Skal afgrødevalget i dansk landbrug tilpasses til fremtidens klima?

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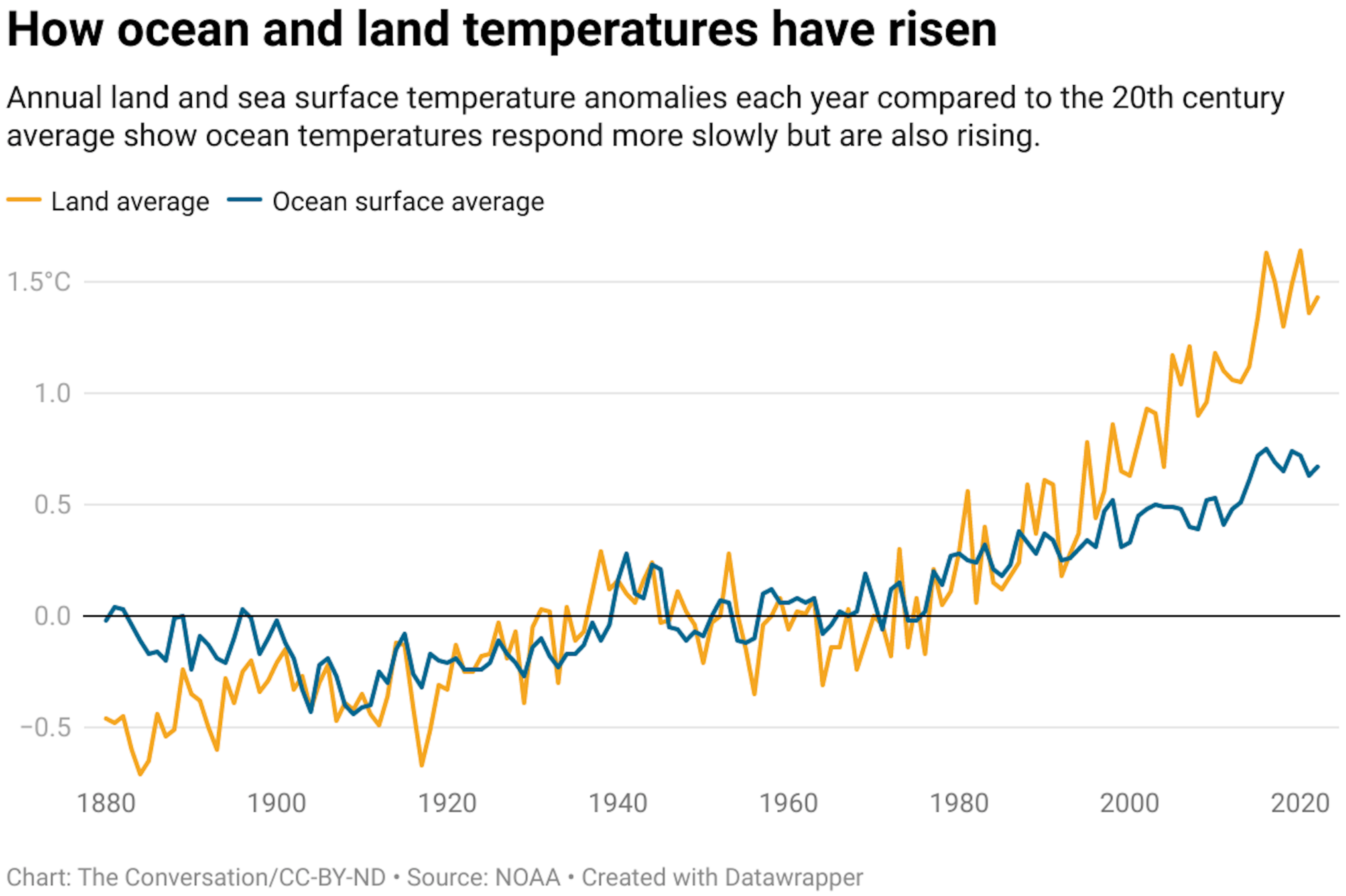
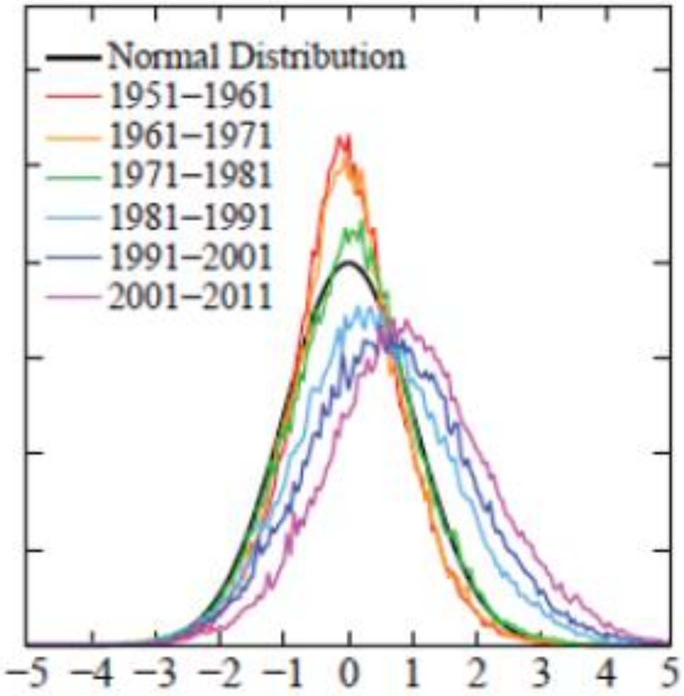
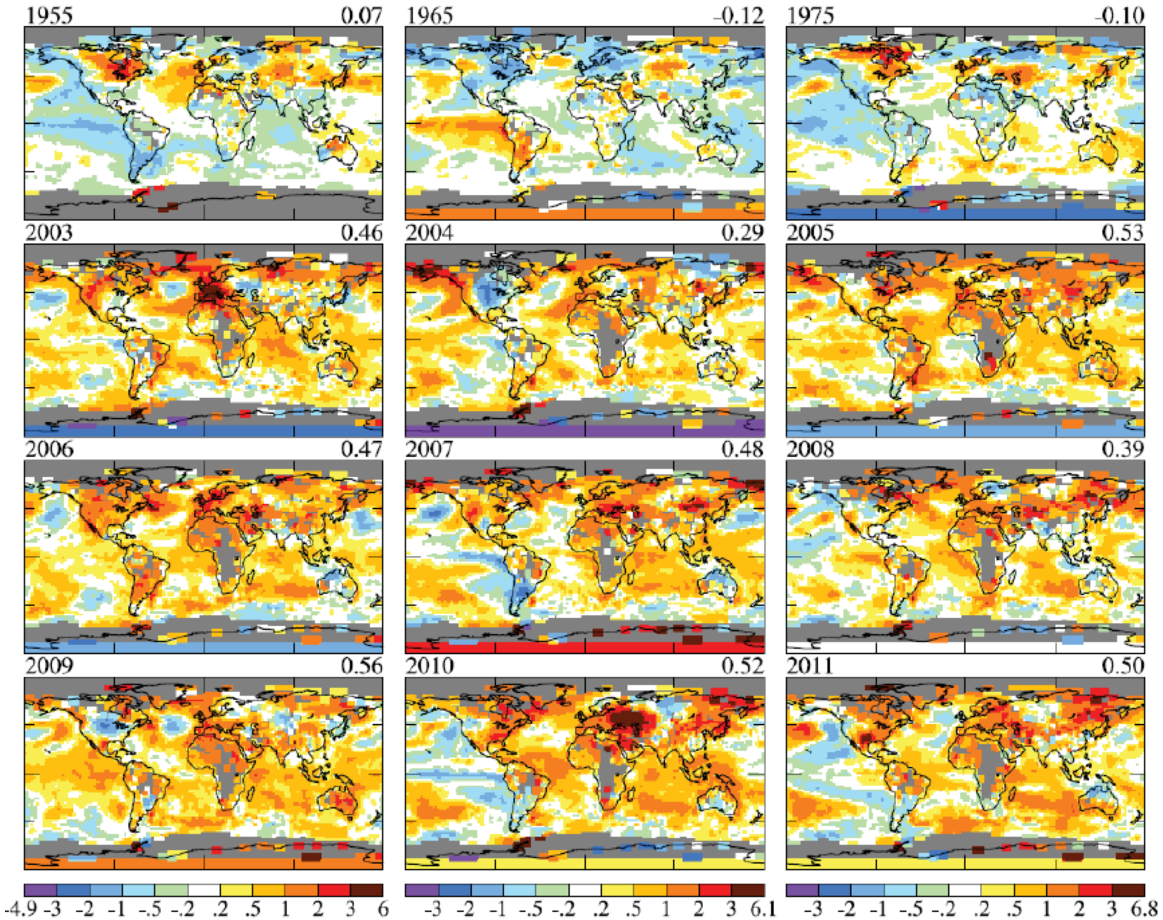
Temperaturen stiger mere over land end over hav



Sommer temperatur bliver mere ekstreme

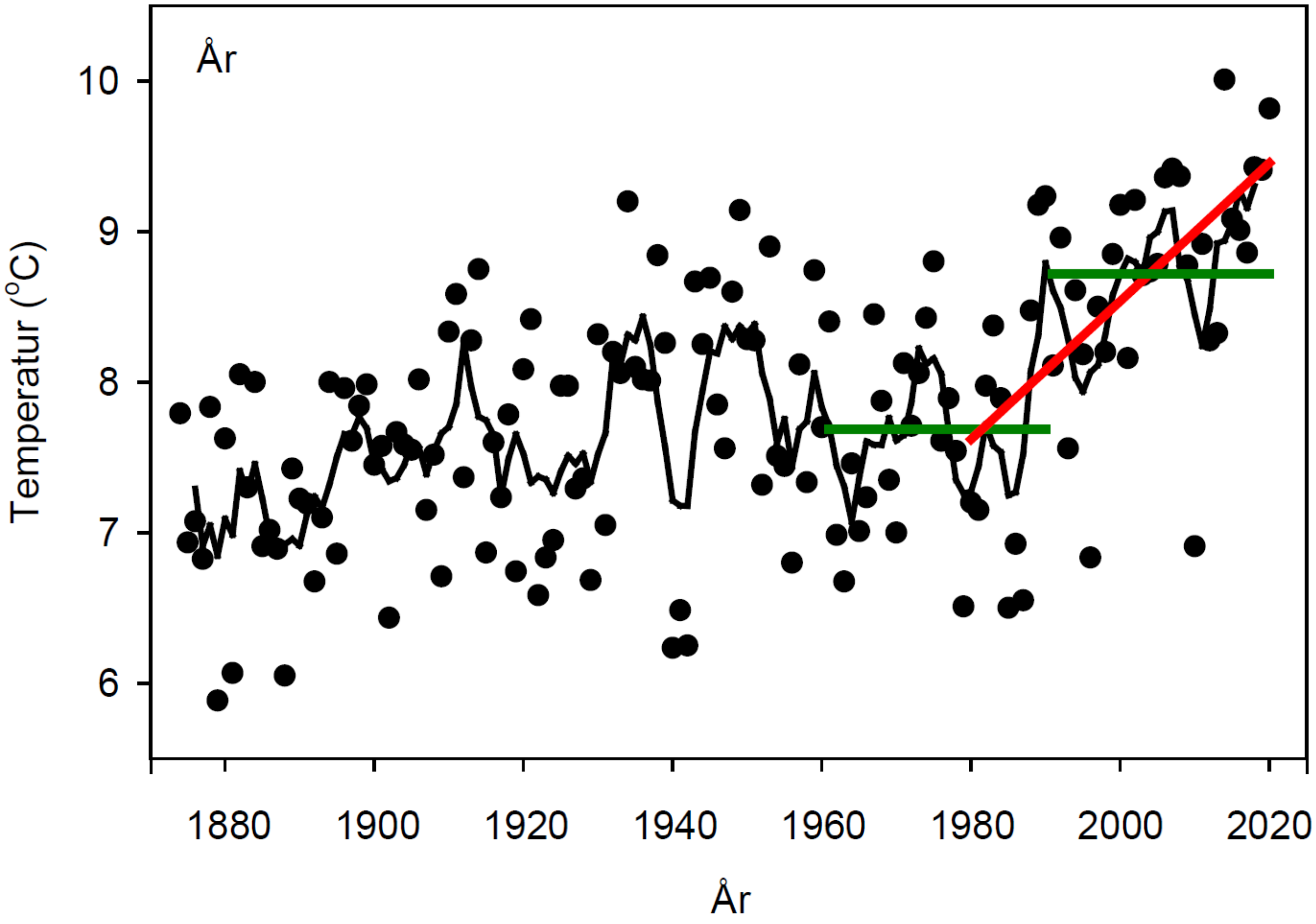
- Den globale middeltemperatur stiger
- Det samme gør variationen mellem år





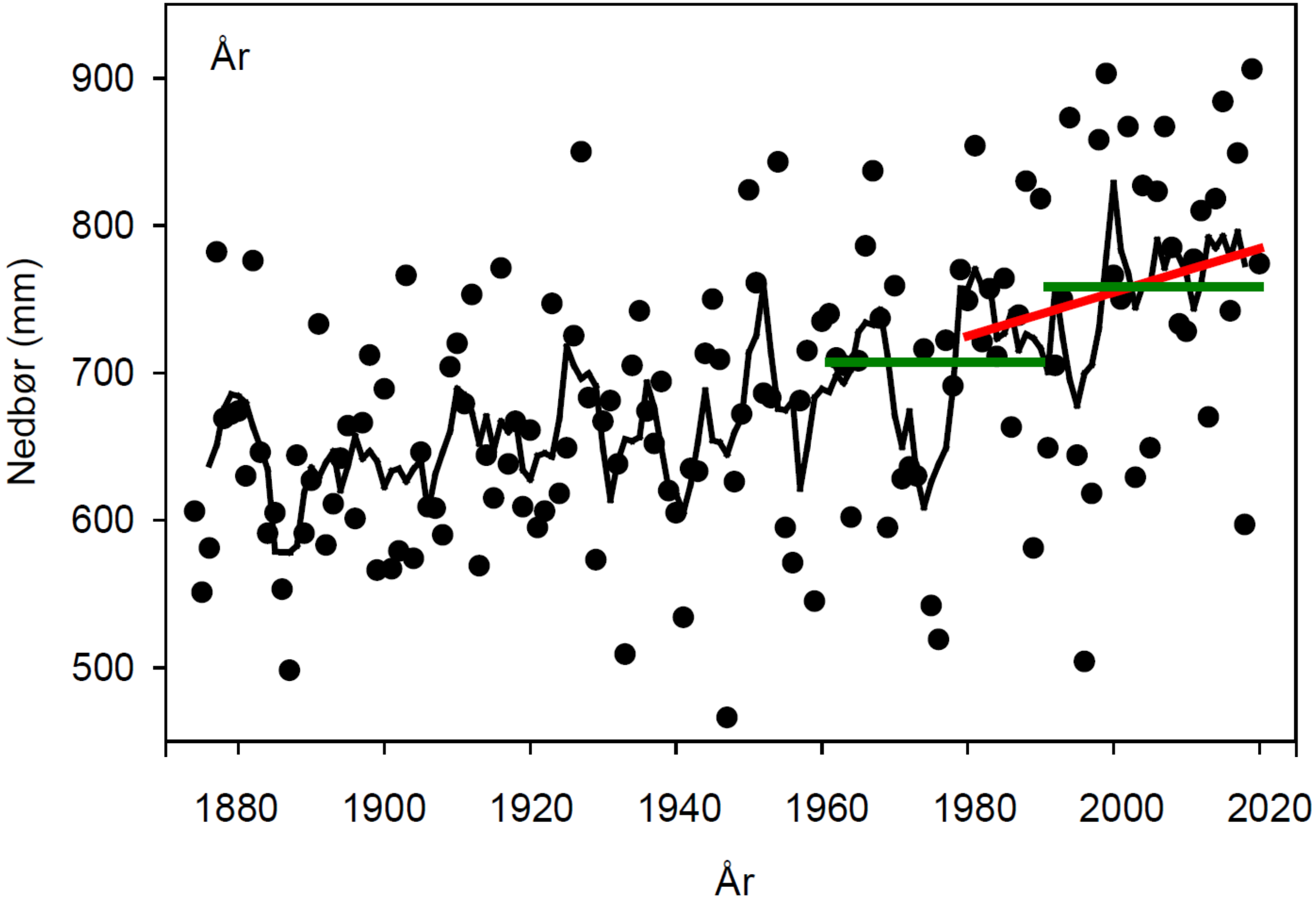
Hansen et al. (2012), PNAS 109 E2415-E2423

Stigende temperatur i Danmark



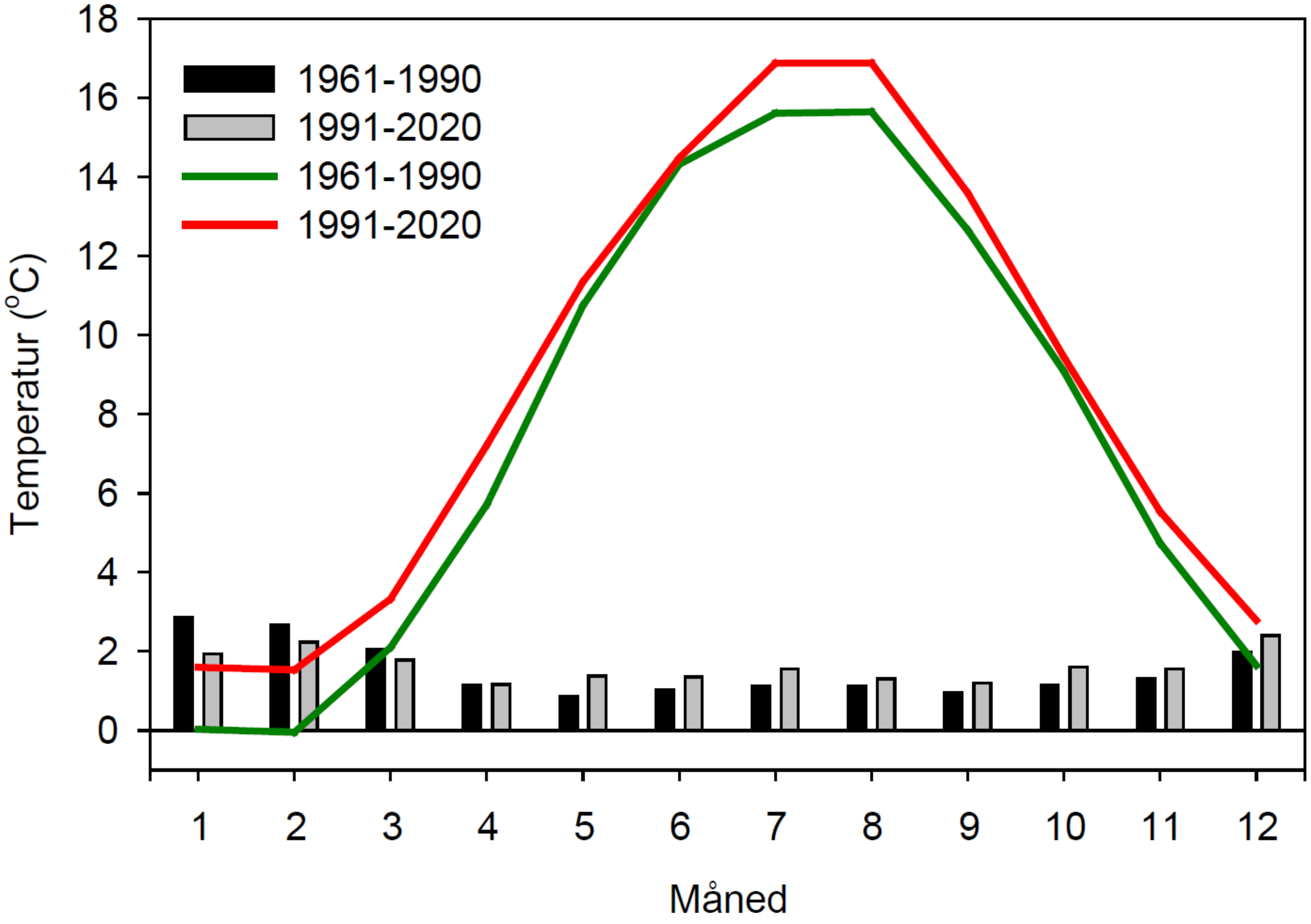
Siden 1980 er temperaturen steget ca. 0,5 C per årti

