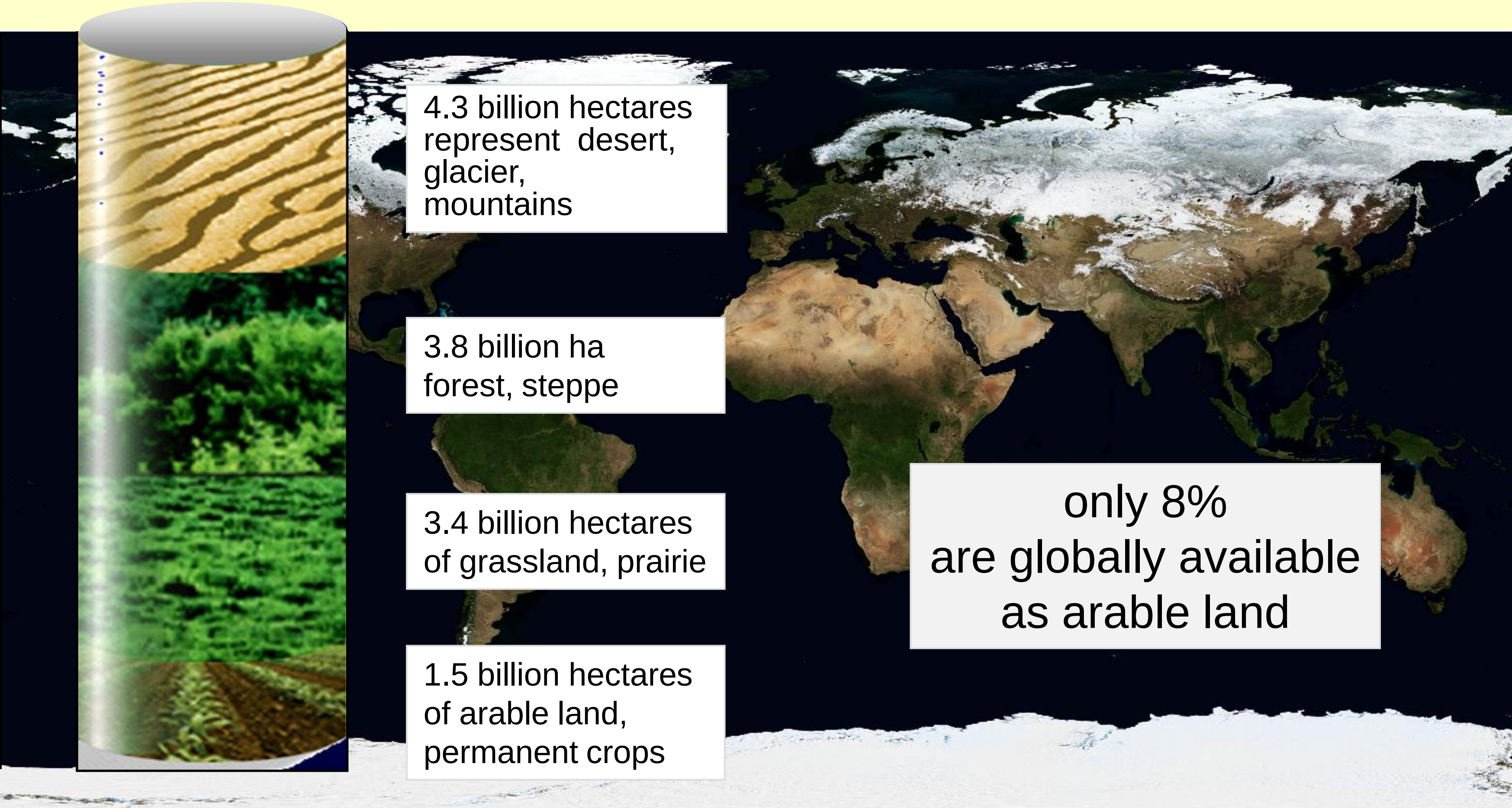
How to overcome yield limitations caused by pest and diseases

Prof. Dr. Joseph-Alexander Verreet

Institute of Phytopathology, CAU Kiel

Theoretical potential of the earth's surface
(Total surface area 50.9 billion ha there of 13 billion ha of land)



4.3 billion hectares represent desert, glacier, mountains

3.8 billion ha forest, steppe

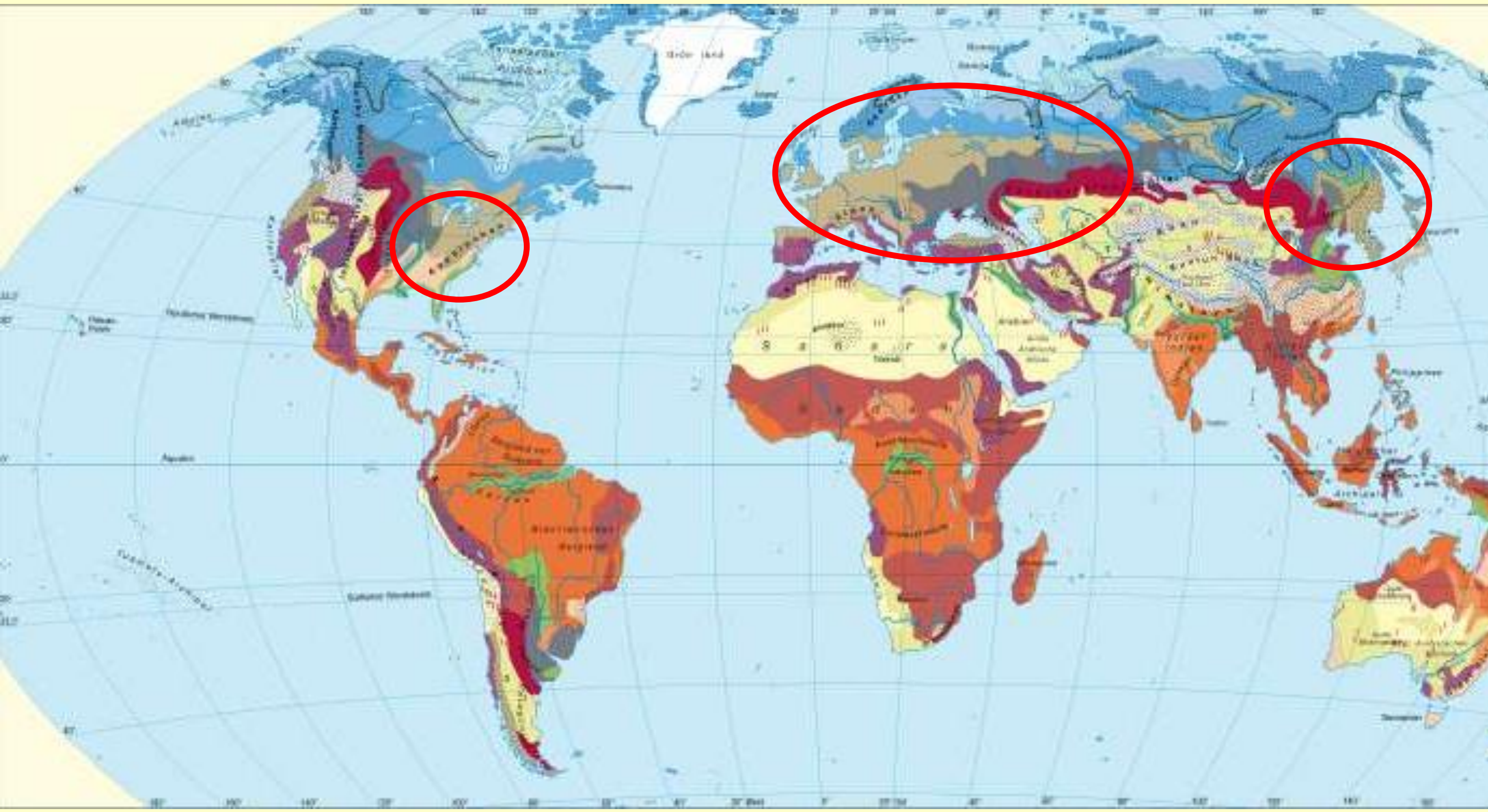
3.4 billion hectares of grassland, prairie

1.5 billion hectares of arable land, permanent crops

only 8%
are globally available
as arable land

Image source: NASA, 2015

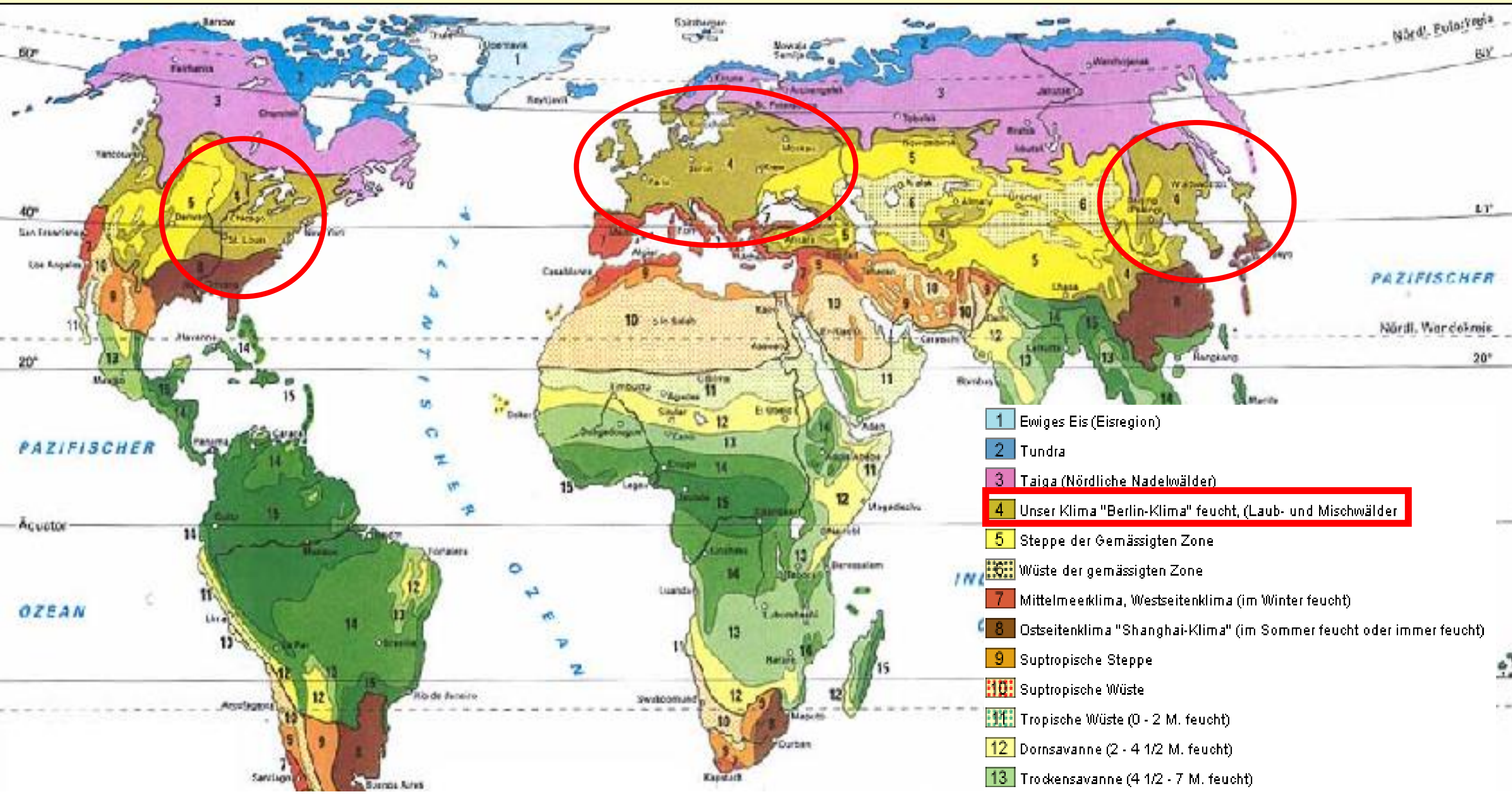
Distribution of different types of soil worldwide



Brown earth

source: Diercke, 2015

Climate map of the world



Ecologically, these "moist medium widths" represent an extremely favorable climate of solar radiation and rainfall as well as the highest soil quality as measure for maximum of yields to be achieved.

Yield

Crop cultivar:
Genetically fixed yield potential

Viruses
Bacteria
Oomycetes
Fungi
Nematodes
Insects

Fertilisation:
Achievement of yield prospect through intensive fertilisation

Crop protection:
Control of infestation and reduction of yield depressions by increased yields

Resource Use Efficiency in Agriculture

C. T. de Wit

Department of Theoretical Production Ecology, Agricultural University,
P.O. Box 430, 6700 AK Wageningen, The Netherlands

de Wit (1992)

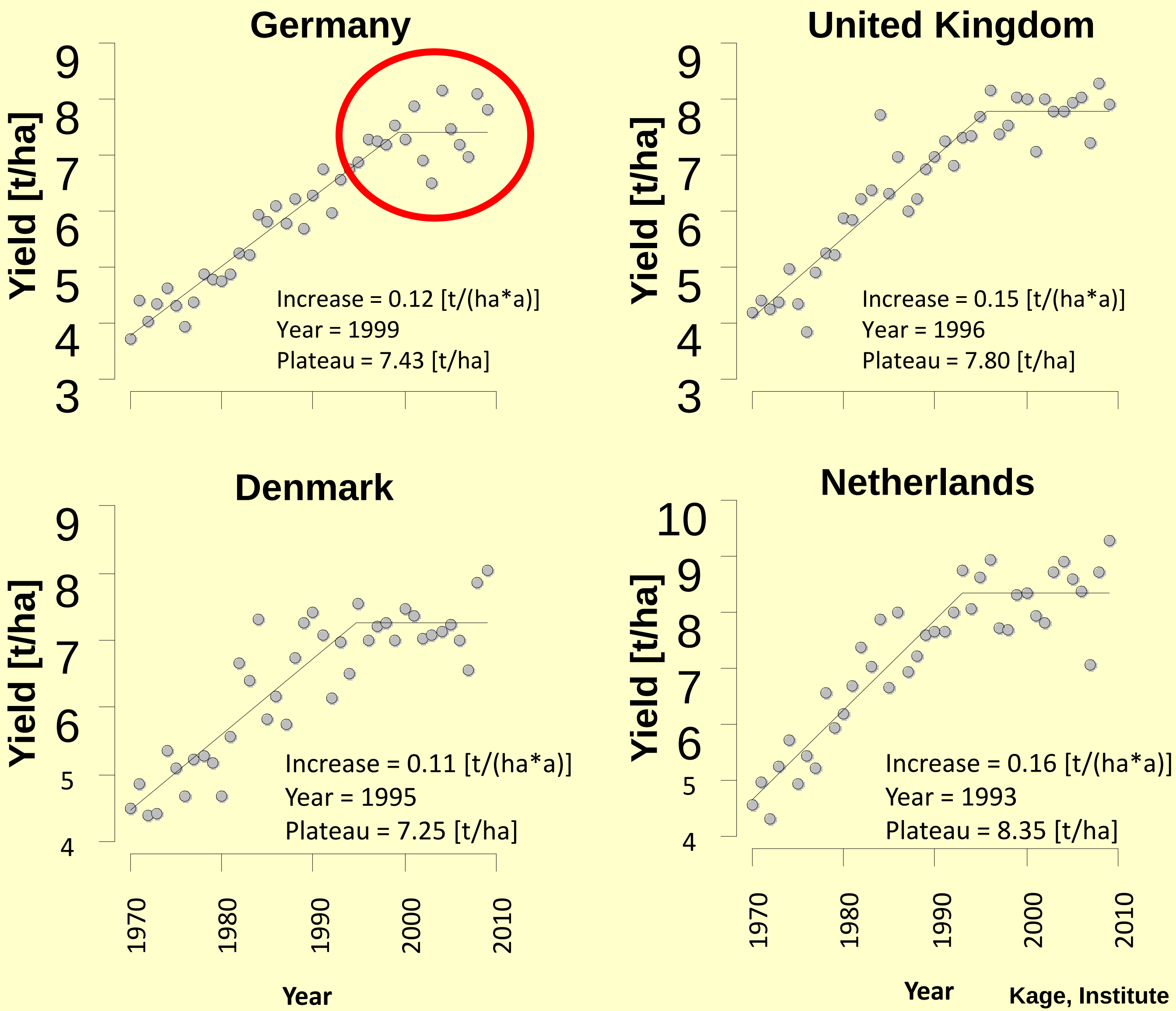
".. a production factor which is in optimum supply" contributes more to production, the closer other production factors are to their optimum."

…

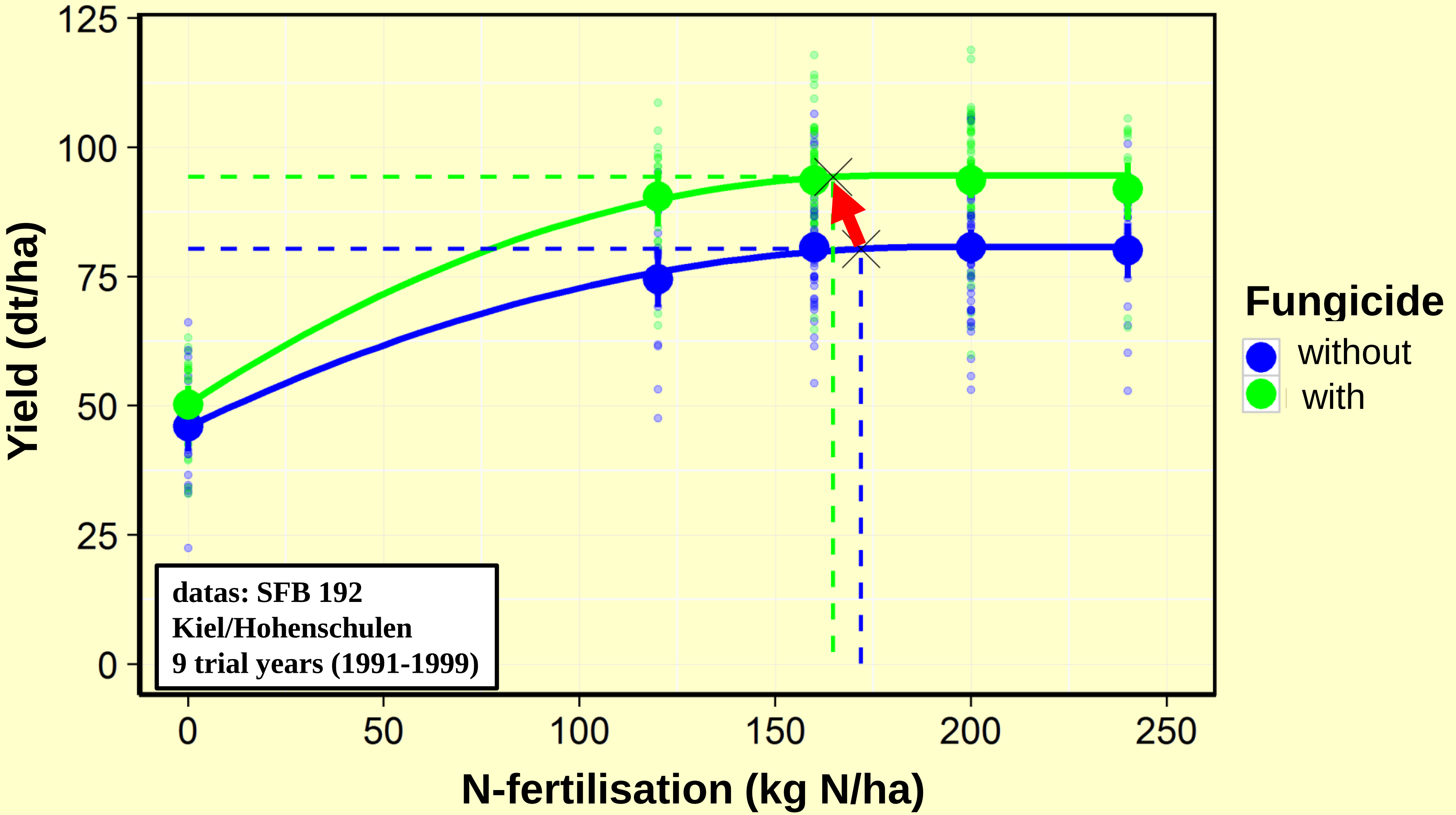
"no production resource is used less efficiently and most production resources are used more efficiently with increasing yield level"

