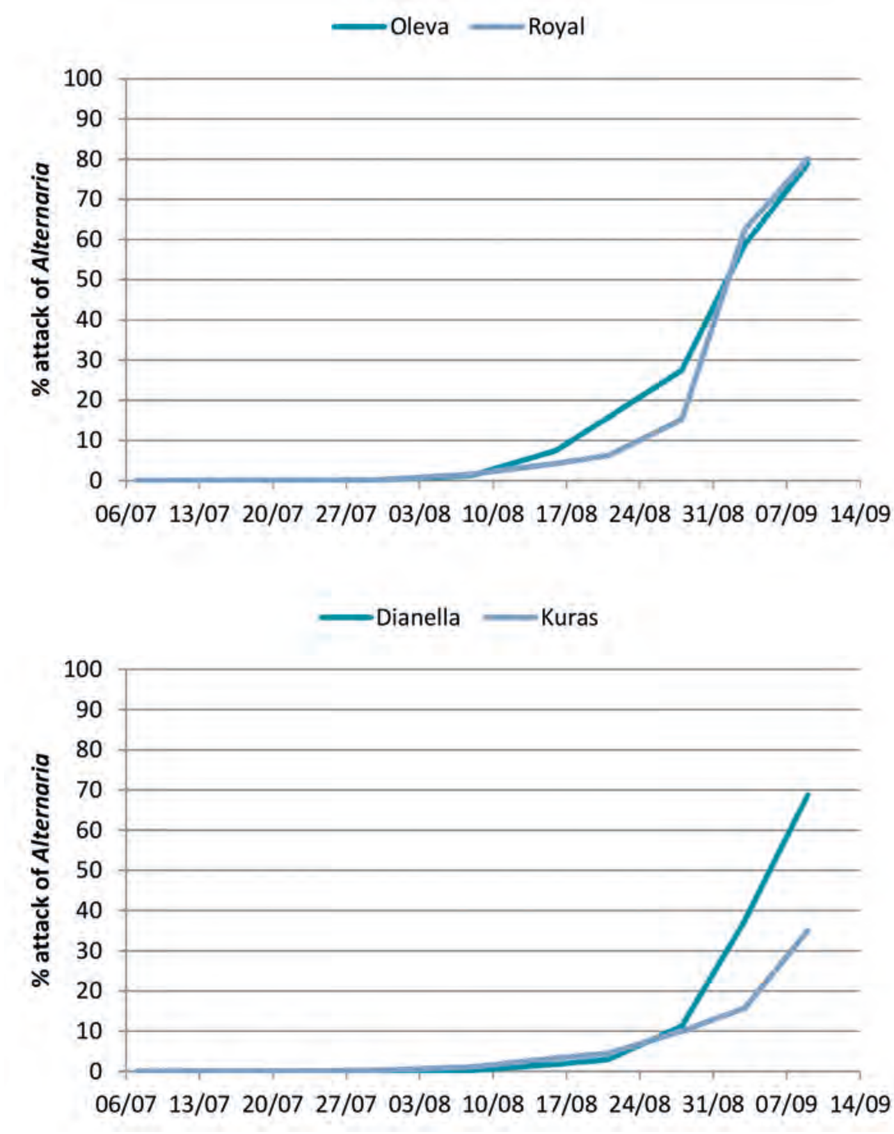


Figure 18. Development of *Alternaria* in different potato varieties. Artificial inoculation with *A. solani* and *A. alternata* on 27 June. The varieties have been divided into maturity groups. Small plot trials (2 m row x 7 m), Flakkebjerg 2014. (Continued).

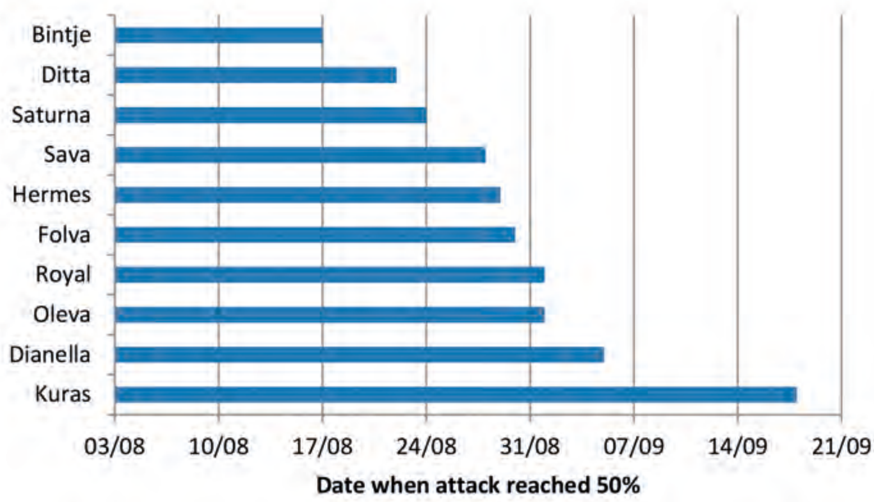


Figure 19. Date when the attack of *Alternaria* (approximately) reached 50%. Artificial inoculation with *A. solani* and *A. alternata* on 27 June. Small plot trials (2 m row x 7 m), Flakkebjerg 2014.

Photo from variety trial with *Alternaria* 28 August 2014.

IX Influence of application technique on control of potato early blight (*Alternaria solani*)

Peter Kryger Jensen & Bent J. Nielsen

The first infections of potato early blight are typically found at the bottom of the crop canopy near soil level. From these infections attacks spread upward in the potato canopy. Using conventional application techniques, it is difficult to deposit spray at the bottom of a dense crop canopy as found in potatoes. Controlling a disease with primary attacks located at the bottom is therefore a challenge. This study was carried out to investigate the possibilities of changing the deposition pattern of spray in the canopy, using alternative application techniques. Further, it was the purpose to investigate if a change in deposition pattern was followed by an improved efficacy against potato early blight. The study included 5 application techniques and the experiment was carried out in 2013 and repeated in 2014. The 5 application techniques tested are shown in Table 1.

Table 1. Application techniques tested in the study. A speed of 6 km/h and a volume rate of 160 l/ha were used in all treatments. The air assistance used was the Hardi Twin principle and air speed was 20 m/s at the outlet.

	Nozzle	Angling	Droplet size
1.	LD-02	Standard vertical	Medium
2.	MD-02	Standard vertical	Coarse
3.	LD-02 + air assistance	30º backwards	Medium
4.	TTJ60-02	30º forwards and backwards	Coarse
5.	AI3070-02	30º forwards and 70º backwards	Coarse

Treatment 1, the LD-02 nozzle standard vertically mounted, is the standard application technique recommended for applying fungicides in potatoes. The MD-02 nozzle is also a standard vertically mounted nozzle but with a coarse atomisation. Treatment 3 is the standard LD-02 nozzle mounted on a Hardi Twin boom, allowing for the use of air assistance and angling the spray. In the study a 30° backwards angling was used and the air assistance was set at 20 m/s at the outlet. The TTJ-02 nozzle is a coarse atomising nozzle with two outlets angling the spray +/- 30° forwards and backwards. Finally, the AI3070-02 is a coarse atomising nozzle with two outlets. The recommendation is to mount the nozzle on the boom angling the spray 30° forwards and 70° backwards.

In both study years late blight was controlled with standard applications during the growing season. For the control of early blight, Signum WG (containing 267 g a.i. boscalid + 67 g a.i. pyraclostrobin per/kg) was applied in 3 dose rates. The dose rates applied were 0.25, 0.125 and 0.0625 kg/ha in 2013 and with a total of 6 applications. Based on the experience in 2013 only 4 applications were carried out in 2014 and the dose rates were further reduced so the 3 dose rates were 0.125, 0.0625 and 0.032 kg/ha.

In both years deposition of spray liquid in the potato canopy was measured. This measurement was carried out adding a fluorescent tracer to the spray liquid when the low fungicide dose was applied in an application around 1 August. Following the application, leaf samples were collected from two levels in the crop canopy. From each plot 10 leaves were collected from the upper part of the canopy directly exposed to the spray and 10 leaves from approximately half the total plant height. The tracer was washed off the samples and the leaf area of the samples was measured. From these figures, the deposit of tracer per leaf area unit in the two canopy levels was determined.

The results are shown in Figures 1 & 2. In the 2013 experiment several significant differences in deposit pattern was found. Generally deposition at the bottom of the canopy was lowest in the reference LD-02 treatment. Using a coarse atomisation more than doubled the deposited amount at the bottom with the standard vertically mounted nozzle (MD-02) as well as with the two double angled coarse applications (TTJ-02 and AI3070-02). The use of air assistance further increased the deposition at the bottom of the canopy. However, air assistance also decreased the deposition at the top of the canopy. The variation in the measured deposition values in 2014 was larger, and as a result insignificant differences in deposited amount at the bottom of the canopy were found.