Stigende nedbør i Danmark



Siden 1980 er nedbøren steget ca. 15 mm per årti

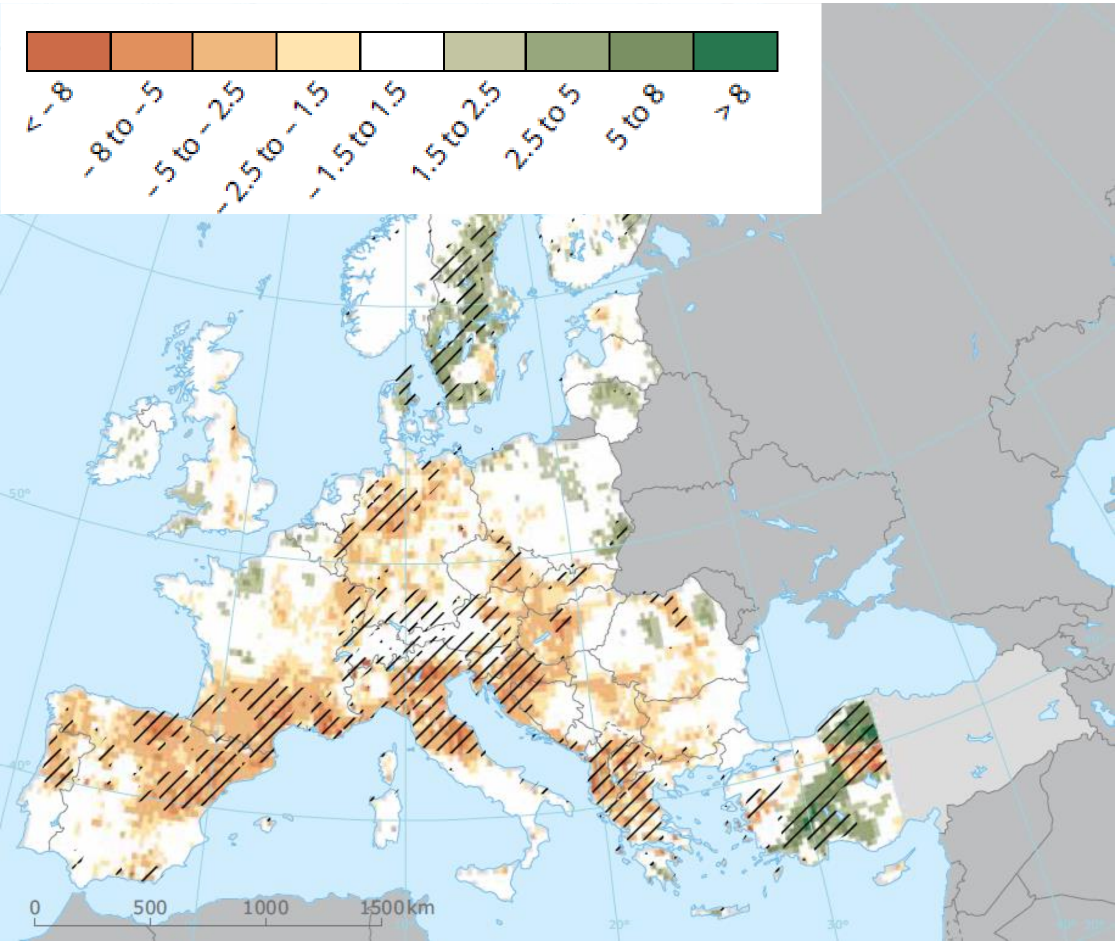
Øget variabilitet i temperatur (om sommeren)



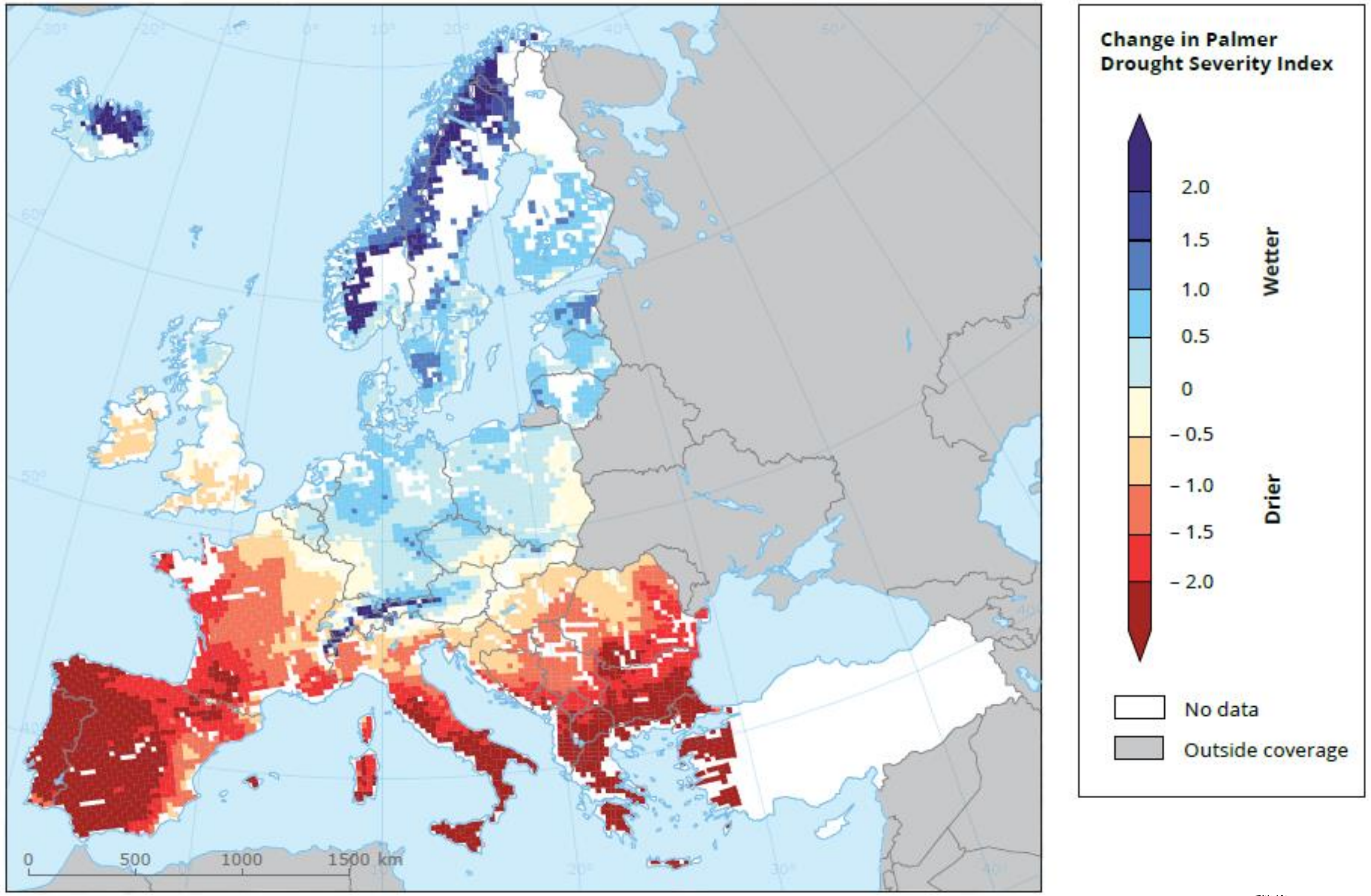
Linjer viser gennemsnit for normalperioder, og søjler viser spredning.

Udvikling i sommer jordfugtighed

Trend 1951-2012

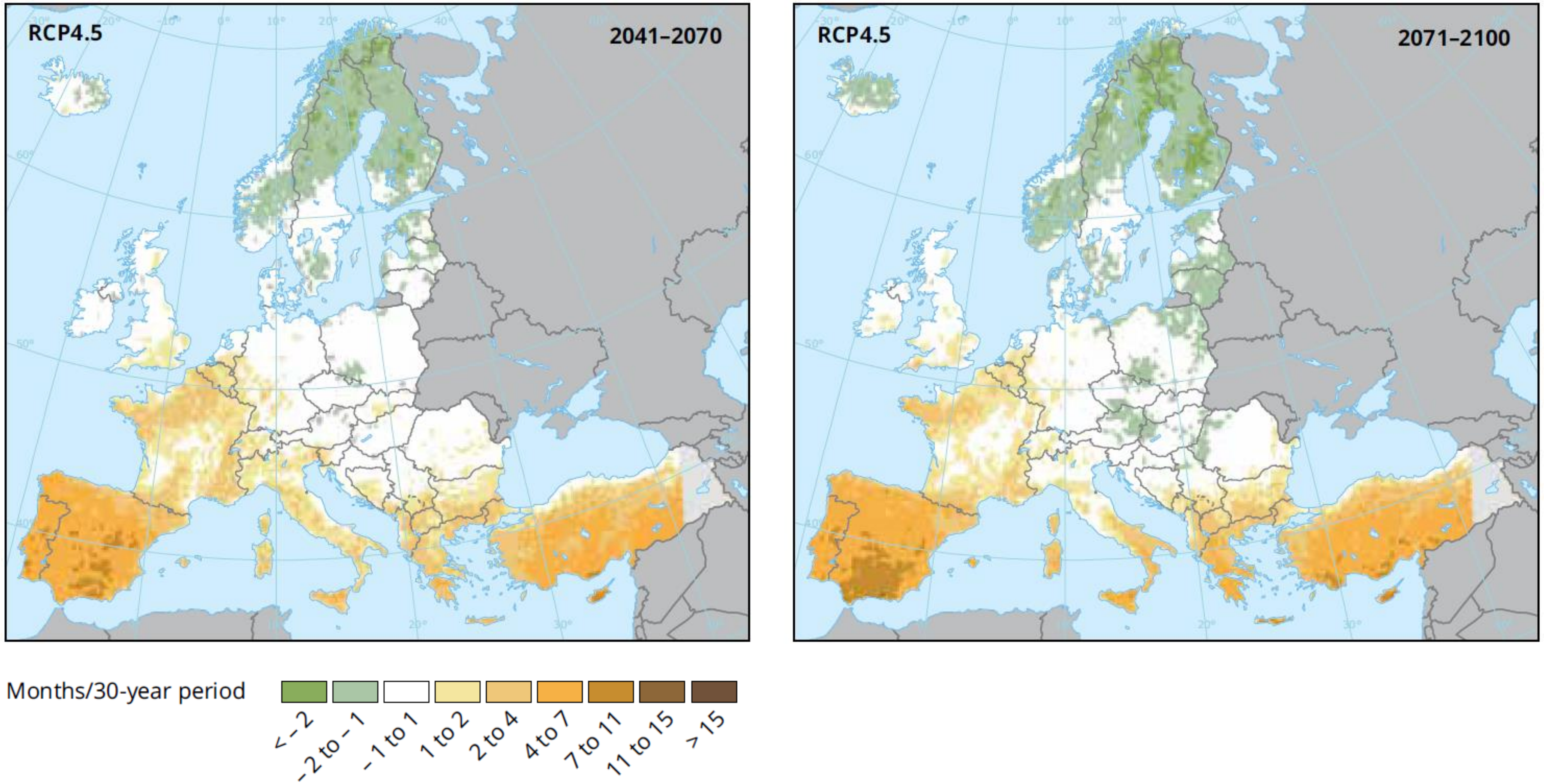


Projection until 2050s



EEA (2017)

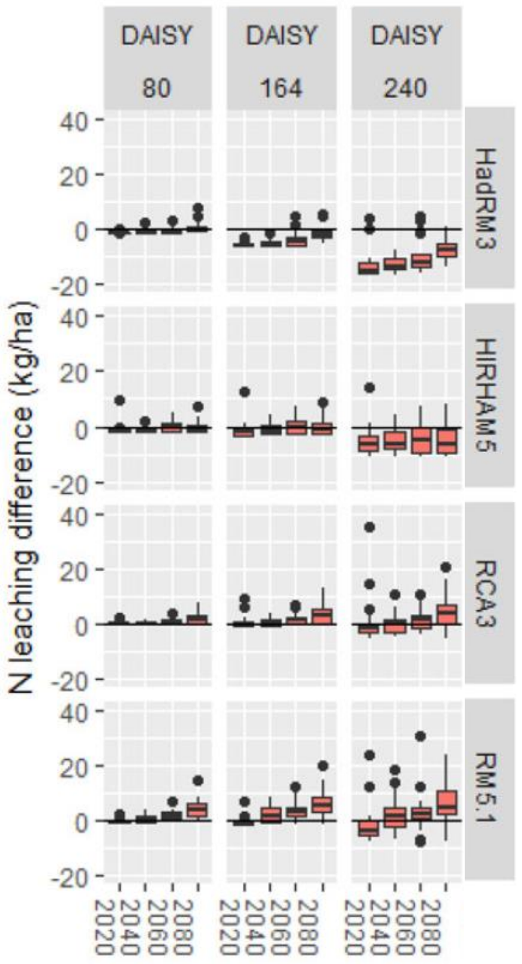
Ændring i frekvens af ekstrem tørke under moderat klimaændring



EEA (2017)

Klimaændringer øger miljøbelastningen

- Øget nitratudvaskning på grund af øget afstrømning og højere temperatur, der stimulerer mineralisering af jordens kvælstof
- Tab af kulstof i jorden som følge af øget mineralisering, der øger CO_2 udledninger og mindsker jordens frugtbarhed
- Øget risiko for sygdomme og skadedyr, med potentielt øget behov for pesticider på 10-20%



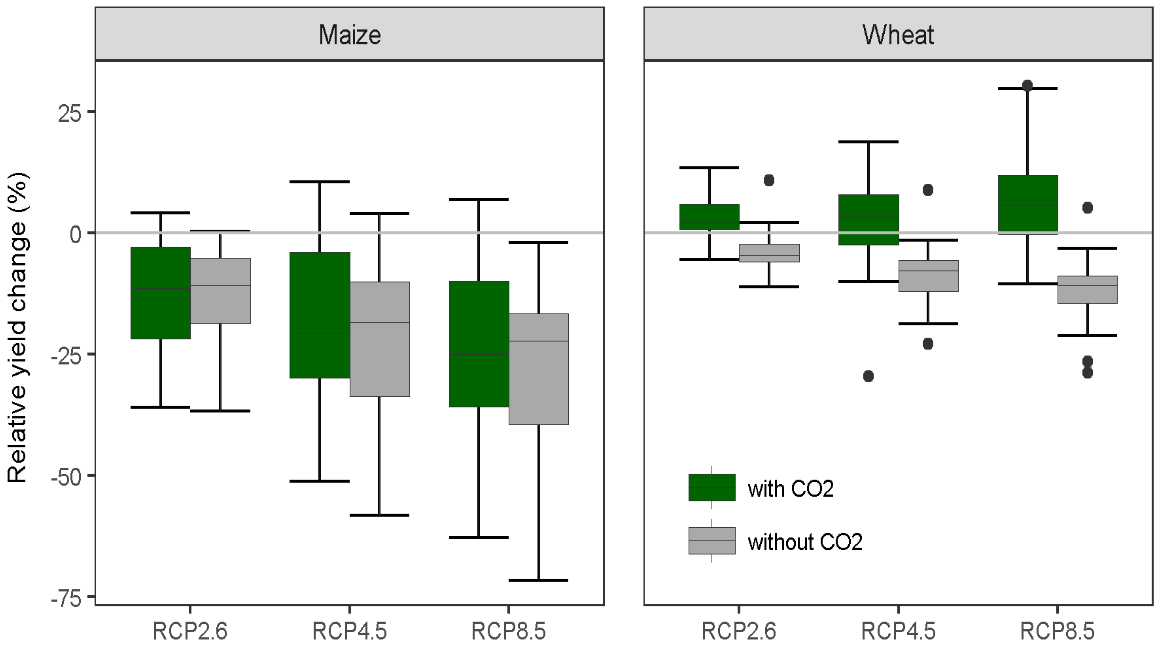
Ændring i nitratudvaskning i vinterhvede ved forskellig N-gødskning

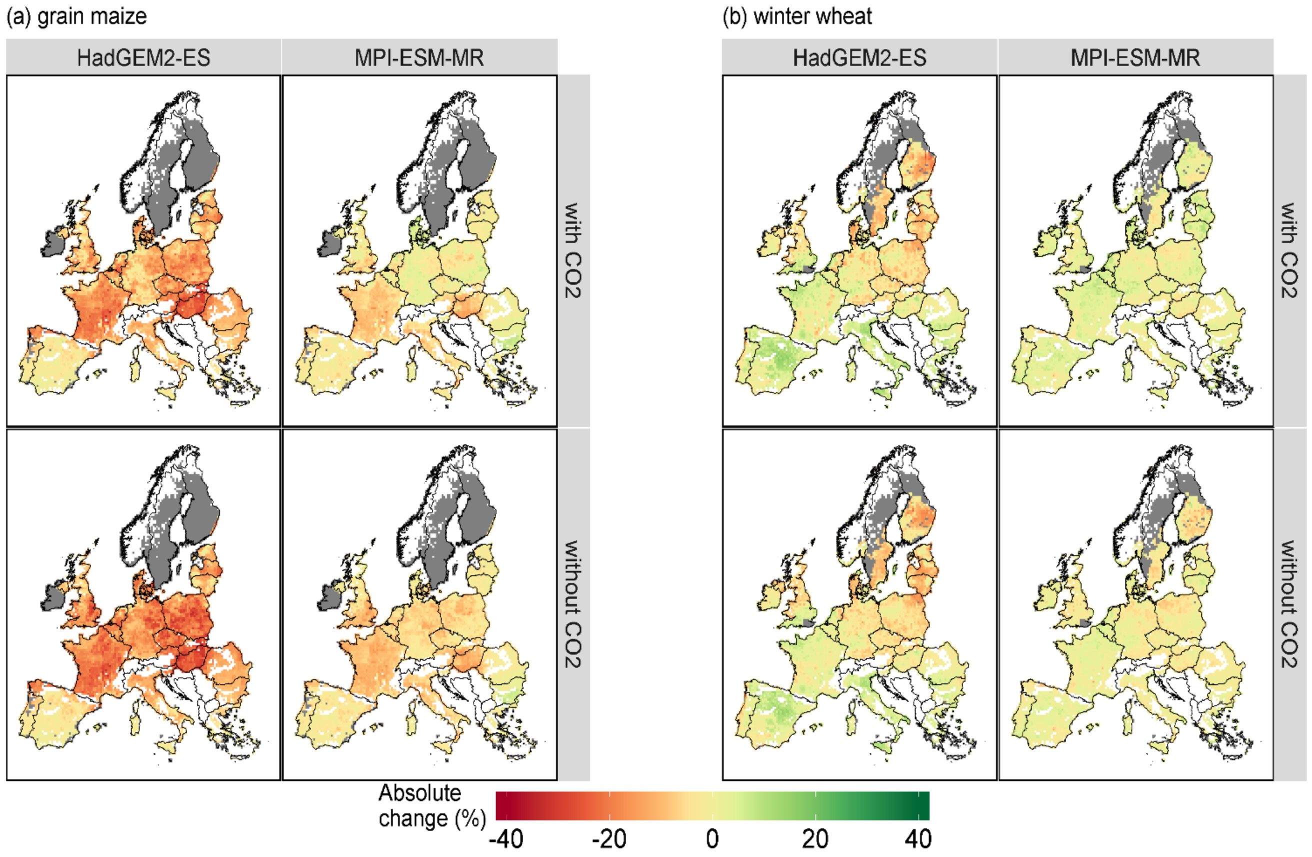
Öztürk et al. (2017)

Klimaændringer øger risiko for fødevareproduktionen

- Risiko i produktionssystemer og økosystemer er mest relateret til ekstreme hændelser og nye biologiske samspil
  - Hedebølger
  - Frost, sne, is
  - Tørke
  - Intens eller langvarig nedbør (oversvømmelser)
  - Storme
  - Sygdomme og skadedyr
- Klimaændringer øger
  - Frekvens af ekstreme hændelser
  - Variabilitet mellem årene

Tørke er den største trussel for korn under klimaændringer i Europa (2050s)