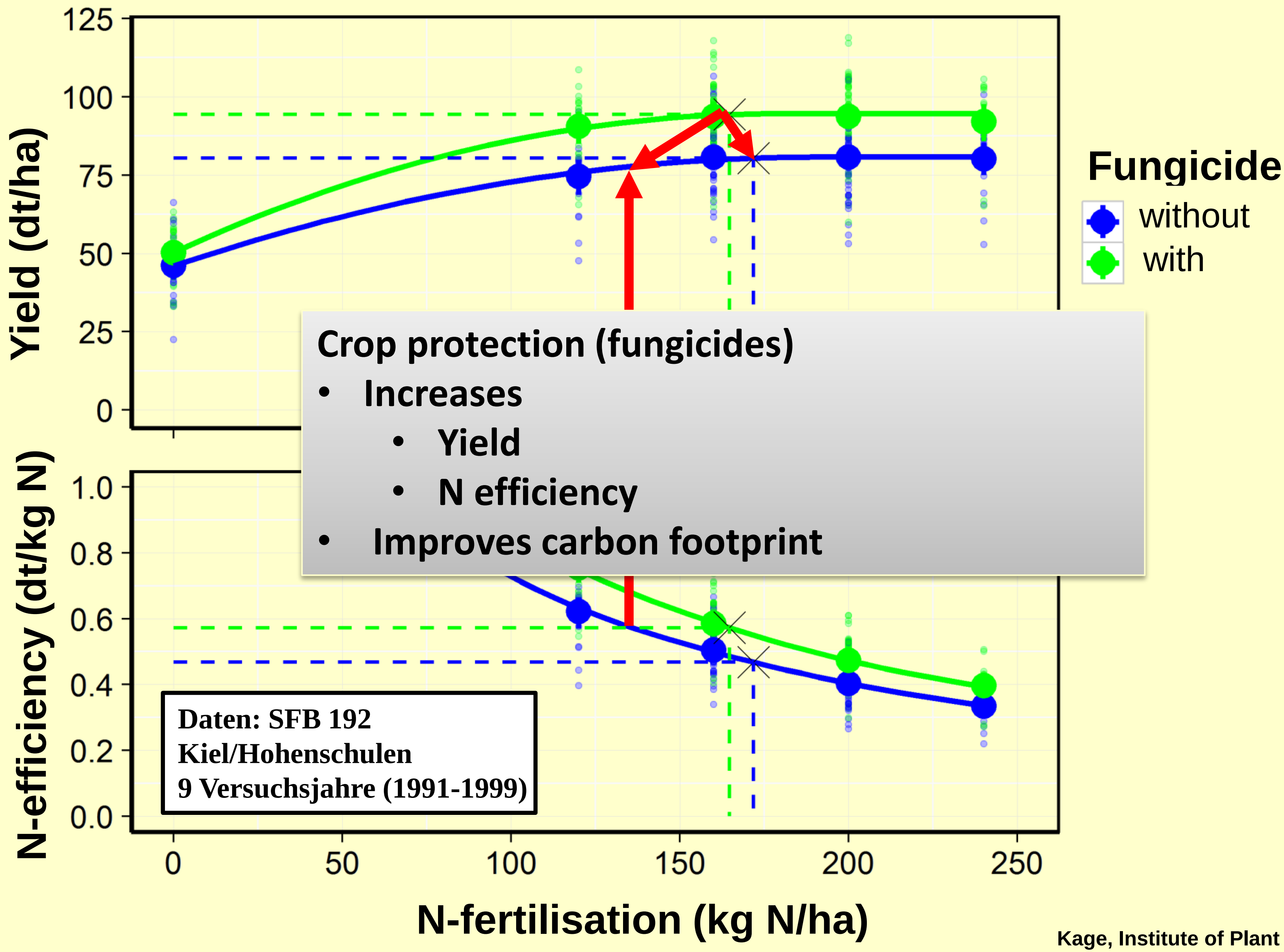
Average national wheat yields 1970-2010 (FAOSTAT)

Yield trends



Wheat yield
as affected by nitrogen fertilisation and fungicides

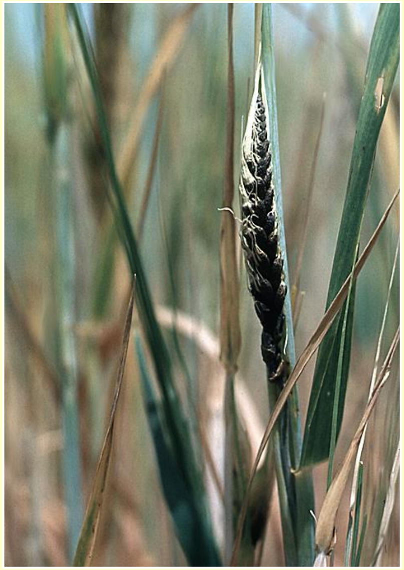




Crop protection (fungicides)

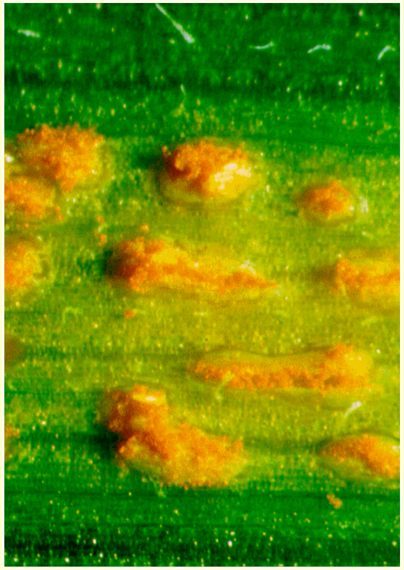
- **Increases**
  - **Yield**
  - **N efficiency**
- **Improves carbon footprint**

Tilletia spp.

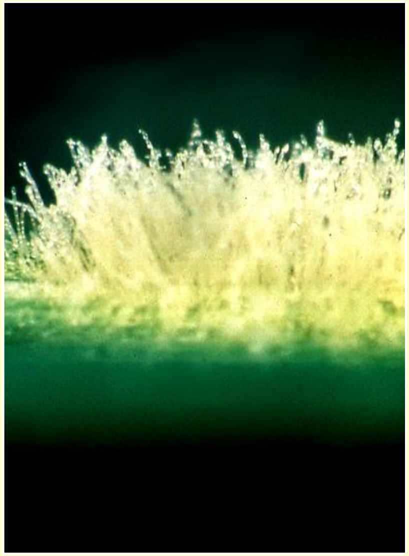


Ustilago spp.

Zymoseptoria spp.



Puccinia spp.



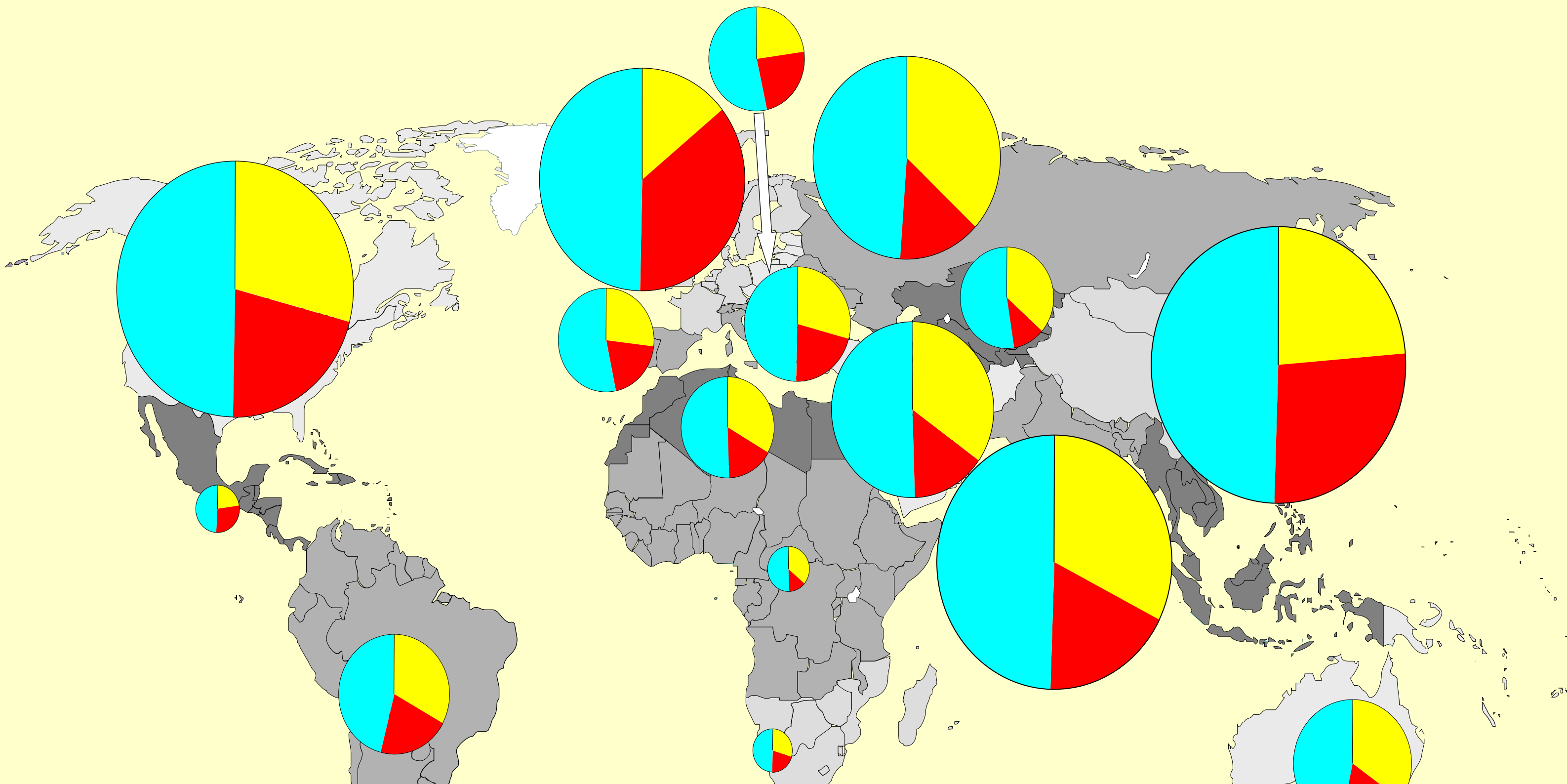
Blumeria graminis

Tapesia spp.

Gaeumannomyces graminis

Fusarium spp.

Estimation of the contribution of crop protection (CP) for safeguarding wheat production

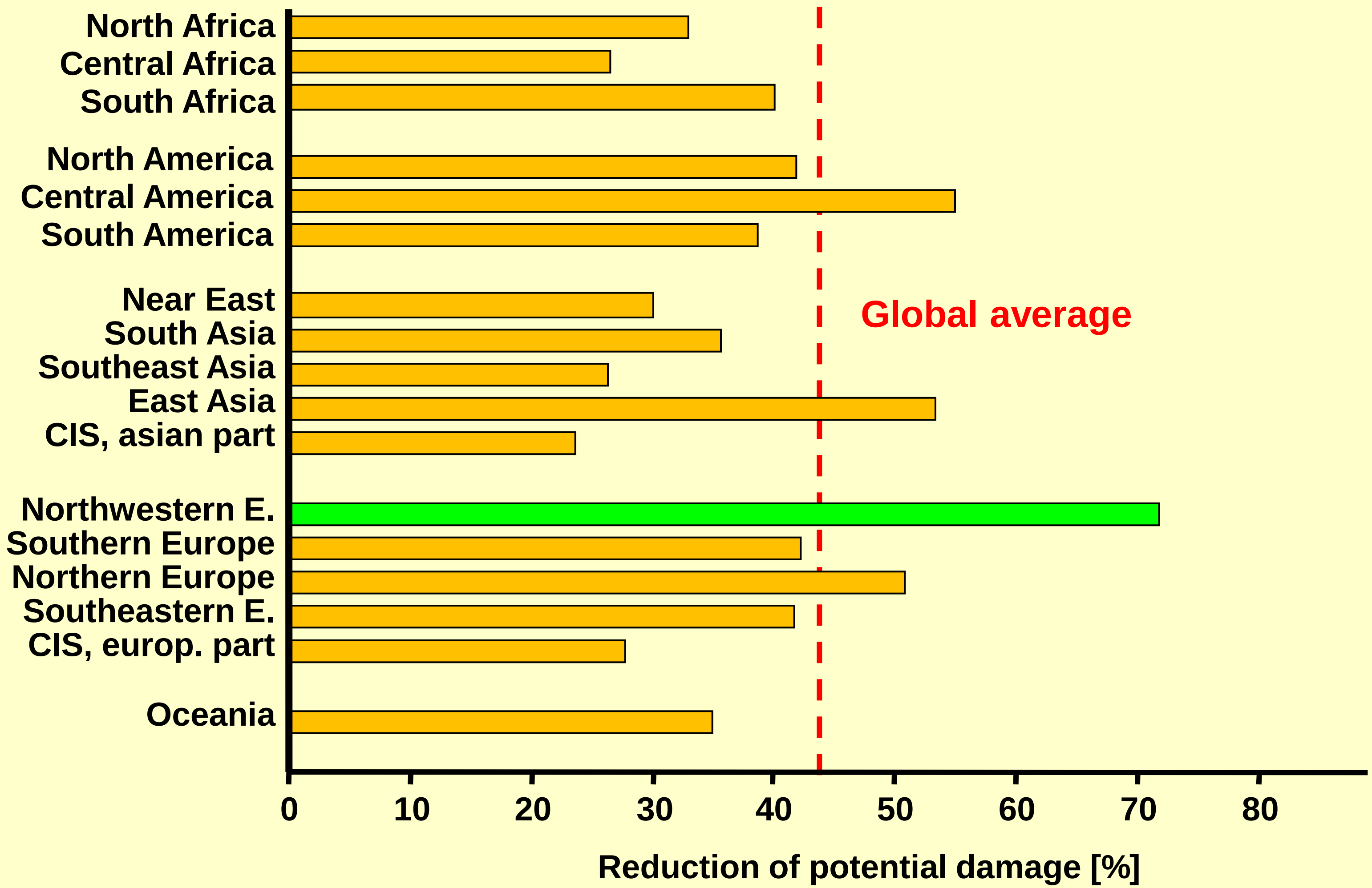


Crop production and crop protection

Source: Oerke & Dehne

Production without CP	Safeguarded by CP	Yield loss despite CP
weltweit: 413.3 mill. t (= 49.6%)	182.6 mill. t (= 21.3%)	237.7 mill. t (= 28.5%)

Estimation of crop protection efficiency in wheat production: Reduction of potential damage of pests and diseases at a regional scale



Without any crop protection, yield reductions of 20 – 40% will result

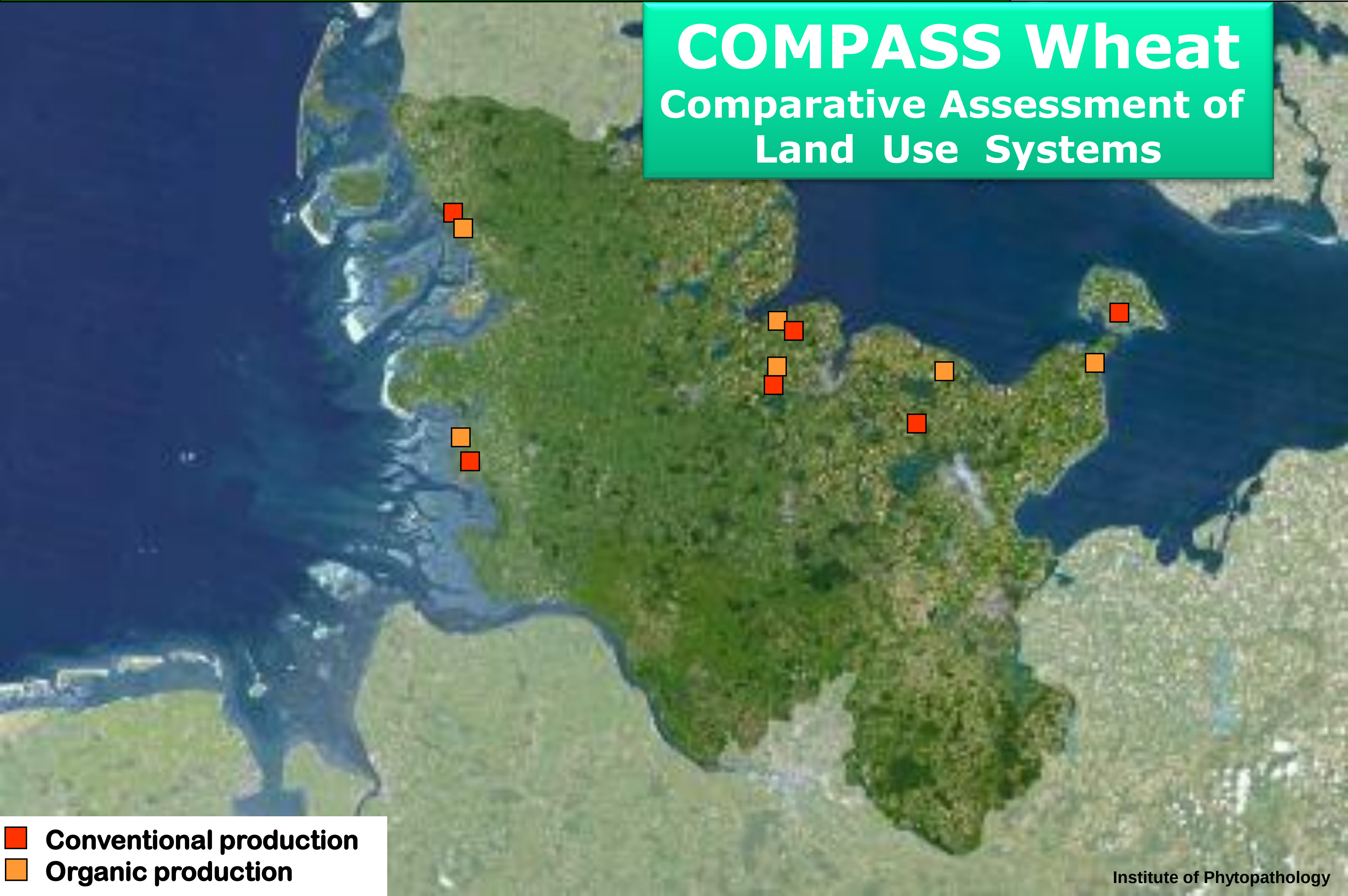
Estimated yield loss caused by weeds, pests and pathogens

Source	Weed	Pest	Diseases	total (%)
Cramer (1967)	**9,5**	**13,8**	**11,6**	**34,9**
Pimental (1978)	**8,0**	**13,0**	**12,0**	**33,0**
Oerke et al. (1994)	**13,2**	**15,6**	**13,2**	**42,1**
Yudelmann et al. (1998)	**12,0**	**13,0**	**12,0**	**37,0**
Oerke u. Dehne (2004)	**9,4**	**10,1**	**12,6**	**32,0**
Oerke (2006)	**-**	**-**	**-**	**21,6 – 53,2**
	10,4	**13,1**	**12,3**	**36,3**

C | A | U
Christian-Albrechts-Universität zu Kiel

COMPASS Wheat

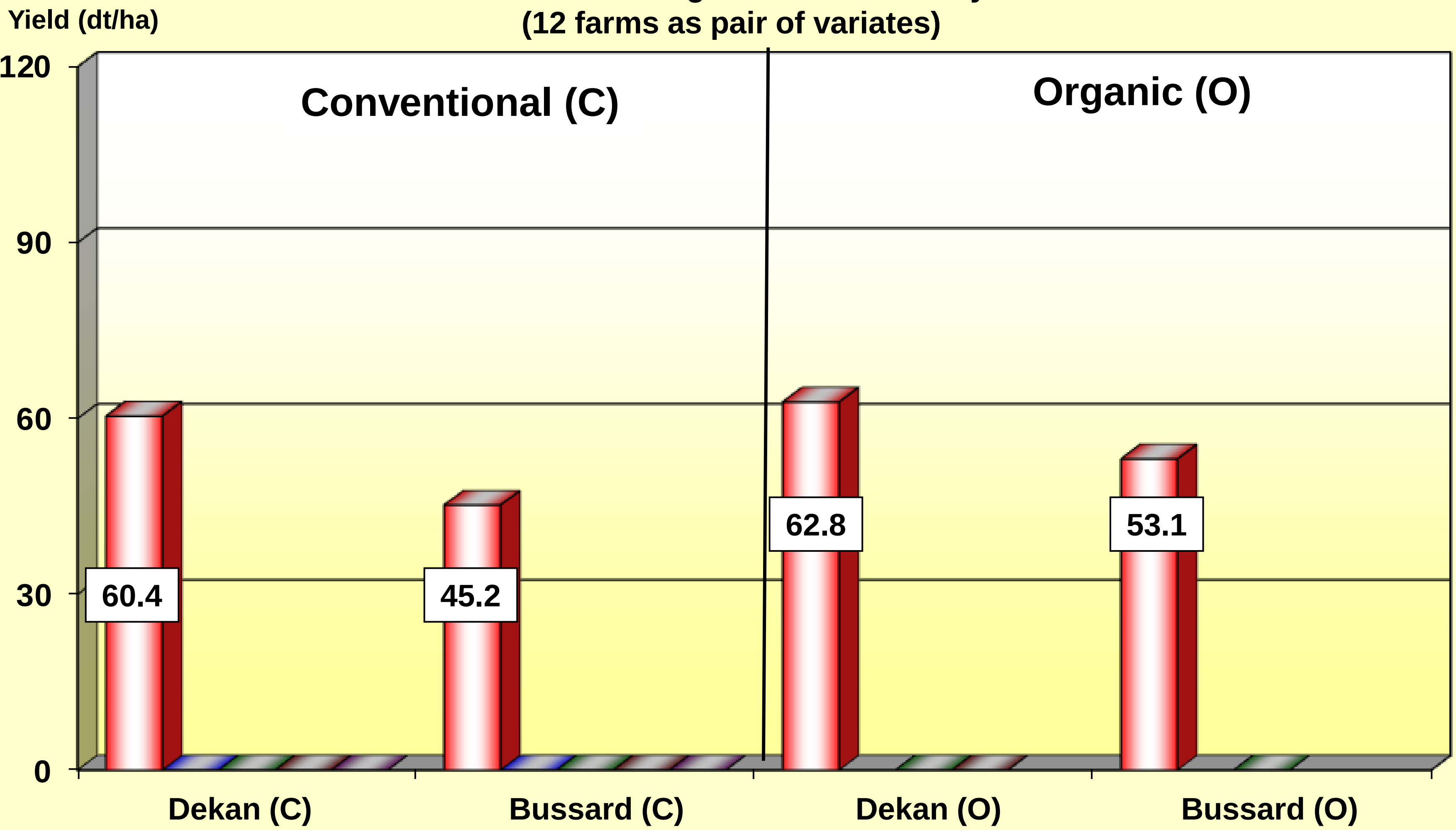
Comparative Assessment of Land Use Systems



Conventional production
Organic production

Comparison of conventional and organic production

Ø Yield - Schleswig-Holstein – over 3 years
(12 farms as pair of variates)