Attack of *Alternaria* was evaluated weekly in the period from the first experimental treatment until maturity of the crop. The result of an assessment late in the season is shown in Figures 3 & 4. The control level obtained was generally very high in 2013 independently of the applied fungicide dose rate (Figure 3). As a result, only small and insignificant differences between treatments and dose rate were found. In 2014 the number of applications was reduced from 6 to 4 and further the applied dose rates were reduced. At the late assessment (20 September) the expected dose response was generally found with decreasing efficacy when the dose rate was reduced. Only small and insignificant differences in disease attack between the 5 application techniques were found, however.

In the study, control of potato late blight was generally initiated before attacks were seen. It is possible that the outcome of the biological efficacy testing would have been different if the attack of early blight was established before the first application of an effective fungicide was carried out. However, the study demonstrated that it is possible to obtain a deeper penetration of the potato canopy using either air assistance or a coarse atomisation. Further, the study showed that the deeper penetration obtained using a coarse atomisation was obtained independently of whether the application followed by standard vertical nozzles or by angled nozzles.

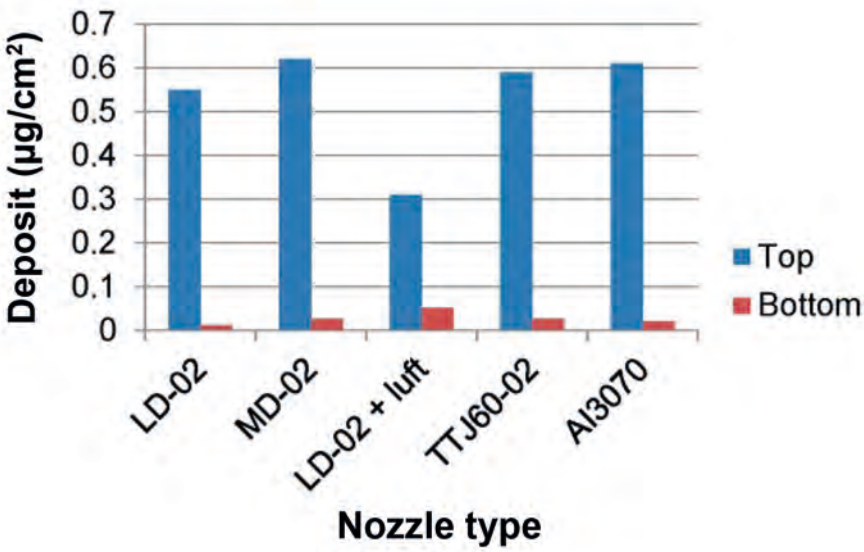


Figure 1. Deposition of spray liquid at two levels in the potato canopy following application around 1 August 2013. LSD = 0.1 at top level and LSD = 0.017 at bottom level.

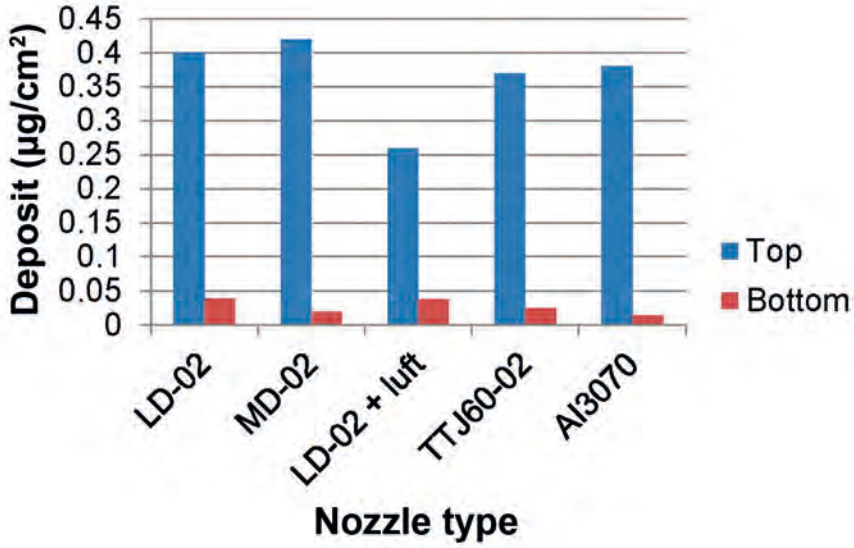


Figure 2. Deposition of spray liquid at two levels in the potato canopy following application around 1 August 2014.

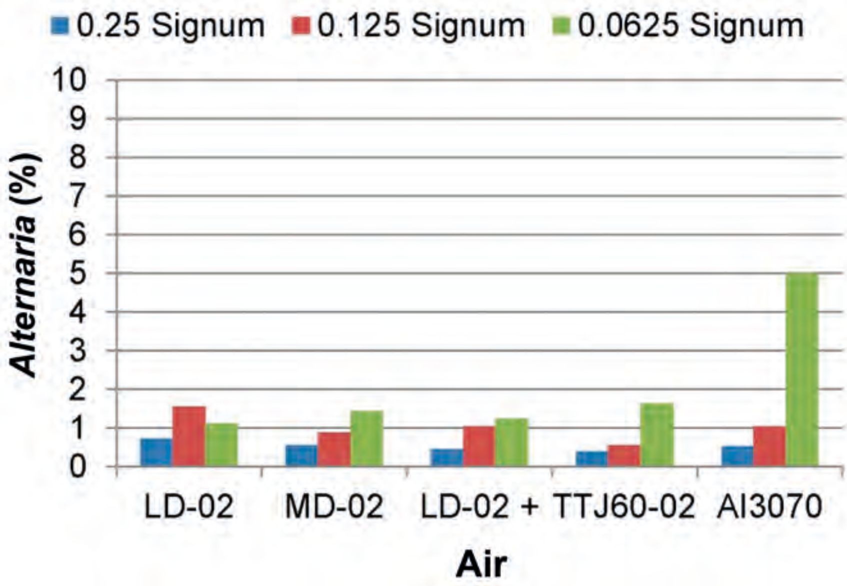


Figure 3. Assessment of attack of *Alternaria solani* on 20 September 2013.

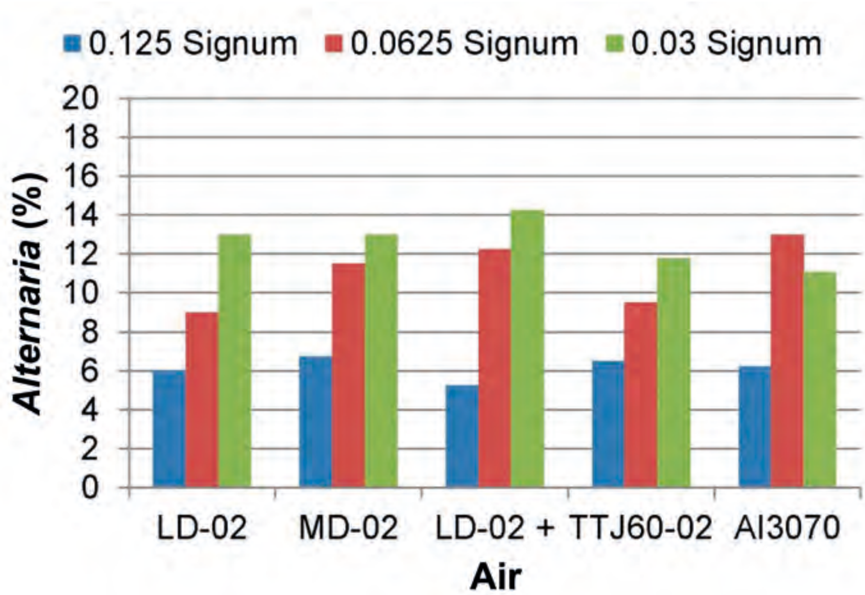


Figure 4. Assessment of attack of *Alternaria solani* on 20 September 2014.

Potato sprayer used for testing of different spraying techniques.

X Innovative IPM solutions for winter wheat-based rotations: cropping systems assessed in Denmark

Per Kudsk, Lise Nistrup Jørgensen, Bo Melander & Marianne LeFebvre

Introduction

A long-term field experiment comparing the agronomic, economic and environmental performance of current practice and two IPM strategies (named IPM1 and IPM2) in winter wheat-based crop rotations was initiated at Flakkebjerg Research Centre in 2011. The experiment is one of 6 long-term on-station experiments, of which the other 5 are located in France (2 locations), Germany, Poland and Scotland, conducted as part of PURE, an EU FP7 project finishing 1 March 2015.

The trial will continue for another 3 years, and more definitive conclusions will have to wait until the results of the coming years' cropping are available, but in this paper we present the results from the first 3 years and the preliminary conclusions that can be made.