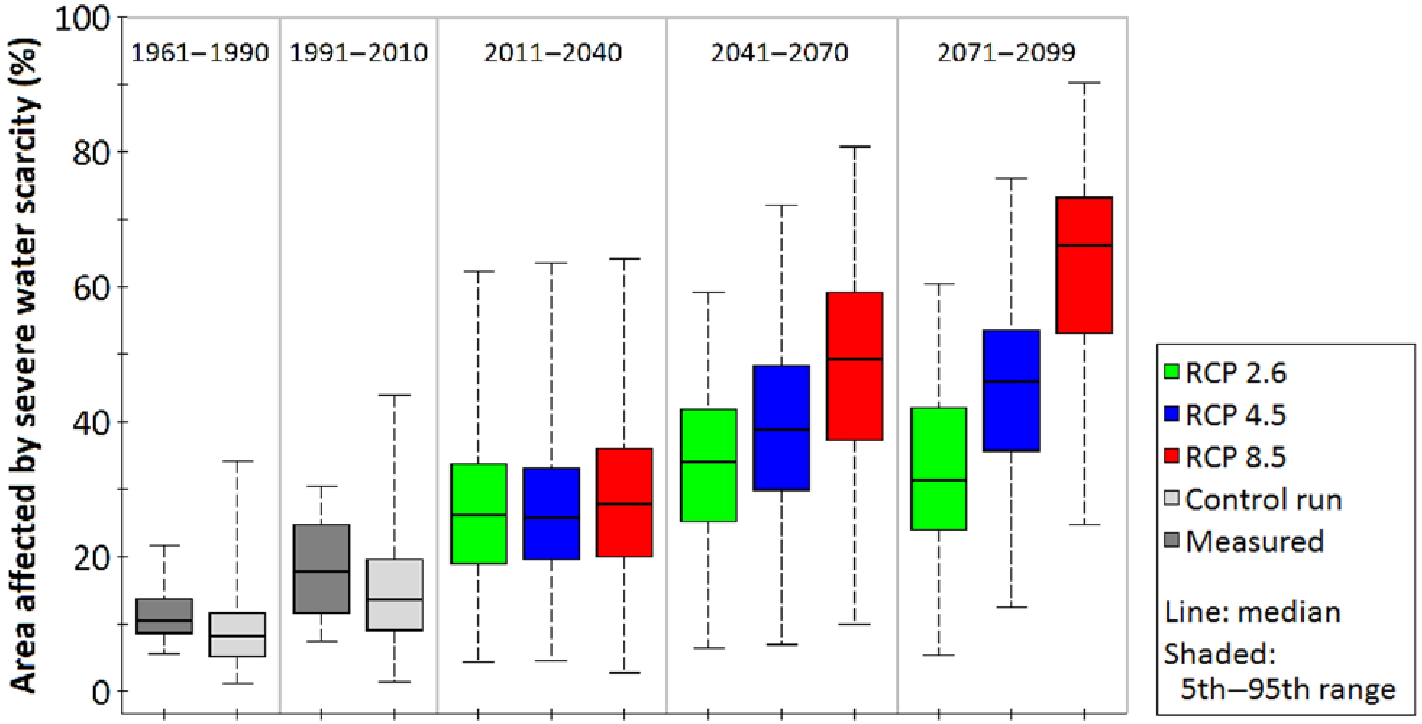




Webber et al. (2018) Nature Com. 9, 4249

Fremtidig alvorlig tørke i hvede

- Beregnet areal med alvorlig tørke for verdens hvedeareal over vækstsæsonen
- Arealet med alvorlig tørke er allerede steget med 50% sammelignet med 1961-1990
- Under moderat klimaændring vil arealet med alvorlig tørke fordobles i midten af århundredet.
- Stigningen i alvorlig tørke sker også i de hvedeeksportende lande – med konsekvenser for hvedeprisen.



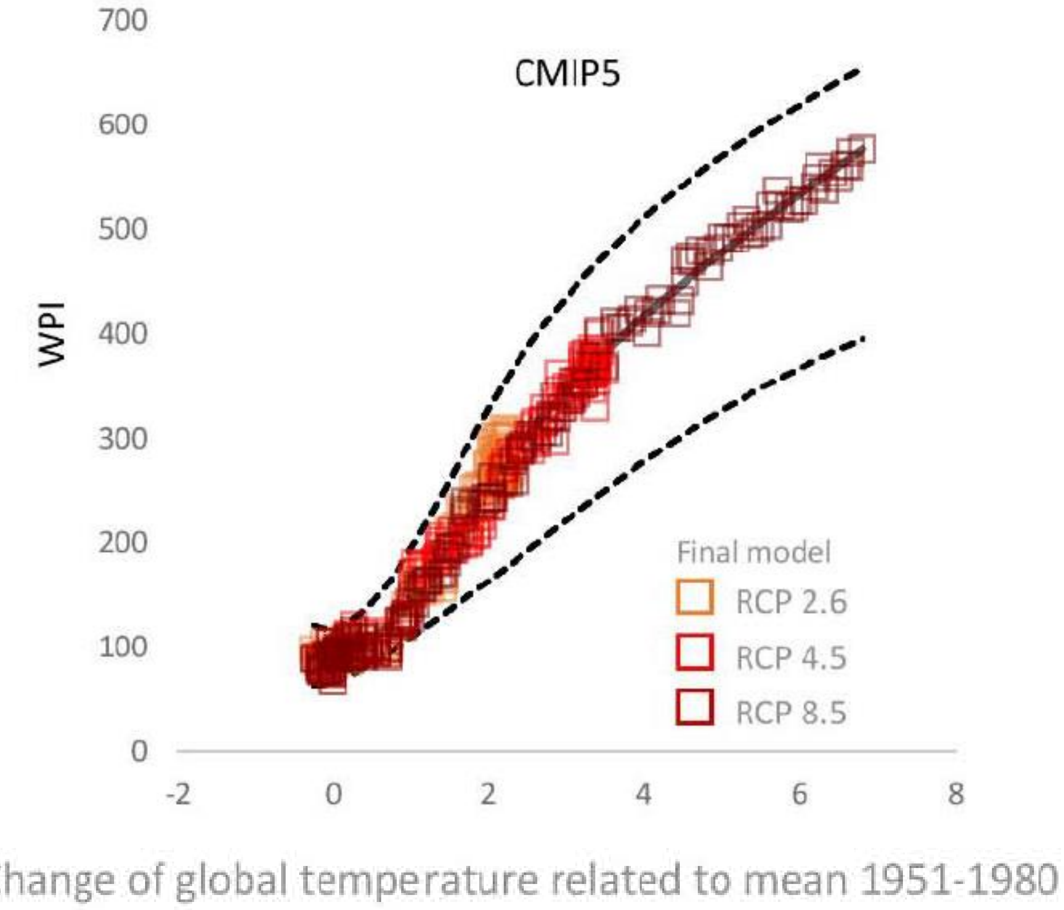
Trnka et al. (2019) Sci. Adv. 5, eaau2406

Fødevareproduktionen trues af klimaændringer

Forsyningsproblemer i 2023 (klimarelateret)
- Grønsager i foråret (tørke i Nordafrika)
- Olivenolie i efteråret (tørke i Spanien)
- Appelsiner (tørke i Californien)

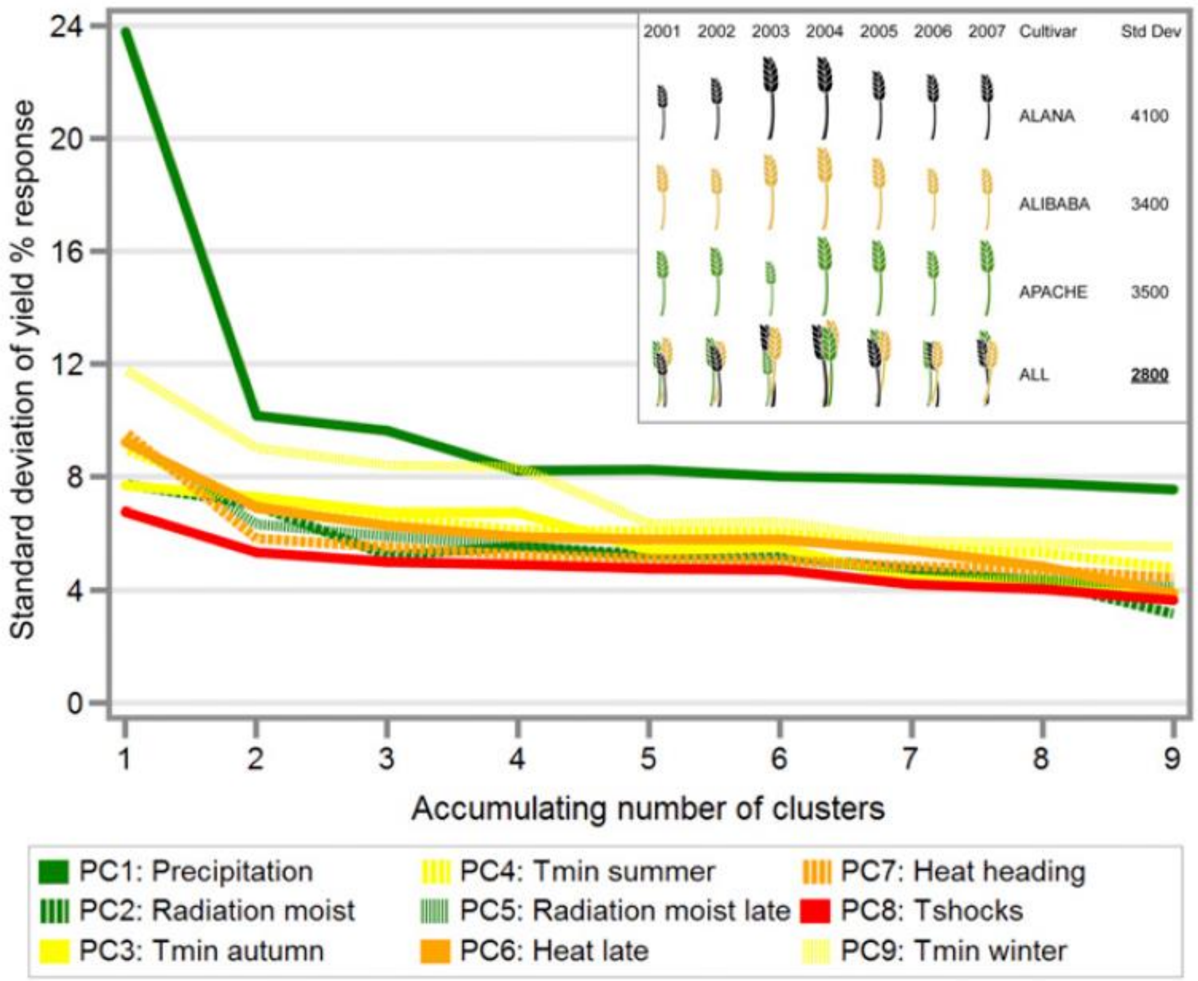
Forventede problemer med klima
- Korn, især hvede (tørke)
- Tomater (varme, tørke)
- Kaffe (varme)
- Kakao (varme)
- Humle (varme)

Kornpris med stigende global middeltemperatur



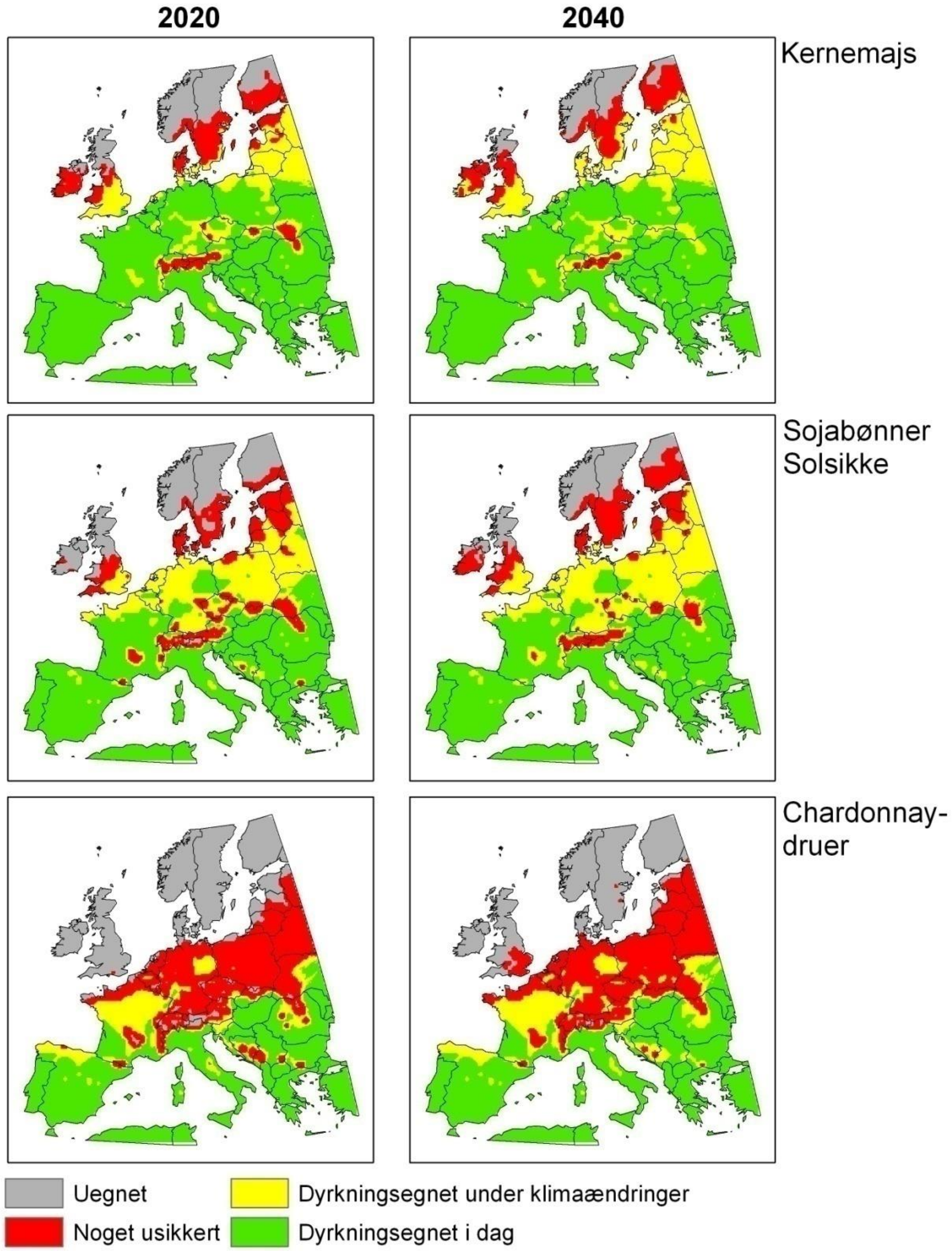
Resiliens – høj produktivitet og lav variabilitet

- Resiliens er evnen til at bevare kritiske systemfunktioner mod klimarelateret usikkerhed og variabilitet
- Resiliens kan opnås ved:
  - Bedre ressourceudnyttelse (vand, lys, næring)
  - Evne til at modstå forskellige ekstremer
- Inden for afgrøder varierer sorter i deres respons på variation i vejrforhold. Øget diversitet (sortsblandinger) blandt sorter kan sikre rimelige udbytter uanset vejrforhold.



Nye afgrøder

- Nye afgrøder er især afhængig af temperaturforhold
- Højere temperaturer øger afgrødernes udviklingshastighed – og afgrøder med større varmekrav kan modne af tidligere
- Det er dog meget begrænset hvilke nye varmekrævende afgrøder, der bliver aktuelle i Danmark
- Desuden kan dobbeltafgrøder blive aktuelle, fx
  - Vårsæd efter tidlig kløvergræsslæt
  - Høst af efterafgrøder efter korn



Fremtidens dyrkningssystemer skal opfylde mange funktioner

FUNKTION OG MANAGEMENT


Foto - Colourbox


Foto - Colourbox


Foto - Colourbox


AU Foto – Lars Kruse

Enårige afgrøder

- Mere biodiverse dyrkningssystemer, inkl. bælgplanter og blandinger
- Tidligere høst af korn og frø – forbedret etablering af efterafgrøder med mulighed for høst til bioraffinering (dobbeltafgrøder)

Foderafgrøder

- Græs-baseret foderproduktion baseret på blanding af flerårige arter

Flerårige dyrkningssystemer

- Nye produktive flerårige dyrkningssystemer (inkl. skovlandbrug)
- Integration med energiproduktion (inkl. solceller)

Management

- Nye gødskningssystemer (inkl. recirkulering af næringsstoffer)
- Præcisionslandbrug (sensorer, modeller and robotter)
- Planteforædling – fokus på resiliens, miljø/klima og effektivitet i forsyningskæden
- Bioraffineringsteknologier - upcycle biomasse fra hele landskabet
- Øge jordkulstof, flerårige afgrøder og biochar (integration med energi)

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Tilpasning af sorter til fremtidens klima

Birger Eriksen, Sejet Planteforædling

Planteforædling: klima og bæredygtighed

- **FØR:**
  - foredlingsmål: udbytte, resistens, kvalitet

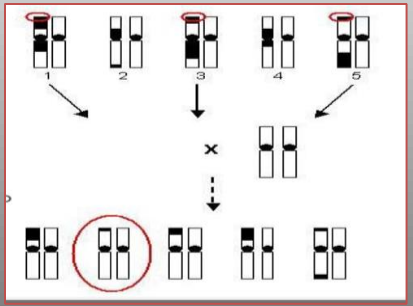
Planteforædling G2 (2. generation)

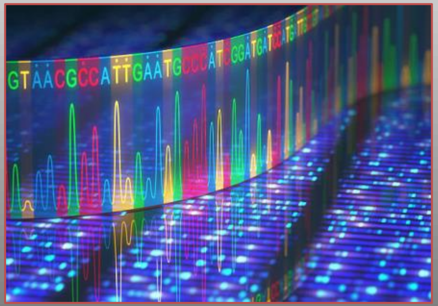
- **NU og fremover:**
  - foredlingsmål: udbytte, resistens, kvalitet

Planteforædling: bæredygtighed og klima

Sejet
plant breeding

- **INPUT-siden**
  fungicider, gødning: **Genetisk resistens som alternativ til kemi, bedre vand og næringsstof-udnyttelse**





Ny teknologi som DNA-markører, BIG DATA (genomisk selektion) og NGT (CRISPR)

- OUTPUT-siden
  udbytte/CO_2-footprint: Udbytte pr. hektar, udbyttestabilitet, design-sorter ift. industrianvendelse, BNI

”a numbers game”

Eksempel: intakt udbytte på trods af 20 års undergødskning og udsultning af jorden