Variant 1: Without any herbicide, fungicide or fertiliser

Comparison of conventional and organic production

Ø Yield - Schleswig-Holstein – over 3 years
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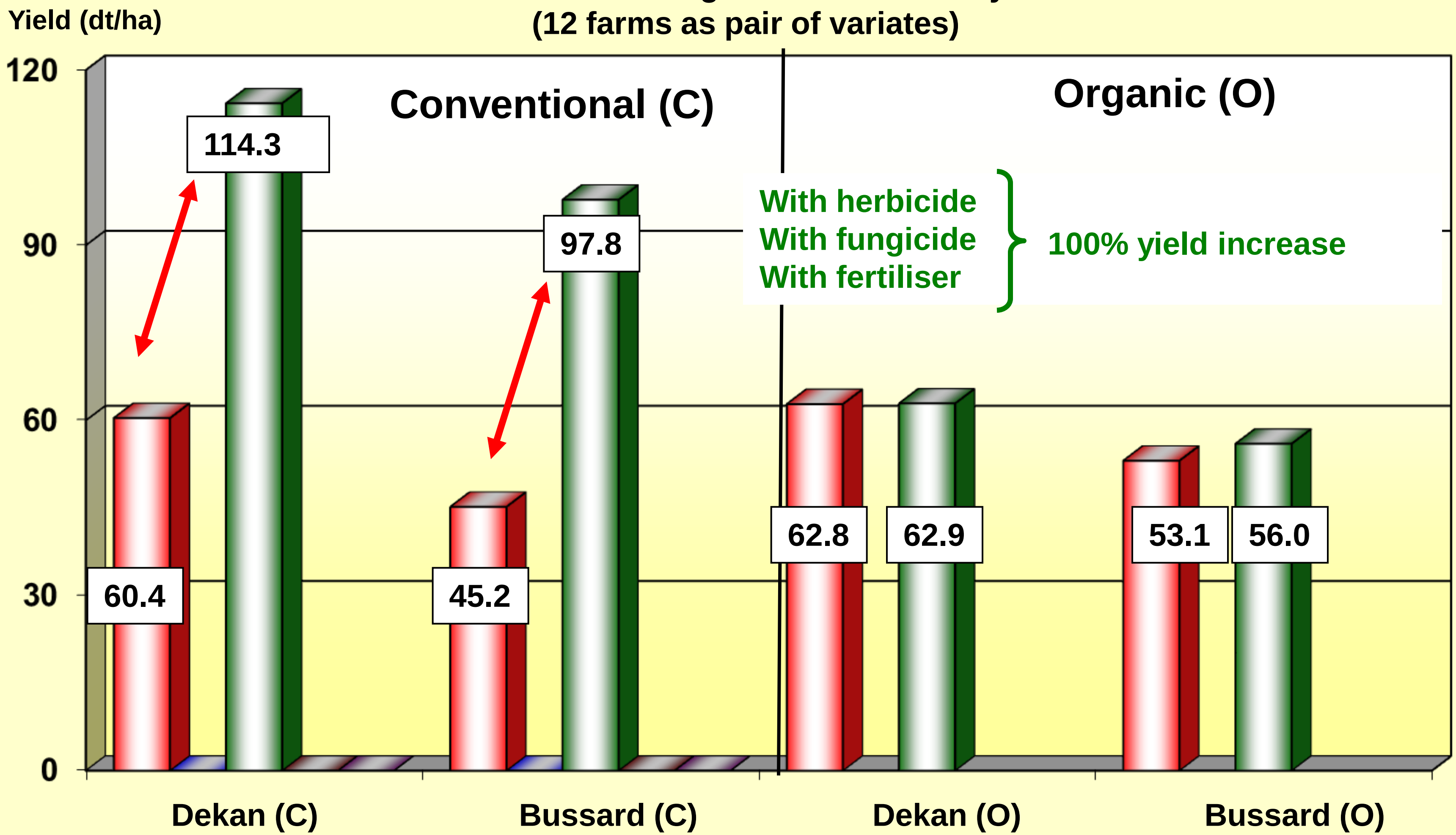
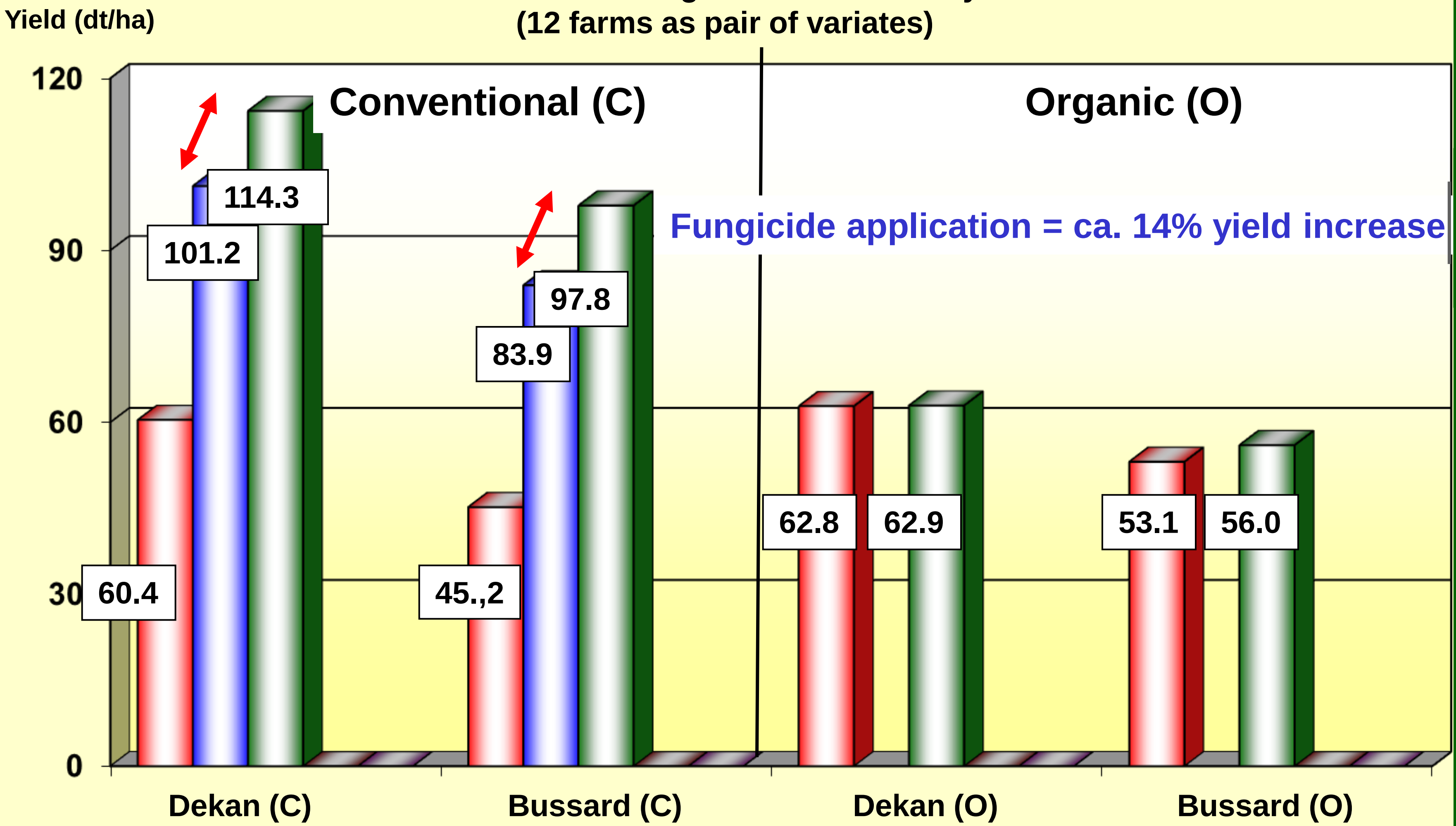


Variant 1: Without any herbicide, fungicide or fertiliser
Conventional: With herbicide and fungicide and fertiliser

Comparison of conventional and organic production

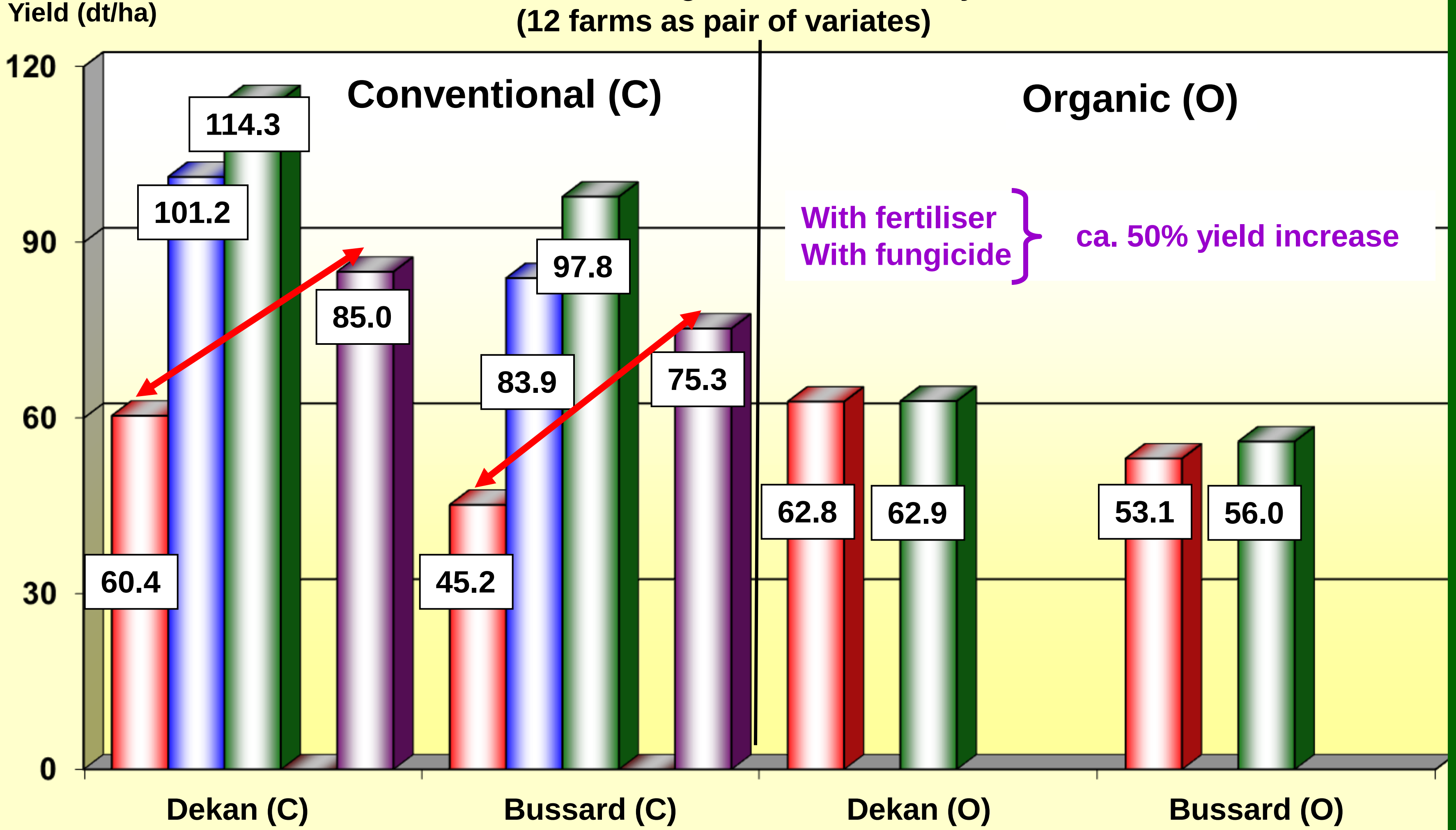
Ø Yield - Schleswig-Holstein – over 3 years
(12 farms as pair of variates)



Variant 1: Without any herbicide, fungicide or fertilizer
Variant 2: with herbicide, no fungicide, with fertilizer
Conventional: With herbicide and fungicide and fertilizer

Comparison of conventional and organic production

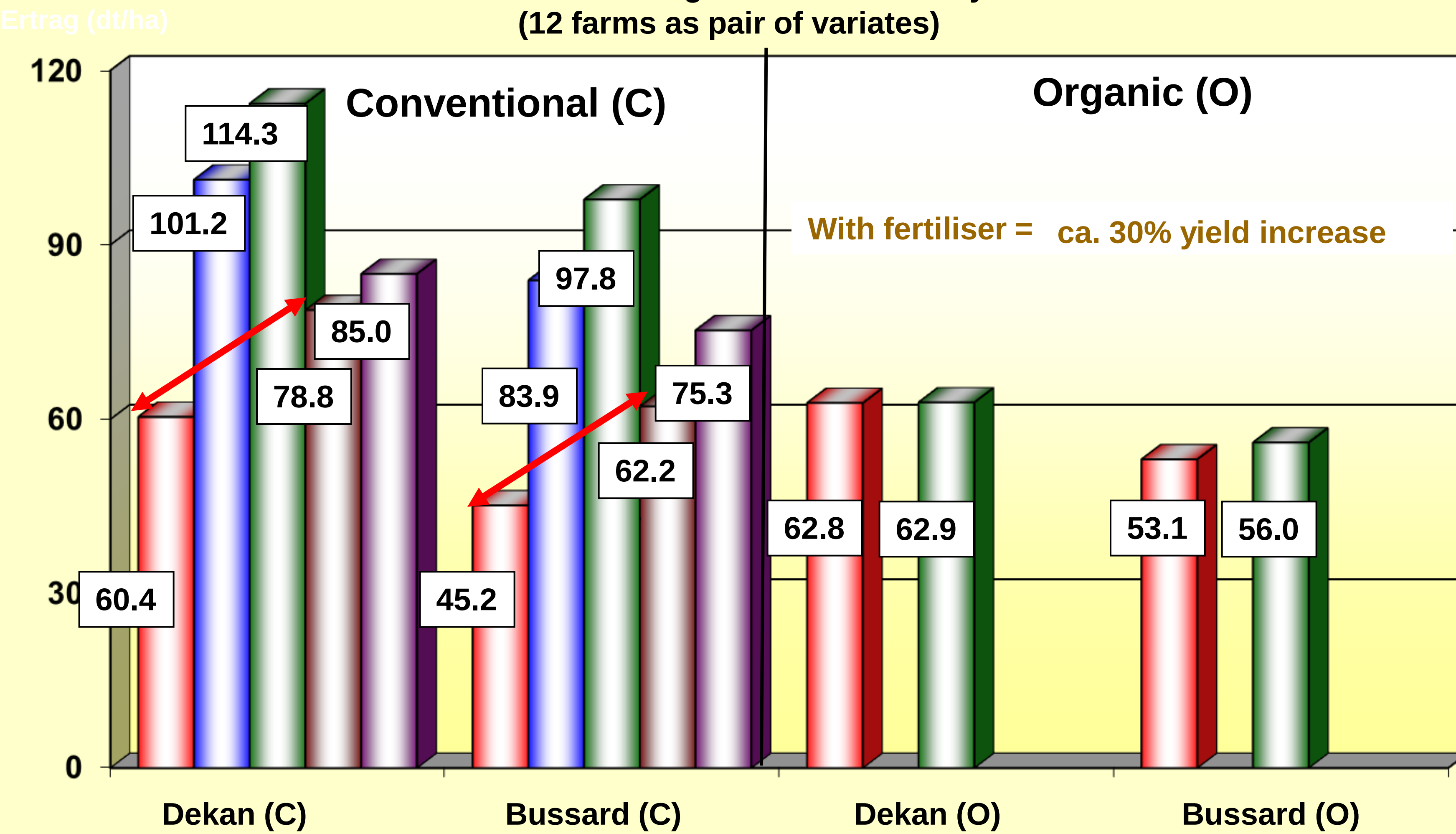
Ø Yield - Schleswig-Holstein – over 3 years
(12 farms as pair of variates)



Variant 1: without any herbicide, fungicide or fertiliser
Variant 2: with herbicide, no fungicide, with fertiliser
Conventional: with herbicide and fungicide and fertiliser
Variant 4: with fungicide and fertiliser

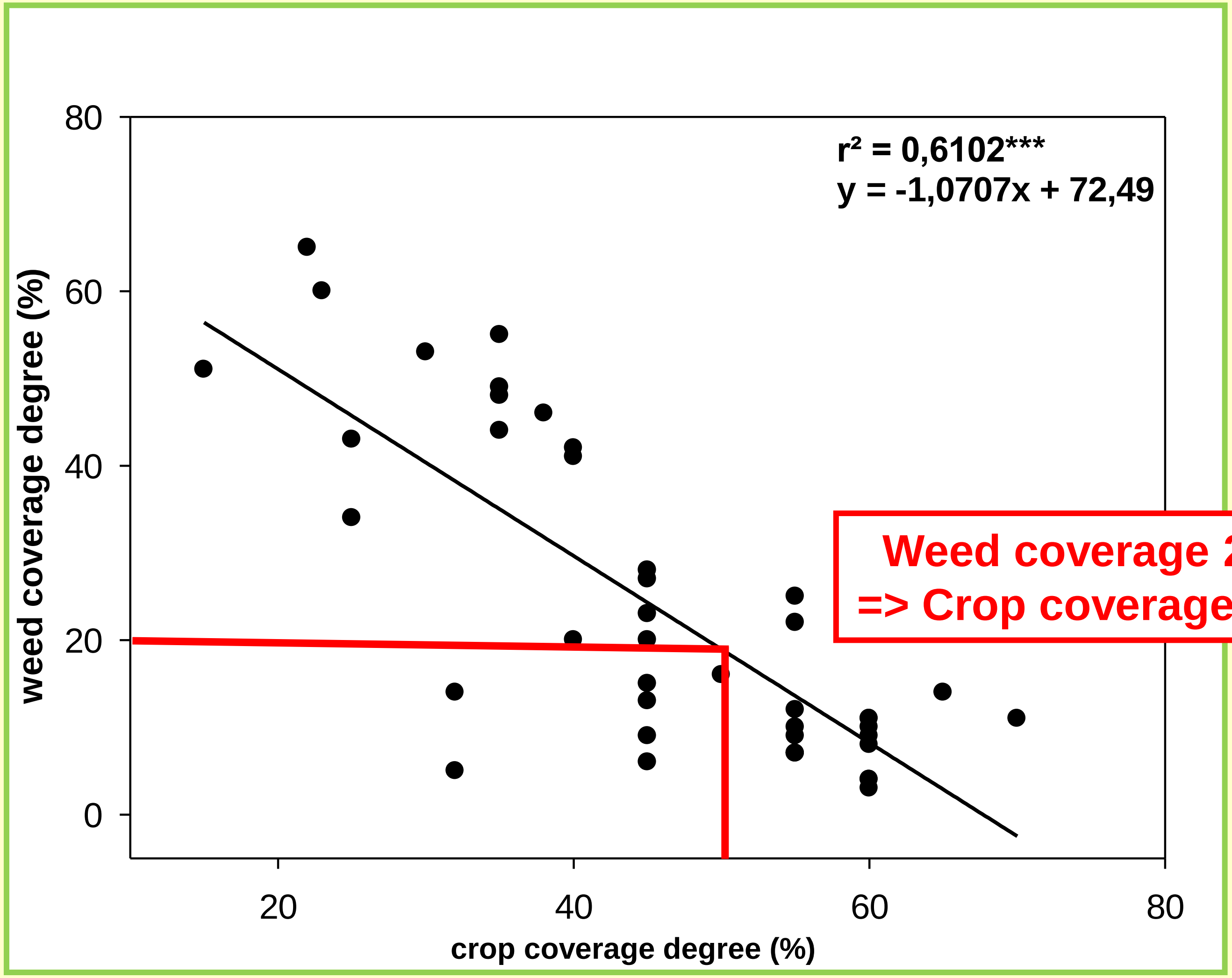
Comparison of conventional and organic production

Ø Yield - Schleswig-Holstein – over 3 years
(12 farms as pair of variates)

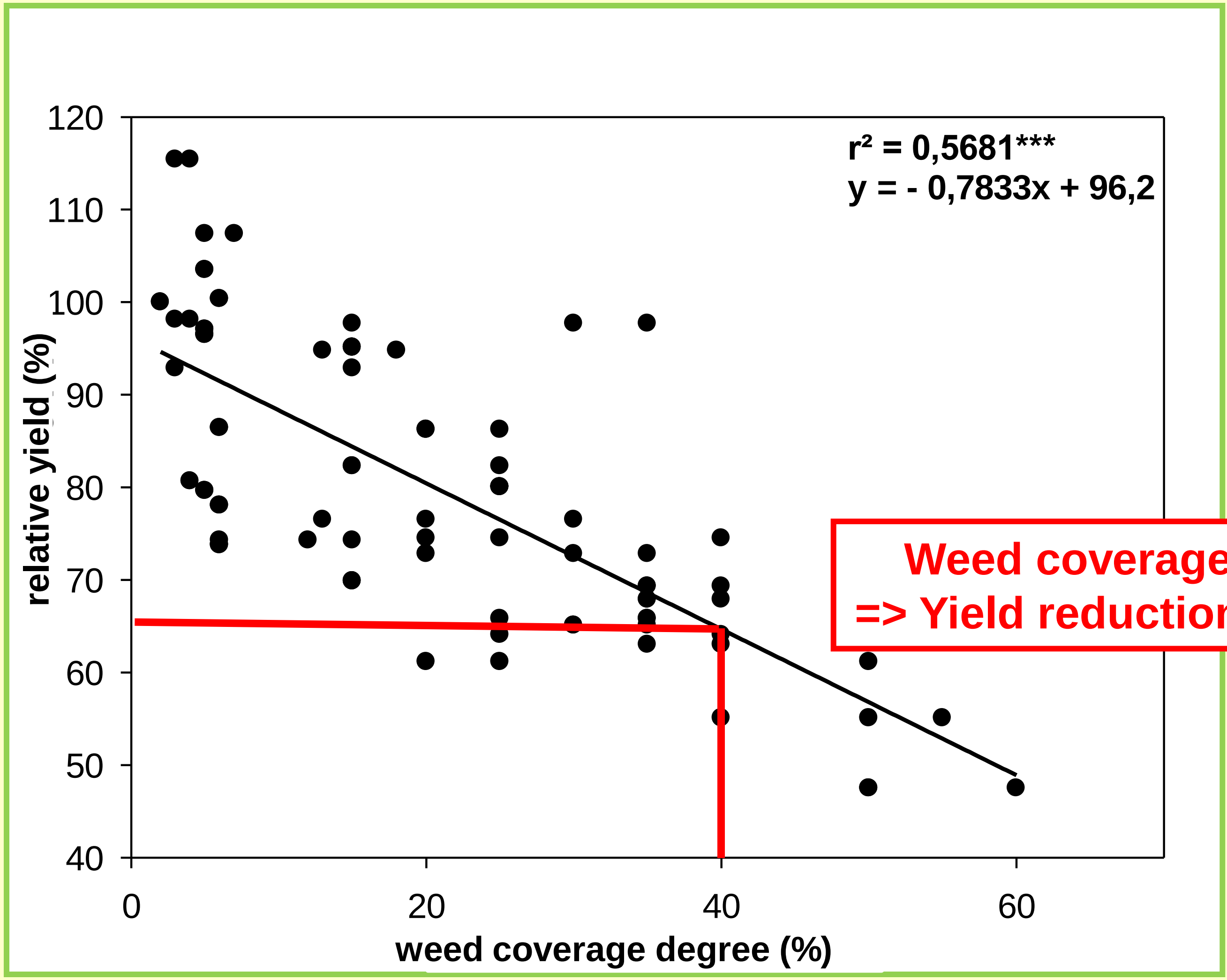


Variant 1: without any herbicide, fungicide or fertiliser
Variant 2: with herbicide, no fungicide, with fertiliser
Conventional: with herbicide and fungicide and fertiliser
Variant 3: only fertiliser
Variant 4: with fungicide and fertiliser