Materials and methods

The experiment in Denmark has only run for three years corresponding to one rotation. Three cropping systems were compared reflecting (1) common agricultural crop protection practice (current system), (2) an intermediate level of IPM, combining existing IPM tools with pesticides (intermediate IPM), and (3) an advanced level of IPM with a reduced reliance on pesticides and increasing adoption of cultural and non-chemical IPM tools (advanced system). Crop rotation and cultivation practices for each system are shown in Table 1. An aerial photo of the experimental site is shown in Figure 1.

Table 1. Description of the three cropping systems (WW=winter wheat (1 and 2 indicate first and second year WW), WOSR=winter oilseed rape, SB=spring barley, SO=spring oats, FR=fodder radish (cover crop), CPO=Crop Protection Online).

	Current system (CS)	Intermediate IPM (IPM1)	Advanced IPM (IPM2)
Crop rotation	WW1-WW2-WOSR	WW-SB-WOSR	WW-SO (FR)-WOSR
Soil cultivation	Mould board ploughing	Mould board ploughing	Mould board ploughing
WW cultivar	Hereford	Maribos	Cultivar mixture
Time of sowing (WW)	Early September	Mid-September	Mid-September (+false seed bed)
WW crop plant density	300-350 plants/m^2	300-350 plants/m^2	300-350 plants/m^2
Fertiliser	Danish quota	Danish quota (split)	Danish quota (split)
Diseases			
WW	Current practice (reduced dose)	CPO CPO	CPO CPO
WOSR	Current practice		
SB		CPO	
SO			None
Pests			
WOSR	Current practice	CPO	CPO
WW	Current practice	CPO	CPO
SB		CPO	
SO			CPO
Weeds			
WW	Current practice (autumn + spring)	Autumn (reduced dose) + spring (CPO)	Only spring (CPO) Mechanical
WOSR	Current practice	Inter-row cultivation + band spraying	Inter-row cultivation only
SB		CPO	CPO
SO			Weed harrowing only

Besides the treatment listed in Table 1, in the first two years some of the plots were patch-sprayed with MCPA against *Cirsium arvense*. No plant growth regulators were applied.

All crops in the rotations were grown every year and each treatment was replicated three times (27 plots in total).

Weed species and numbers were determined at the onset of the experiment and soil samples were collected for determining the soil seed bank (data not shown). Weed numbers and biomass were assessed prior to treatment when CPO was used and again approximately. 3 weeks after the last treatment. Diseases and pests were monitored according to the CPO guidelines. Crops were harvested at maturity and yields were determined at 85% and 91% dry matter content for cereals for oil seed rape, respectively.

A cost-benefit analysis including all variable costs was conducted and the average gross margin of each cropping system was calculated for each year by subtracting production costs from income. Income was calculated as the actual commodity prices of the grain and oilseed rape seeds. Production costs was calculated by putting in the actual costs of inputs such as fertilisers, pesticides, etc., while the costs of field operations such as ploughing, inter-row cultivation, etc. were estimated using standard values.

Pesticide use was assessed by calculating the Treatment Frequency Index, and the potential health and environmental impact was assessed by calculating the Pesticide Load, a new Danish pesticide impact indicator, for each cropping system. For more information on the indicator, see www.mst.dk.

Figure 1. Aerial photo of the experimental site.

Results and discussion

Effects on weeds

Overall, weeds were controlled effectively in all three systems and weed biomass in June was generally low. Nonetheless, weed biomass in the cereal crops was significantly higher in the advanced IPM system than in the two other systems except for second year WW in the current system (Figure 2).

Inter-row cultivation in winter oilseed rape was very effective in all three years; however, in the advanced system in which inter-row cultivation was not combined with band spraying with clopyralid, significant numbers of *Tripleurospermum inodorum* were observed in the rows. No effects were observed on yields but the seeds produced by the surviving *T. inodorum* plants could pose problems later in the crop rotation. Actually, high numbers of *T. inodorum* were observed in the third cropping year when the seeds shattered in the first year were brought back to the upper soil layer by ploughing.

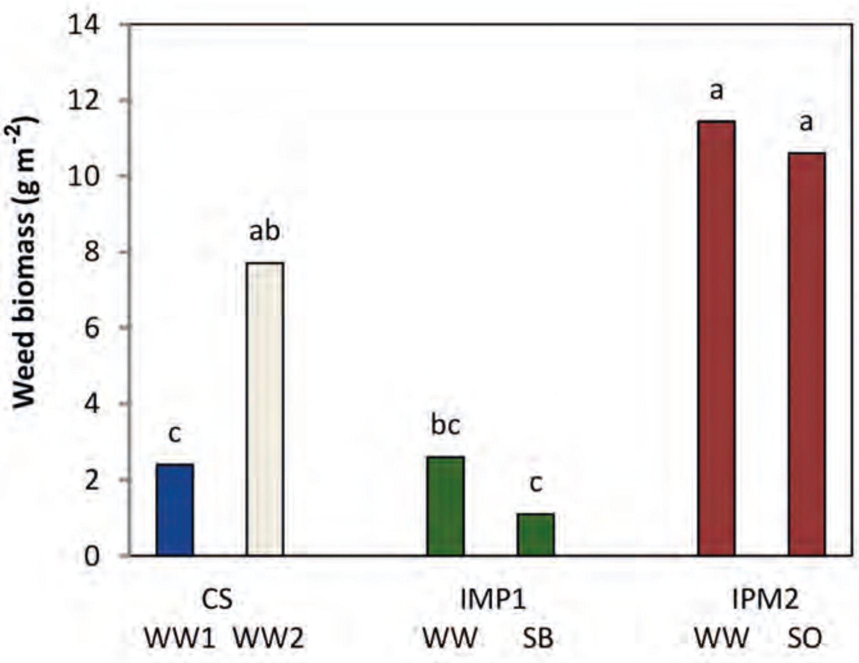


Figure 2. Weed biomass in cereal crops in late June 2014 (back-transformed LSMs).

Effects on disease and pests

In winter wheat, *Septoria* disease dominated during the 3 seasons. The level of attack varied depending on the cultivars grown. In general, the level of diseases was lowest in the cultivar mixture grown in IPM2. As an average of the 3 years, there was a clear ranking of attack between the 3 systems. Severe attack was seen in the most susceptible cultivar - Hereford, less in Mariboss and least in the cultivar mixture grown in IPM2. In the spring crops - spring barley and spring oats - only limited levels of disease attack were present. In oil seed rape, no attack of *Sclerotinia* was seen in any of the years and only minor attacks of blossom beetles were found in the trials during the 3 years. Similarly, aphids were not a major problem in cereals.

Table 2. Per cent of *Septoria* attack on the flag leaf of winter wheat assessed at GS 75. The treatments in treated oats varied from 0 to 2 treatments.

	% attack of *Septoria* on flag leaves			
	2012	2013	2014	Average
CS Untreated	10.0	30.0	53.0	31.0
CS Treated	0.7	3.0	21.0	8.2
IPM1 Untreated	0.1	32.0	21.0	17.7
IPM1 Treated	0	3.0	2.2	2.6
IPM2 Untreated	0.5	0.7	13.0	4.7
IPM2 Treated	-	0	7.3	-

Yields

Crop yields within cropping systems and years revealed some differences (Table 3). In 2012, winter wheat yields were similar for the current and IPM1 systems, while the yield in the IPM2 system was lower due to severe weed competition until it was effectively controlled in late April. In 2013, the higher winter wheat yield in the conventional system was due to its earlier sowing time than the other two systems, presumably making the conventional wheat more resistant to the harsh winter in 2012/2013 and the drought in the spring of 2013. No major yield differences for winter wheat were encountered among the three systems in 2014. Overall, the variation in winter wheat yields between years was more variable in the IPM2 system than in the other two cropping systems.

Winter oil seed rape produced consistent yields across cropping systems within all three years despite differences in row spacing and herbicide inputs. Very dry growing conditions prevailed in the spring and early summer of 2014, which may have caused the relatively low yields of the two spring cereals in that particular year (Table 3).

Table 3. Least square means (LSM) of crop yields (t ha^{-1}) from mixed analyses on cropping system and crop effects. LSMs are shown for each crop type within cropping system and year. LSMs for similar crop having different letters within years are significantly different (P<0.05). Standard errors from the mixed analyses are given in parentheses.