Kornforædlingsfirmaer i Europa

Sejet
planteforædling

CO_2-footprint

Vinterhvede 3.000 kg CO_2-ækvivalenter pr. hektar

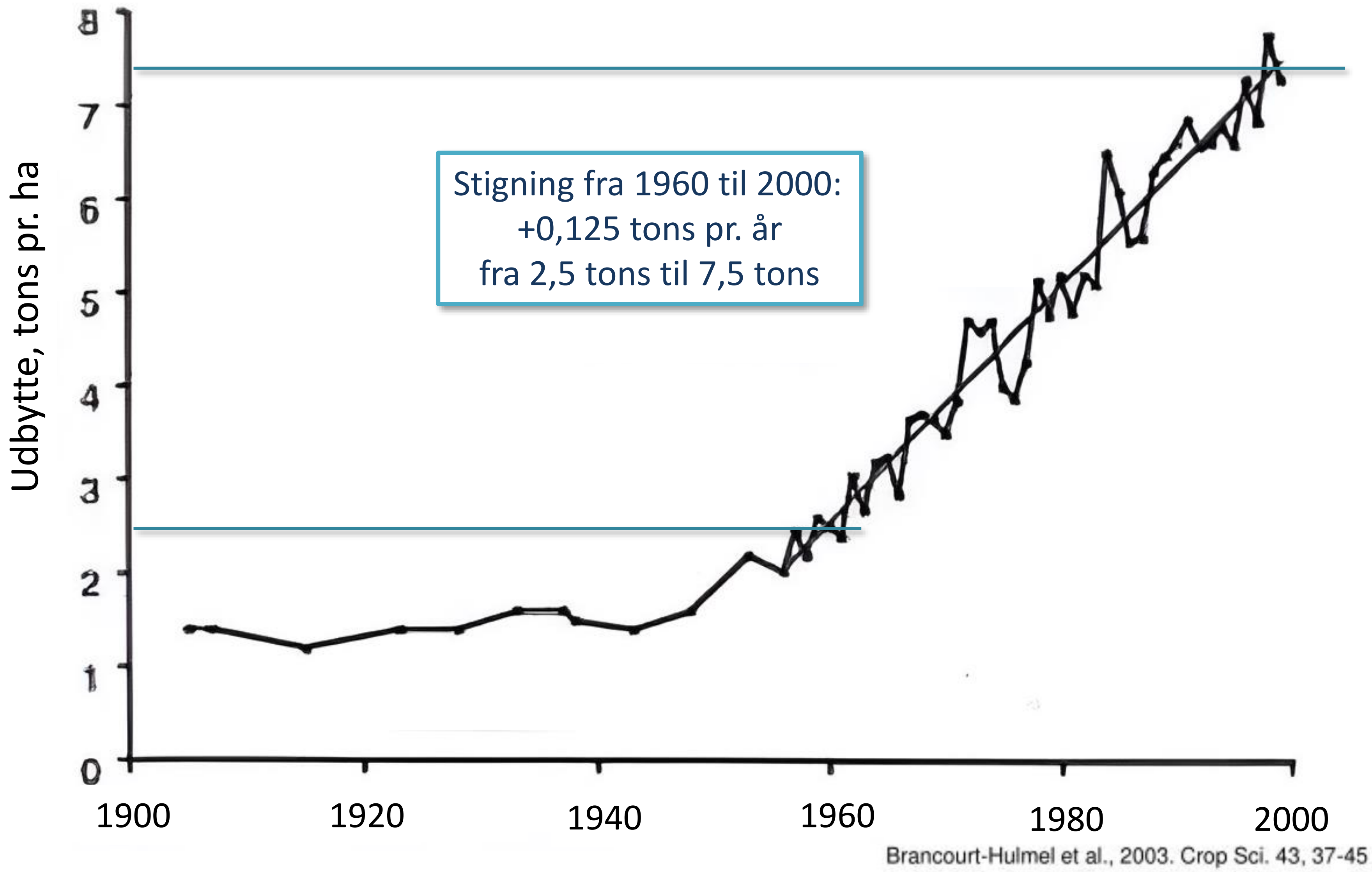
10 tons pr. hektar = 0,300 kg CO_2-ækvivalenter **pr. kg korn**

8 tons pr. hektar = 0,375 kg CO_2-ækvivalenter **pr. kg korn**

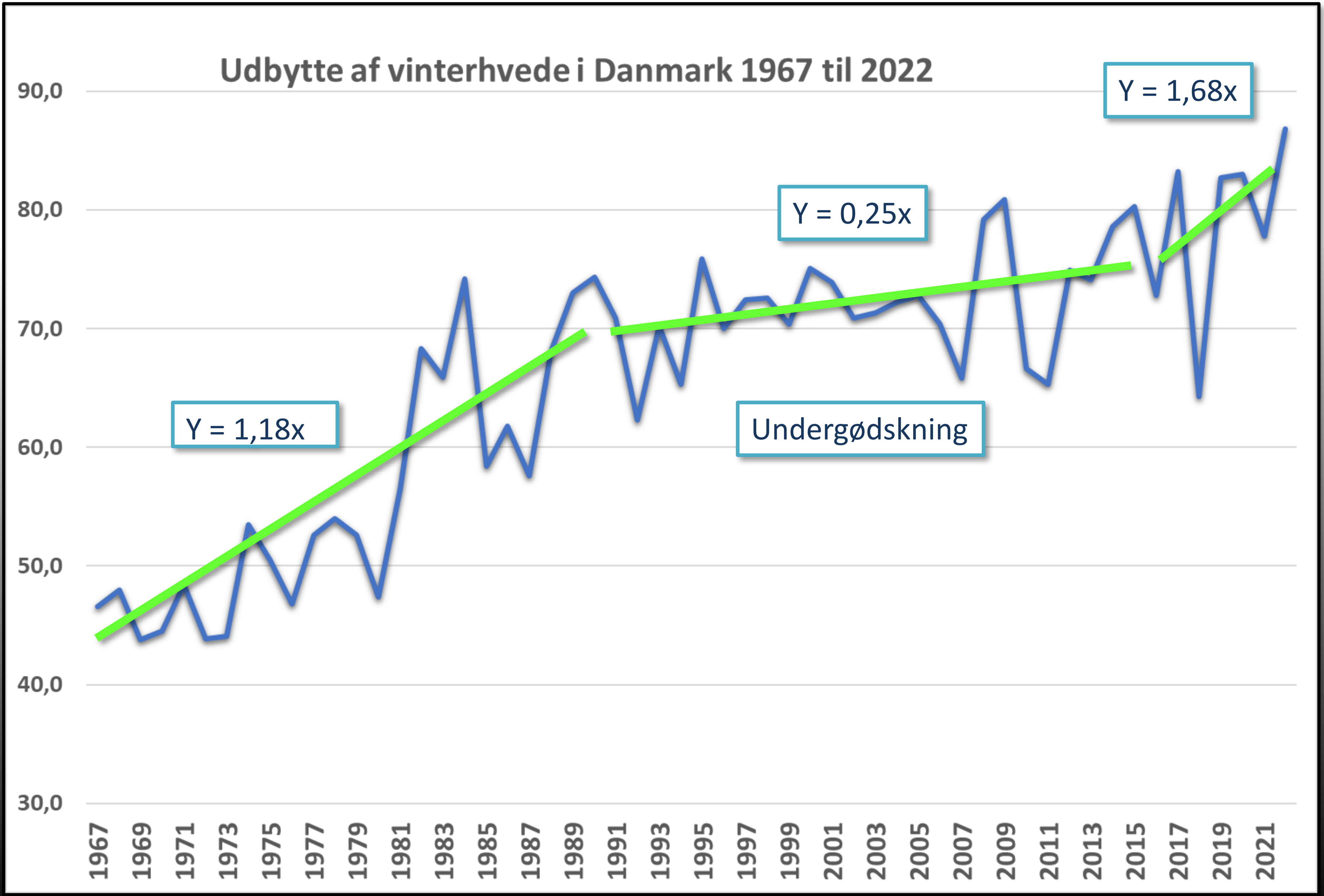
↓ 25% højere

YIELD is KING

Udvikling i hvedeudbytter i Frankrig fra 1900 til 2000



Sejet plant breeding



Sejet plant breeding

Forædlings-relateret udbyttestigning (pct) i perioden 2000-2019

Figure 2.23: Annual plant breeding-induced yield growth rates of arable farming in the EU and selected member states between 2000 and 2019 (in percent)

Crop/Region	EU	DE	FR	IT	ES	UK
Wheat	0.95	0.61	0.69	1.04	0.57	0.86
Corn	1.43	1.10	1.06	0.64	1.09	1.03
Other cereals	1.07	1.01	0.78	0.80	0.36	0.94
OSR	0.98	0.82	1.47	3.58	1.66	1.77
Sunflower seeds	2.38	1.10	1.29	0.87	0.84	N.A.
Other oilseeds	0.84	2.46	1.13	0.28	0.85	3.05
Sugar beets	1.51	1.39	1.57	1.35	1.30	1.68
Potatoes	1.33	0.66	0.65	0.70	0.77	0.84
Pulses	0.76	0.91	0.99	1.14	1.23	0.84
Green maize	1.39	0.73	1.36	0.30	1.63	1.52

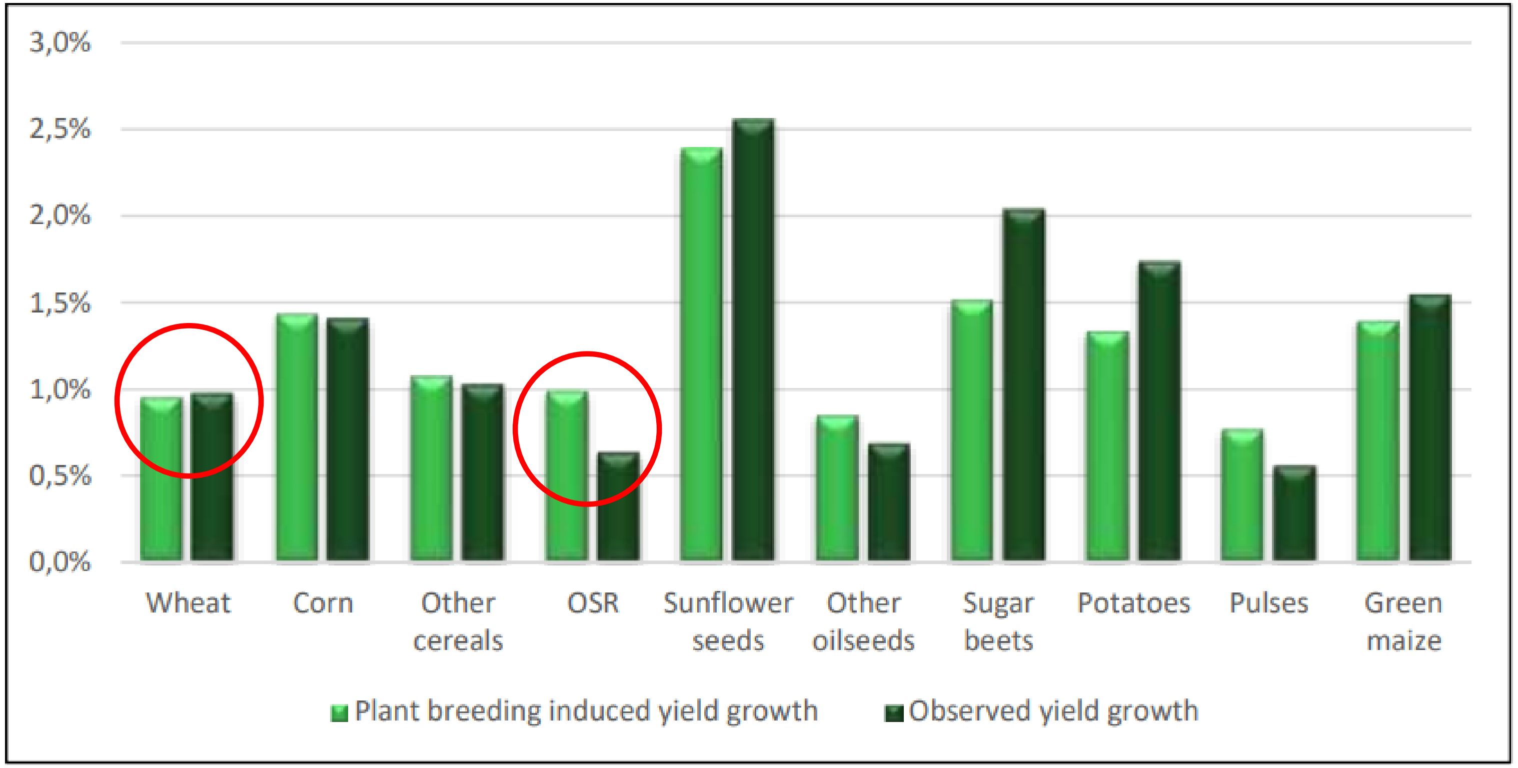
Source: Own calculations and figure.

Steffen Noleppa, HFFA Research Gmbh
The socio-economic and environmental value of plant breeding in the EU
May 17, 2021

Forædlings-relateret udbyttestigning ift. aktuelt udbytte i perioden 2000-2019

Sejet plant breeding

Figure 2.24: Annual plant breeding-induced yield growth and annual observed yield growth of arable farming in the EU between 2000 and 2019

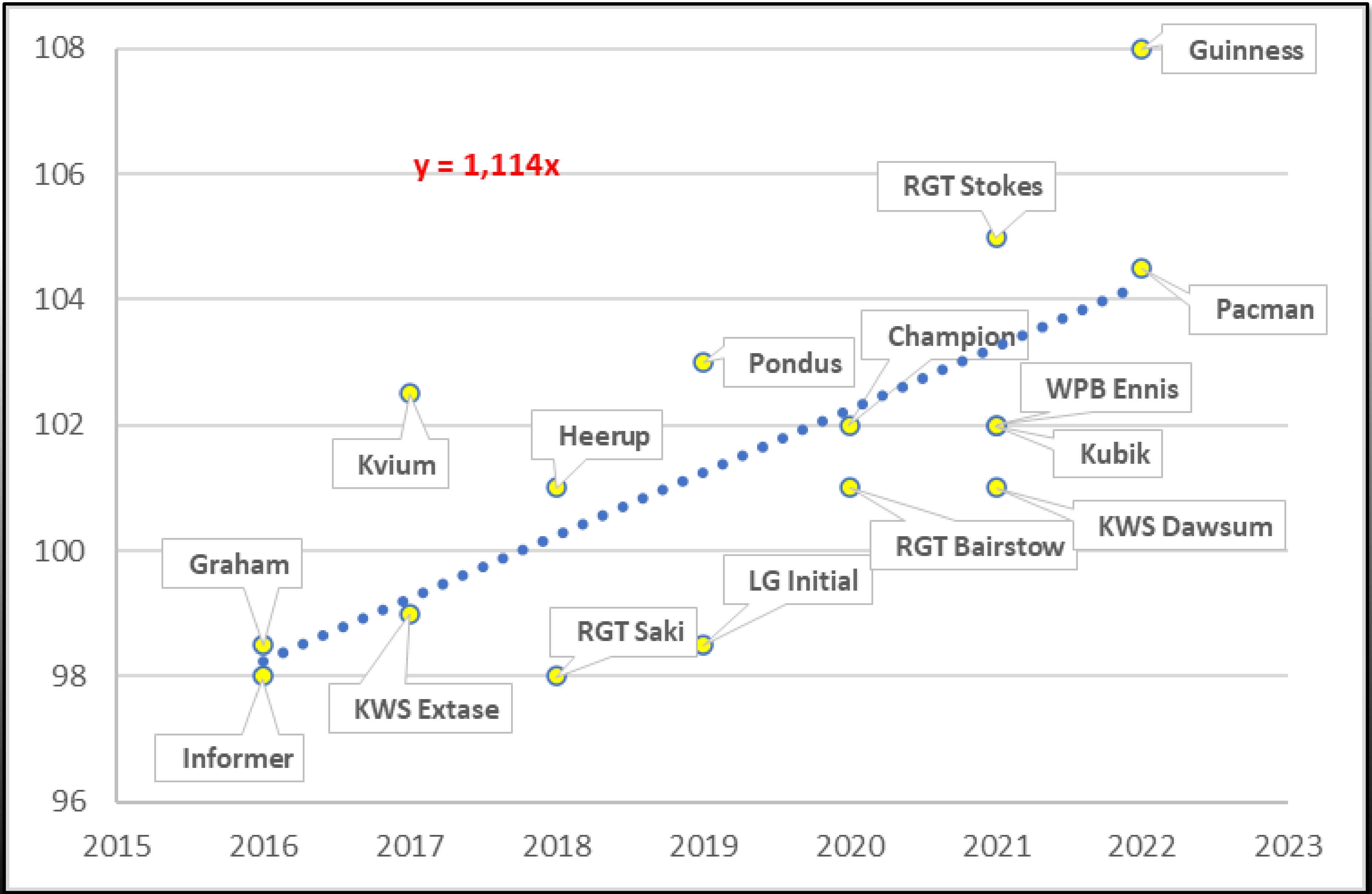


Source: Own calculations and figure.

Steffen Noleppa, HFFA Research Gmbh
The socio-economic and environmental value of plant breeding in the EU
May 17, 2021

Vinterhvede udbytte ift. registreringsår, Landsforsøgene 2021-2022

Sejet plant breeding



For Guinness og Pacman er 2021-udbytte fra Statsforsøg

Sejet plant breeding

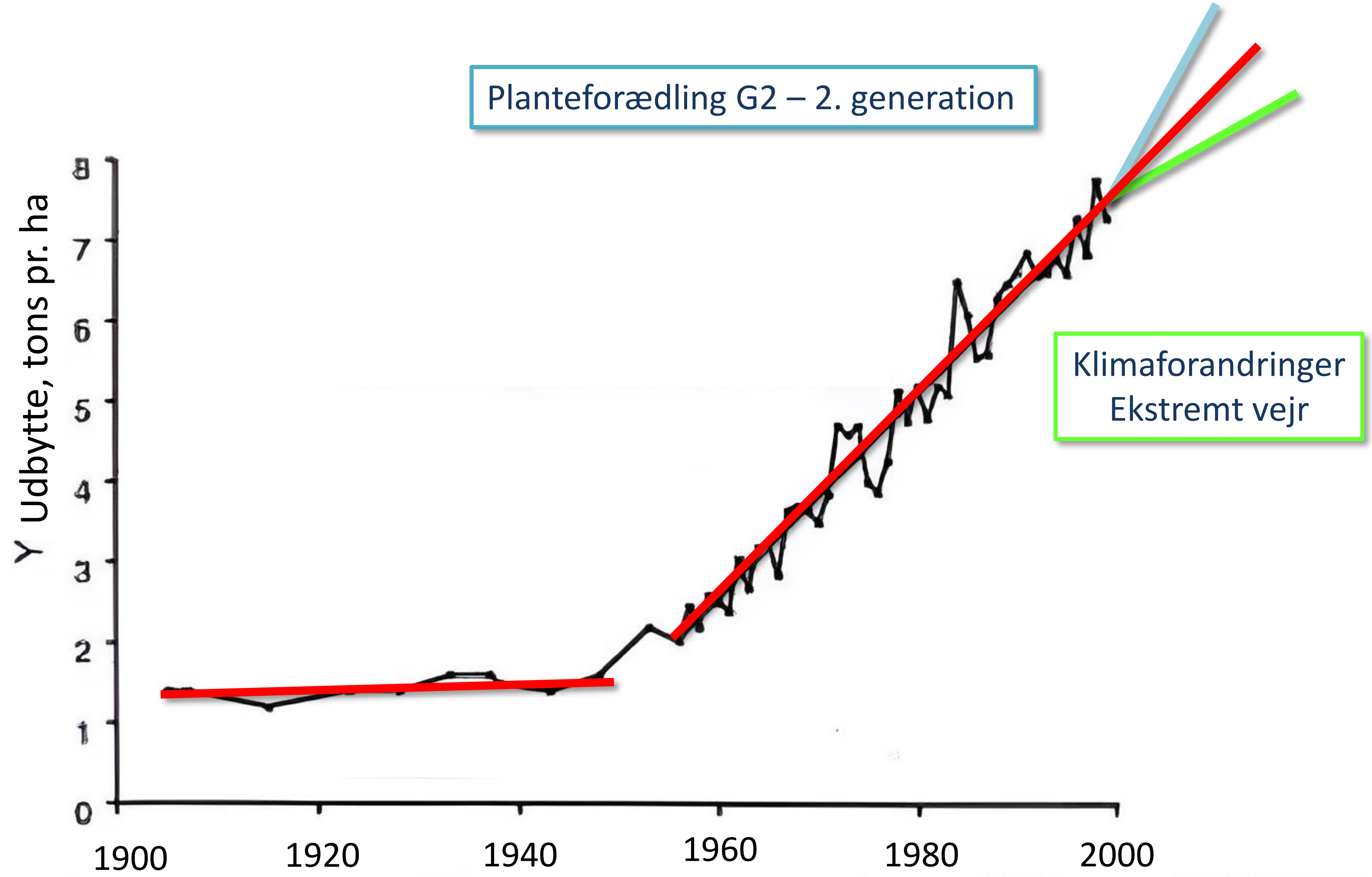
Top 5 vinterhvede-sorter i Danmark gennem 15 år

2022		2021		2020		2019		2018		2017		2016		2015	
Pondus	🇩🇰	Informer		Informer		Benchmark	🇩🇰	Benchmark	🇩🇰	Torp	🇩🇰	Torp	🇩🇰	Mariboss	🇩🇰
Informer		KWS Extase		KWS Extase		Sheriff	🇩🇰	Torp	🇩🇰	Benchmark	🇩🇰	Mariboss	🇩🇰	KWS Dacanto	
Heerup	🇩🇰	Kvium	🇩🇰	Kvium	🇩🇰	Kalmar	🇩🇰	Sheriff	🇩🇰	Pistoria	🇩🇰	KWS Dacanto		Hereford	🇩🇰
Kvium	🇩🇰	Heerup	🇩🇰	Heerup	🇩🇰	Torp	🇩🇰	Kalmar	🇩🇰	KWS Lili		Hereford	🇩🇰	Jensen	🇩🇰
KWS Extase		LG Skyscraper		LG Skyscraper		Informer		KWS Lili		KWS Dacanto		Pistoria	🇩🇰	KWS Cleveland	