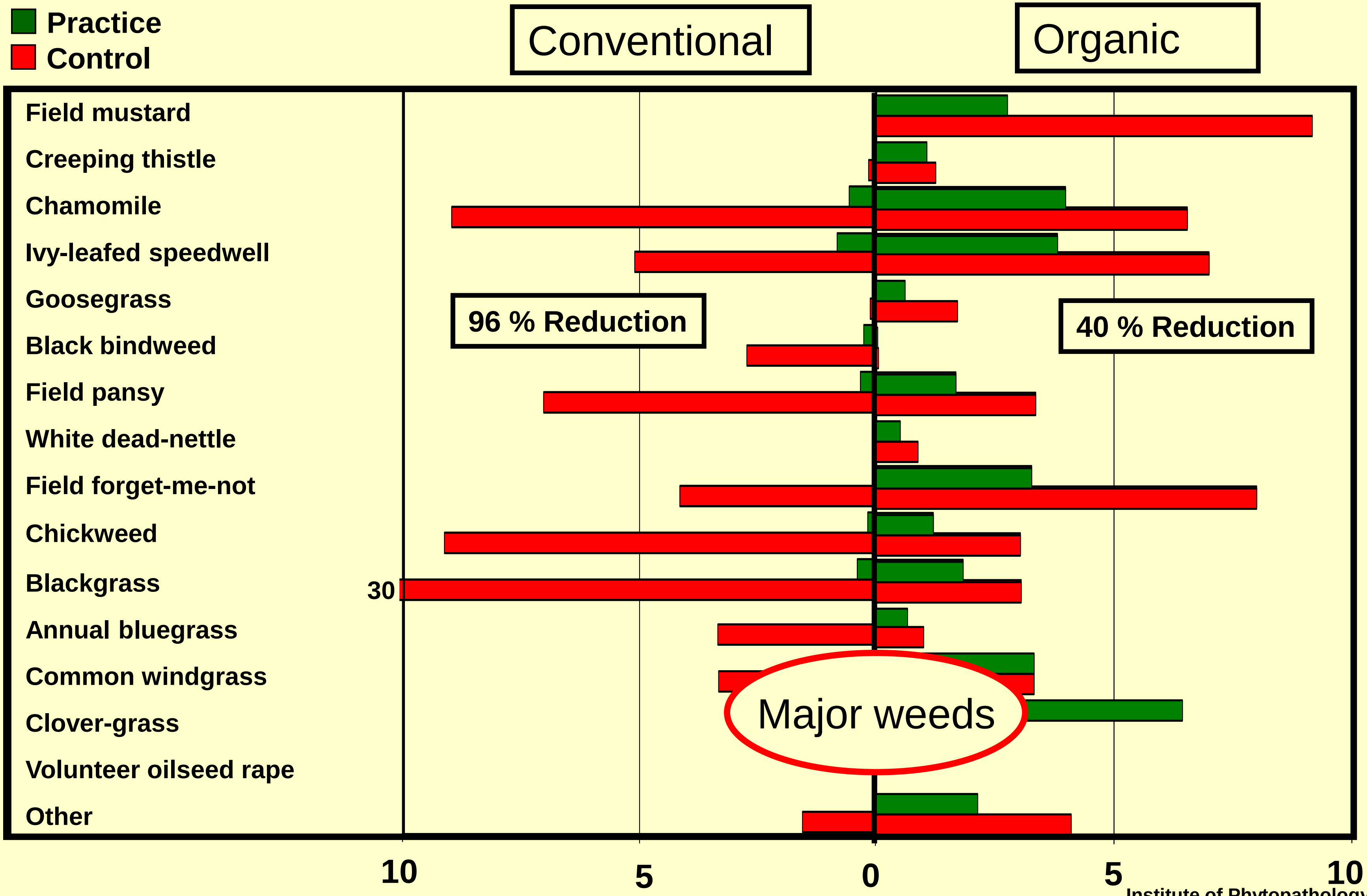
Relationship between weed coverage and wheat coverage (beginning of June, GS 39-51)



Relative wheat yield as affected by weed coverage (Ø yield: 79.56 dt/ha = 100 %)



Weed plants per m², spring

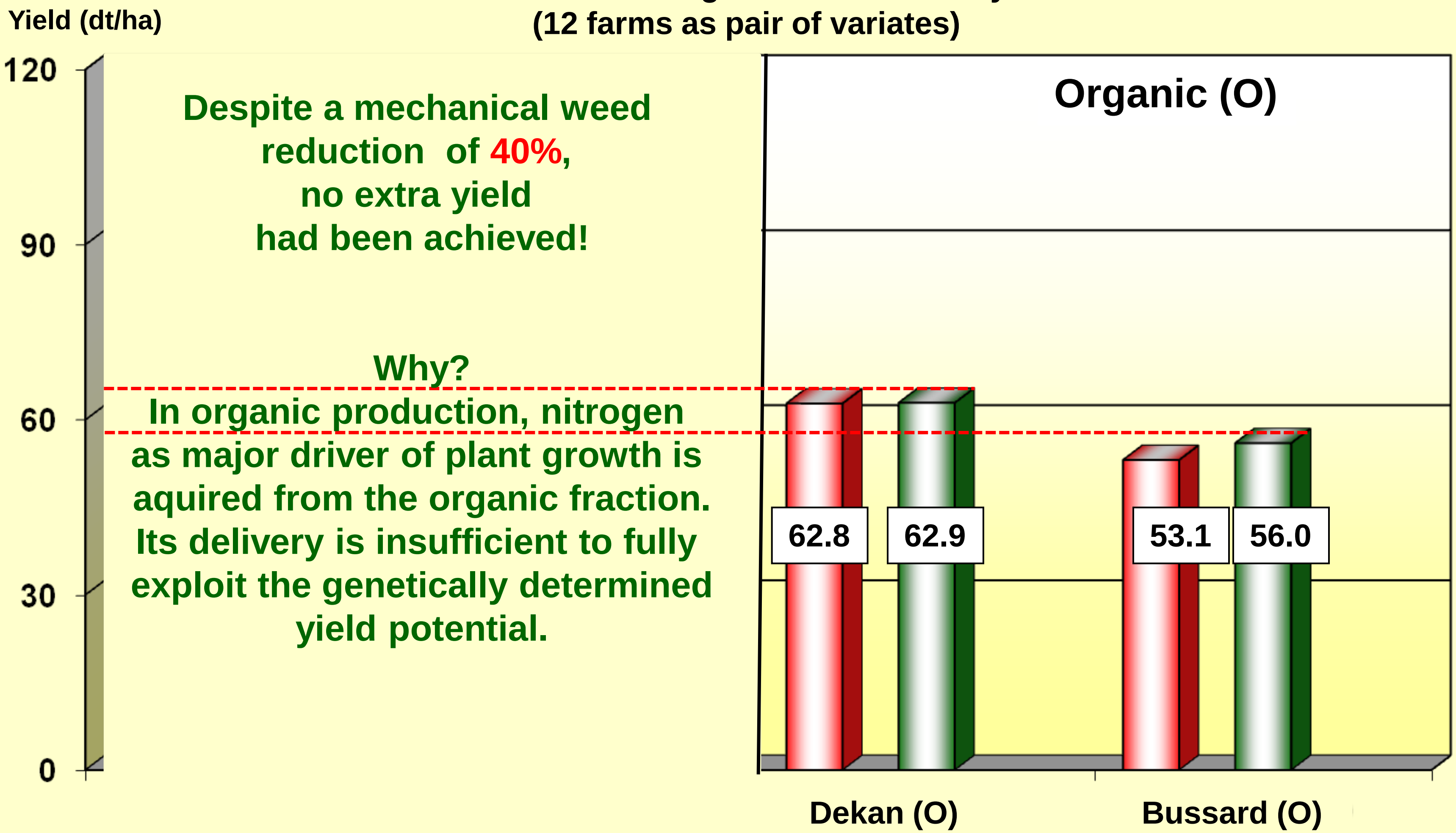


Comparison of conventional and organic production

Ø Yield - Schleswig-Holstein – over 3 years
(12 farms as pair of variates)

Despite a mechanical weed reduction of 40%, no extra yield had been achieved!

Why?
In organic production, nitrogen as major driver of plant growth is aquired from the organic fraction. Its delivery is insufficient to fully exploit the genetically determined yield potential.



Quality parameters (raw protein, sedimentation, wet gluten, falling number)

(Optimal: 13 - 14 % 20 - > 50 30 - 35 % 250-275 sec)

2004 **Practice variant**	**Conventional** Dekan	**Organic** Achat, Bussard, Capo, Ökostar
Raw protein (%)	**12,8**	**11,0**
Sedimentation (ccm)	**57,0**	**38,2**
Falling no. (sec)	**346**	**326**

2005	**Conventional**		**Organic**	
Practice variant	Dekan	Bussard	Dekan	Bussard
Raw protein (%)	**12,3**	**13,9**	**9,3**	**10,6**
Sedimentation (ccm)	**49,2**	**72,0**	**29,3**	**35,5**
Wet gluten (%)	**25,6**	**31,9**	**16,1**	**19,9**
Falling no. (sec)	**324**	**238**	**298**	**281**

Yield and yield differences in conventional and organic farming in different crops in Germany

Crop	Yield (dt/ha)		Yield difference	
	Organic	Conventional	dt/ha	%
Wheat	30.8	68.1	37.3	+ 121
Rye	25.4	50.9	25.6	+ 100
Barley	30.3	57.8	27.5	+ 90
Oilseed rape	23.6	36.8	13.2	+ 56
Potato	200.4	363.2	162.8	+ 81
Sugarbeet	519.4	627.1	107.7	+ 21

Quelle: von Witzke und Noleppa, 2011

Modern pesticides cause higher and more stable yields. This effect has been substantiated in several scientific studies.

Pesticide tax proposal for Germany, 2015

„We recommend - as in Denmark, France and Sweden - also in Germany a tax on plant protection products (hereinafter “pesticides") within the meaning of article 2 paragraph 1 of the EU Pesticide Regulation 1107/2009 concerning the placing on the market of pesticides in order to participate manufacturers, traders and users in financing the costs of environmental and health consequences of pesticide use as well as to finance research on alternative plant protection concepts and to offer an economic incentive to reduce the hitherto increasing pesticide use. Similar to Danish taxation, pesticides with high environmental or health-harmful risks should also be subject to above-average taxation in order to encourage the use of pesticides with lower risks (internal substitution). Such an effect- and risk-based pesticide tax / charge is both constitutional and under European law legitimate, whereby a federal excise tax seems to us to be legally preferable.”

Report of the Helmholtz Institut Leipzig,

Mandate: Minister of the Environment of Schleswig-Holstein,
Dr. Robert Habeck

Objection: The report has been prepared by three toxicologists, a jurist and a social worker;
agronomists and biologists were not involved;
The tax will probably be used for subsidisation of organic farming!

Economic assessment of pesticide taxes

Extra costs for crop production

Westfalen	WW - Kosten €/ha				WG - Kosten €/ha				WR - Kosten €/ha				Mais - Kosten €/ha			
	alt	Abgabe	neu		alt	Abgabe	neu		alt	Abgabe	neu		alt	Abgabe	neu	
Beizmittel	17	27	43	+161%	19	31	50	+158%	1)	40	40		23	22	46	+95%
	0,32 EfA				*0,45 Rubin TT*				*0,05 DMM, 0,033 Thiram 80 FB*				*0,3 Mesurol*			
Fungizide	132	41	173	+31%	97	32	129	+33%	106	65	171	+62%				
	1 Aviator Xpro, 0,5 Orius, 1,25 Osiris, 0,75 Skyway Xpro, 0,15 Talius				*0,65 Aviator Xpro, 1,25 Credo, 0,8 Input Classic*				*1 Carax, 1 Symetra, 1 Tilmor*							
Herbizide	63	40	103	+64%	76	57	133	+74%	92	51	143	+56%	99	151	250	+153%
	0,22 Broadway, 1 U 46 M-Fluid				*0,75 Bacara Forte, 0,3 Cadou SC*				*2,5 Butisan Kombi, 0,5 Fox, 0,2 Runway*				*0,15 Arrat, 1,25 Aspect, 1 Elumis, 3 Gardo Gold*			
Insektizide	10	29	39	+302%					25	80	105	+321%				
	0,2 Bulldock, 0,125 Pirimor								*0,6 Bulldock, 0,075 Decis forte, 0,2 Trebon*							
Wachstumsregler	19	30	49	+157%	39	38	78	+97%								
	1,4 CCC 720, 0,25 Moddus				*0,4 Camposan-Extra, 0,5 Moddus*											
Summe	**240**	**168**	**409**	**+70%**	**242**	**187**	**429**	**+77%**	**241**	**237**	**477**	**+98%**	**122**	**173**	**296**	**+142%**

Winter wheat + 70% **Winter barley + 77%** **Oilseed rape + 98%** **Maize + 142%**

Source: Back, H., Bahrs, E.; Institut für landwirtschaftliche Betriebslehre, University of Hohenheim; Top Agrar, 9/2016

Economic assessment of pesticide taxes

Extra costs for crop production

Niedersachsen	WW - Kosten €/ha				WG - Kosten €/ha				ZR - Kosten €/ha			
	alt	Abgabe	neu		alt	Abgabe	neu		alt	Abgabe	neu	
Beizmittel	34	44	78	+128%	19	31	50	+158%	64	40	104	+63%
	0,32 EfA, 0,12 Contur plus				*0,45 Rubin TT*				*Cruiser Force* [1)]			
Fungizide	91	54	145	+59%	68	35	104	+52%	41	24	64	+58%
	1 Adexar, 1 Ampera, 0,6 Cirkon, 0,5 Gladio,				*0,8 Adexar, 0,6 Cirkon, 1 Credo*				*1 Spyrale*			
Herbizide	97	64	161	+66%	76	57	133	+74%	313	103	415	+33%
	0,4 Atlantis WG, 0,03 Pointer SX, 1 Starane XL, 1 U 46 M-Fluid				*0,75 Bacara Forte, 0,3 Cadou SC*				*3,6 Betanal MAXXPRO, 0,075 Debut, 3 Glyphosat, 3,9 Goltix Titan, 0,9 Targa*			
Insektizide	8	16	24	+209%	8	16	24	+209%				
	0,075 Karate Zeon				*0,075 Karate Zeon*							
Wachstumsregler	23	36	59	+158%	42	43	86	+102%				
	1,7 CCC 720, 0,3 Moddus				*0,7 Camposan-Extra, 0,4 Moddus*							
Summe	**253**	**214**	**467**	**+85%**	**214**	**182**	**396**	**+85%**	**417**	**166**	**583**	**+40%**

Winter wheat + 85% **Winter barley + 85%** **Sugarbeet + 40%**

Source: Back, H., Bahrs, E.; Institut für landwirtschaftliche Betriebslehre, University of Hohenheim; Top Agrar, 9/2016

Economic assessment of pesticide taxes

Tax-specific extra costs for different crop rotations:

Schleswig-Holstein = WW-WB-WR: extra costs 815 €/ha

Lower Saxony = WW-WB-WR: extra costs 592 €/ha

Lower Saxony = WW-WB-M: extra costs 528 €/ha

North Rhine-Westphalia = WW-WW-WR: extra costs 590 €/ha

North Rhine-Westphalia = WW-WW-M: extra costs 526 €/ha

Source: Back, H., Bahrs, E.; Institut landwirtschaftliche Betriebslehre, Universität Hohenheim; Top Agrar, 9/2016

(WW = winter wheat; WB = winter barley; WR = winter oilseed rape; M = maize)

“How to overcome yield limitations caused by pest and diseases”

``Plant protection can not increase yields, but lead to a reduction in losses in the form of a yield increase``

- Exploitation of innovations of plant protection -

- Directed application of pesticides -

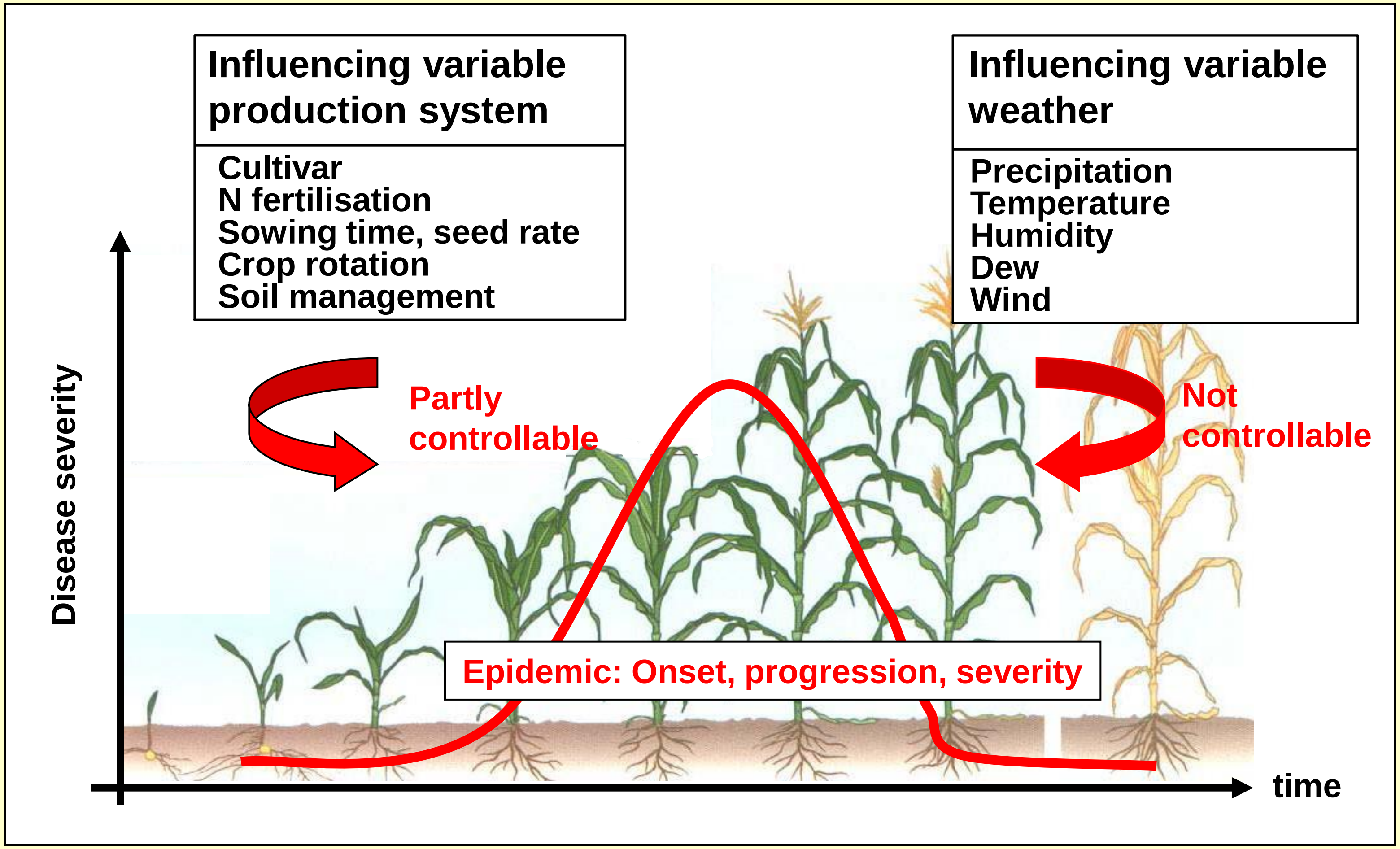
- Integrated Pest Management -

- Control thresholds and infection prognosis in order to optimise and minimise plant protection measures -

!!! Key – continuous training !!!

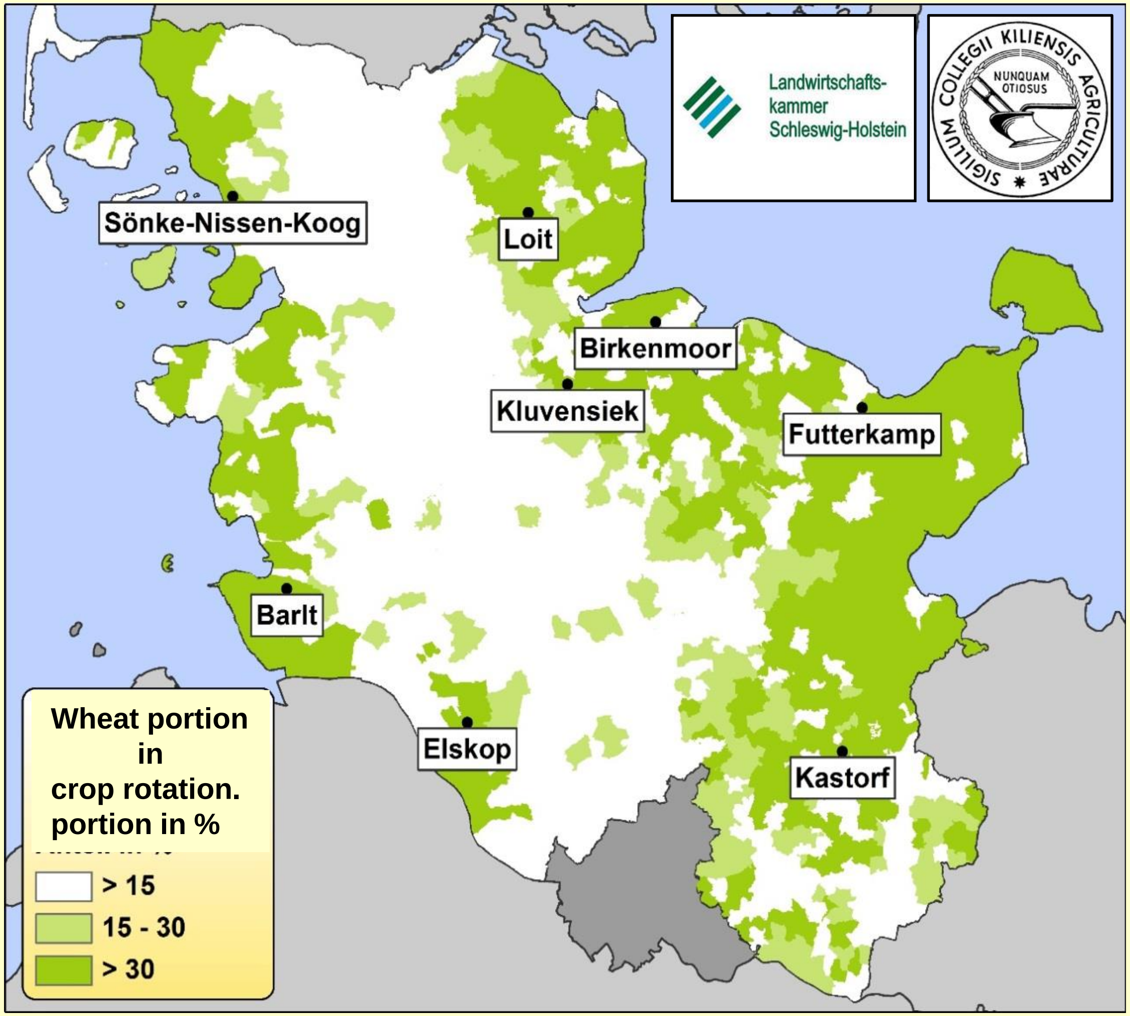
- Transfer of knowledge to farmers and advisers -

Which effect do production system factors have on mycotoxins in cereals?