Year	Crop type	Cropping system		
		CS	IPM1	IPM2
2012	Winter wheat	10.95^a (0.411)	10.11^a (0.582)	6.69^b (0.582)
	Winter oil seed rape	3.23^a (0.391)	3.05^a (0.391)	3.25^a (0.391)
	Spring cereals: barley	-	8.02^a (0.409)	-
	Spring cereals: oats	-	-	6.68^a (0.409)
2013	Winter wheat	9.10^a (0.556)	6.34^b (0.556)	6.34^b (0.556)
	Winter wheat 2nd year	7.70^{ab} (0.556)	-	-
	Winter oil seed rape	3.97^a (0.087)	4.02^a (0.087)	3.90^a (0.087)
	Spring cereals: barley	-	6.00^a (0.666)	-
	Spring cereals: oats	-	-	6.45^a (0.666)
2014	Winter wheat	8.77^{ab} (0.609)	9.31^b (0.609)	8.40^a (0.609)
	Winter wheat 2nd year	9.33^b (0.609)	-	-
	Winter oil seed rape	4.69^a (0.221)	4.58^a (0.221)	4.28^a (0.221)
	Spring cereals: barley	-	6.00^a (0.627)	-
	Spring cereals: oats	-	-	5.35^a (0.627)

Cost-benefit analysis

The outcome of the cost-benefit analysis is shown for each cropping system and the years 2013 and 2014 in Table 2. The 2012 results were omitted from the analysis because there was no second year winter wheat crop in that year.

The gross margins for all cropping systems were higher in 2013 than in 2014 and for the two IPM systems even higher in 2012. Besides yield variations the key factor determining the gross margin was commodity prices that went down significantly from 2013 to 2014. In contrast, production costs varied very little between cropping systems and years. In both 2013 and 2014, the current system had a higher gross margin than the two IPM systems, and the IPM1 system was consistently performing better than the IPM2 system (Table 4).

In the IPM1 and IPM2 systems, second year winter wheat was replaced by spring barley and spring oats. In 2013 the gross margins of the spring cereal crops were comparable to that of the second year winter wheat crop while in 2014, due to the very high winter wheat yield, gross margins of the spring cereal crops were significantly lower.

Table 4. Average gross margins (EUR/ha) for each cropping system.

Harvest year	Cropping system		
	CS	IPM1	IPM2
2012		1079	815
2013	747	608	523
2014	299	190	92
Average 2013-2014	523	399	308

Treatment Frequency Index (TFI) and Pesticide Load (PL)

The TFI and PL values for each cropping system and each year is shown in Table 5.

Table 5. The TFI and PL values for each cropping system and each year.

Harvest Year	Cropping system					
	TFI			PL		
	CS	IPM1	IPM2	CS	IPM1	IPM2
2012	2.90	1.96	0.66	2.45	2.08	0.57
2013	2.63	1.18	0.53	2.78	1.48	0.51
2014	1.98	1.08	0.24	2.75	1.85	0.39
Average	2.51	1.41	0.48	2.65	1.36	0.50

The TFIs of IPM1 and IPM2 were on average 44 and 80% lower than that of the current system. The TFI of the current system was comparable to the average national TFI values reported in the annual "Bekæmpelsesmiddelstatistik (see www.mst.dk) . For example in 2012, the average TFI of winter cereals and winter oilseed rape was 2.81 and 3.24, i.e. the average national TFI of a crop rotation consisting of two winter wheat crops and one oilseed rape crop would be 2.95, which is not different from the value of 2.90 calculated for the experiment. In 2013 the average national TFI of a crop rotation similar to the current system was 2.98, being slightly higher than the value of 2.63 calculated for for the experiment.

Throughout the 3 years, pesticides were not selected with the objective to minimise the PL. For example, prosulfocarb was applied in the IPM1 system although this is one of the herbicides with the highest PL value per recommended dose. Similarly, fungicide and insecticide recommendations from CPO were strictly followed whether the decision support system proposed products with a high or low PL value. Nonetheless reductions in PL were comparable to those of the TFI with reductions of 49 and 81%, respectively.

Conclusions

The results of the first 3 years have shown that weeds could be effectively controlled with reduced herbicide doses (winter wheat) and partial or complete replacement of herbicides by mechanical weeding (winter oilseed rape and spring oats). Except for winter wheat in the first year, weeds were not assumed to have caused yield reductions. The long-term experiment was established in a field that had been farmed organically for several years and although spring barley was cultivated in the whole field the year before initiating the experiment, weed infestation was high albeit dominated by dicotyledonous weed species in contrast to many farmers' fields where grass weeds are the main weed issue. Thus the acceptable effect of the integrated and non-chemical weed control methods could not be ascribed to a low weed density. A conclusion also supported by the significant yield loss in the IPM2 system in 2012.

Disease control mainly focused on *Septoria* in winter wheat. The level of attack was highly influenced by the cultivars chosen. The yield reductions seen in IPM2 and IPM3 cannot be linked to the lack of disease management but is more linked to delayed sowing.

Delayed sowing was one of the IPM tools that were applied in the IPM1 and IPM2 systems. Delayed sowing can reduce weed infestation and minimise the risk of some of the most important cereal diseases like *Septoria* and barley yellow dwarf virus, which is spread by aphids in early autumn and may require insecticide treatments. The main risk associated with delayed sowing is early onset of the winter hampering plant growth and especially root development. If early onset of the winter is followed up by a dry spring, then the reduced root volume can result in crop plants being drought stressed early in the season. This was most likely the cause of the significant yield reduction of approx. 30% in the IPM1 and IPM2 systems in 2013. In contrast, the winters of 2012 and 2014 were mild and yield differences could not be attributed to delayed sowing.

The outcome of the cost-benefit analyses clearly showed that IPM, as it was implemented in the present experiment, was associated with a loss of income. Production costs were similar in all systems, i.e. the costs of inter-row cultivation, weed harrowing, etc. were made up by the reductions in pesticide costs. However, due to overall lower yields in winter wheat and the replacement of second year winter wheat by spring barley and spring oat the overall gross margins of the IPM1 and IPM2 systems were on average 24 and 41% lower, which would be unacceptable to farmers. The benefits of the IPM systems were very pronounced reductions in pesticide use (TFI) as well as in the potential impact of the pesticide on health and environment (PL) particularly in the IPM2 system.

An ongoing discussion is whether the benefits of IPM in terms of lower pest infestations due to for example a more diverse crop rotation in the long term will make it up for short-term yield losses. The present experiment cannot answer this question as it has only been running for three years but the economic losses observed within the first three years were significant and question whether farmers will adopt such changes. The experiment will be continued for another three years and at that time we can or will be in a better position to answer the question of long-term benefits of IPM versus short-term losses. Up till now, no shifts were observed in the composition of the weed flora but this may become more apparent in three years' time. Finally, it should be stressed that this experiment represents just one location and one cropping system and therefore more general conclusions cannot be drawn. Fortunately, the five other experiments within the PURE project will also continue and with results from six experiments running for six years at six locations more firm conclusions can be drawn.

XI Desiccation of potatoes – influence of maturity/green biomass

Peter Kryger Jensen

When potatoes are desiccated in order to stop tuber development or to ease harvest, crop canopy development might vary considerably across the field. This has inspired research in site specific application of the desiccant adapted to the crop development and maturity. A Dutch algorithm has been developed and is commercially available. The purpose of this experiment was to investigate the potential benefit of adapting the dose rate of a desiccant to the crop development in order to obtain an even desiccation of the crop independently of the development and greenness at the time of application. A trial was carried out in potatoes cv Kuras grown according to normal practice concerning time of establishment, plant density and row distance. However, in order to achieve different levels of green crop biomass at the time when the desiccation was carried out, three different levels of nitrogen were applied. These were 37.5, 75 and 150 kg nitrogen per hectare. Weed control and control of diseases and pests were also carried out according to normal practice. The desiccation treatment was carried out using Reglone (containing 374 g. a.i. diquat-dibromid per litre) at three dose rates, 3.0, 1.5 and 0.75 l/ha. The desiccation treatments were applied on 26 August using a conventional spray technique. The desiccation treatments were repeated on 2 September.

Crop development was recorded electronically, measuring a vegetation index (RVI). One measurement was carried out on 20 August before the desiccation treatment (Table 1). The RVI values obtained on 20 August reflect the green biomass obtained as a result of the three nitrogen levels. Despite the large difference in nitrogen amount applied, differences in biomass and RVI obtained seemed to be less than the variation often seen in large potato fields. Visual assessments of desiccation were carried out 3 and 10 days after the first application. The assessments were divided into two layers, desiccation of the top of the canopy and desiccation of the bottom of the canopy (Table 2). On the first assessment date (29 August) a limited desiccation was generally found at the bottom of the canopy. Desiccation of the top layer of the canopy showed a better efficacy at the low nitrogen rate and a generally decreasing efficacy

Table 1. Assessments of vegetation index measured before the application of desiccant (20 August) and three times following the desiccant treatments.