2014		2013		2012		2011		2010		2009		2008		2007	
Mariboss	🇩🇰	Mariboss	🇩🇰	Mariboss	🇩🇰	Hereford	🇩🇰	Hereford	🇩🇰	Frument	🇩🇰	Ambition	🇩🇰	Smuggler	
Jensen	🇩🇰	Jensen	🇩🇰	Jensen	🇩🇰	Mariboss	🇩🇰	Frument	🇩🇰	Ambition	🇩🇰	Smuggler		Skalmeje	
KWS Dacanto		Hereford	🇩🇰	Hereford	🇩🇰	Frument	🇩🇰	Ambition	🇩🇰	Hereford	🇩🇰	Skalmeje		Robigus	
Hereford	🇩🇰	KWS Dacanto		KWS Dacanto		Tuareg		Oakley		Smuggler		Frument		Samyl	🇩🇰
KWS Cleveland		Tuareg		Tuareg		Tabasco		Tuareg		Audi	🇩🇰	Opus		Opus	

Sejet plant breeding

Udvikling i hvedeudbytter i Frankrig fra 1900 til 2000



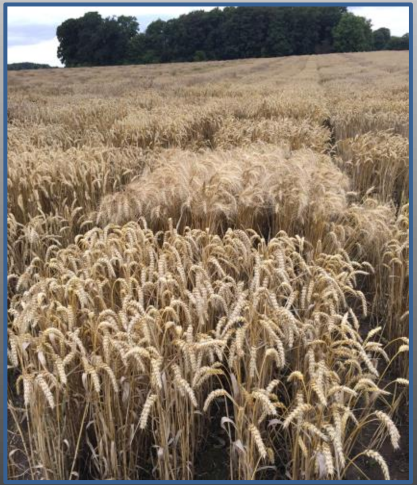
Brancourt-Hulmel et al., 2003. Crop Sci. 43, 37-45

Planteforædling G2 – 2. generation

Sejet plant breeding

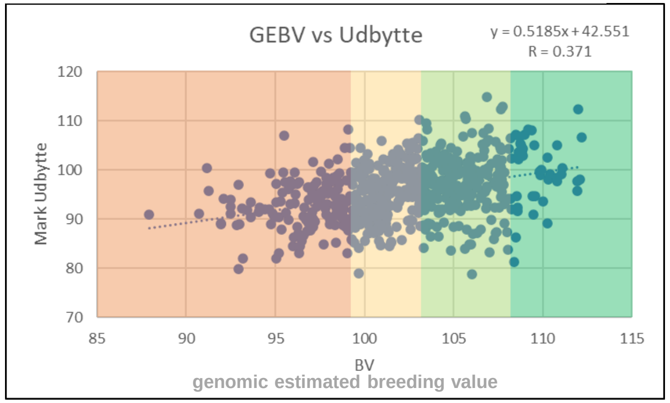
- Business as usual (toptunet selektions-setup i mark og lab.) plus:
- **Genomisk selektion og prædiktion af forædlingsværdier**
- **Berigede pop. vha. DNA-markør teknologi**
- **Stacking af gener vha. DNA-markør teknologi**
- **Mutationsforædling vha. CRISPR teknologi – nye egenskaber**
- Kombination af ovenstående – **DEN PERFEKTE SORT**
- **Reduceret lattergas emission – Biologisk Nitrifikations Inhibering**

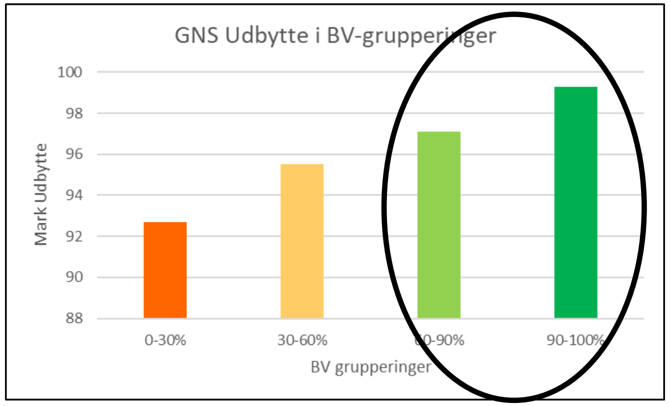
Numbers game



20.000 per. year

Genomic selection

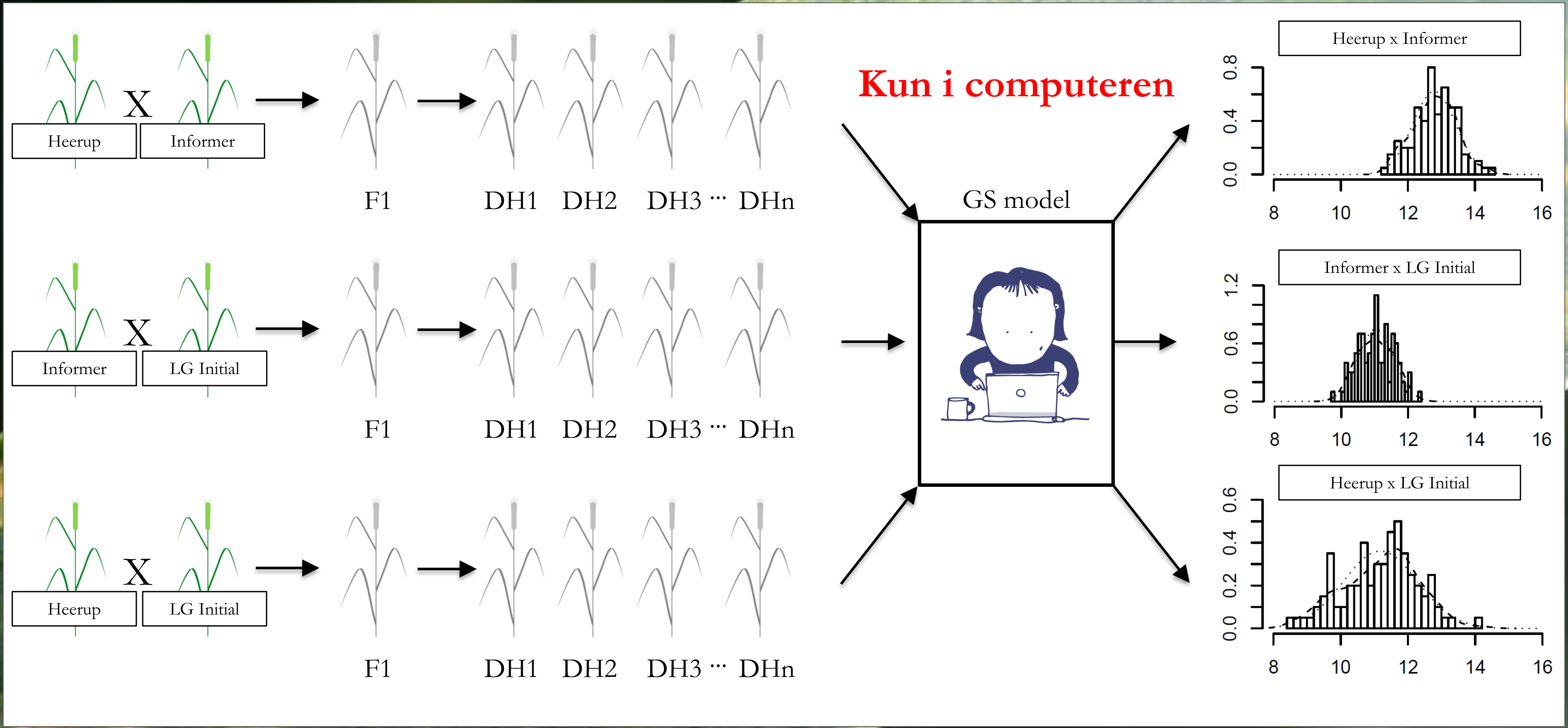




Winnie FÜCHTBAUER

10 per. year

Specifik kombination prediktion

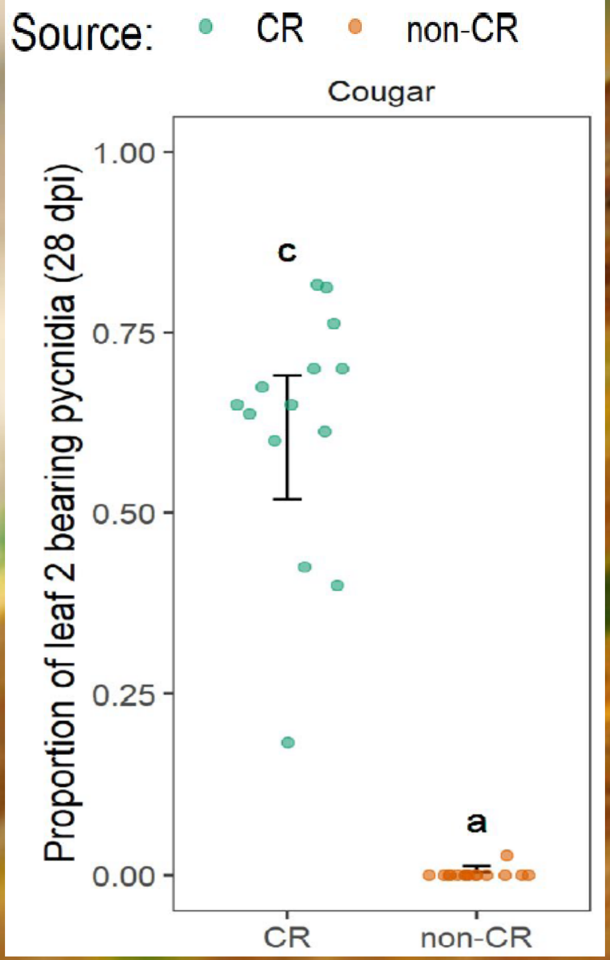


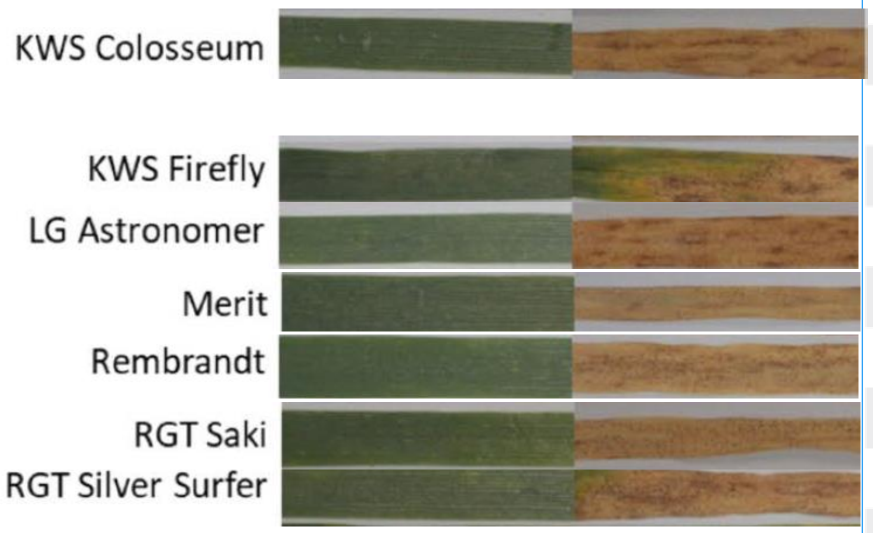
Stacking af gener

Observationsparceller Septoria dækning(%) 2022	
KWS Firefly	23
RGT Saki	18
SY Insitor	16
Graham	14
WPB Ennis	14
Champion	13
KWS Dawsum	12
LG Skyscraper	12
Kubik	10
KWS Colosseum	10
SY Volley	10
Mascula	9
Rembrandt	9
Guinness	8
RGT Bairstow	8
Bright	7
Kask	7
Kvium	7
Pacman	7
Shaun	7
Informer	6
SY Revolution	6
KWS Danicum	5
LG Initial	5
RGT Stokes	5
KWS Extase	5
KWS Brise	5
Heerup	4
SU Fiete	3
Pondus	3

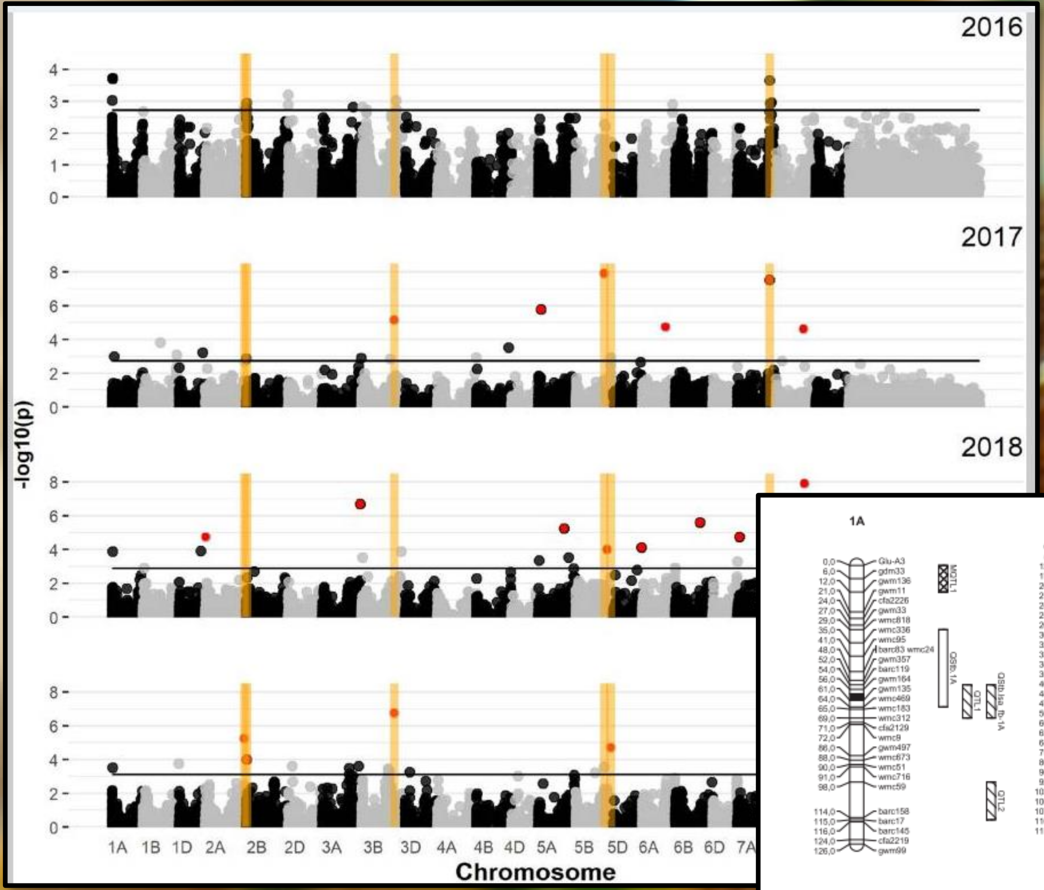
Septoria resistente sorter, men hvad er baggrunden ?

Nedbrud af Cougar sepetoria-resistens først opstået i Irland i 2020





Cultivar	Pedigree
Cougar	Tuscan × Robigus
KWS Lumos	Cordiale × Dover
Cadenza[c]	Axona × Tonic
Cellule	Nogal × Almirante
J.B. Diego	3351b1 × Stru2374
KWS Colosseum	Cougar × Beluga
KWS Extase	Boisseau × Solheio
KWS Firefly	Cougar × KWS Rowan
LG Astronomer	(Cougar × Leeds) × Brittania
Merit	Cougar × Brittania
Rembrandt	Cougar × Kerrin
RGT Saki	Cougar × KWS Santiago
RGT Silversufer	Cougar × Relay
SY Graham	Premio × Expert



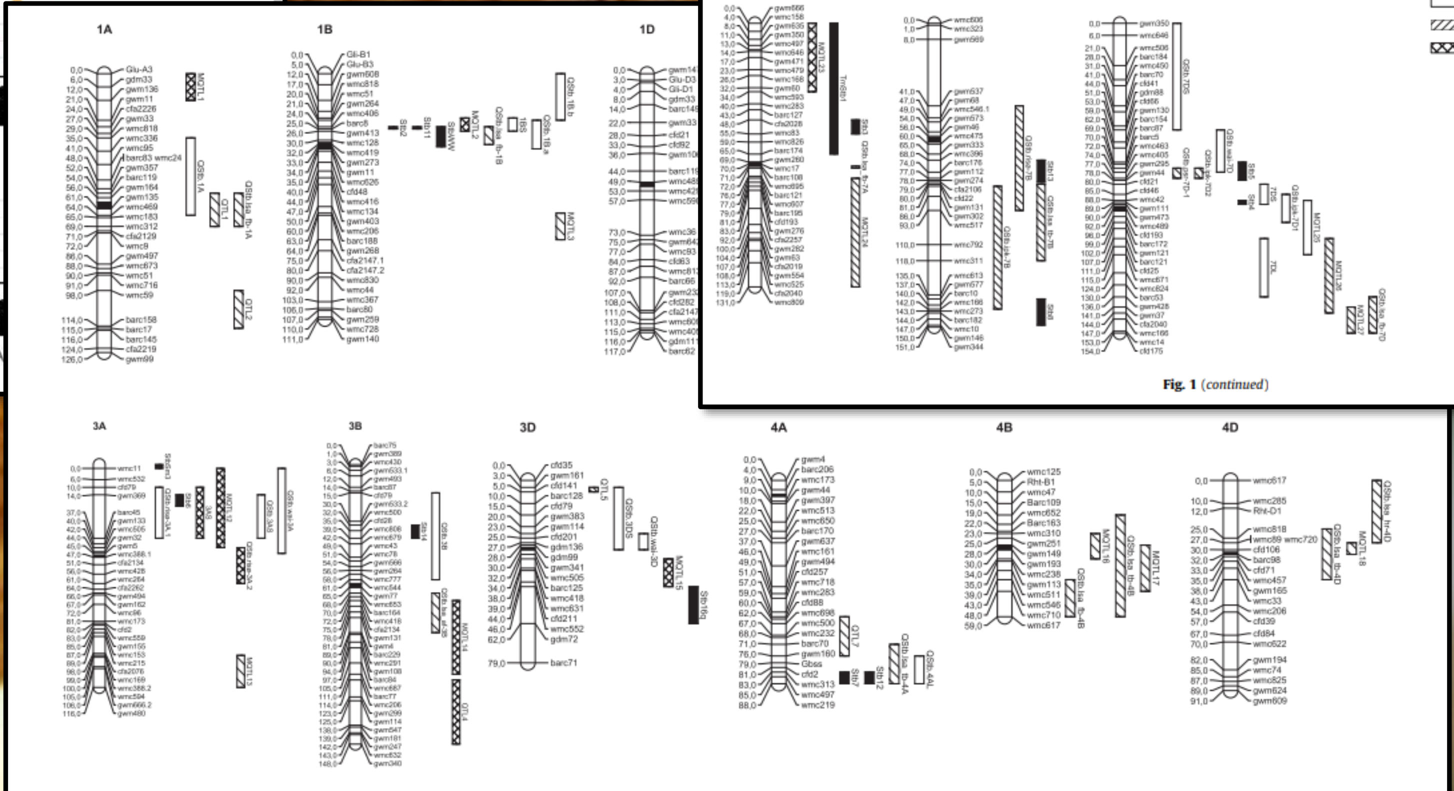


Fig. 1. Location in the wheat genome of major genes, QTL and meta-QTL involved in resistance to *Septoria tritici* blotch. Loci have been projected on the simplified SSR consensus map of Somers et al. (2004). Five QTL from Table S1 were not included in the map due to a lack of shared markers between the original paper and the consensus map. Solid bars represent major genes (see Section 1 and Table 1) and other bars patterns indicate QTL identified at different plant growth stages.