Symptoms of *Fusarium* Head Blight (FHB) in wheat
Control of mycotoxins

Fusarium-monitoring – winter wheat - Schleswig-Holstein 2008 - 2016

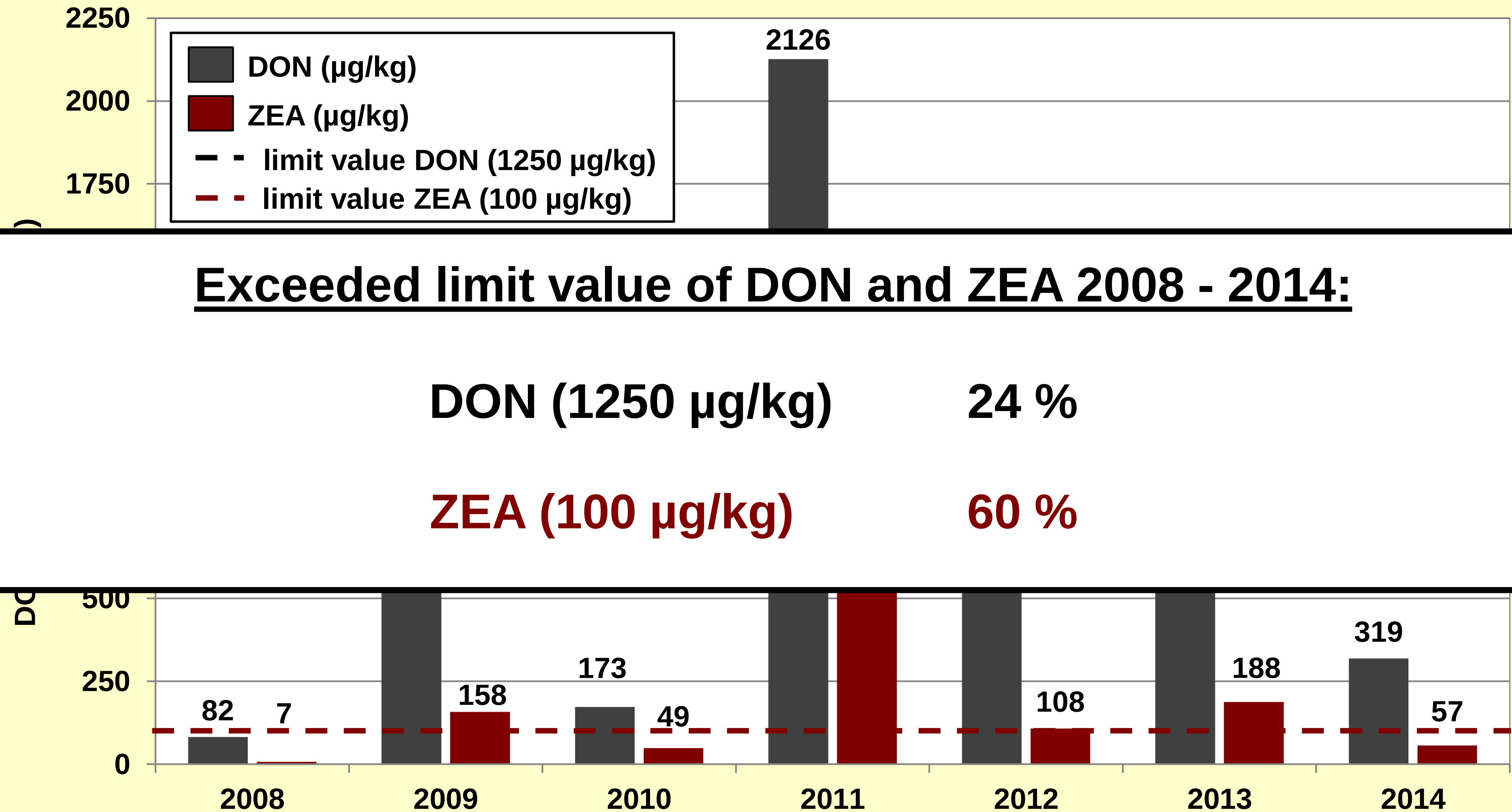


Source: Statistikamt Nord, 2014

crops	grain
years	2008 - 2016
location	8 - 10
cultivars	Ritmo, Dekan, Inspiration
susceptibility (*Fusarium* spp.)	7, 4, 6
previous crops	oilseed rape, wheat
tillage	plough after wheat; minimized tillage after oilseed rape
treatments	untreated control, & fungicide treatment (with 4 repetitions)
weather	online weather station inside the crop
analytics	✓ qual. & quant. proof of *Fusarium* spp. (qPCR) ✓ mycotoxin analytics (LC/MS) DON, ZEA, D3G, NIV

DON and ZEA contents (µg/kg)

- wheat Schleswig-Holstein 2008 – 2014; cultivar Ritmo; untreated control –



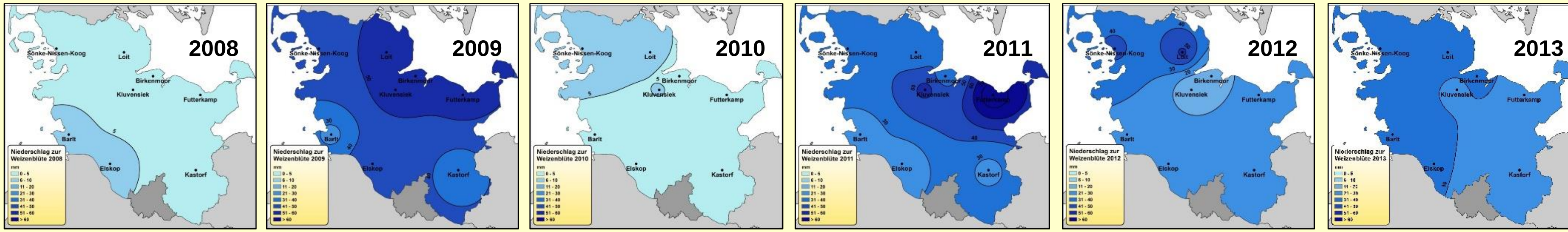
Exceeded limit value of DON and ZEA 2008 - 2014:

DON (1250 µg/kg)	**24 %**
ZEA (100 µg/kg)	**60 %**

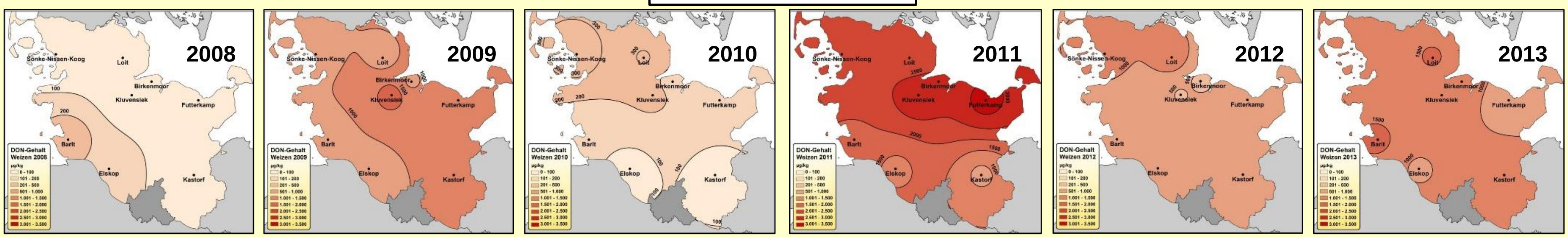
exceeded limit value (%)	2008	2009	2010	2011	2012	2013	2014
DON	0	25	0	86	13	43	0
ZEA	0	100	13	100	50	71	14

Relationship between the precipitation (mm) and the DON and ZEA content (µg / kg) in wheat grain (Ritmo) Schleswig-Holstein 2008-2013

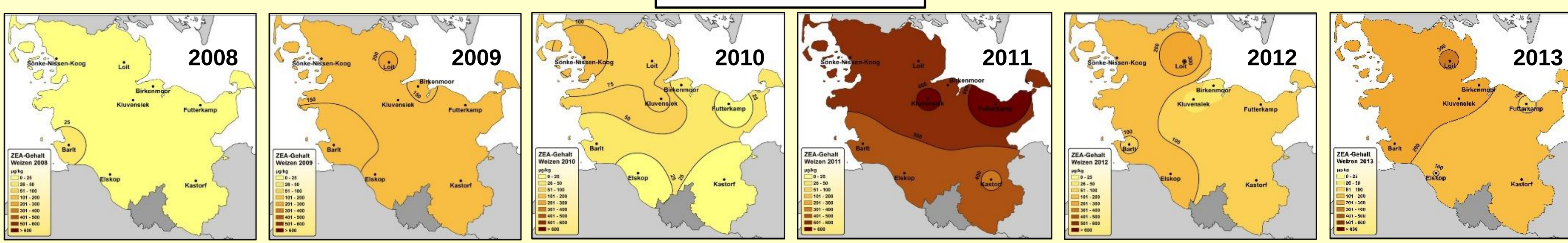
Precipitation at wheat flowering



DON-content

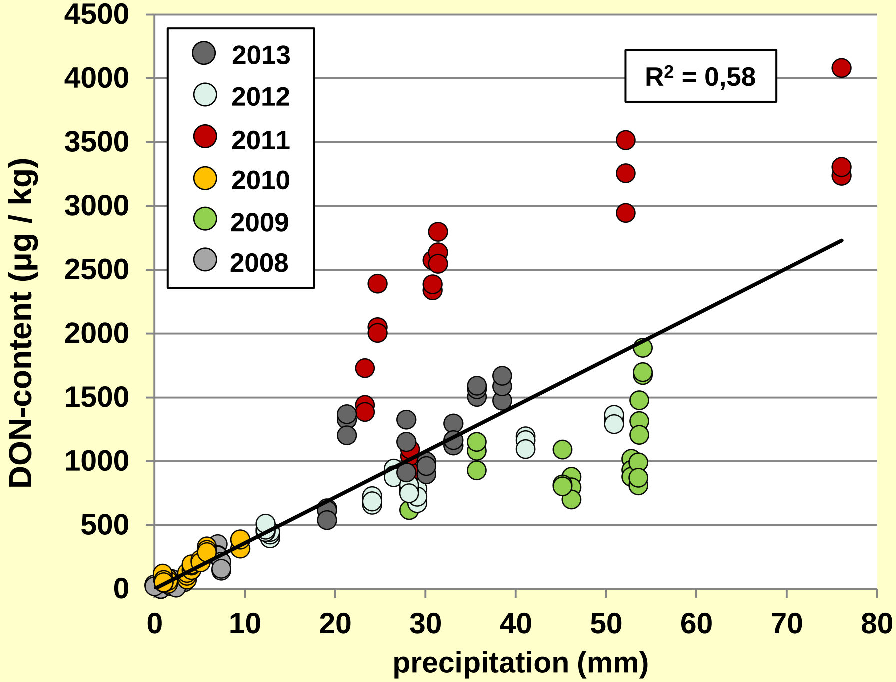


ZEA-content

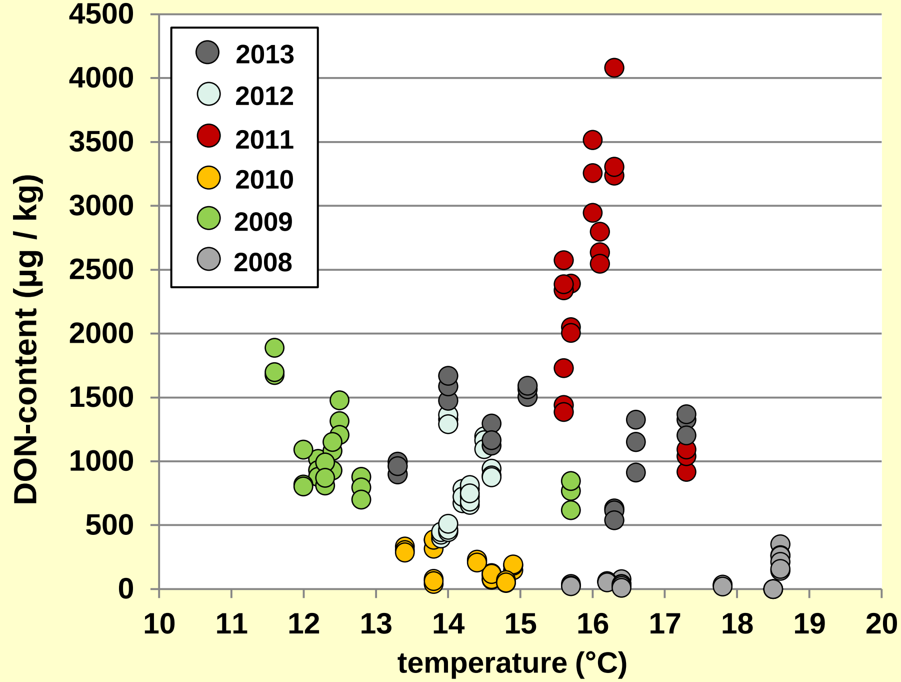


Relationship between precipitation (mm) and temperature (° C) at wheat flowering and the DON content (µg / kg) in grain

- wheat Schleswig-Holstein 2008 – 2013; cultivar Ritmo; untreated control –



precipitation sum at flowering

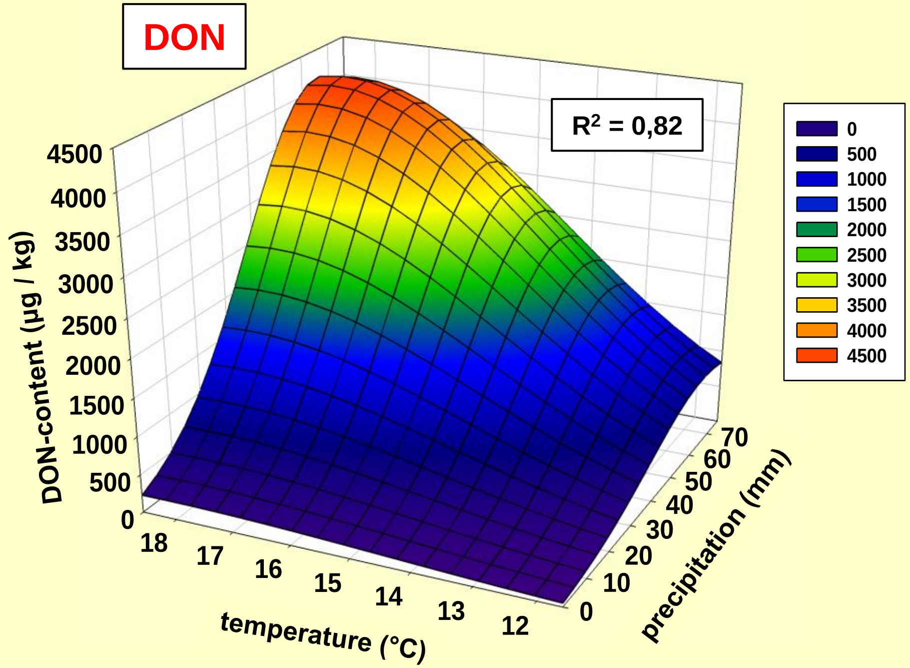


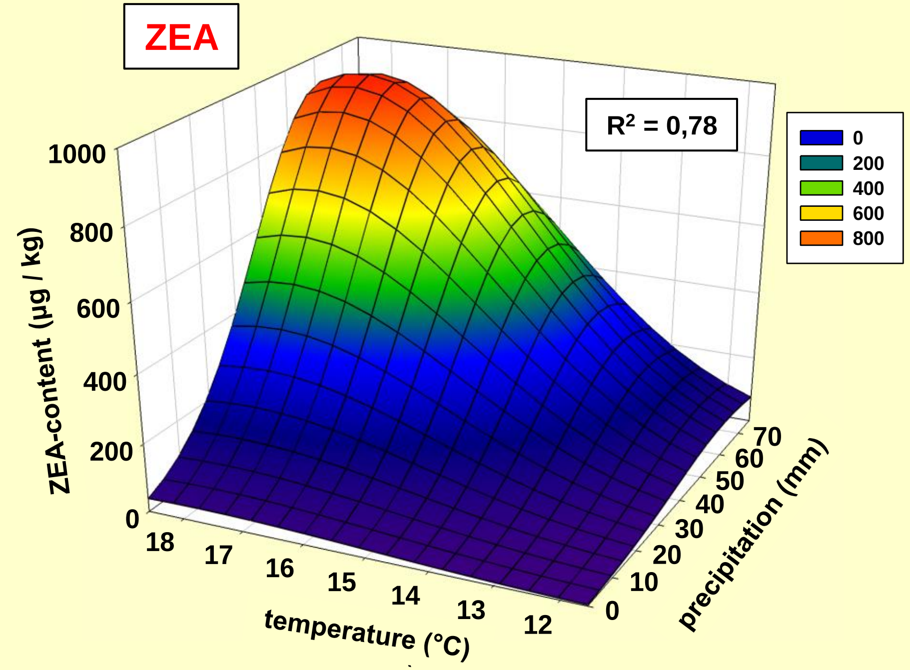
average temperature at flowering (mean of daily means)

→ the DON load is not influenced solely by the amount of precipitation at wheat flowering → temperature

Relationship between precipitation (mm) and temperature (° C) at wheat flowering and the DON and ZEA content (µg / kg) in grain

- wheat Schleswig-Holstein 2008 – 2013; cultivar Ritmo; untreated control –





DON_{prog} = 681-28,94*PT-29,37*Temp+3,93*PT*Temp

PT= precipitation (mm); Temp = temperature (°C)

ZEA_{prog} = 54,62-0,93*PT-2,03*Temp+0,44*PT*Temp

PT= precipitation (mm); Temp = temperature (°C)

Precipitation sum & average temperature at flowering (means of daily means)

significant correlation between precipitation and temperature at the wheat flowering period and the DON and ZEA loads analyzed in the grain samples

Prognosis of DON and ZEA content (µg / kg) in wheat grains

Prognosis formulas

Ritmo – high susceptible:

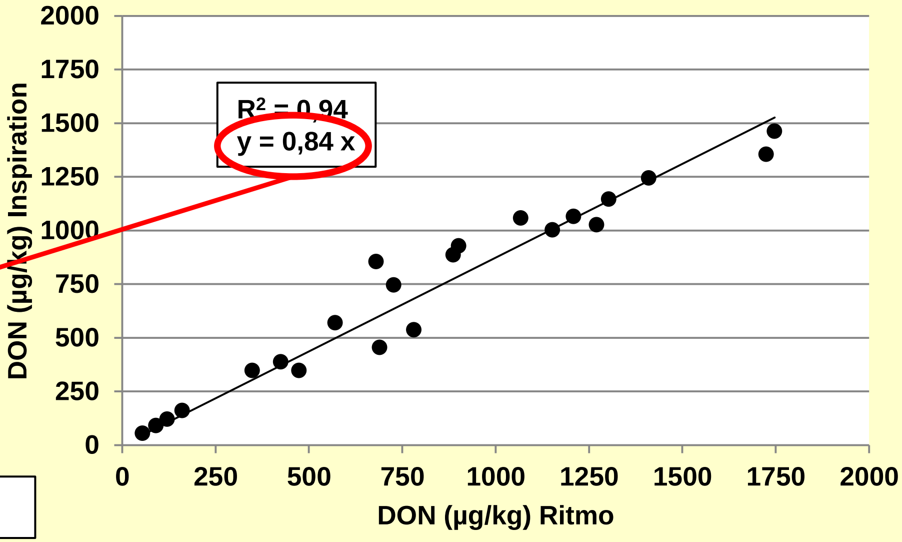
DON_{prog} = 681-28,94*PT-29,37*Temp+3,93*PT*Temp

ZEA_{prog} = 54,62-0,93*NS-2,03*Temp+0,44*NS*Temp

Inspiration – moderate susceptibility:

DON_{prog} = 0,84 * 681-28,94*PT-29,37*Temp+3,93*PT*Temp

ZEA_{prog} = 0,74 * 54,62-0,93*PT-2,03*Temp+0,44*PT*Temp



Dekan – low susceptibility:

DON_{prog} = 0,49 * 681-28,94*PT-29,37*Temp+3,93*PT*Temp

ZEA_{prog} = 0,45 * 54,62-0,93*PT-2,03*Temp+0,44*PT*Temp

PT= precipitation (mm); Temp = temperature (°C)
Precipitation sum & average temperature at flowering (means of daily means)

Prognosis of the mycotoxin load of wheat grains- Schleswig-Holstein

IPS WEIZEN

Home

Geben Sie die *Fusarium*-Anfälligkeit der angebauten Sorte (repräsentiert durch die hochanfällige Sorte Ritmo, die mittel bis hochanfällige Sorte Inspiration und der gering anfälligen Sorte Dekan), die während der Weizenblüte gefallenen Niederschläge und Durchschnittstemperatur ein und Sie erhalten die prognostizierten Mykotoxingehalte im Weizenerntegut. Wenn Sie *fusariumspezifische* Triazolfungizide (Prothioconazol, Tebuconazol, Metconazol) zur Weizenblüte eingesetzt haben, so wählen Sie in der Kategorie Triazolfungizid zur Blüte „ja“ und Sie erhalten die prognostizierte Mykotoxinreduktion durch die Fungizidapplikation.