Dose of Reglone (l/ha)	Nitrogen (kg/ha)	RVI 20/8	RVI 29/8	RVI 5/9	RVI 10/9
3.0	37.5	10.8	4.6	2.9	2.5
1.5	37.5	10.7	5.3	3.6	3.3
0.75	37.5	10.8	6.1	5.0	4.8
3.0	75	11.7	5.1	3.2	2.8
1.5	75	11.3	5.4	4.1	3.7
0.75	75	11.4	6.5	5.1	4.8
3.0	150	12.4	5.2	3.3	2.8
1.5	150	12.6	6.2	4.7	4.3
0.75	150	12.9	7.5	5.8	5.5
LSD (p=0.05)		0.77	0.57	0.48	0.48

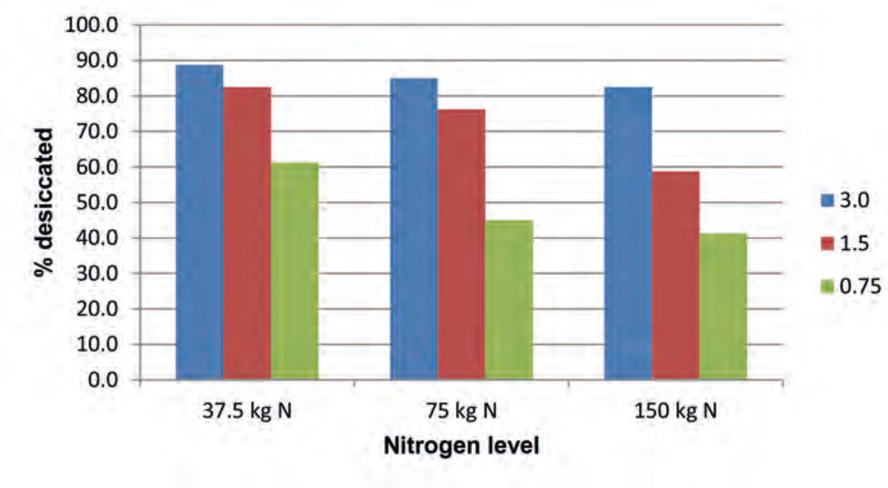


Figure 1. Desiccation scored on 29 August. The figure shows the desiccation of the upper canopy layer.

with increasing nitrogen level. This is also shown in Figure 1. Due to the limited desiccation at the bottom of the canopy, the desiccation treatments were repeated. Following this application, desiccation of the canopy was assessed three days later (Table 2). At this assessment date, a high level of desiccation was generally found but still with dose response curves at the three nitrogen levels. The desiccation was also followed measuring a vegetation index 3 times in the period following the application of the desiccant (Table 2).

Table 2. Visual assessments of desiccation of the potato canopy at two levels following the desiccation treatments.

Dose of Reglone (l/ha)	Nitrogen (kg/ha)	% desiccated foliage at bottom of crop 29/8	% desiccated foliage at top of crop 29/8	% desiccated foliage at bottom of crop 5/9	% desiccated foliage at top of crop 5/9
3.0	37.5	20.75	88.75	87.5	95
1.5	37.5	17.75	82.5	66.25	93.75
0.75	37.5	7	61.25	25	80
3.0	75	11.5	85	81.25	95
1.5	75	8.5	76.25	51.25	91.25
0.75	75	6	45	30	68.75
3.0	150	8.5	82.5	82.5	95
1.5	150	4.75	58.75	52.5	83.75
0.75	150	6	41.25	22.5	73.75
LSD (p=0.05)		9.1	11.8	15.3	5.5

Differences in crop development, biomass and maturity following the different nitrogen levels were evaluated to be less than the differences often seen in large, heterogeneous potato fields. The potential to adjust the desiccant dose rate under normal conditions therefore seems to be at least as large as those found in the experiment. The dose response curves obtained at the three nitrogen levels indicate that the desiccant dose rate should be varied significantly if the purpose is to obtain the same desiccation level independent of the biomass/greenness of the crop at the time of desiccation. Further experiments are required to develop an algorithm enabling the application of a variable desiccant dose rate in heterogeneous maturing potato crops.

XII Integrated control of blackgrass - long-term effects

Peter Kryger Jensen

In autumn 2011 a long-term experiment with the purpose of determining the effects of various IPM initiatives on the population development of blackgrass was initiated at Flakkebjerg. The experiment is located on an area with a heavy infestation of blackgrass. Blackgrass is a winter annual weed favoured by crop rotations with a large proportion of autumn-established crops. The experiment contains 4 crop rotations shown in Table 1.

Table 1. Crop rotations in blackgrass long-term experiment.

Year	R1	R2	R3	R4
2012	Winter wheat	Winter rye*	Spring barley	Spring barley
2013	Winter wheat	Winter rye*	Winter wheat	Spring barley
2014	Winter barley	Winter barley	Winter barley	Winter barley
2015	Winter oilseed rape	Winter oilseed rape	Winter oilseed rape	Winter oilseed rape
* Late sown, at least 14 days after winter wheat				

The difference between 3 of the rotations is the proportion of autumn-established crops that is varied from 100, 75 and 50 per cent. Two of the crop rotations have 100 per cent autumn-established crops. The difference between the two (R1 and R2) is that winter wheat in R1 is substituted with winter rye in R2. The winter rye was established at least 14 days later than the winter wheat. Winter rye is more competitive against weeds and the late sowing is unfavourable for germination of blackgrass.

The four crop rotations are combined with two levels of stubble cultivation, and with two levels of direct control of blackgrass. These 4 combinations are:

1. No stubble treatment, 70% control of blackgrass
2. No stubble treatment, 90% control of blackgrass
3. Stubble treatment shortly after harvest, 70% control of blackgrass
4. Stubble treatment shortly after harvest, 90% control of blackgrass

Stubble management has a large influence on the survival of blackgrass seeds. In treatments in which the field is left uncultivated a much larger turnover of seeds has been found compared to fields where the seeds have been incorporated with stubble cultivation shortly after harvest. In the study it is tested whether this influences the long-term seedbank. The stubble cultivation was carried out cultivating the soil to 2-4 cm depth. The two control levels of blackgrass, 70% and 90%, are the weed control levels aimed at following herbicide applications in the crop each year. The herbicide and dose rate to achieve this was found using Crop Protection Online. Foliar-acting herbicides are chosen in order to allow assessment of the population of blackgrass in the crop before the herbicide application. All crops are established conventionally with ploughing prior to sowing. Due to this the outcome of applied treatments will be delayed for two years (or more). The experiment was initiated in the 2012 season and hence 2014 was the first year in which differences of the treatments in the first year could be seen. The results of the 2014 assessment are shown in the following 3 tables (Tables 2-4).

Table 2. Influence of crop in 2012 on blackgrass population in 2014.

Crop in 2012	Blackgrass plants per m^2, spring 2014
R1 (winter wheat)	83
R2 (winter rye, late sown)	46
R3 (spring barley)	52
R4 (spring barley)	60
LSD	16

Table 3. Influence of stubble cultivation and control level.

Stubble treatment and control level	Blackgrass plants per m^2, spring 2014
No stubble treatment, 70% control of blackgrass	64
No stubble treatment, 90% control of blackgrass	53
Stubble treatment shortly after harvest, 70% control of blackgrass	68
Stubble treatment shortly after harvest, 90% control of blackgrass	56
LSD	ns

Table 4. Influence of weed control level.

Control level aimed at	Blackgrass plants per m^2, spring 2014
70% control of blackgrass	66.2
90% control of blackgrass	54.5
LSD	10.9

XIII Screening of new adjuvants for herbicides

Solvejg K. Mathiassen

The efficacy of new adjuvants was examined in a series of pot trials. The experiments were conducted outdoors and included different combinations of herbicides and weed species. Glyphosate (Glyfonova Plus) and MCPA (Metaxon) were tested on *Centaurea cyanus* (CENCY), metsulfuron (Ally SX) on *Viola arvensis* (VIOAR), pyroxsulam+ florasulam (Broadway) and fenoxaprop-P (Primera Super) on *Alopecurus myosuroides* (ALOMY) and sulfosufuron (Monitor) on *Bromus sterilis* (BROST). A list of the tested adjuvants is shown in Table 1.

Table 1. Adjuvants included in the experiments

Trade name	Adjuvant type	Dose	Recommended use
Contact	Non-ionic surfactant	0.2%	ALS inhibitors, ACCase inhibitors, diquat
Ammonium sulphate (AMS) + Contact	Non-ionic surfactant	2 kg/ha + 0.2%	Glyphosate
Renol	Vegetable oil	0.5 L/ha	Phenmedipham, clodinafop
Dash	Non-ionic surfactant	0.5 L/ha	Cycloxydim, tepraloxydim
PG 26N	Non-ionic surfactant	0.5 L/ha	Pyroxsulam+ florasulam, clopyralid+ picloram, florasulam+ aminopyralid+ pyroxsulam
Silwet Gold	Super surfactant	0.15 L/ha	Herbicides, fungicides, insecticides
NovaBalance	pH adjusting surfactant	0.2%	Glyphosate, phenmedipham
pH Fix 5	pH adjusting surfactant	0.2%	Herbicides, fungicides, insecticides
Squall*	Polymer	1 L/ha	Herbicides, fungicides, insecticides
Fieldor Max*	Penetration oil	0.15%	Herbicides, fungicides, insecticides

*not marketed in Denmark

The spray solutions were prepared as recommended on the adjuvant labels, specifically for the pH adjusters by preparing the water and adjuvant solution before adding the herbicide. All spray solutions were prepared in tap water with a hardness of 18 and a pH of 7.8. The herbicides were applied at 4 to 5 doses in a spray volume of 150 L/ha. Fresh and dry weights were recorded 3 to 4 weeks after application. A dose response model was fitted to data and ED_{90} values were estimated (Table 2).