J.K.M. Brown et al. / Fungal Genetics and Biology 79 (2015) 33–41 35

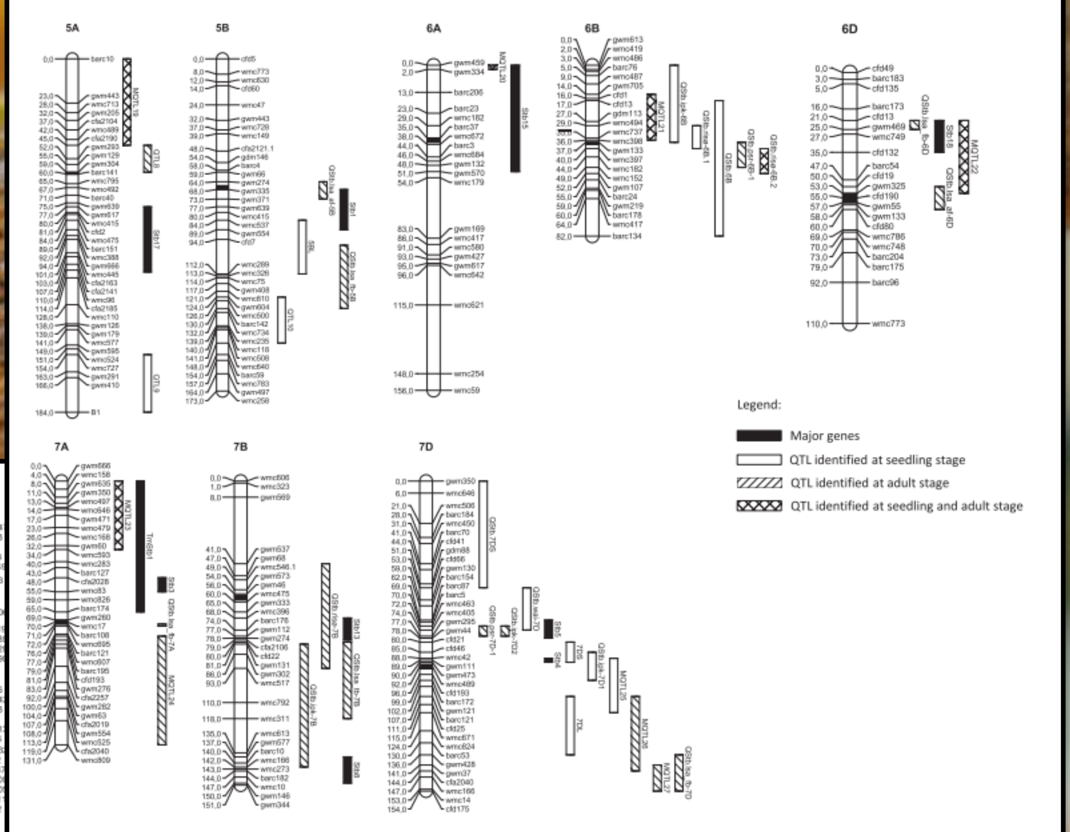
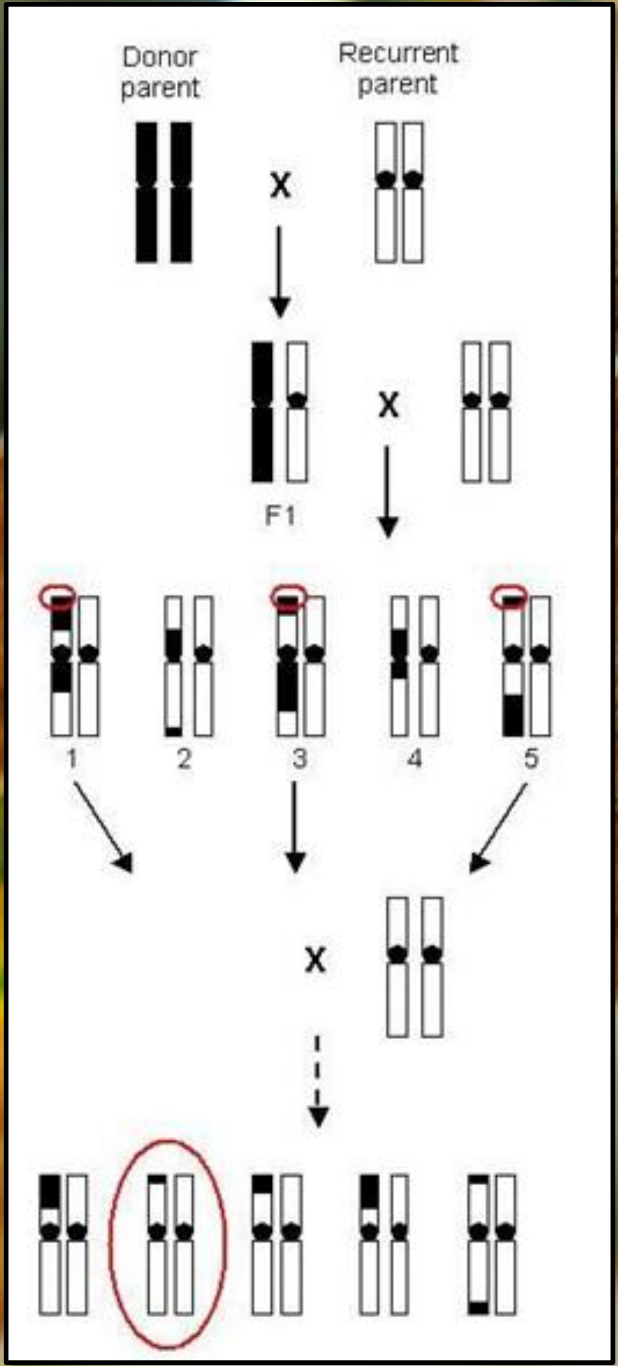
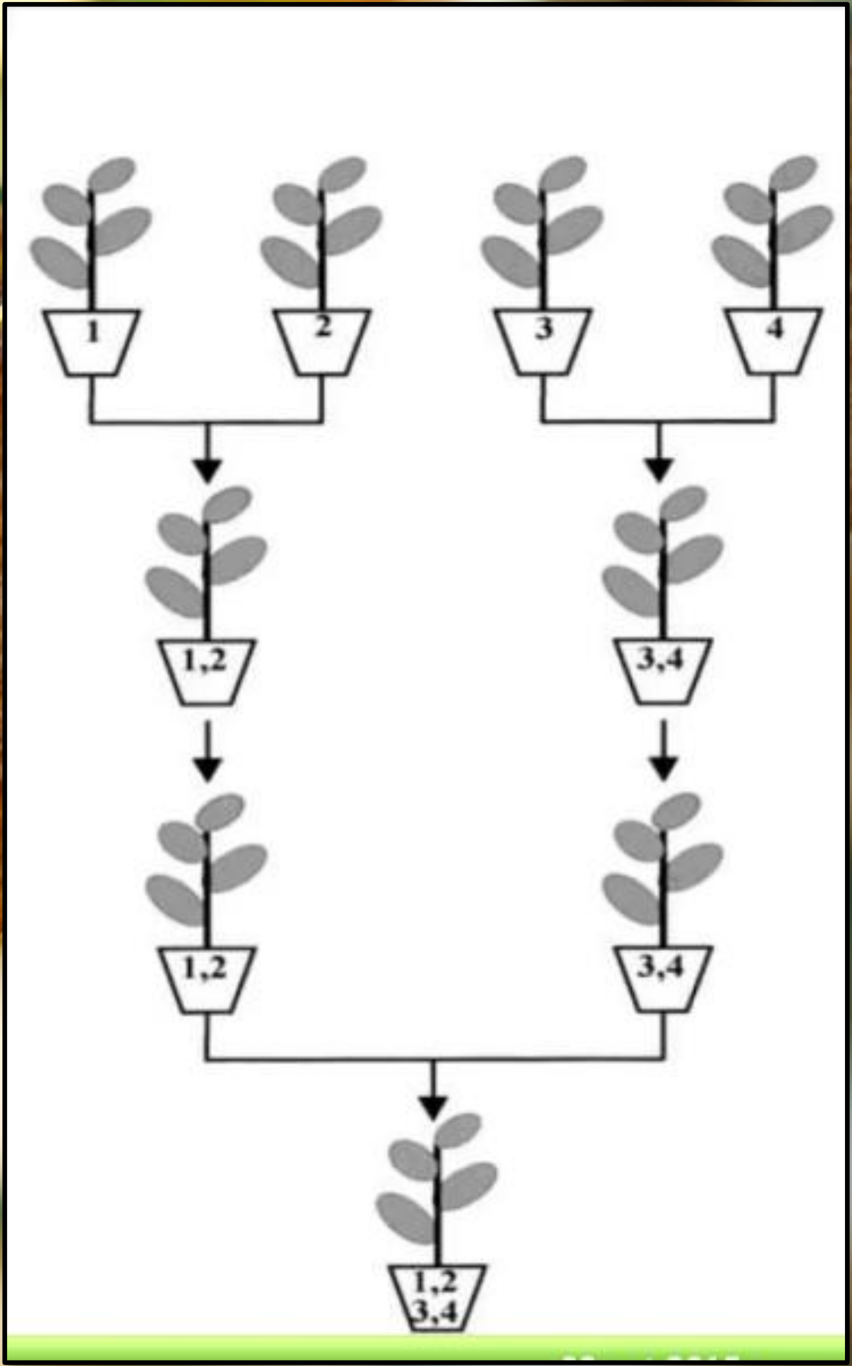


Fig. 1 (continued)


Donor parent
Recurrent parent
X
F1
X
1
2
3
4
5
X


1
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1,2
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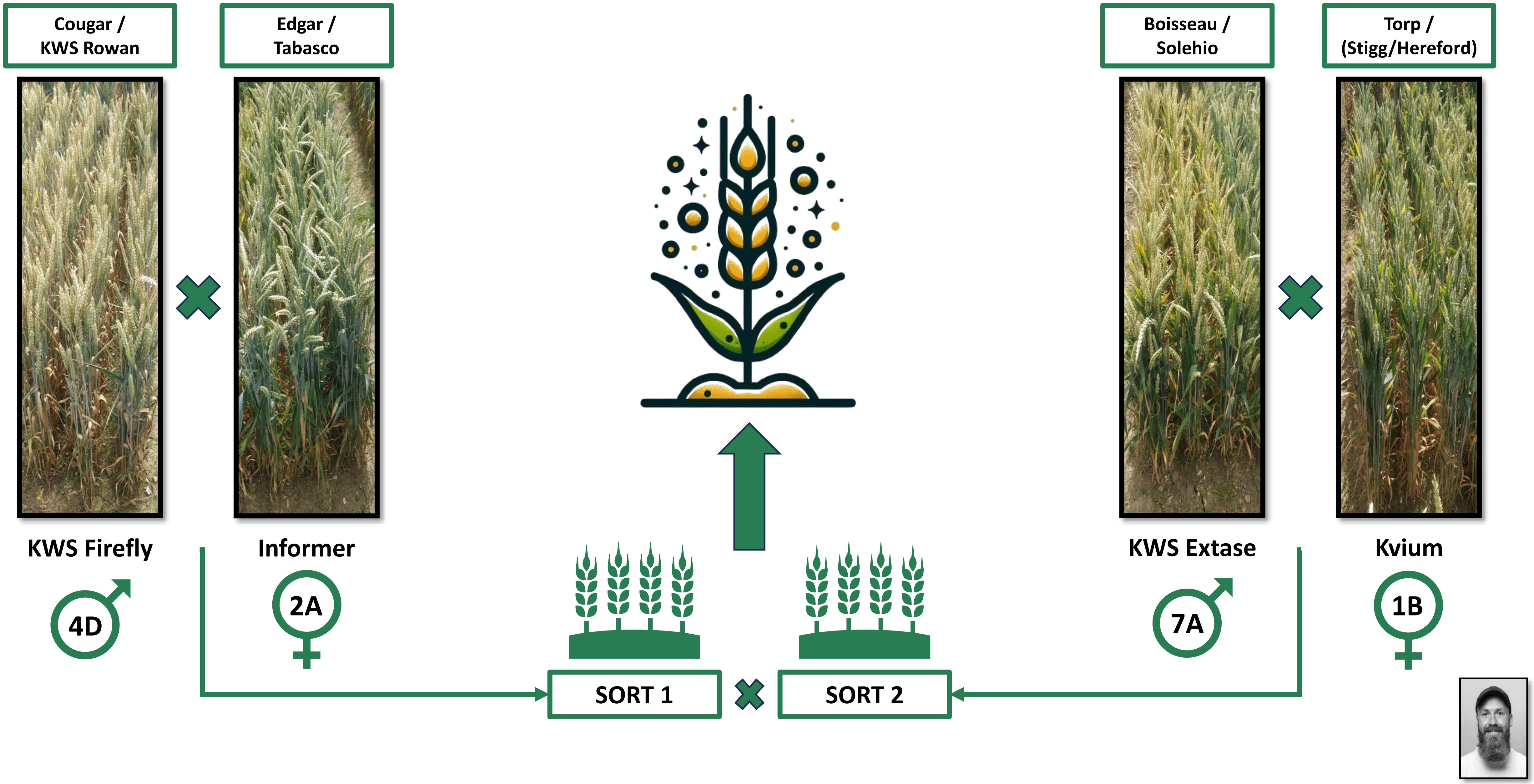
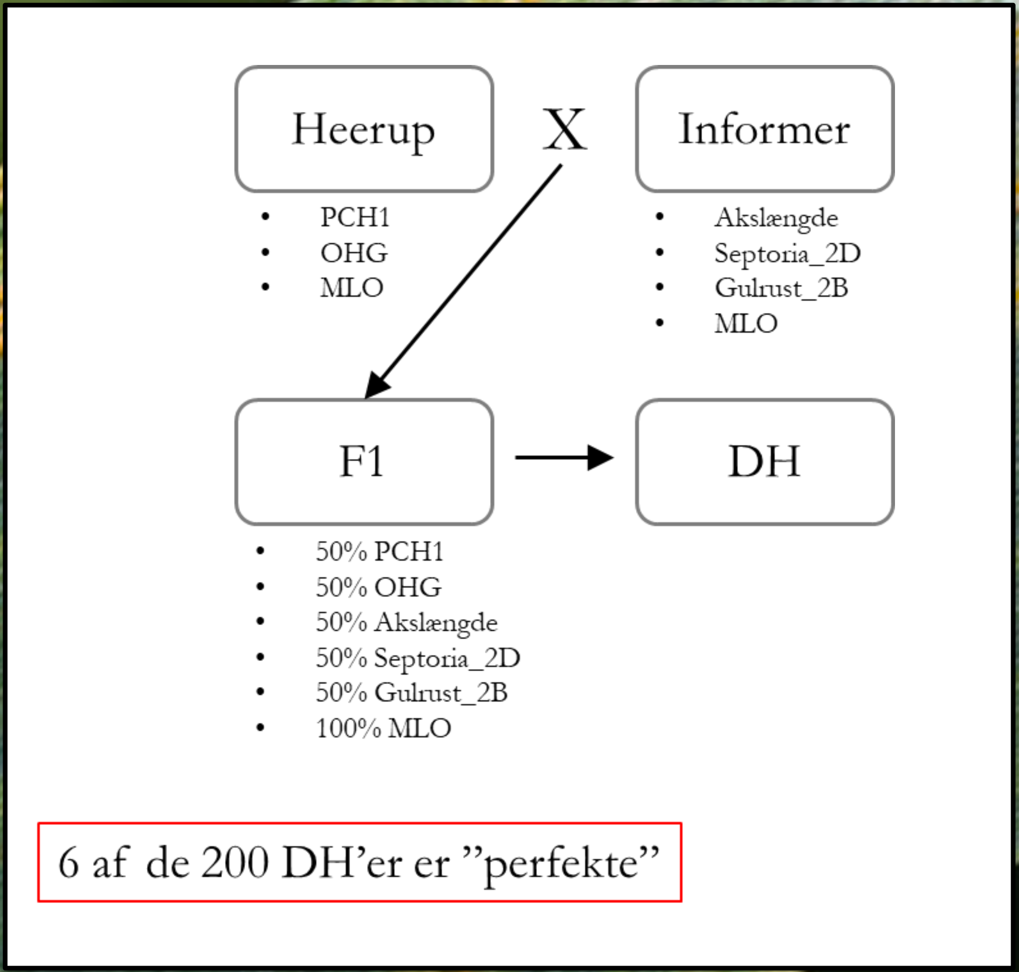
1,2
3,4



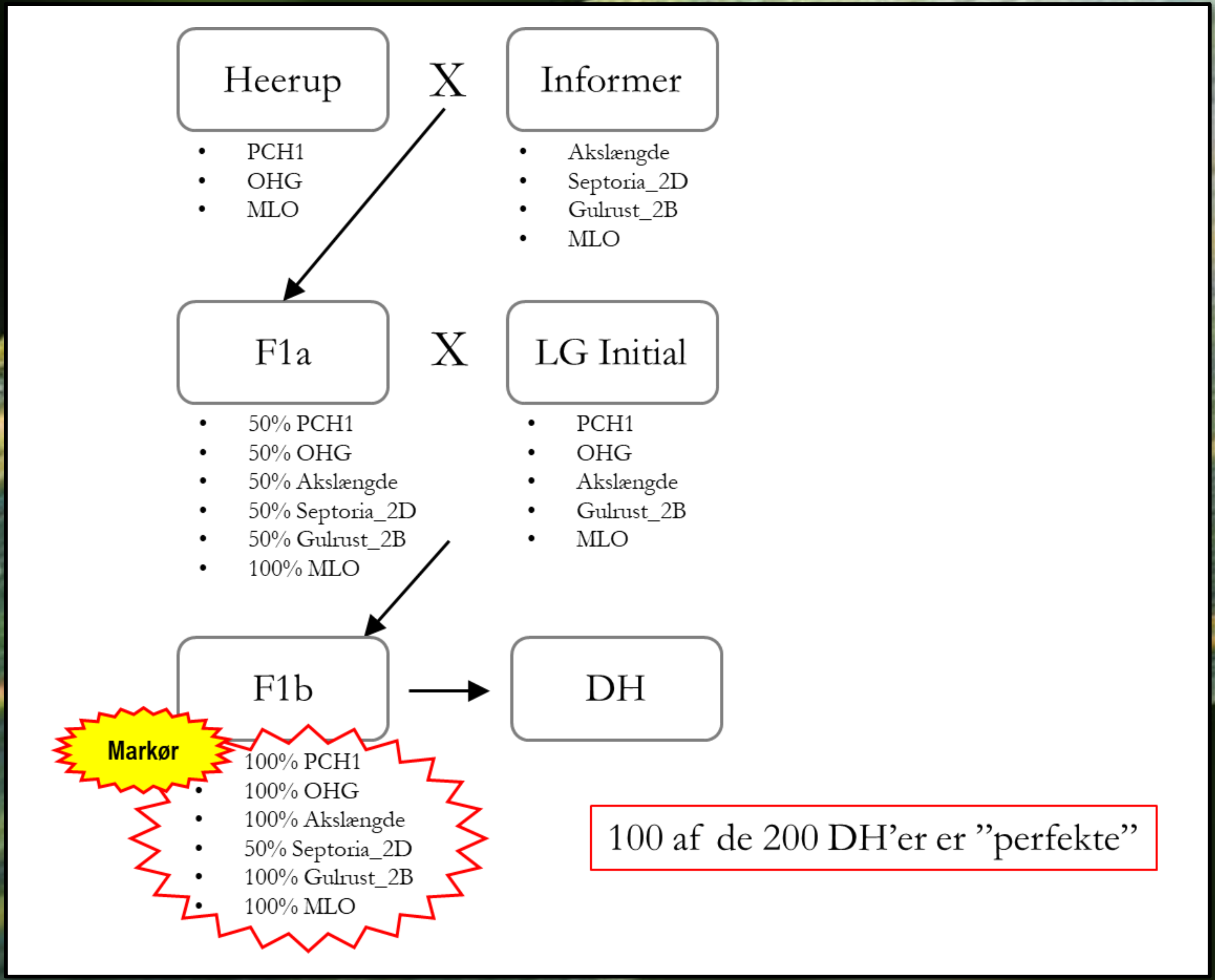
Niels Frederik L. Vestergård

"Identifying and stacking genes against Septoria tritici blotch (STB) in winter wheat cultivars"