Prognosis of the mycotoxin contamination of wheat grain - Schleswig-Holstein | Weiterführende Artikel

Input parameters

Cultivar susceptibility	low susceptibility, BSA grade 4 (Dekan)	
Precipitation flowering	26	mm
Temperature flowering	17	°C
triazole flowering	yes / no	

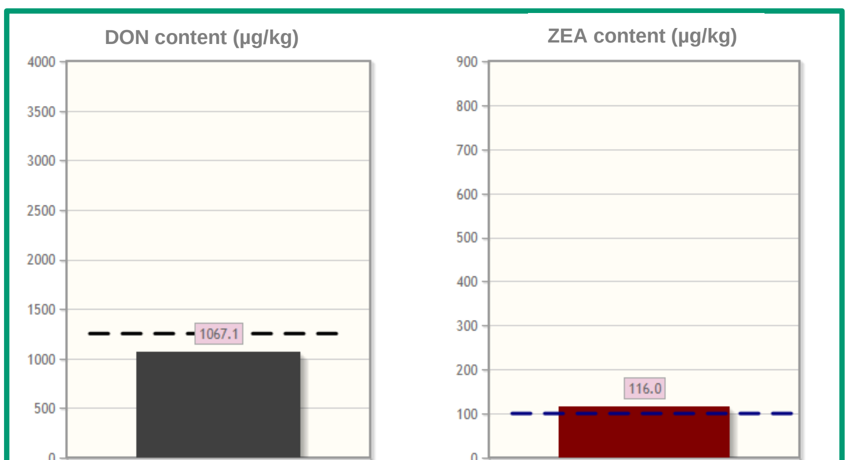
threshold value DON (1250 µg/kg)

threshold value ZEA (100 µg/kg)

www.ips-weizen.de

> *Fusarium*-Prognose

Prognosis



Prognose der Mykotoxinbelastung in Schleswig-Holstein

cultivar susceptibility	low susceptibility, BSA grade 4 (Dekan)		
precipitation flowering		26	mm
temperature flowering		17	°C

aquisition of meteorological data

determination of the flowering period (GS 61 - 69) duration: approx. 7 days

Cultivar susceptibility

3 reference cultivars

Ritmo = high susceptible BSA-grade 7

Inspiration = average susceptibility BSA-grade 6

Dekan = low susceptibility BSA-grade 4

GS 61
Start of flowering! First anther at the ears respectively the middle of the ears

GS 65
Full flowering! Most spikelets have ripe anthers.

GS 69
End of flowering! There are still some dry anthers hanging on the spikelets.

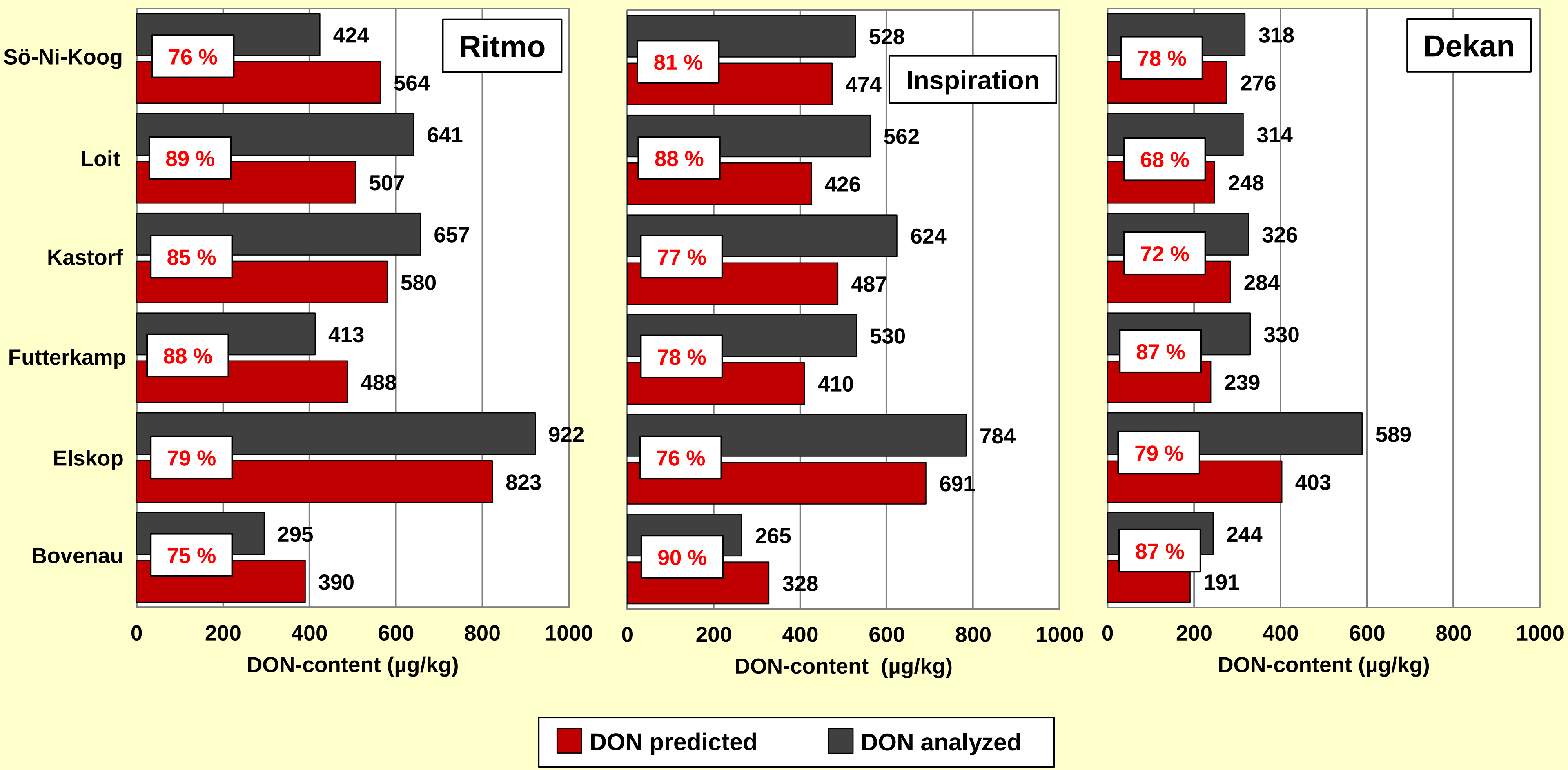
DON contents (µg/kg) – forecast vs. real value

- wheat Schleswig-Holstein 2016; untreated control –

accuracy of prediction : Ø 83 %

accuracy of prediction : Ø 79 %

accuracy of prediction : Ø 76 %

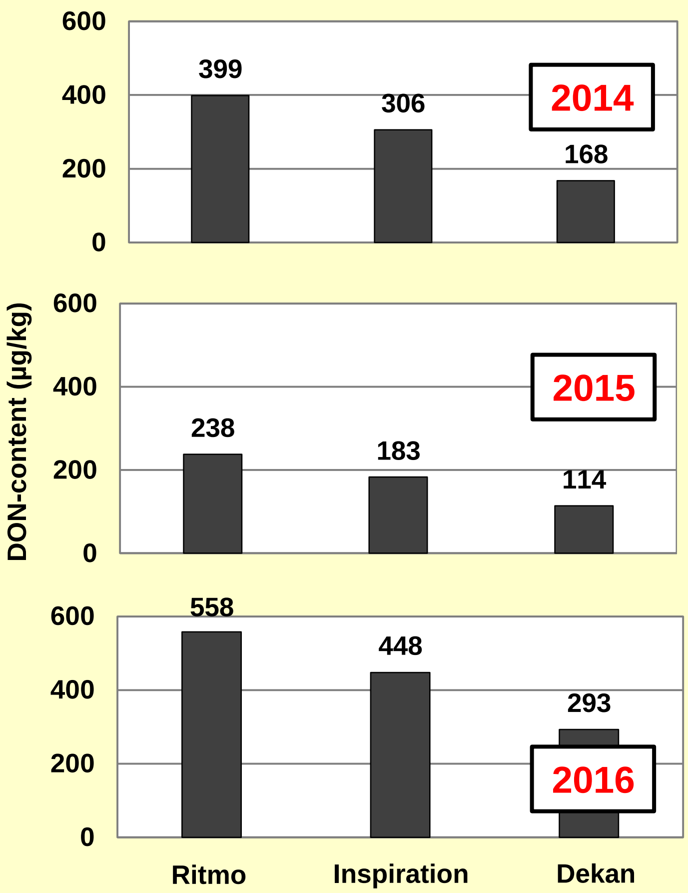


Accuracy of prediction of DON

- wheat Schleswig-Holstein 20
2014 – 2016; cultivar Ritmo; untreated control –

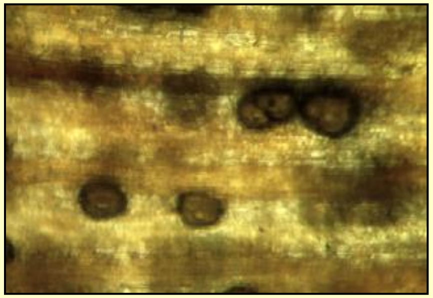
DON - Accuracy of prediction 2014 - 2016

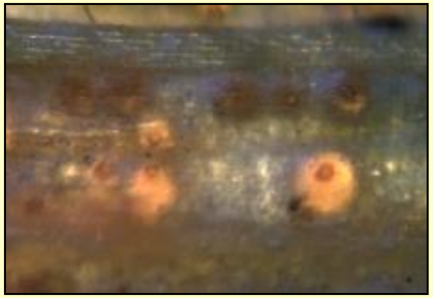
	Ritmo	Inspiration	Dekan
2014	81 %	83 %	79 %
2015	86 %	82 %	88 %
2016	83 %	79 %	76 %
Ø (2014 – 2016)	83 %	81 %	80 %
Ø cultivars (2014 – 2016)	Ø 81 %		

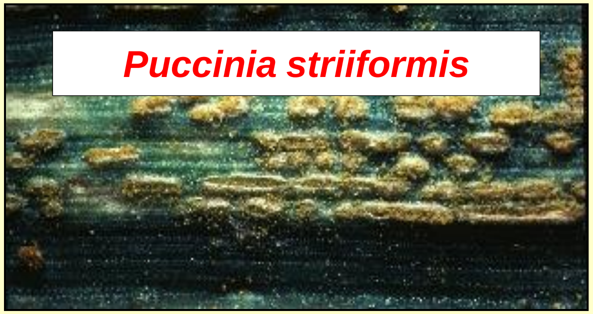


The IPM Wheat Model(concept) - Diagnosis

Exact diagnosis with pathogen-specific fungal structures: Key for an optimal disease management !!!





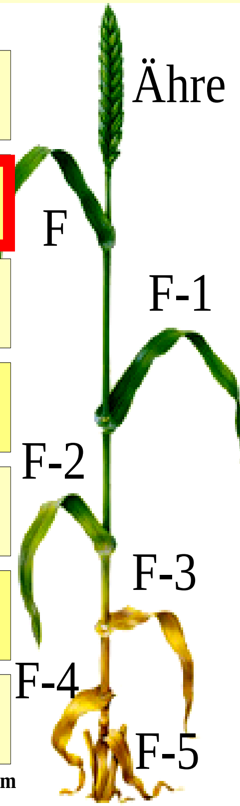


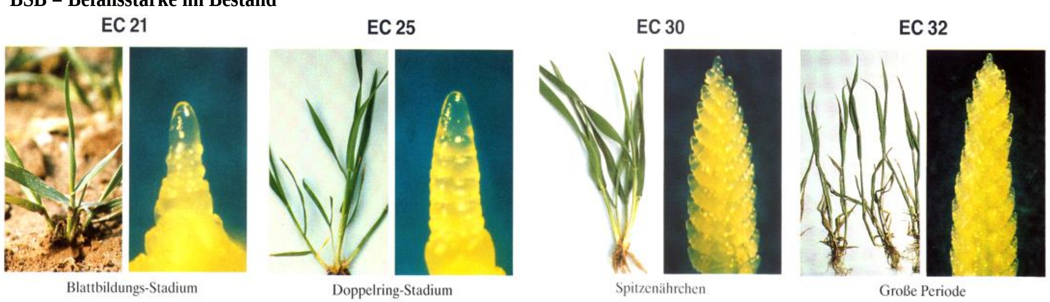
IPM Wheat Model - threshold for *Blumeria graminis*

EC: 29 30 31 32 37 39 49 51 59 61-69

	Schwellenwert
Pseudocercosporella herpotrichoides	EC 32 BHB > 25% EC 37 BHB > 30%
Erysiphe graminis	1. BHB >70% / Pflanze 2. BHB >70% / Pflanze im Durchschnitt von F bis F-2
Puccinia striiformis	BHB > 30% oder erste Befallsnester
Puccinia recondita	BHB > 30%
Septoria tritici	BHB > 50% auf F-6 + 48 Stunden Blattnässe > 98%
Septoria nodorum	BSB > 1 Pyknidie oder BHB > 12 % auf Indikationsblattetage
Drechslera tritici-repentis	1. BHB > 5% auf Indikationsblattetage 2. BSB > 5% auf Indikationsblattetage

BHB = Befallshäufigkeit im Bestand
BSB = Befallsstärke im Bestand
Schwellenorientierter Behandlungszeitraum





Fungicide management

Threshold values IPM Wheat Model

First application:
from GS 30
► 70% DI

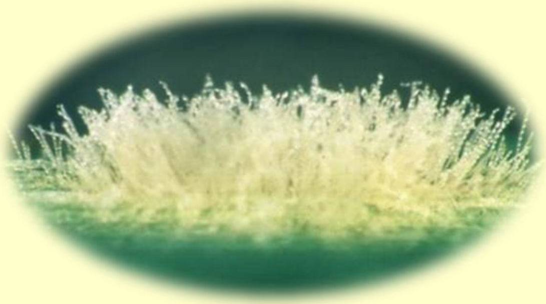
Follow-up application:
► 70% DI on F-F-2

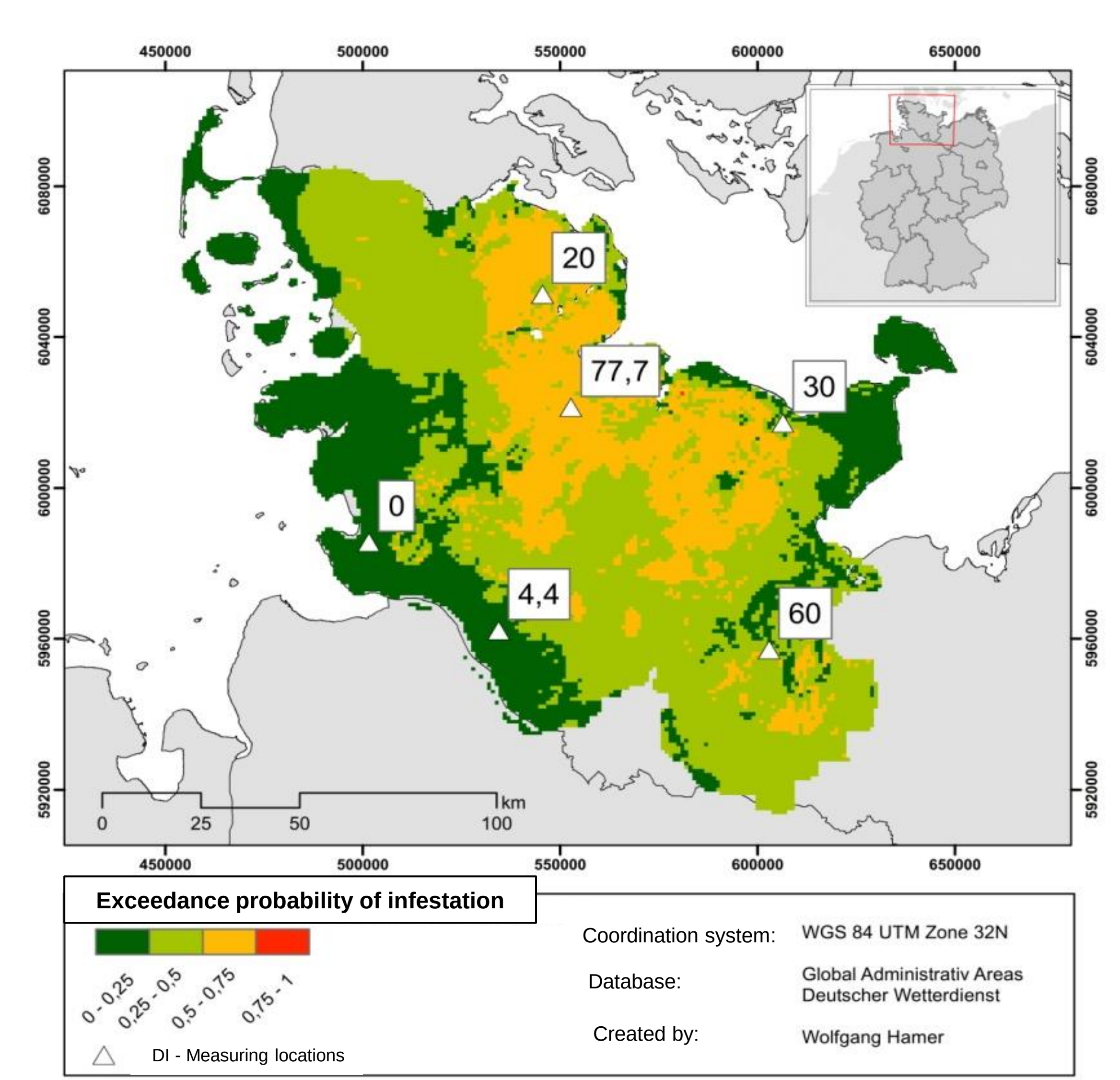
DI = Disease incidence
= infected plants in %
DS = Disease severity
= infected leaf area in %

Exceedance probability of infestation

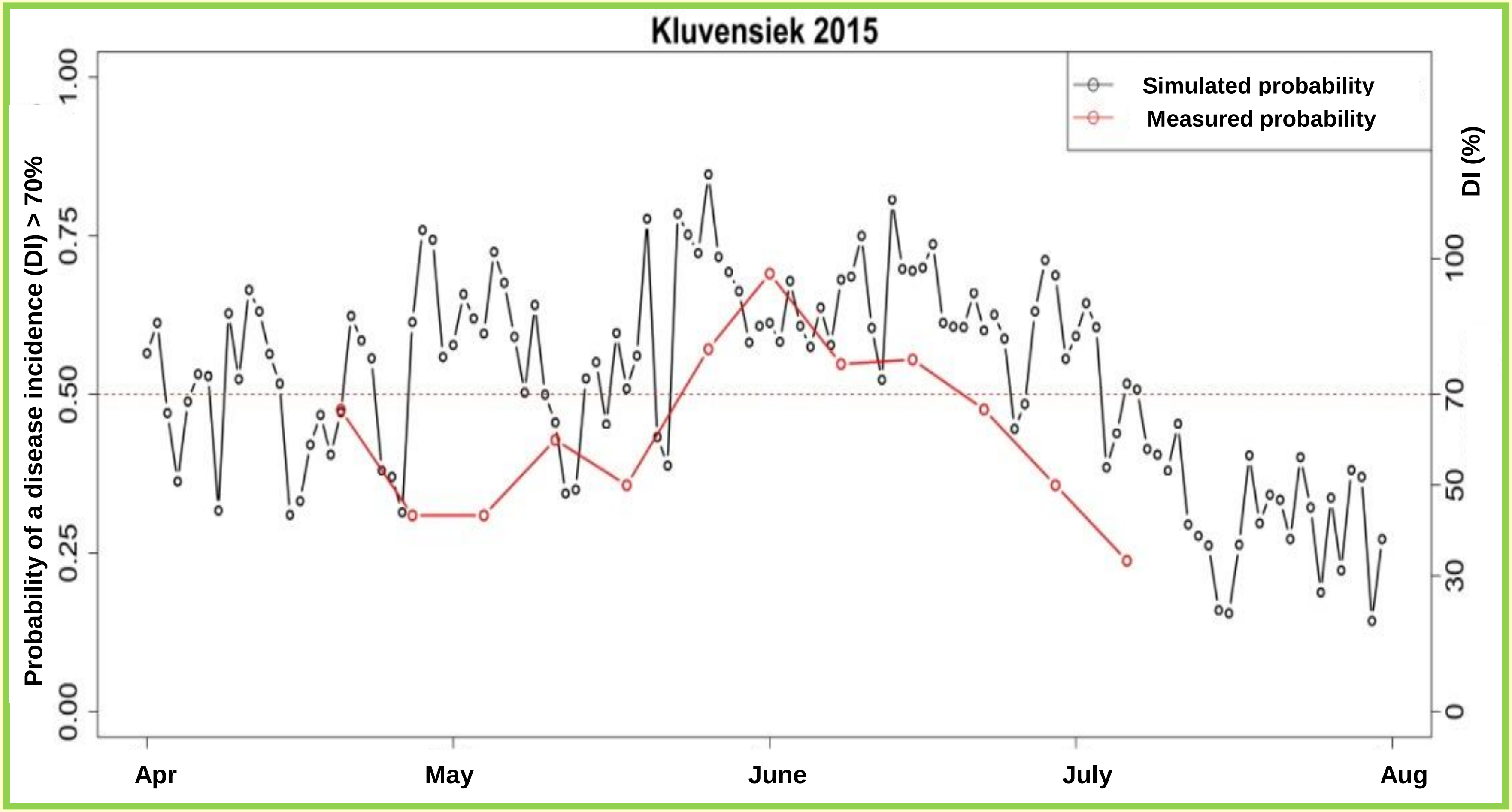
Blumeria graminis forecast model

Model output for June 15, 2015 with the grid-based map of the probable exceedance of the threshold (70 % disease incidence)