Results and discussion

NovaBalance and Ph Fix 5 are pH adjusters that reduce the pH of the spray solution. With glyphosate the pH decreased from 5.1 without adjuvant to 4.4 in mixture with NovaBalance and 4.5 in mixture with Ph Fix 5. Similarly, the pH of the MCPA solution decreased from 6.8 to 4.4 in mixture with NovaBalance and 5 in mixture with Ph Fix 5. In general, differences in the pH values of mixtures with NovaBalance and Ph Fix 5 were small and in most cases their effects on herbicide performances were similar. NovaBalance and Ph Fix 5 significantly improved the activity of glyphosate by a factor from 1.6 to 1.8 and of MCPA by a factor from 1.6 to 2.3 (Table 2). They had no significant effect on the activity of metsulfuron and fenoxaprop-P and in mixture with sulfosulfuron the activity was 6 to 8 times lower with NovaBalance and Ph Fix 5 compared to the recommended non-ionic surfactant. Interestingly, the activity of pyroxsulam + florasulam was 14 times lower in mixture with NovaBalance compared to PG 26N, while Ph Fix 5 provided an effect similar to PG 26N.

Table 2. Efficacy of different herbicides in mixture with adjuvants. Figures show ED_{90} in L/ha or g/ha. ED_{90} is the dose required to obtain 90% reduction in weed biomass. Not applied treatments are marked n.a. Significant responses in comparison to the recommended adjuvant are illustrated by bold (improved efficacy) or red (reduced efficacy) font.

	No or recommend-ed adjuvant	AMS + Contact	Nova-Balance	Ph Fix 5	Squall	Silwet Gold	Dash	Fieldor Max	Renol
Glyphosate/CENCY	0.160	0.013	0.085	0.099	0.147	0.010	0.057	0.132	0.038
MCPA/CENCY	0.100	0.048	0.043	0.061	0.101	0.393	0.411	0.093	0.053
Metsulfuron/VIOAR	2.424	n.a.	2.213	1.173	1.617	0.228	0.513	1.560	0.564
Pyroxsulam + florasulam/ALOMY	1.01 (PG 26N)	n.a.	14.39	1.45	10.12	3.78	0.58	5.16	4.23
Fenoxaprop-P/ALOMY	0.280	n.a.	0.447	0.278	0.296	0.285	0.438	0.390	0.366
Sulfosulfuron/ BROST	2.50	n.a.	19.93	15.31	n.a.	n.a.	n.a.	n.a.	n.a.

The pH of the spray solution affects several processes. It can change the chemical composition and stability of the active ingredient and affect the solubility and degradation of the active ingredient. For example, the solubility of sulfonylurea herbicides increases at high pH, while the uptake of most herbicides is improved at low pH. Furthermore, at low pH the negative effect of interaction between active ingredients and cations like Ca^{++} in the water is prevented. Water with a hardness of 18 contains approximately 3.3 mmol Ca^{++} per L. With a spray volume of 150 L/ha the content of calcium can theoretically inactivate 84 g glyphosate and as the maximum dose of glyphosate in the experiment was 360 g/ha this amounts to 23% reduction in available glyphosate. Actually the ED_{90} doses of glyphosate with NovaBalance and pH Fix 5 reflected an even higher improvement of activity.

Squall is a polymer which is marketed in the Netherlands. It is claimed to improve the efficacy of all pesticides. Squall increases the deposition on plants, narrows the drop size distribution to efficiently reduce the drift and improves rainfastness. Squall did not improve the efficacy of any herbicide-weed combination in our experiments (Table 2). In contrast, results from the Netherlands report that Squall improved herbicide performance in 8 of 15 combinations of herbicides and weeds in pot experiments. Improved efficacy was specifically observed with rimsulfuron (Titus), mesosulfuron + iodosulfuron (Atlantis OD) and mesotrion + terbuthylazin (Calaris) in the Dutch experiments, whereas no significant effects were found in mixture with glyphosate in field trials.

Fieldor Max is a penetration oil imported from France. It is claimed to increase the uptake and translocation of the active ingredient in plants. No significant effects on the herbicide activity of Fieldor Max were observed for any of the tested herbicide/weed combinations (Table 2). Fieldor Max has, however, been tested in mixture with iodosulfuron + mesosulfuron (Cossack) in the National Field Trials (Landsforsøgene) in which the performance was equal to Renol.

Efficacy of glyphosate in mixture with adjuvants. Back row: 0.123 L/ha, front row: 0.25 L/ha.
From left to right: Control, no adjuvant, AMS + Contact, NovaBalance, Ph Fix 5, Squall, Silwet Gold, Dash, Fieldor Max and Renol.

Growth stage of *Centaurea cyanus* at spraying.

Silwet Gold is a super wetter that decreases the surface tension of the spray solution considerably more than common surfactants. This effect is easily detectable as the leaves are fully covered by the spray liquid and look as if they have been painted. The high surface coverage is expected to promote herbicide uptake. Silwet Gold is marketed in Denmark as an adjuvant for all pesticides. Our results show positive effects in mixture with glyphosate, MCPA and metsulfuron. Silwet Gold did not affect the activity of fenoxaprop-P and it gave lower effects in mixture with pyroxsulam+ florasulam than the recommended adjuvant (PG 26N) (Table 2). Silwet Gold was not tested with sulfosulfuron.

Overall the results show that it is difficult to select the optimum adjuvant. Several adjuvants improved the efficacy of glyphosate (AMS + Contact, NovaBalance, Ph Fix 5, Silwet Gold, Dash and Renol), whereas for pyroxsulam+florasulam, fenoxaprop-P and sulfosulfuron no adjuvant was superior to the recommended ones. Herbicide efficacy is influenced by several factors including climatic conditions, spraying technique and weed species. Adjuvants affect specifically the drop distribution, deposition and uptake in the weeds and their effects interact with the application conditions. Previous reports have concluded that adjuvants often have no or low influence on herbicide activity under optimum conditions, while they can overcome unfavourable application conditions. Ideally, the effect of adjuvants should be tested under contrasting conditions to fully explore their potential.

This work was carried out as commercial sector-funded activities.

XIV Results of the testing of herbicides, growth regulators and desiccants in agricultural crops and herbicides in horticultural crops 2014

Peter Hartvig, Henrik Jespersen, Verner Lindberg, Steen Sørensen, Lis Madsen, Jakob Sørensen & Morten Zielinski

In 2014 the herbicide testing group at AU Flakkebjerg conducted 104 field trials. They comprised 74 trials in agricultural crops, 23 trials in vegetables, fruit, berries and garden seed and 7 trials in nurseries, Christmas trees and on uncultivated areas.

Materials and methods

All testing trials are conducted as field trials. Most are sited with farmers to meet special requirements regarding soil and composition of crops and weed flora, but a small number of trials are located at AU Flakkebjerg's own fields. The majority of the trials were located in Zealand but a few are conducted in Funen and Jutland. Since 2009 a small number of trials have also been conducted in the South of Sweden. All trials are conducted as GEP trials with 4 replicates and in accordance with EPPO guidelines. Trials are conducted as tolerance/yield trials or efficacy trials, but in some trials both efficacy and tolerance are recorded. This applies to growth regulation trials and most of the trials in horticultural crops. When efficacy trials are laid out, the aim is to find areas with considerable weed populations in the form of many weed species, often also certain "target weeds", whereas the aim is to find areas with no or a very small weed population when tolerance/yield trials are laid out.

In the agricultural crops a self-propelled trial sprayer is used, which is standardly equipped with Hardi lowdrift fan nozzles. Usually, 150 l of water per hectare and a pressure suitable for a driving speed of 4.5 km/h are used. In the horticultural trials various types of sprayers are used depending on the crop and the task, but generally fan nozzles and 150-200 litres of water per hectare are used.