DNA-markør baseret selektion, berigede populationer



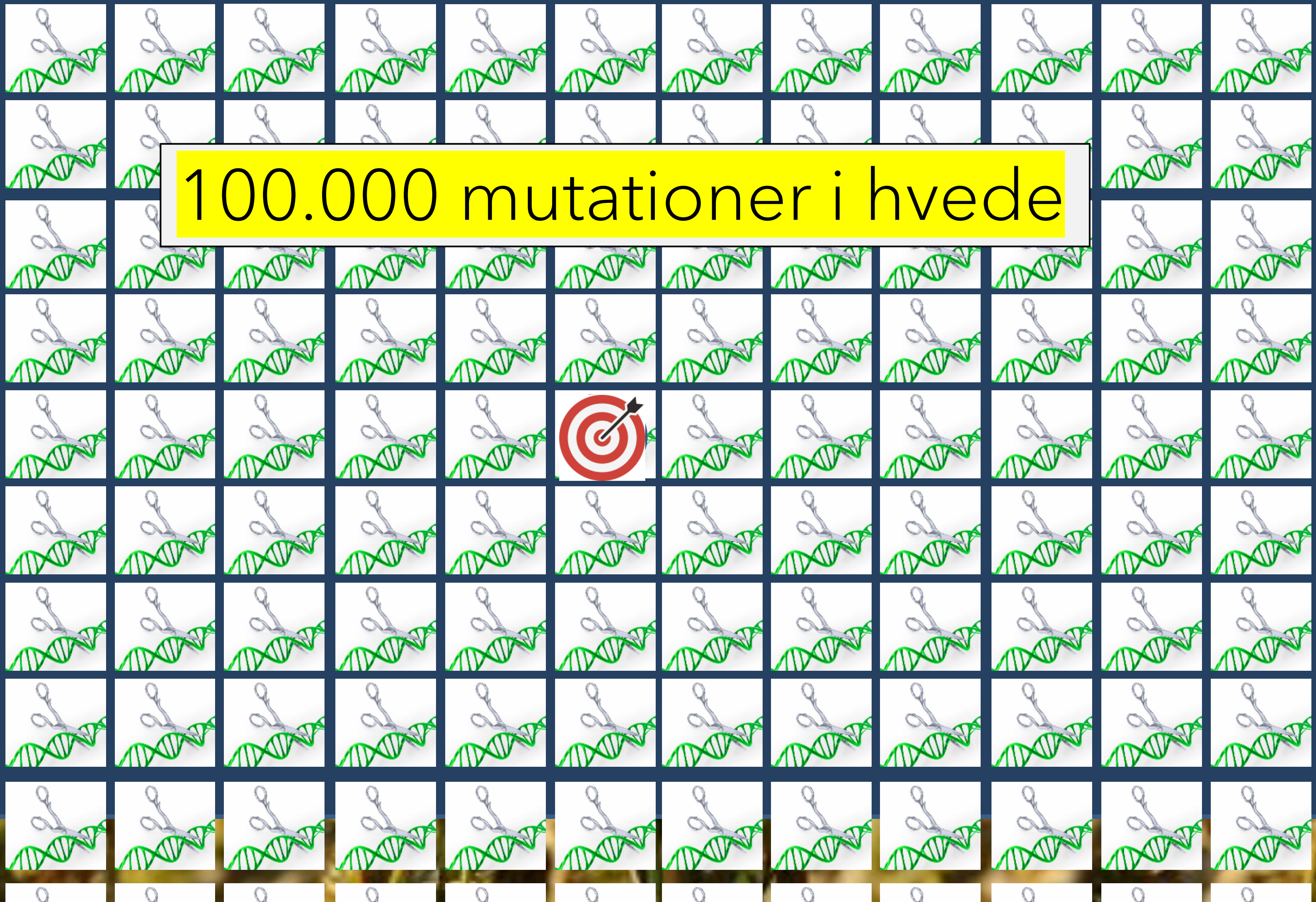
DNA-markør baseret selektion, berigede populationer



CRISPR

Mutation-forædling

Induceret mutagenese:
Stråling eller kemisk behandling



100.000 mutationer i hvede

Mutation-forædling

SDN1 – site directed nuclease – (CRISPR)

PRODUCT CATEGORIES

NGT - Verification Procedure

Conventional

- cross-breeding, including by using advanced techniques such as embryo rescue, induced polyploidy and bridge crosses
- GMO techniques listed under Annex IB of 2001/18
  - Mutagenesis
  - Protoplast fusion (cells from crossable species)

No risk assessment

No labelling

No detection method

Allowed for organic farming

NGT Category 1 (conventional-like)

equivalent to conventional plants if equivalence criteria are met

No risk assessment

Seed bag NGT labelling + NGT info public register

No detection method

Not allowed for organic farming

GMO

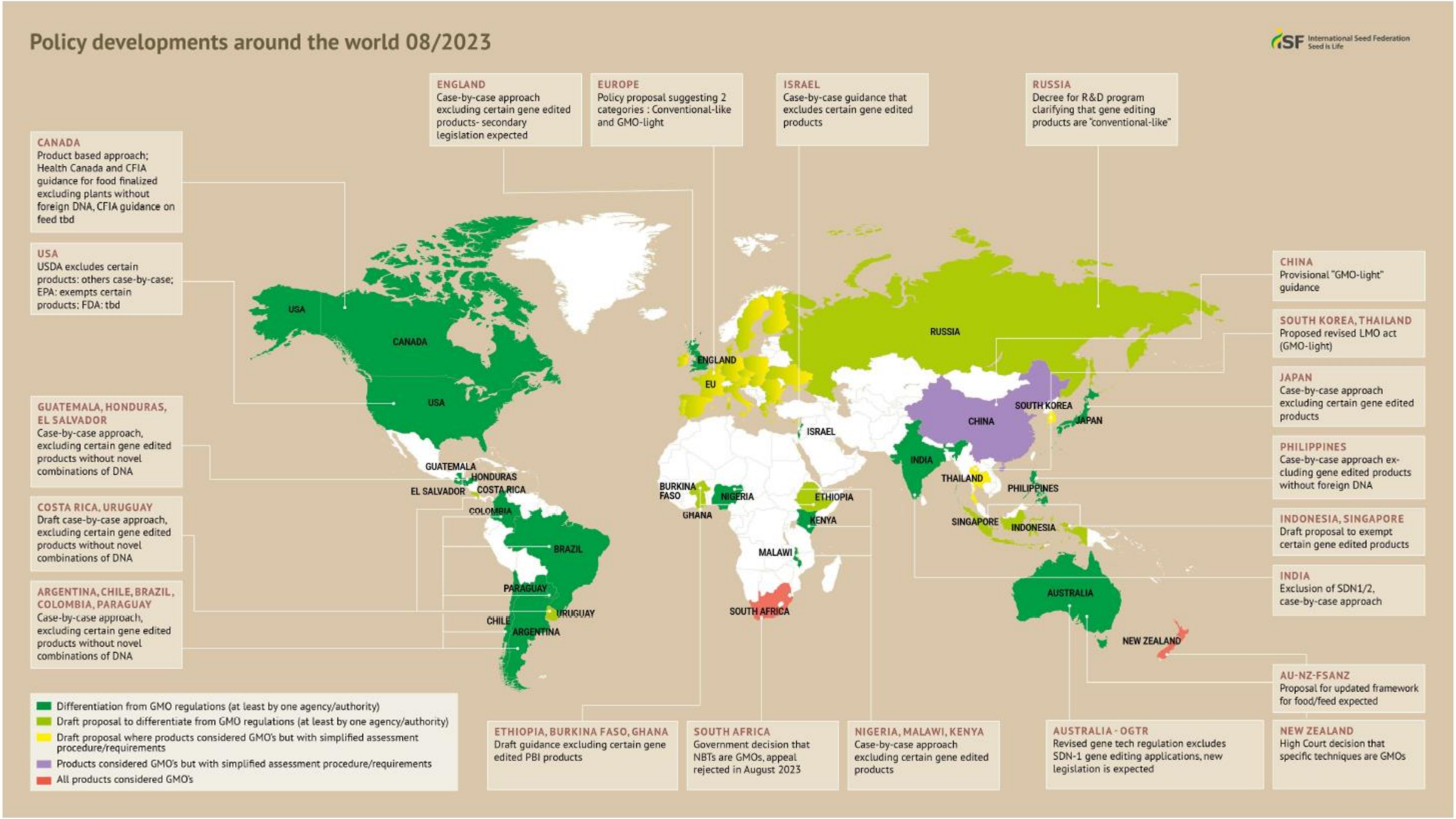
NGT Category 2	Transgenic plants
Adapted GMO risk assessment	Full GMO risk assessment
GMO labelling (+trait) + Public GMO register	GMO labelling Public GMO register
(adapted) detection method	detection method
No Opt out by MS	Opt out by MS

Not allowed for organic farming

Listing in National and EU Variety Catalogue

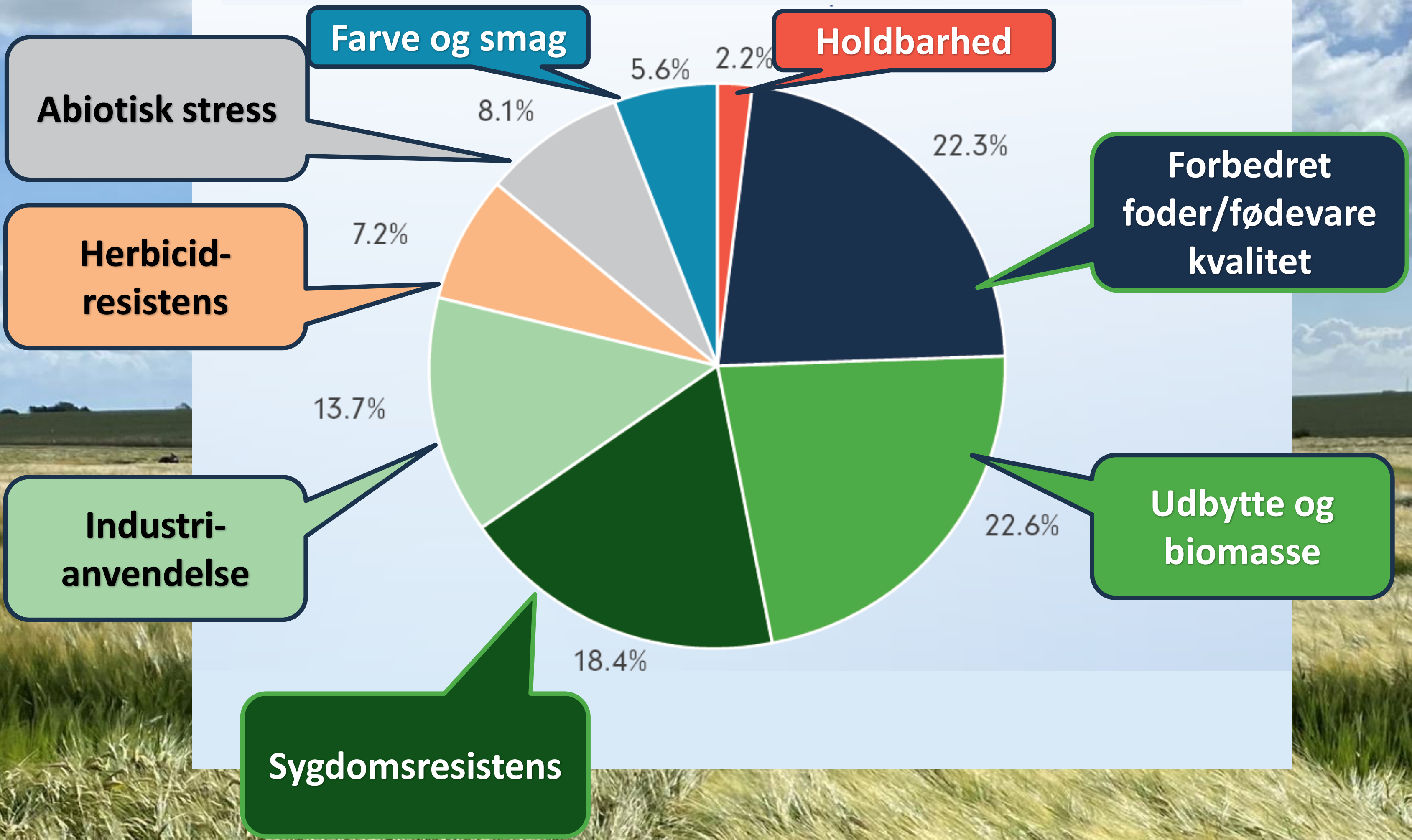
SeedWorld EUROPE


PEKING DUCK SAUCE 32 Kr
CHILLI BEAN SAUCE 35 Kr
Green Curry Paste
Green Curry Paste
DISCOVER ASIA'S FINEST
Thaidancer Panang curry paste 20 kr
Instant Nam Ya Curry Paste 25 kr
Thaidancer Massaman curry paste 20 kr
MAE PLOY Yellow Curry Paste 400g 25 kr
GOLDEN CURRY
GOLDEN CURRY
HEART OF PALM
THAI DANCE / 28
AROY-D
AROY-D


Policy developments around the world 08/2023
ISF International Seed Federation
Seed is Life
ENGLAND
Case-by-case approach excluding certain gene edited products- secondary legislation expected
EUROPE
Policy proposal suggesting 2 categories : Conventional-like and GMO-light
ISRAEL
Case-by-case guidance that excludes certain gene edited products
RUSSIA
Decree for R&D program clarifying that gene editing products are "conventional-like"
CANADA
Product based approach; Health Canada and CFIA guidance for food finalized excluding plants without foreign DNA, CFIA guidance on feed tbd
USA
USDA excludes certain products: others case-by-case; EPA: exempts certain products; FDA: tbd
GUATEMALA, HONDURAS, EL SALVADOR
Case-by-case approach, excluding certain gene edited products without novel combinations of DNA
COSTA RICA, URUGUAY
Draft case-by-case approach, excluding certain gene edited products without novel combinations of DNA
ARGENTINA, CHILE, BRAZIL, COLOMBIA, PARAGUAY
Case-by-case approach, excluding certain gene edited products without novel combinations of DNA
CHINA
Provisional "GMO-light" guidance
SOUTH KOREA, THAILAND
Proposed revised LMO act (GMO-light)
JAPAN
Case-by-case approach excluding certain gene edited products
PHILIPPINES
Case-by-case approach excluding gene edited products without foreign DNA
INDONESIA, SINGAPORE
Draft proposal to exempt certain gene edited products
INDIA
Exclusion of SDN1/2, case-by-case approach
AU-NZ-FSANZ
Proposal for updated framework for food/feed expected
NEW ZEALAND
High Court decision that specific techniques are GMOs
AUSTRALIA - OGTR
Revised gene tech regulation excludes SDN-1 gene editing applications, new legislation is expected
NIGERIA, MALAWI, KENYA
Case-by-case approach excluding certain gene edited products
SOUTH AFRICA
Government decision that NBTs are GMOs, appeal rejected in August 2023
ETHIOPIA, BURKINA FASO, GHANA
Draft guidance excluding certain gene edited PBI products
USA
CANADA
USA
ENGLAND
EU
RUSSIA
ISRAEL
CHINA
SOUTH KOREA
JAPAN
INDIA
THAILAND
PHILIPPINES
SINGAPORE
INDONESIA
AUSTRALIA
NEW ZEALAND
GUATEMALA
HONDURAS
EL SALVADOR
COSTA RICA
COLOMBIA
BRAZIL
PARAGUAY
URUGUAY
CHILE
ARGENTINA
BURKINA FASO
NIGERIA
GHANA
ETHIOPIA
KENYA
MALAWI
SOUTH AFRICA
Differentiation from GMO regulations (at least by one agency/authority)
Draft proposal to differentiate from GMO regulations (at least by one agency/authority)
Draft proposal where products considered GMO's but with simplified assessment procedure/requirements
Products considered GMO's but with simplified assessment procedure/requirements
All products considered GMO's

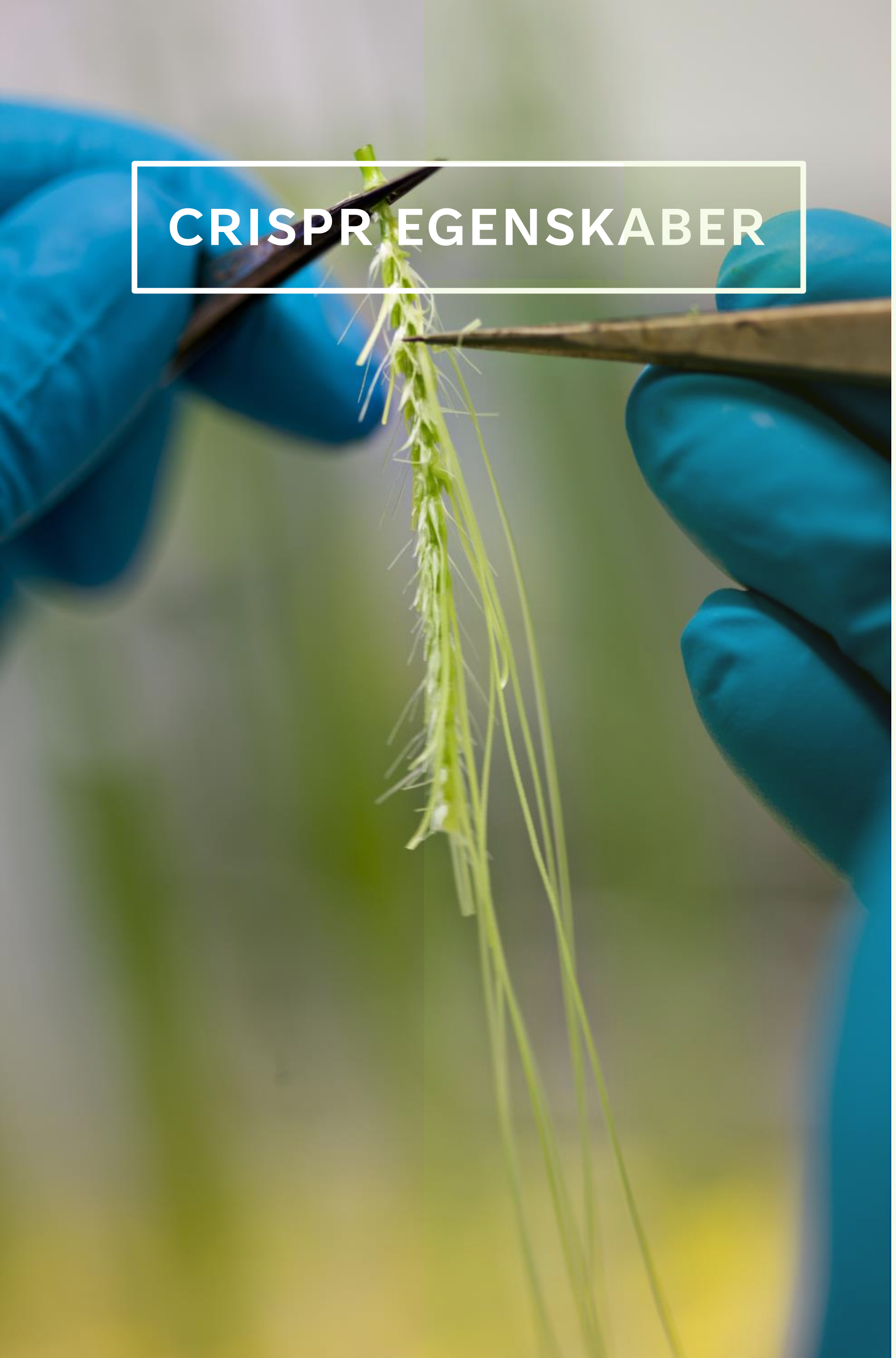
Sejet
plant breeding

Aktuelle offentliggjorte CRISPR-egenskaber i afgrøder.
750 egenskaber i 65 afgrøder



SeedWORLD EUROPE
https://www.eu-sage.eu/our_network_list

CRISPR EGENSKABER



Sejet plant breeding

RETRAQUE – UNI/FORÆDLER PROJEKT

- Forbedret fotosyntese
- Fusarium-resistens i hvede/byg
- Bedre proteinfordøjelighed i hvede/byg