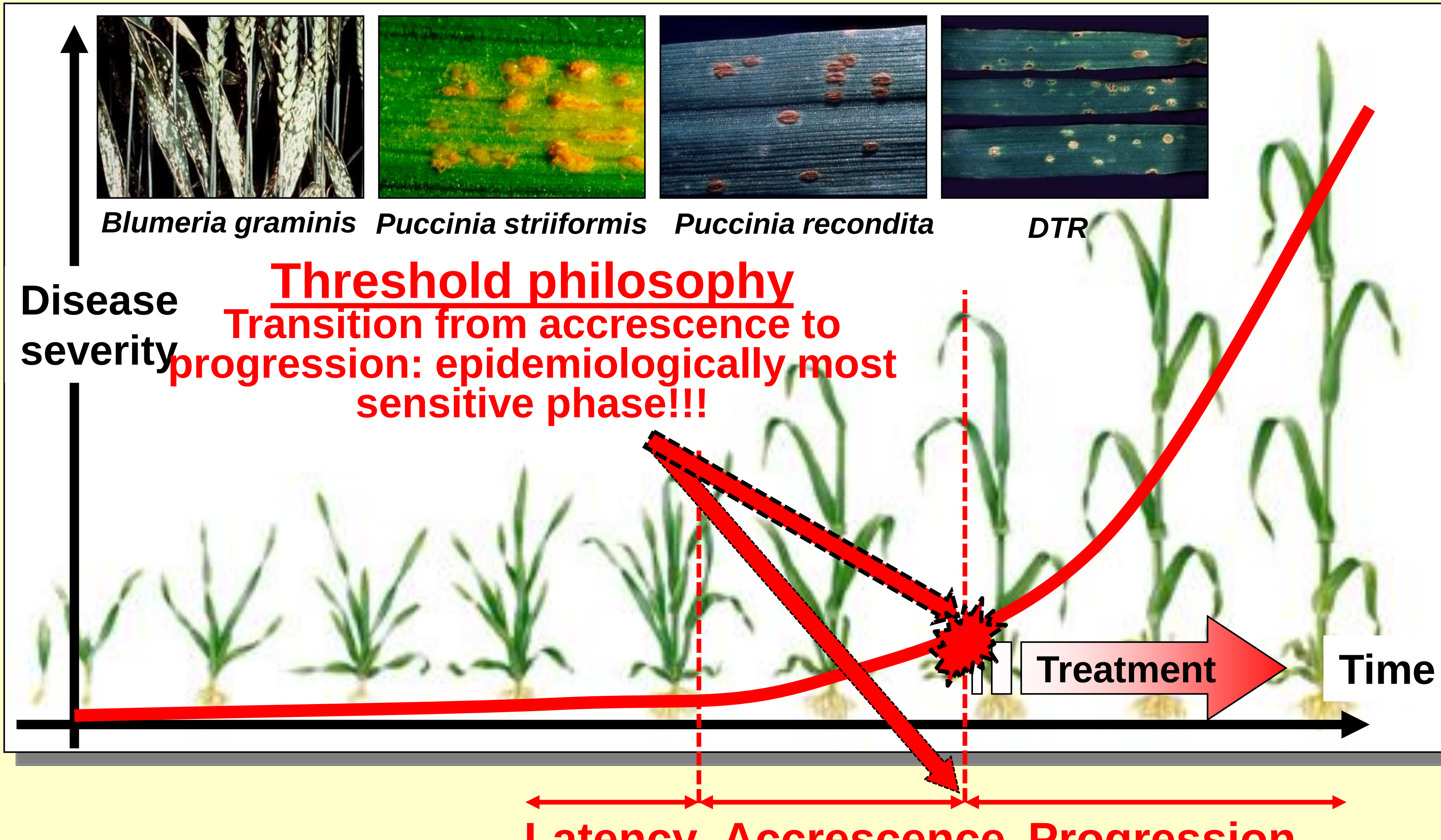


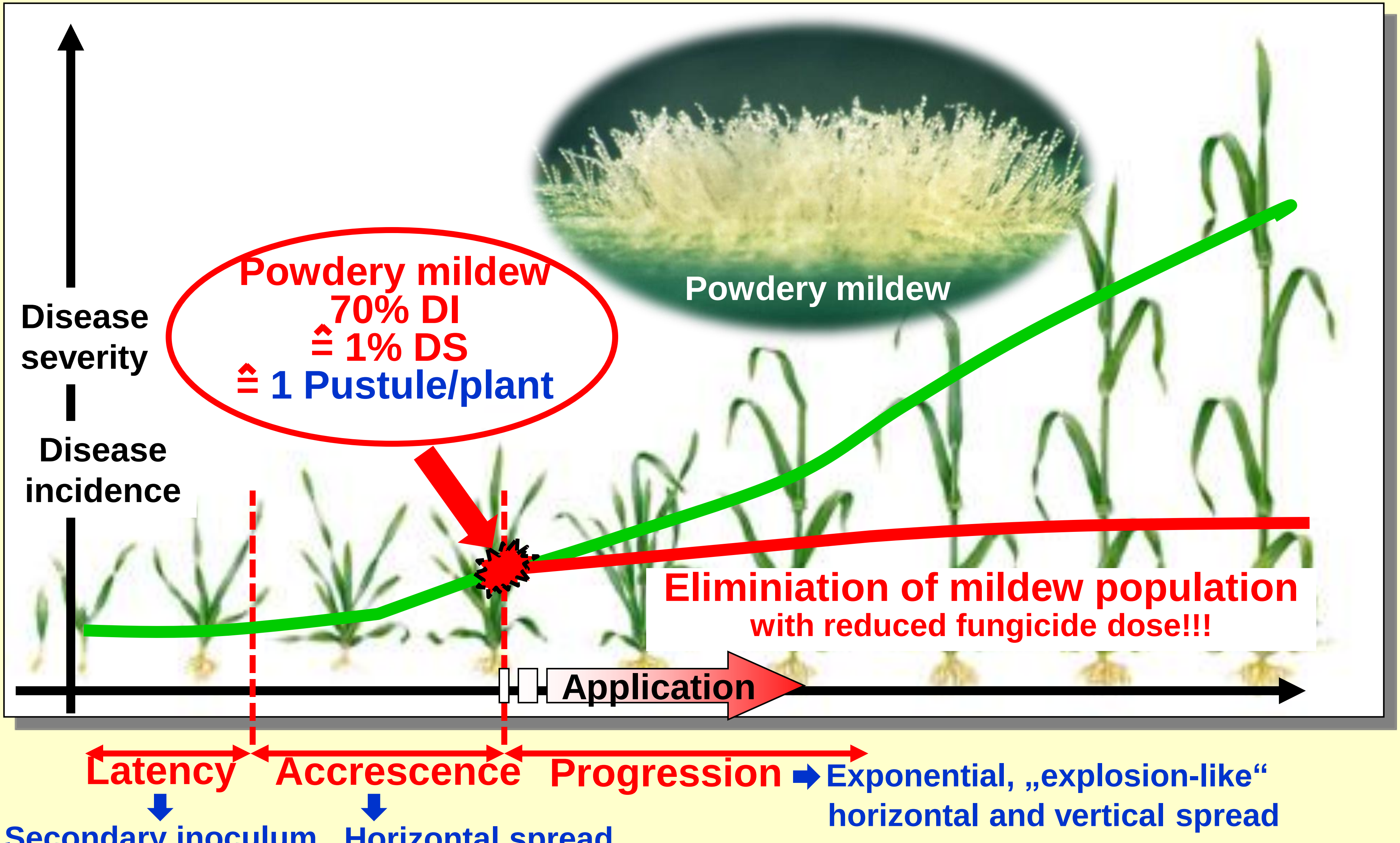
Case study - *Blumeria graminis* – forecasting model



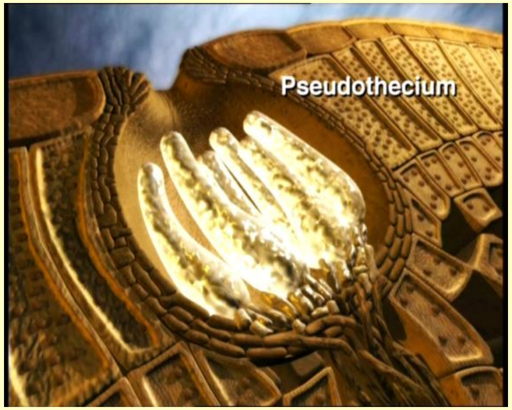
Course of determined and simulated disease incidence (DI > 70 %) in Kluvensiek 2015

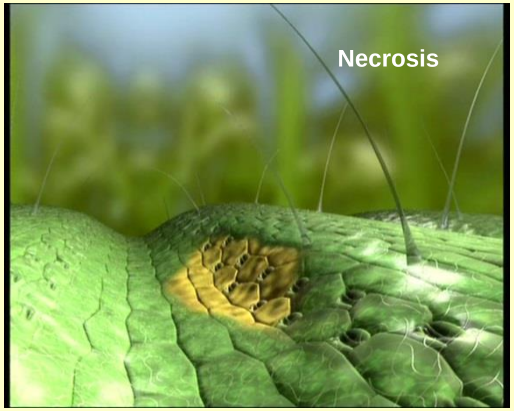
The IPM Wheat Model (concept) – theshold values

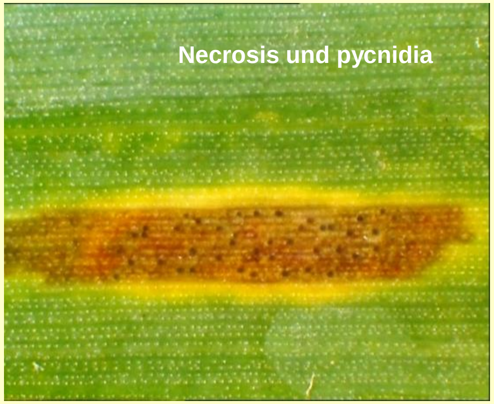



Powdery mildew
Disease severity
Disease incidence
Powdery mildew
70% DI
≙ 1% DS
≙ 1 Pustule/plant
Eliminiation of mildew population
with reduced fungicide dose!!!
Application
Latency
Accrescence
Progression
Exponential, „explosion-like“ horizontal and vertical spread
Secondary inoculum
Horizontal spread

Life history of *Zymoseptoria tritici*

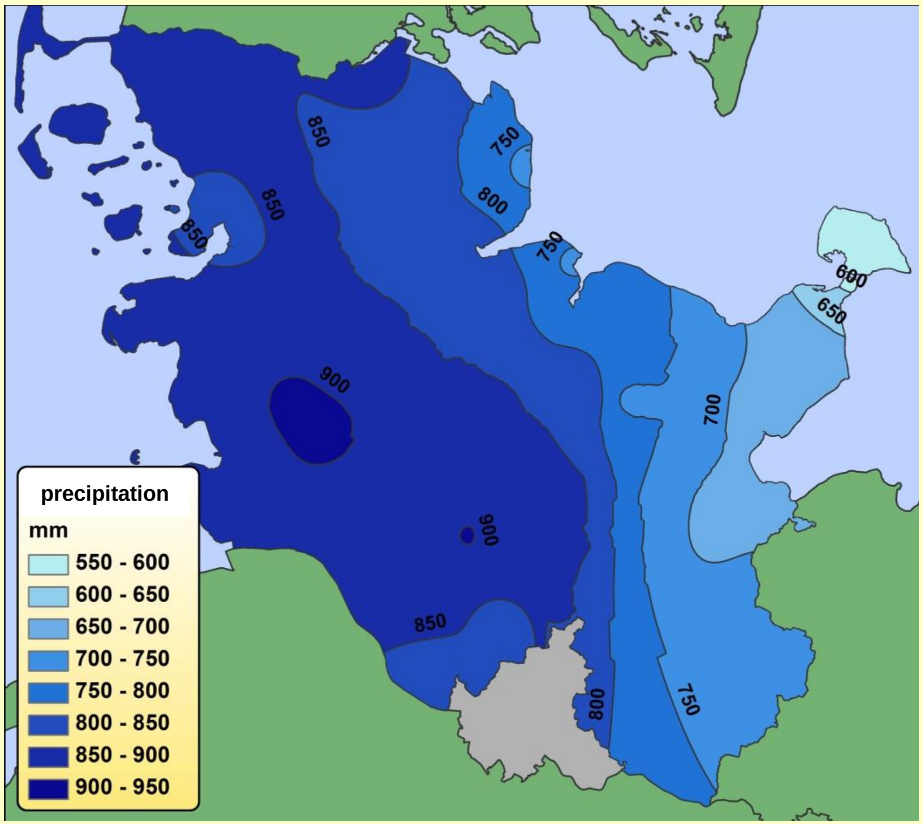




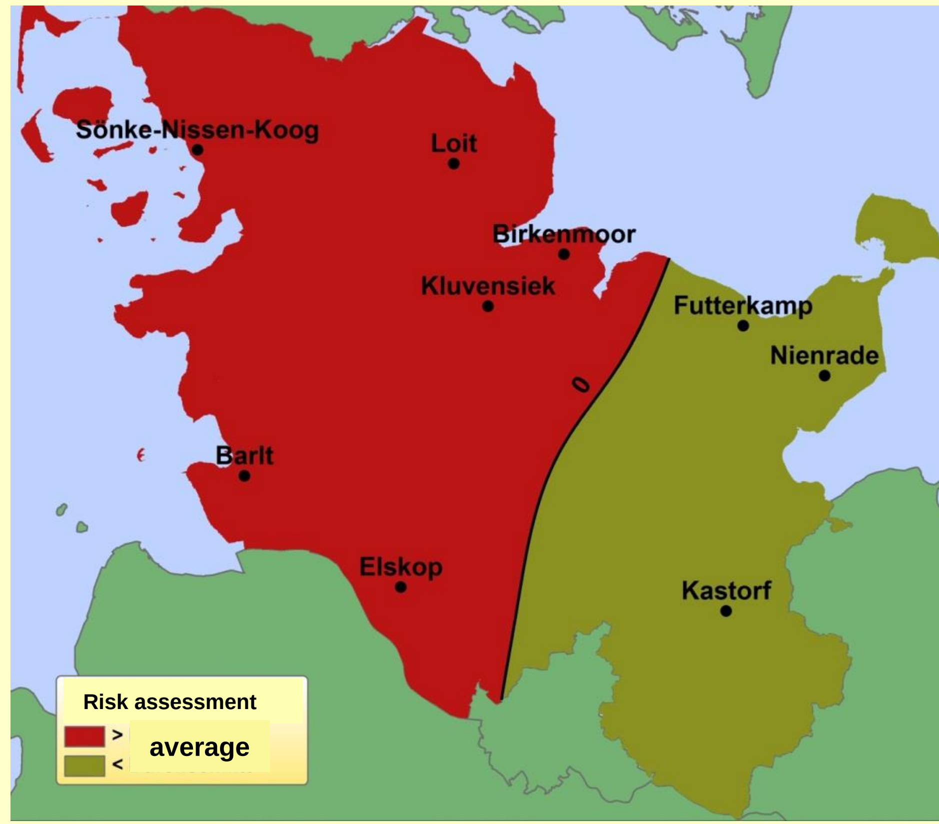


Comparison of average yearly precipitation and *Septoria tritici* blotch infection risk from 1995 to 2012 in Schleswig-Holstein, winter wheat cv. ´Ritmo´, untreated control

Geographic Information System (GIS)

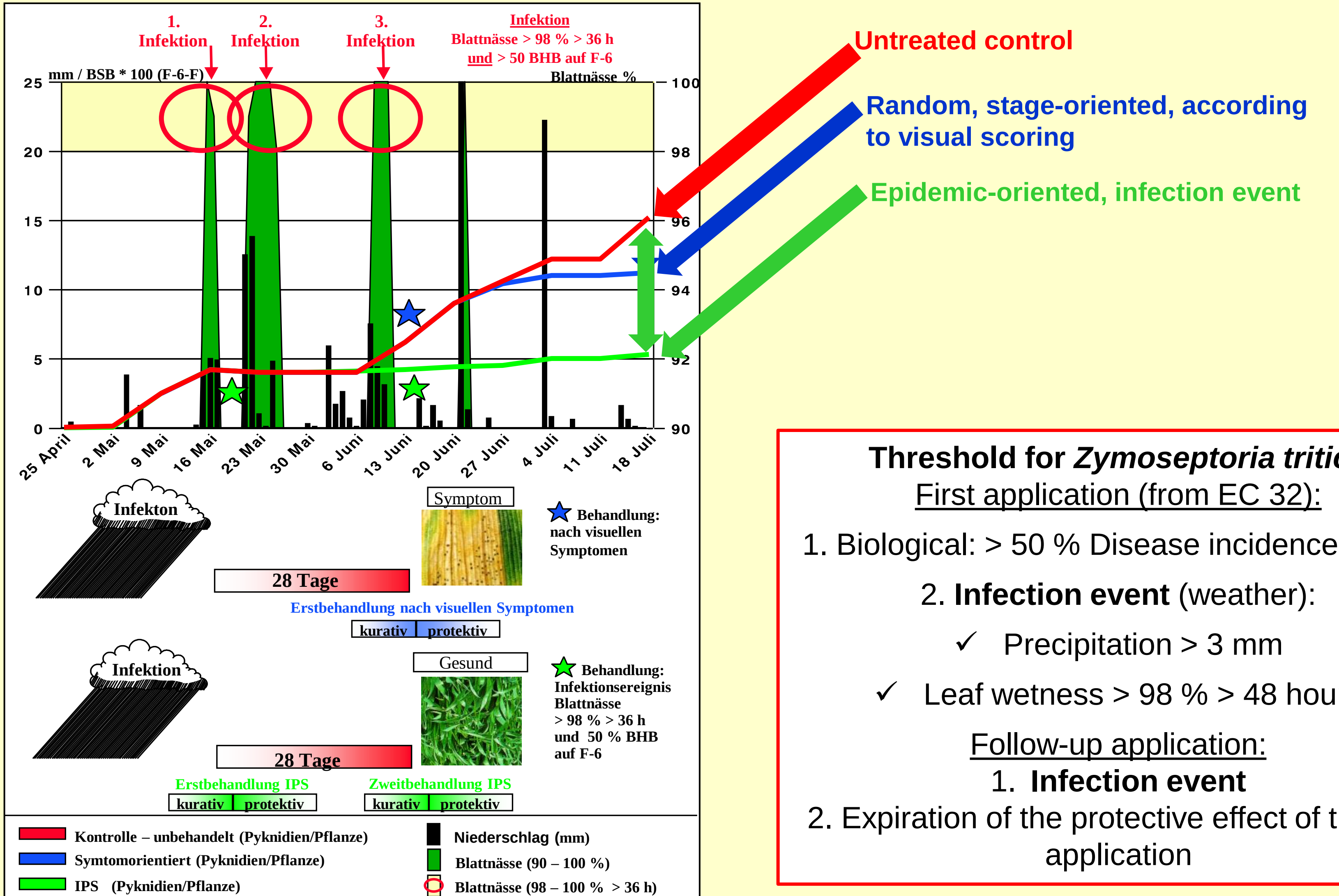


- Average yearly precipitation 1970 - 2012



- Infection risk as deviation from average final infection ratel of *Zymoseptoria tritici* (1995 – 2012) (number of pycnidia per plant)

Management of *Zymoseptoria tritici*



Threshold for *Zymoseptoria tritici*:

First application (from EC 32):

1. Biological: > 50 % Disease incidence on F-6
2. **Infection event** (weather):
   - ✓ Precipitation > 3 mm
   - ✓ Leaf wetness > 98 % > 48 hours

Follow-up application:

1. **Infection event**
2. Expiration of the protective effect of the first application

IPS Wheat Model
Threshold *Zymoseptoria tritici*

Septoria Timer

Infection event caused by

Zymoseptoria tritici

Leaf wetness > 98% for > 48h

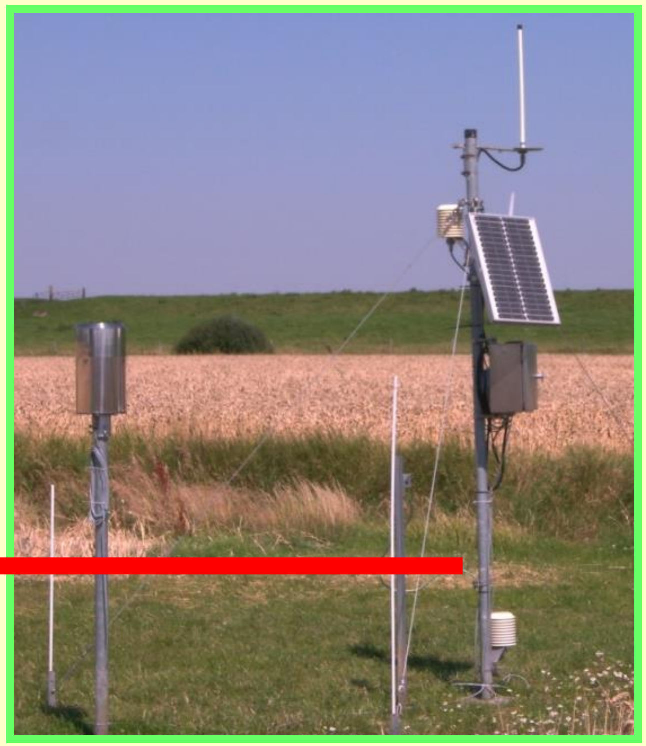
and disease incidence > 50 on F-6

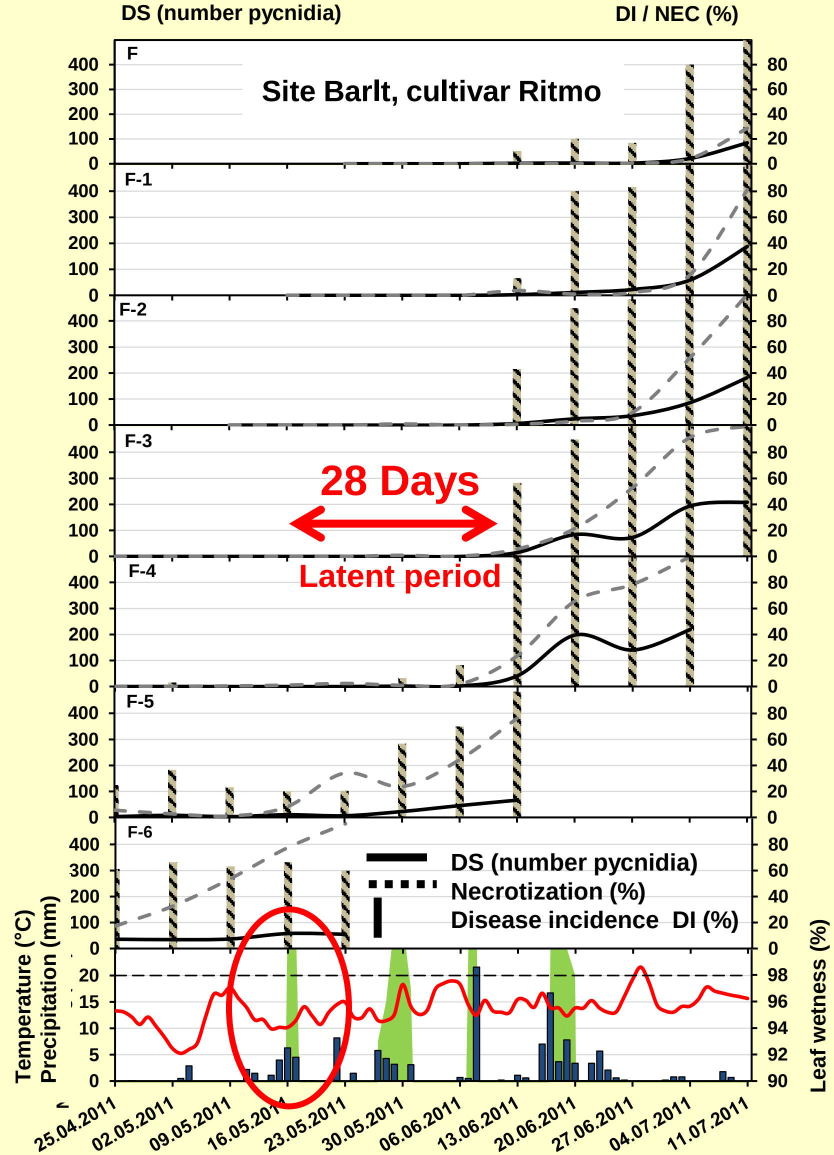
Prerequisites for *Zymoseptoria tritici* infections