There is a growing tendency as regards the agricultural trials that the company ordering the trials decides which recordings are to be made in the trials and when. In the weed trials the efficacy of the herbicides is normally calculated either through visual assessments or by counting and measuring the fresh weight of the individual weed species in 3-4 sample plots of 0.25 m^2 per plot. Counting and weighing of the weeds are at the earliest conducted 6 weeks after finalisation of the spring sprayings, and as regards the autumn sprayings this recording is conducted 2-3 weeks after growth has begun in the spring. The assessments of efficacy are typically conducted approximately 2 and 6 weeks after spraying, but they can also be placed at other dates according to the wishes of the company ordering the trial. At the same time damage to the crop is also assessed. During the growing season assessments are made another 1-2 times; for cereals and grass seed it is established that the assessments are made at earing and immediately before harvest. The recordings are the same for efficacy and selectivity trials; however, the yield is only measured in the selectivity trials.

In the growth regulations trials assessments of crop damage, lodging and crop height are made until harvest at intervals of approximately 3 weeks after spraying in grass seed and earing in cereals, respectively. In cereals the recording of crop height is conducted through measuring, and in the same crops assessments are also conducted of straw and ear breakage. The yield is always measured in growth regulation trials.

Small crops (vegetables, fruit, berries, nursery, horticultural seed, Christmas trees, etc.) are generally more susceptible to herbicides than the agricultural crops, and therefore assessments of damage are conducted more often and at shorter intervals. Typically, assessments will be made 1, 2 and 4 weeks after treatment to record acute damage, while assessments in the interval of 4-16 weeks after treatment aim to record how quickly the crop recovers after the damage. Experience shows that early recorded damage that disappears quickly may be at a relatively high level without loss of yield or negative influence on quality, whereas more lasting damage may be at a lower level, yet still with a negative influence on yield and/or quality. The effect on weeds is recorded as in the agricultural crops. Subsequent weeding is necessary in most cases. The reason for this is that the horticultural crops are often less competitive than the agricultural crops, and therefore weeds in the untreated plots and not controlled weeds in the treated plots will often affect the yield negatively. If the weeds are not removed, it will be difficult to determine whether any recorded differences in yield are caused by the weed pressure or the effect of the herbicides.

Results – herbicides in agricultural crops 2014

More than half the trials were conducted in cereal crops and all were financed by the agrichemical companies. The same applies to forage maize, in which there were relatively many trials in 2014, and to winter oilseed rape, potatoes and beets. The trials in grass seed were financed by the GUDP project *"3030 i 2020 – mere græsfrø med relativt mindre input"* (Green Development and Demonstration Programme project "3030 in 2020 – more grass seed with relatively less input").

Results – herbicides in small crops 2014

The trials in small crops are to a great extent financed directly by the industry in Denmark or by foundations related to the industry. The trial unit has also conducted an increasing number of trials in Sweden in recent years. Within the field of small crops many herbicides have disappeared from the market over a number of years and only few new ones have been added, and Danish and Swedish growers share this problem. Due to a small market the agrichemical companies have relatively little interest in the small crops, and this seems to be intensified after Denmark has been placed in the North Zone in connection with EC Regulation 1107/2009. Financing of testing and development of new herbicide strategies in small crops is thus by now a task for which the industry itself is mostly responsible.

Due to a critical herbicide situation in many small crops the main purpose of the weed trials has for some years been to find alternatives to herbicides that have disappeared from the market or are feared will disappear in connection with new criteria in EC Regulation 1107/2009. In vegetables the main activities since 2009 have thus concentrated on developing strategies without pendimethalin in seeded onions, carrots and parsnips (Stomp and others), ioxynil (Totril) and tepraloxydim (Aramo). A very large part of this development work has been conducted in Sweden. In strawberry the prospect of losing Stomp is one of the motives behind the trials, while there has been a search for many years for an alternative to asulam (Asulox) in spinach for seed production. Fruit production is not at an immediate risk of losing herbicides. On the contrary, in recent years several authorisations have been given for minor use, and therefore work has been going on in fruit in recent years to develop weed control that is tailored to the needs.

Weed control in seeded onions is just about the most difficult job in weed control. The slow growth and weak competitiveness of onions and their general susceptibility to herbicides make weed control in onions a subject for specialists, and they now face major challenges. The most important herbicides for onions are thus expected to disappear from the market in the years to come and they must be replaced by other herbicides. Experiences from trials in recent years suggest that these herbicides are less effective against weeds and that onions are less tolerant to them.

XV Insecticide resistance experiments

Michael Kristensen, Caroline Kaiser & Dorte Højland

Pyrethroid resistance in the pollen beetle (*Meligethes aeneus*)

The current level of resistance from Danish pollen beetle populations was assessed in 2014 in comparison with some populations from Germany and Sweden. Populations were collected from randomly selected fields in collaboration with consultants and farmers (Figure 1). The established IRAC Adult-Vial-Test methods # 11 and # 21 with the active ingredients of lambda-cyhalothrin and thiacloprid, respectively, were used.

Beetles were collected from untreated and treated oilseed rape fields at growth stages BBCH 50 to 69 of the oilseed rape in April-May 2014. Beetles were stored for at least 24 h in climatic chambers at 4-6°C with food and water supply before testing. For the bioassay only live and fit beetles were used for the assessment. Ten beetles were selected for each glass vial. Four concentrations of lambda-cyhalothrin equivalent to 100% (0.075 µg per cm^2), 20%, 4% and 0.08% of the field application rate were used. Three concentrations of thiacloprid equivalent to 200% (1.44 µg per cm^2), 100% and 20% of the field application rate were used. Acetone-coated glasses were used as a control. Two replicates per rate. The assessment was carried out after 24 h. Beetles were classified as affected or alive; affected beetles showed uncoordinated movements, were not able to spread their wings properly or were dead.

Figure 1. Monitoring of pyrethoid resistance in 2014. In this map locations from the monitoring are shown. Every circle symbolises one population, collected in an oilseed rape field. The IRAC scheme for the susceptibility rates was used to group the populations according to their response to lambda-cyhalothrin.

In Zealand the majority of the tested populations with lambda-cyhalothrin were classified as resistant, whereas in Funen and in Jutland the means of the tested populations were classified as moderately resistant (Figure 2). The tested populations from Sweden near Linköping were dominated by highly susceptible populations in comparison to the pollen beetle population from Malmö, which was classified as resistant.

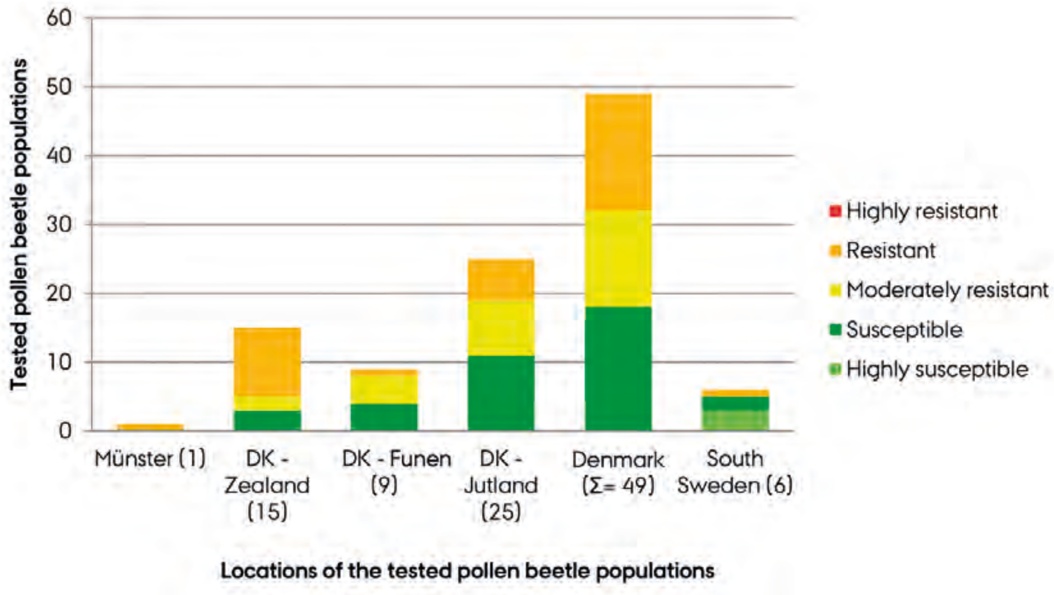


Figure 2. Results for pyrethroid resistance with IRAC #11 in 2014. In this figure the tested populations with different concentrations of lambda-cyhalothrin from the monitoring in 2014 are shown. The resistance level is shown in 5 groups.

There is a clear trend towards susceptibility against thiacloprid. Exceptions were noticed in Jutland with 4 pollen beetle populations which were grouped in 94-75% and on Funen there was one population with only 70% susceptibility (Figure 3).