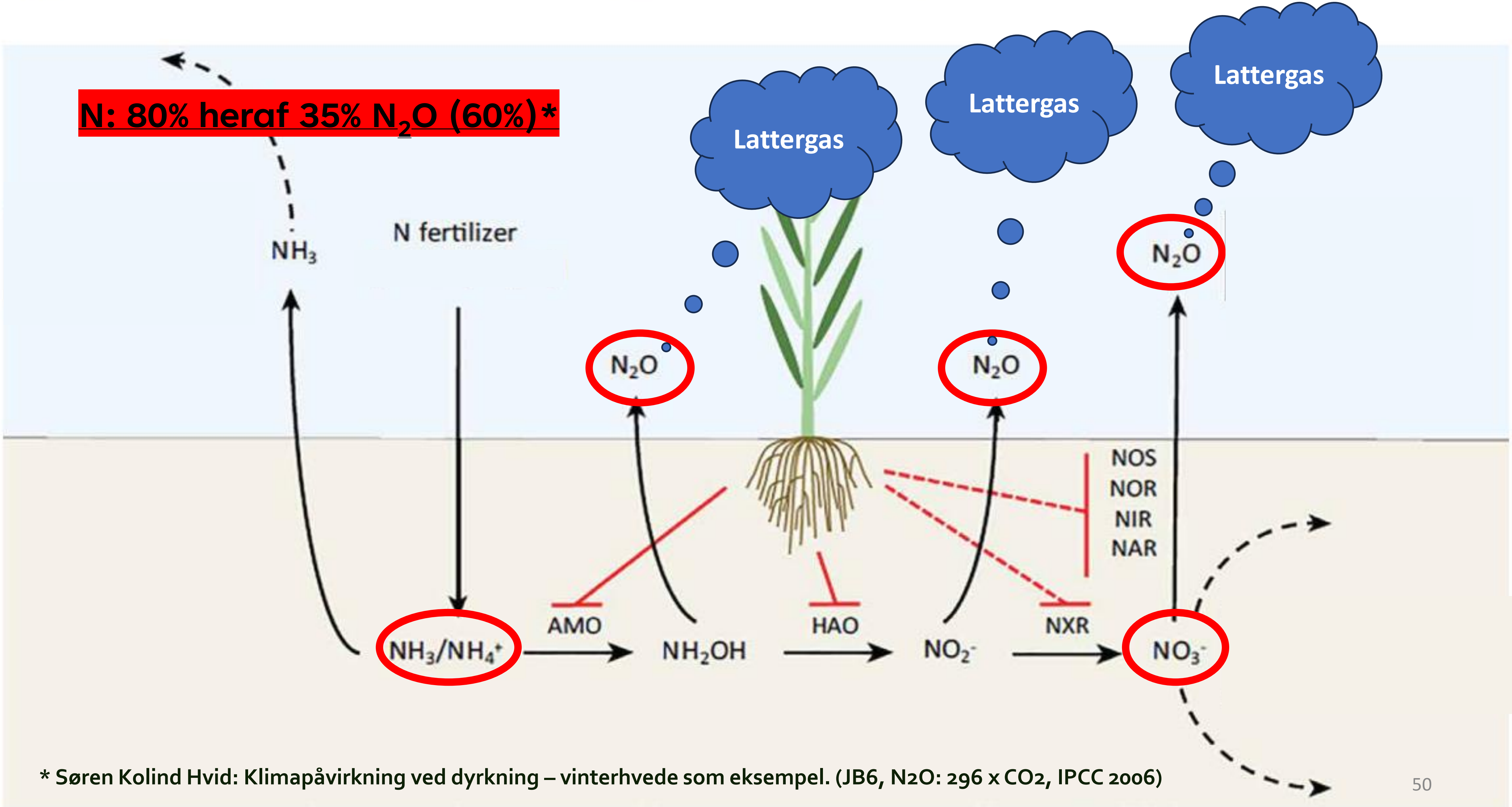
ANDRE EGENSKABER

- Meldugresistens i hvede
- Nedsat acrylamid i hvedebrød
- Glutenfri hvede og byg
- Lav-fytinsorter i hvede og byg
- Amylose hvede

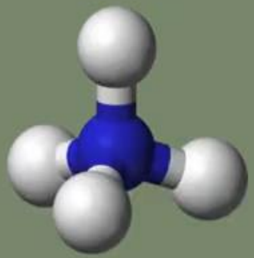
HESTEBØNNER TIL PLANTEBASEREDE FØDEVARER

- Formindsket ANF-indhold
- Forøget proteinfordøjelighed
- Forbedret smag
- Nedsat flatulens(oligosaccarider/raffinose)

Figure 1: Root exudates as a mean of mitigating nitrogen losses in agriculture (Coskun et al., 2017)

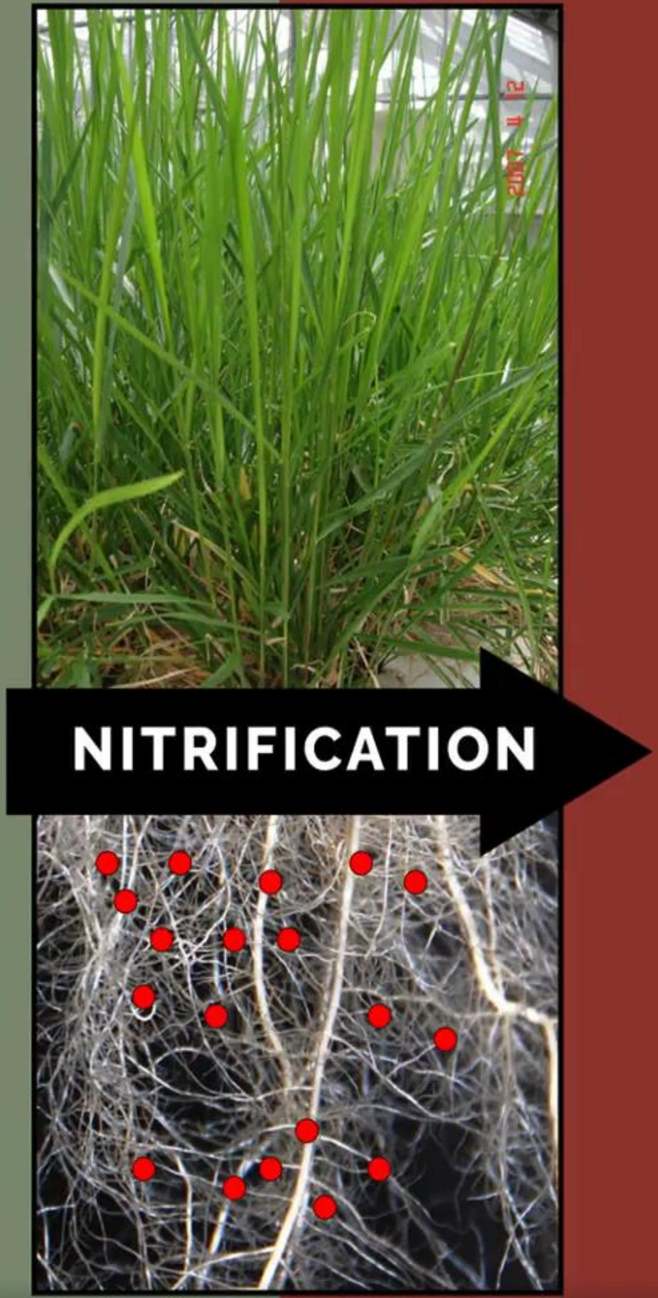


* Søren Kolind Hvid: Klimapåvirkning ved dyrkning – vinterhvede som eksempel. (JB6, N2O: 296 x CO2, IPCC 2006)



NH_4^+ Ammonium

- + stays in soil
- + moves into organic-N forms
- + efficient to assimilate
- + results in healthy agricultural system
- + good for environment

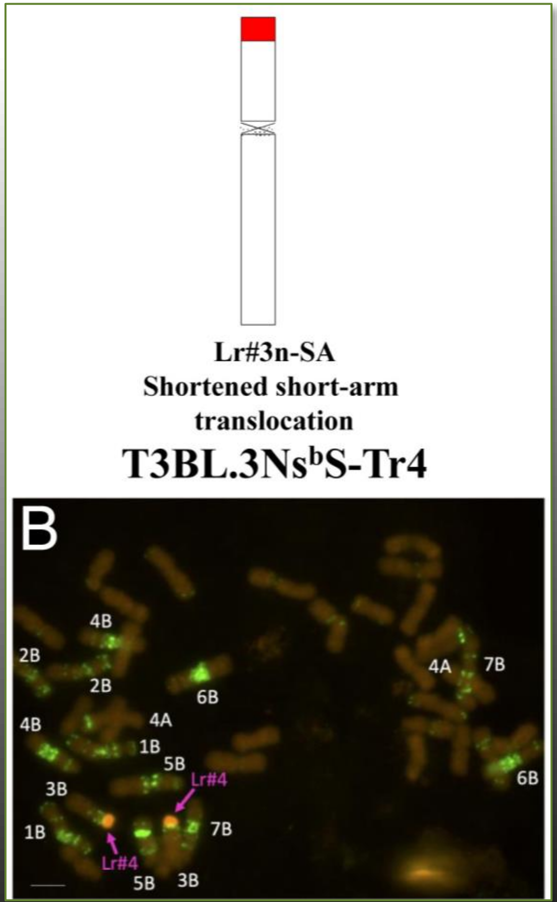


Nitrate NO_3^-

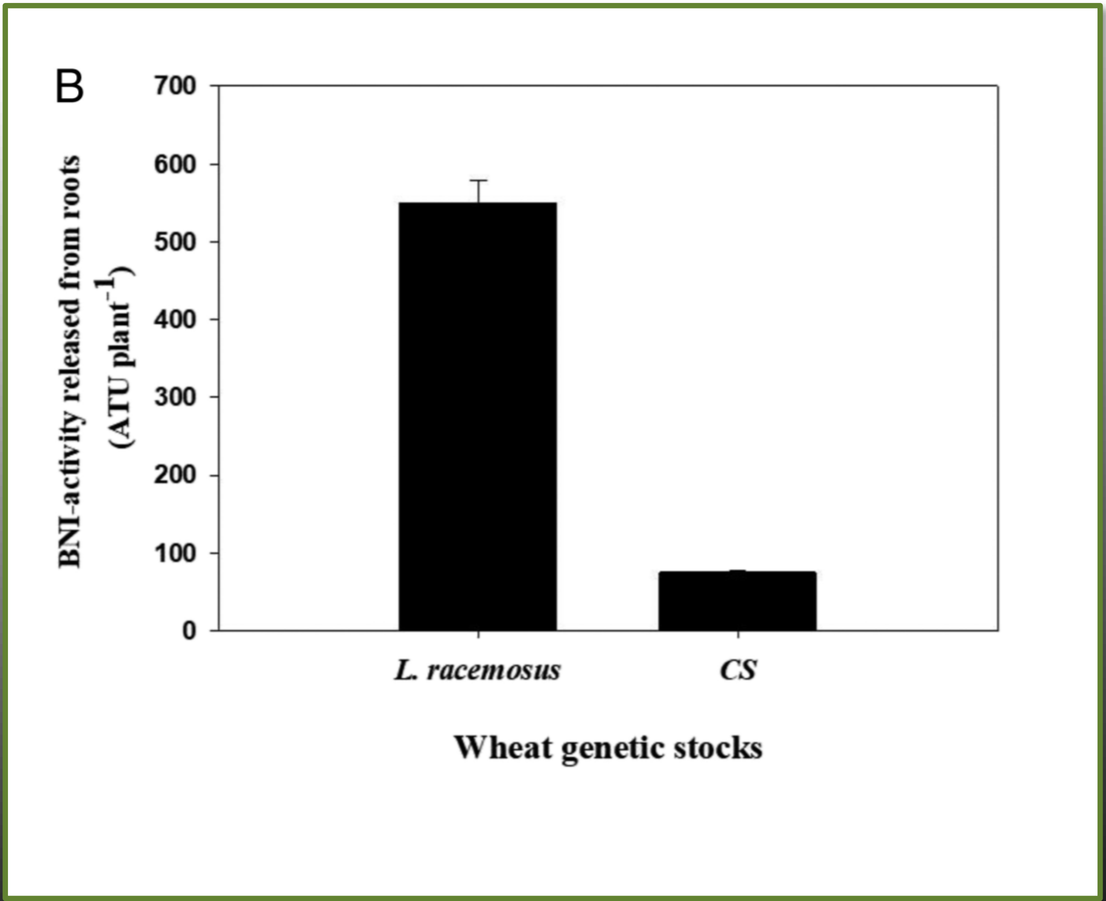
- − leaches out of soil
- − denitrification - N_2O, NO, N_2
- − inefficient to assimilate
- − results in unhealthy agricultural system
- − harmful to environment

Biologisk Nitrifikations Inhibering i hvede

Krydsning med vild hvede (Leymus racemosus) giver trans-lokationsliner med BNI effekt

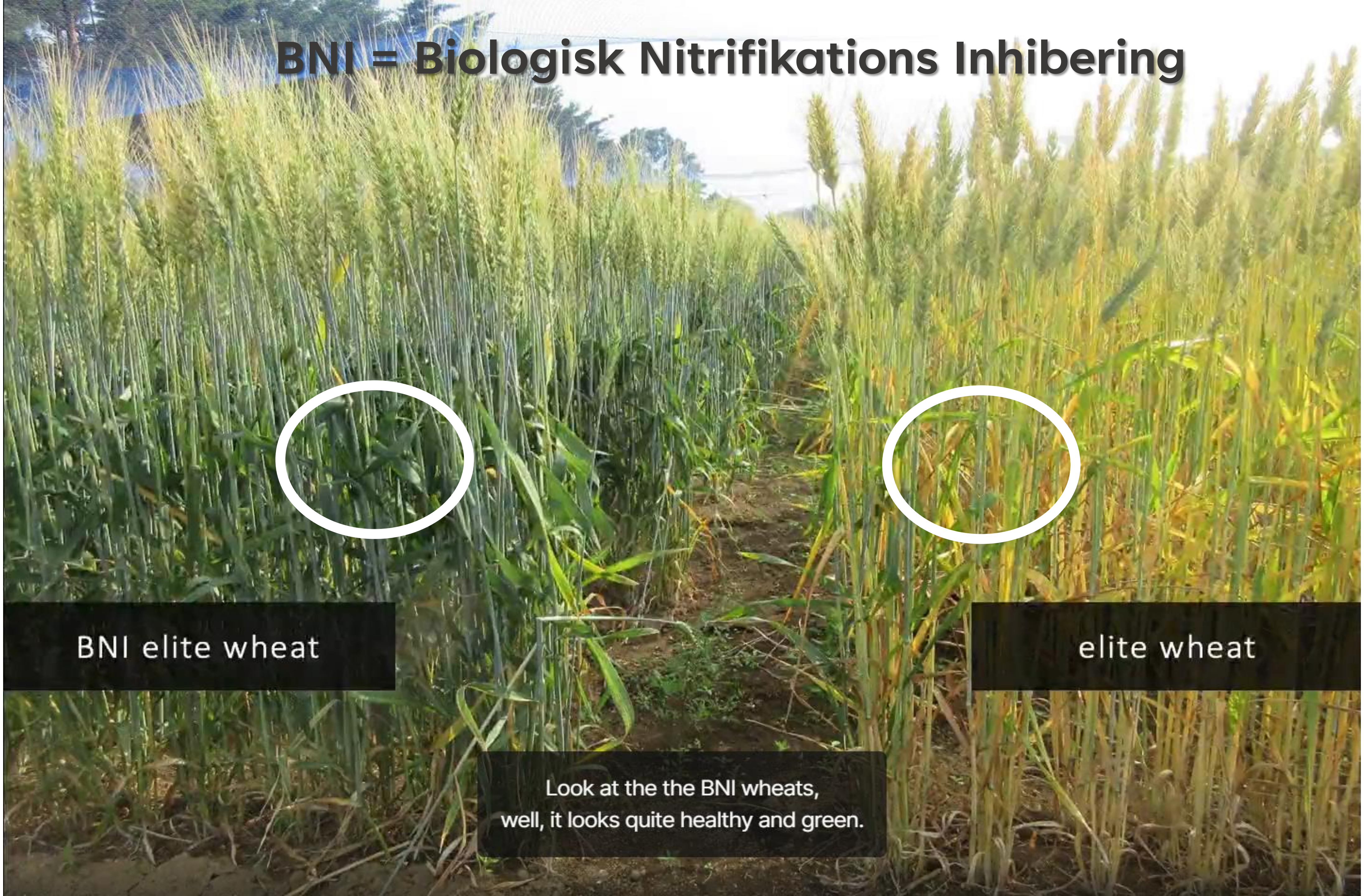


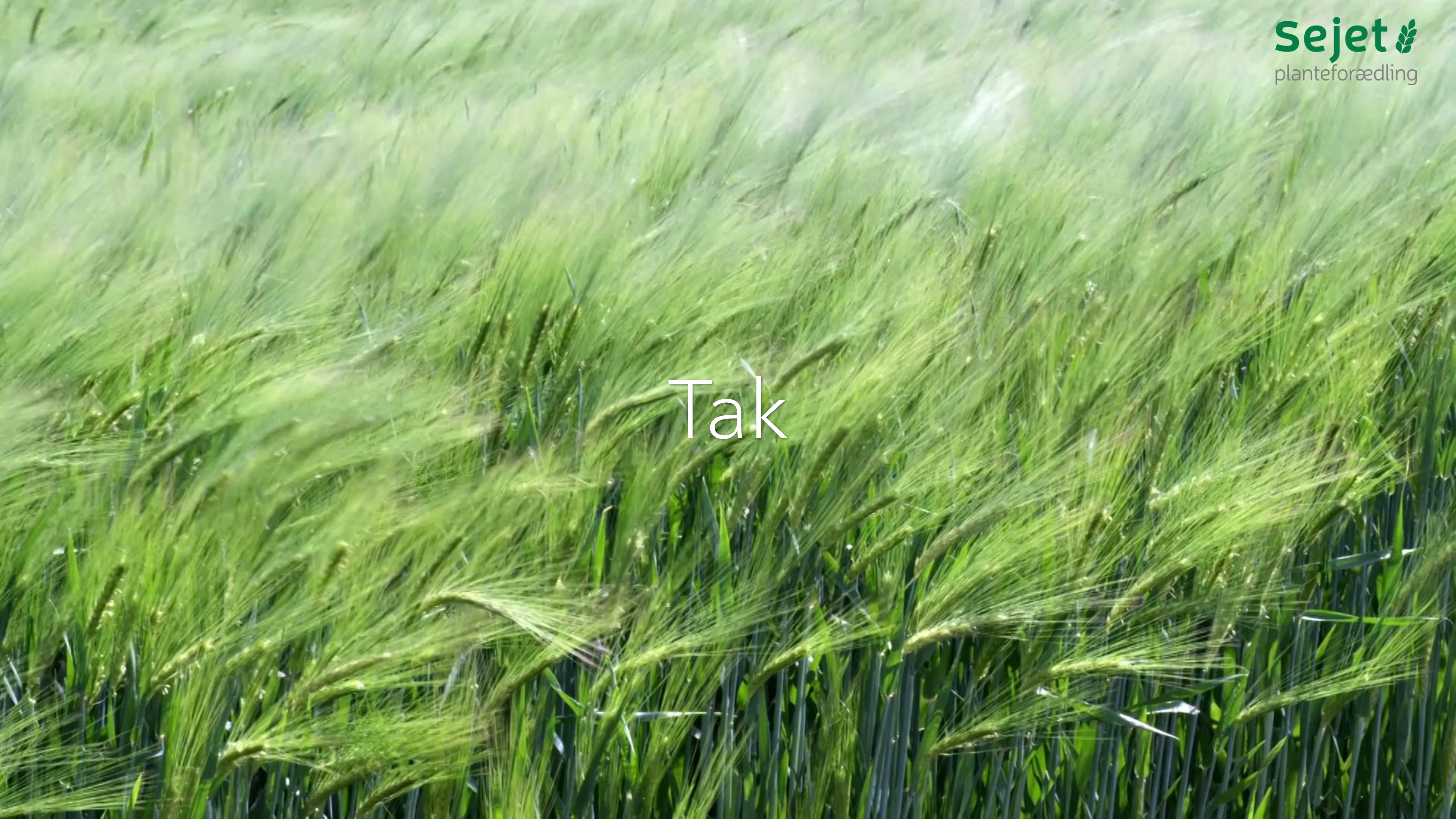
BNI-aktivitet udskilt fra rødder



BNI = Biologisk Nitrifikations Inhibering

sejet plant breeding




Sejet
planteforædling
Tak