SEPTORIA TIMER

Precipitation 3 mm per day
Disease incidence > 50 % on F-6

> 36 h leaf wetness ≥ 98 %
(WEIHOFEN leaf wetness sensor)





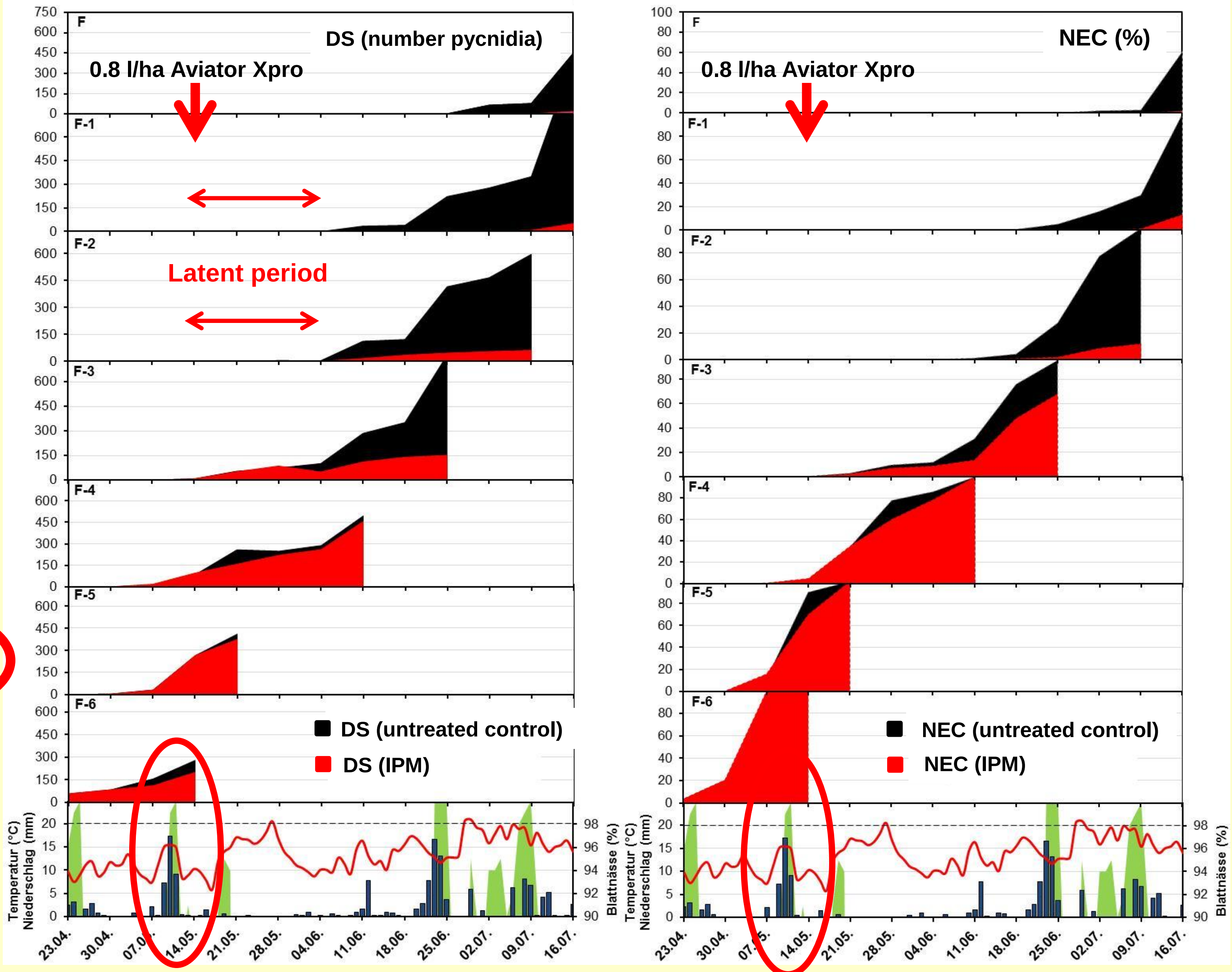
Effect of an IPM fungicide application on *Zymoseptoria tritici* infection and necrotisation rates of wheat Cultivar´Ritmo´, Schleswig-Holstein 2012, untreated control, IPM variant

- **Left: Disease severity (DS)**
- **Right: Necrotisation**
- **Control: 87.1 dt/ha**
- **IPM variant: 106.3 dt/ha**

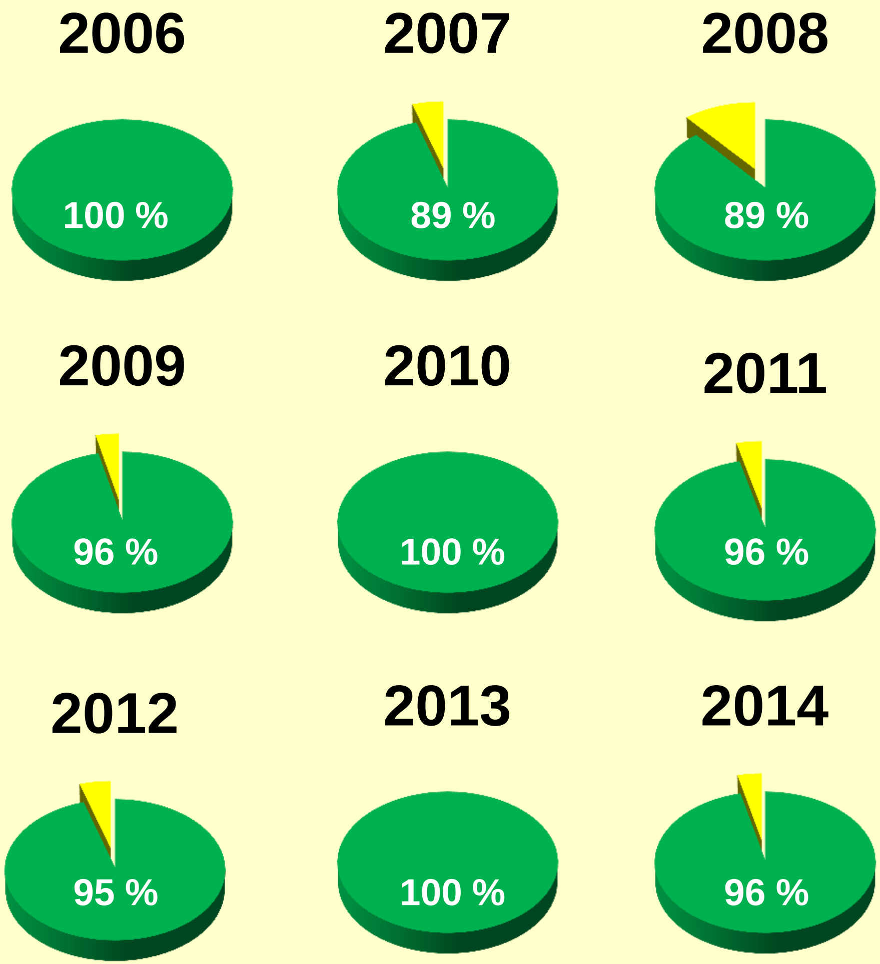
+ 19.2 dt/ha

Control DS

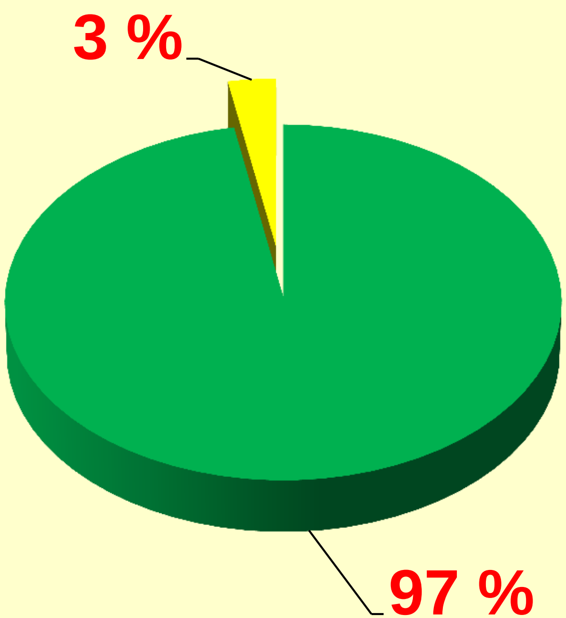
IPM DS



Success of detection of specific *Zymoseptoria* infection events

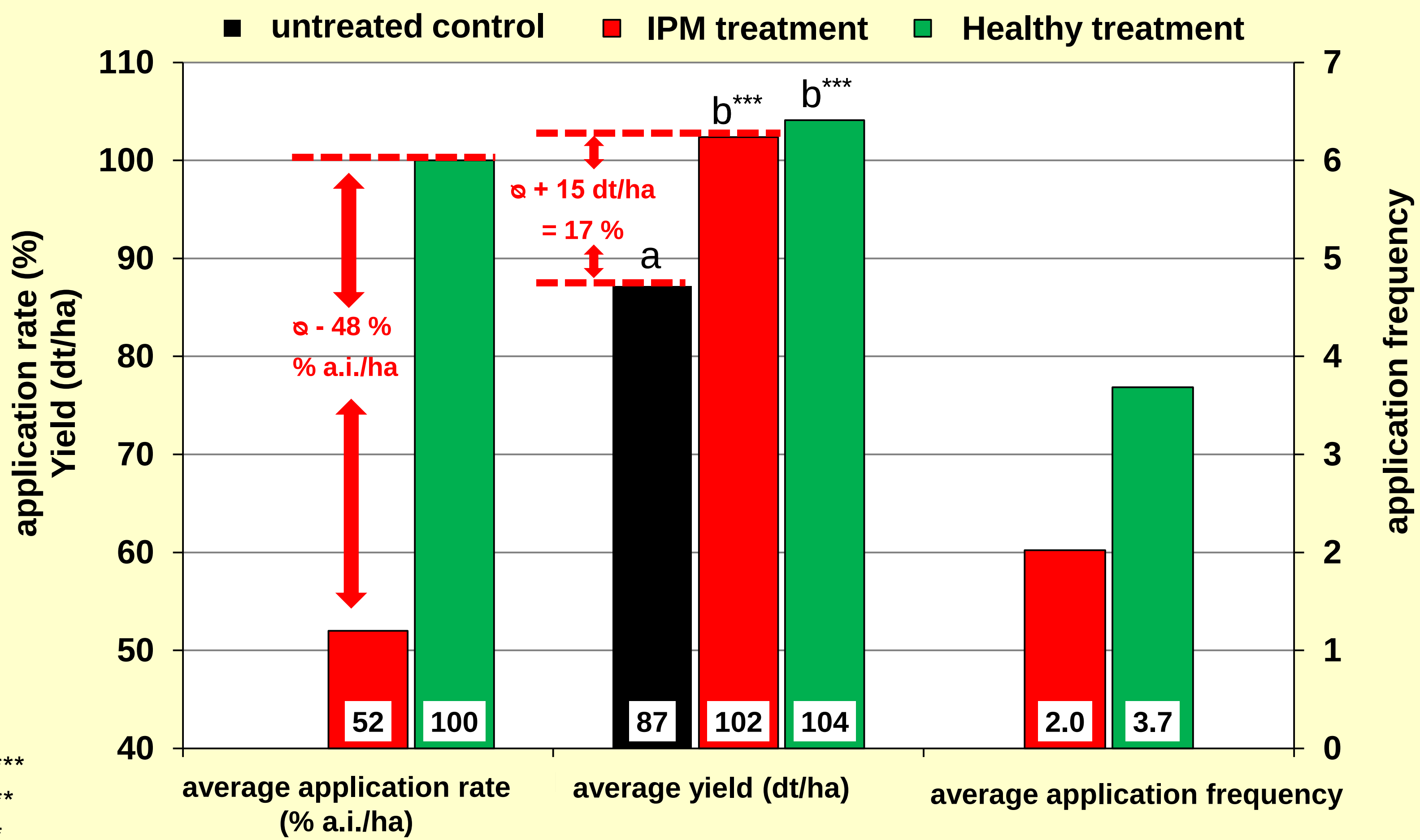


Average of 2006 - 2015



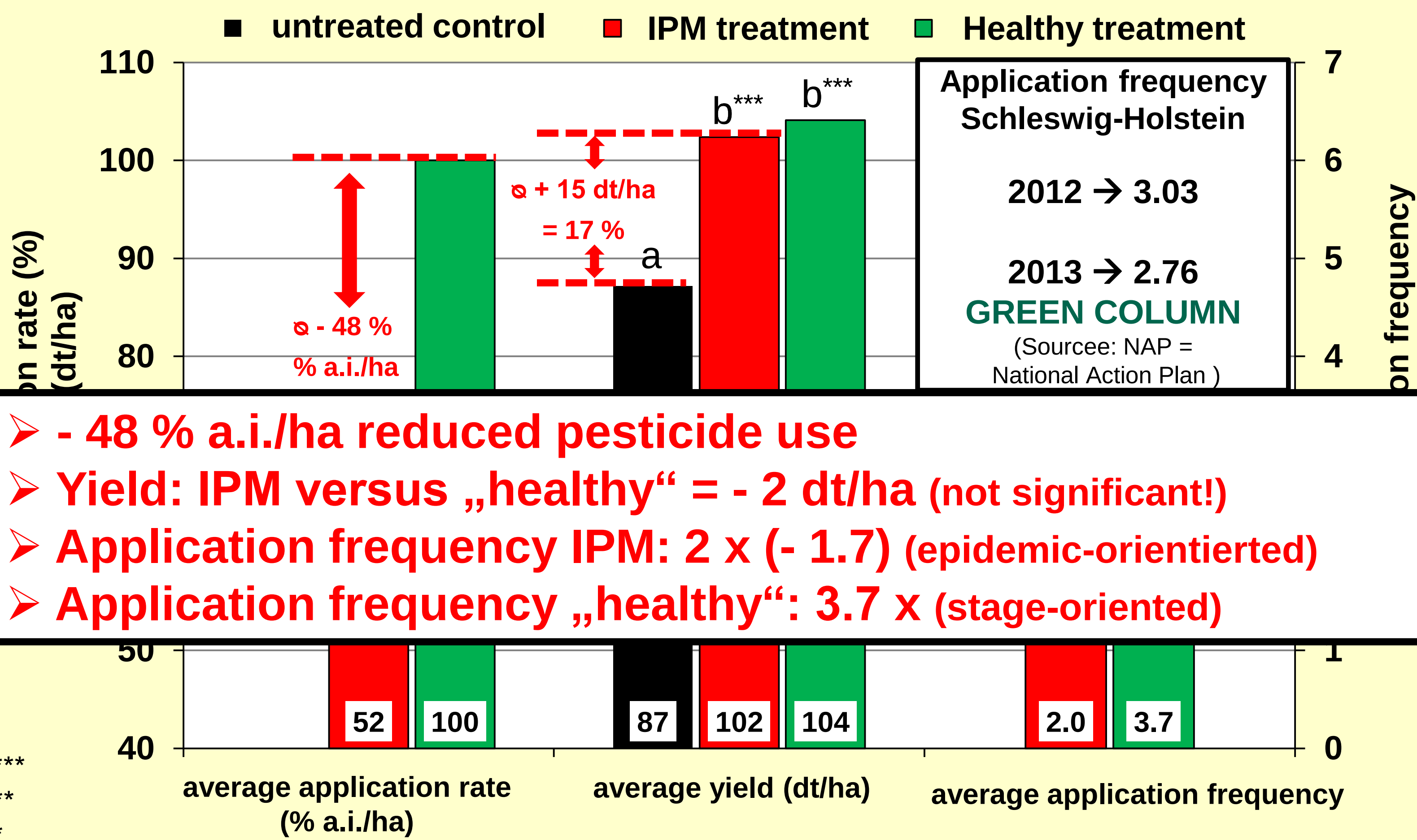
Increases of infection rates (>70 pycnidia) could be predicted with an accuracy of
97%

Fungicide application rate, application frequency and yield
IPM Wheat Model, Schleswig-Holstein 1995 - 2015



P ≤ 0,001 = ***
P ≤ 0,01 = **
P ≤ 0,05 = *

Fungicide application rate, application frequency and yield IPM Wheat Model, Schleswig-Holstein 1995 - 2015



- **- 48 % a.i./ha reduced pesticide use**
- **Yield: IPM versus „healthy“ = - 2 dt/ha (not significant!)**
- **Application frequency IPM: 2 x (- 1.7) (epidemic-orientierted)**
- **Application frequency „healthy“: 3.7 x (stage-oriented)**

P ≤ 0,001 = ***
P ≤ 0,01 = **
P ≤ 0,05 = *

Summary

1. The achievement of maximum yields in the world's ecologically preferred cultivation regions is a political and ethical necessity in order to safeguard the global food supply.

2. Nitrogen fertilisation as a motor of plant growth fully exploits the genetically fixed yield potential.

3. Disease epidemics dynamically develop due to annual and site-specific weather conditions.

4. De Wit: „ A production factor which is in optimum supply contributes more to production, the closer other production factors are to their optimum." "No production resource is used less efficiently and most production resources are used more efficiently with increasing yield level".

5. Political and non-agronomic demands for the reduction of a production factor (such as nitrogen or pesticides) reduce yields and qualities of the harvest; Exporting countries will become importing countries at the expense of the developing countries.

6. A pesticide tax, as discussed in Germany, leads to considerable additional costs in crop production.

7. The key to optimizing and minimizing the use of pesticides is the application of reliable prognosis models and / or control threshold values.

8. Another key to optimizing and minimizing pesticide use is communication of modern concepts and methods to farmers.

9. The terms "integrated pest management" or "good professional practice" are currently pushed forward, at least until stage-oriented routine measures are still recommended by industry. Scheduling errors and under-dosing support the development of resistances. Optimized management of cultivation factors significantly reduces infestation rates with excellent phytosanitary effects.

Plant quarantine:

Import and export control

Cultivation methods:

Farming site selection and amelioration
Soil management
Cultivation techniques
Crop rotation
Resistant and tolerant cultivars
Eradication of infection clusters
Eradication of secondary hosts
Production of healthy seeds and propagation materials

Biological methods:

Vertebrates
Arthropods
Microorganisms

Biotechnical methods:

Physical and chemical cues
Pheromones
Fertility regulators
Developmental regulators
Self-destruction methods

Chemical methods:

Seed treatment
Soil treatment
Direct application of fungicides, insecticides, herbicides, etc.

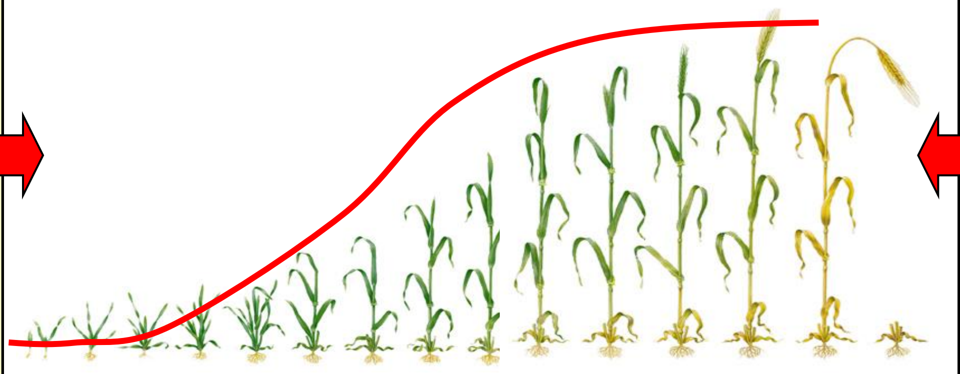
Physical methods:

Mechanical eradication
Thermal processing
Irradiation

Variable: production system

- Cultivar
- N fertilisation
- Sowing time
- Crop rotation
- Soil management

Epidemic (onset, course, severity)



Variable: weather

- Temperature
- Precipitation
- Leaf wetness
- Humidity

Principles of the IPM Wheat Model

Qualitative and quantitative **diagnosis** based on pathogen-specific fungal structures ⬅ **Key role**

⬇

Threshold values = Limit values of the pathogen population

⬇

Decision: fungicide application yes/no
Fungicide strategy – smart selection of fungicides

⬇ ⬇ ⬇

Optimisation and minimisation of fungicide applications