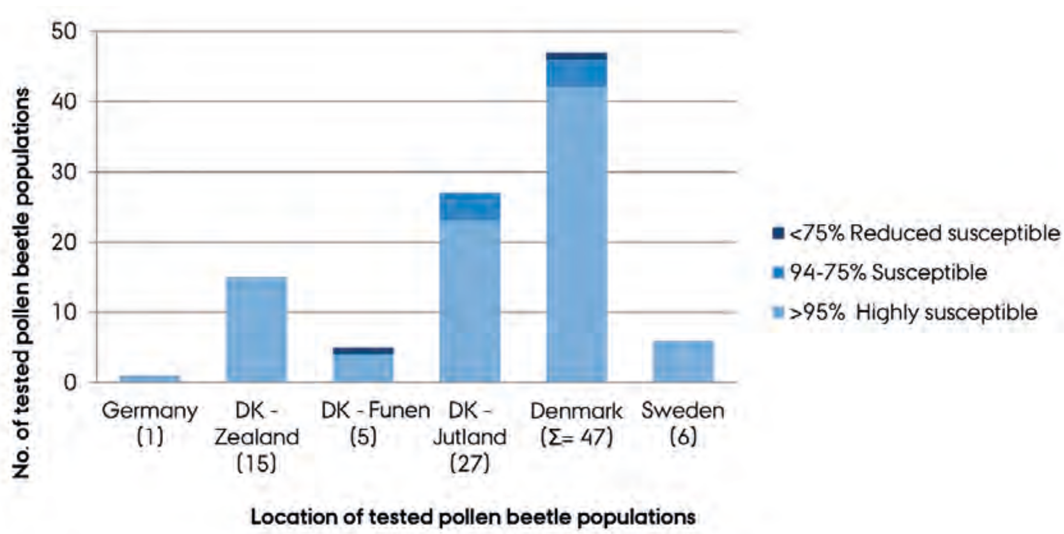


Figure 3. Monitoring of thiacloprid susceptibility level in 2014. The figure shows the mortality rate at a thiacloprid dose of 1.44µg per cm^2. In this case mortality > 95% indicated susceptibility towards thiacloprid.

Pyrethroid resistance in the cabbage stem flea beetle (*Psylloides chrysocephala*)

Beetles were collected from untreated oilseed rape fields shortly after germination of the oilseed rape in September 2014. Oilseed rape fields were selected through the national monitoring system in collaboration with consultants and farmers (Figure 4). Beetles were stored for at least 24 h in climatic chambers at 4-6°C with food and water supply before testing. For the bioassay only live and fit beetles were used for the assessment. Ten beetles were selected for each glass vial. Four concentrations of lambda-cyhalothrin equivalent to 100%, 20%, 4% and 0.8% of the recommended field rate were used.

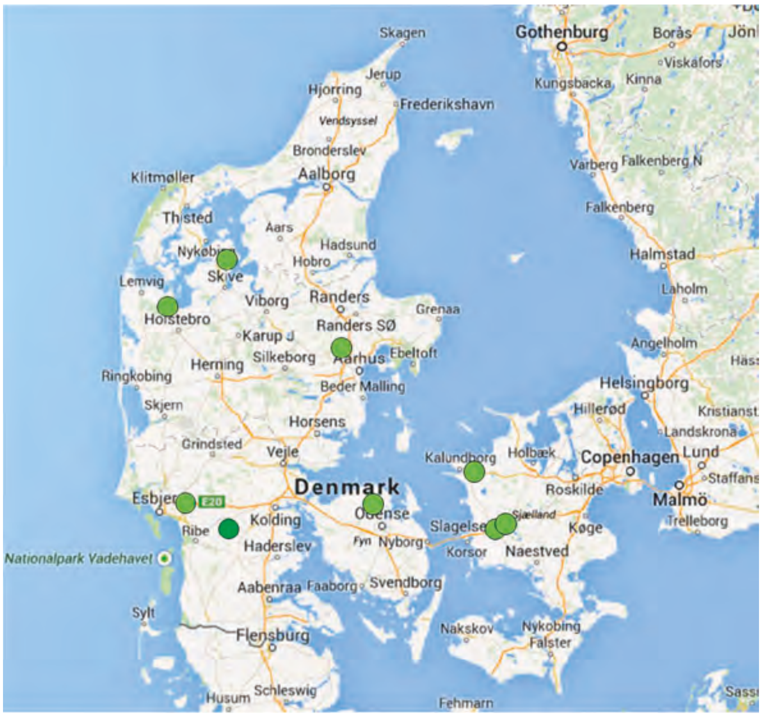


Figure 4. Monitoring of pyrethoid resistance in 2014. In this map locations from the monitoring are shown. Every circle symbolises one population, collected in an oilseed rape field. The IRAC scheme for the susceptibility rates were used to group the populations according to their response to lambda-cyhalothrin.

We examined 9 Danish populations in 2014, all of which were sensitive to pyrethroids. In one population in the South of Denmark, 20% of the recommended field rate did not kill all cabbage stem flea beetles, but left 10% surviving, classifying this population as a level 2 of the IRAC classification system. The remaining eight populations were all of level 1 of the IRAC classification system showing no survival at 20% and low survival at 4% of the recommended field rate.

The knock-down resistance (kdr) mutation believed to be responsible for pyrethroid resistance was observed in a frequency of 10% in the tested beetles. Beetles with two copies of the mutation (homozygotes) were observed in beetles surviving 20% of the field rate, but were also present in one beetle, which died at 0.8% of the recommended field rate.

XVI List of chemicals

Fungicides, sprays		
Name	Active ingredients	G active per L or kg
Acanto	Picoxystrobin	250
Adexar	Epoxiconazole + fluxapyroxad	62.5 + 62.5
Alto	Cyproconazole	240
Amistar	Azoxystrobin	250
Amistar Xtra	Azoxystrobin + cyproconazole	200 + 80
Aproach	Picoxystrobin	250
Armure	Difenoconazole + propiconazole	150 + 150
Aviator Xpro	Bixafen + prothioconazole	75 + 160
Banjo Forte	Dimethomorph + fluazinam	200 + 200
Bell	Boscalid + epoxiconazole	233 + 67
Bell Super	Boscalid + epoxiconazole	140 + 50
Bravo 500 SC	Chlorothalonil	500
Bumper 25 EC	Propiconazole	250
Caramba Star	Metconazole	60
Caramba 90	Metconazole	90
Ceando	Epoxiconazole + metrafenon	83 + 100
Comet	Pyraclostrobin	250
Comet 200	Pyraclostrobin	200
Cymbal	Cymoxanil	450
Dithane NT	Mancozeb	750
Epox Extra	Epoxiconazole + folpet	50 + 375
Fandango S	Prothioconazole + fluoxastrobin	100 + 50
Flexity	Metrafenon	300
Folicur EC 250	Tebuconazole	250
Folicur EW 250	Tebuconazole	250
Folicur Xpert	Prothioconazole + tebuconazole	160 + 80
Folpan 500 SC	Folpet	500
Ignite	Epoxiconazole	83
Imtrex	Fluxapyroxad	62.5
Juventus 90	Metconazole	90
Kayak	Cyprodinil	300
Maredo 125 EC	Epoxiconazole	125
Olympus	Azoxystrobin + chlorothalonil	80 + 400
Opera	Pyraclostrobine + epoxiconazole	133 + 50
Option	Cymoxanil	600
Opus	Epoxiconazole	125
Opus Max	Epoxiconazole	83
Osiris	Epoxiconazole + metconazole	37.5 + 27.5
Osiris Star	Epoxiconazole + metconazole	56.3 + 41.3

Fungicides, sprays		
Name	Active ingredients	G active per L or kg
Proline 275	Prothioconazole	275
Proline EC 250	Prothioconazole	250
Proline Xpert	Tebuconazole + prothioconazole	80 + 160
Propulse SE250	Fluopyram + prothioconazole	125 + 125
Prosaro EC 250	Prothioconazole + tebuconazole	125 + 125
Proxanil	Propamocarb + cymoxanil	333.6 + 50
Ranman Top	Cyazofamid	160
Revus	Mandipropamid	250
Revus Top	Mandipropamid + difenoconazole	250 + 250
Rubric	Epoxiconazole	125
Shirlan	Fluazinam	500
Signum	Pyraclostrobin + boscalid	67 + 267
Siltra EC 260	Bixafen + prothioconazole	60 + 200
Sphere	Trifloxystrobin + cyproconazole	187 + 80
Spyrale	Difenoconazole + fenpropidin	100 + 375
Talius	Proquinazid	200
Tilt 250 EC	Propiconazole	250
Tridex	Mancozeb	750
Twist	Trifloxystrobin	500
Viverda	Epoxiconazole + pyraclostrobin + boscalid	50 + 60 + 140
Zignal	Fluazinam	500

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The centre coordinates knowledge exchange and advice with regard to the departments that are heavily involved in food and agricultural science. They are:

Department of Animal Science
Department of Food Science
Department of Agroecology
Department of Engineering
Department of Molecular Biology and Genetics

DCA can also involve other units at AU that carry out research in the relevant areas.

SUMMARY

This publication contains results from crop protection trials which have been 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 also 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

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