RESEARCH PROGRAM ON Wheat

CGIAR

IAPN in Dialogue

"Wheat for Food Security and Health: The World Needs More"

University Goettingen, December 6, 2016

Wheat for Food Security: Meeting the World's Demand

Hans-Joachim Braun

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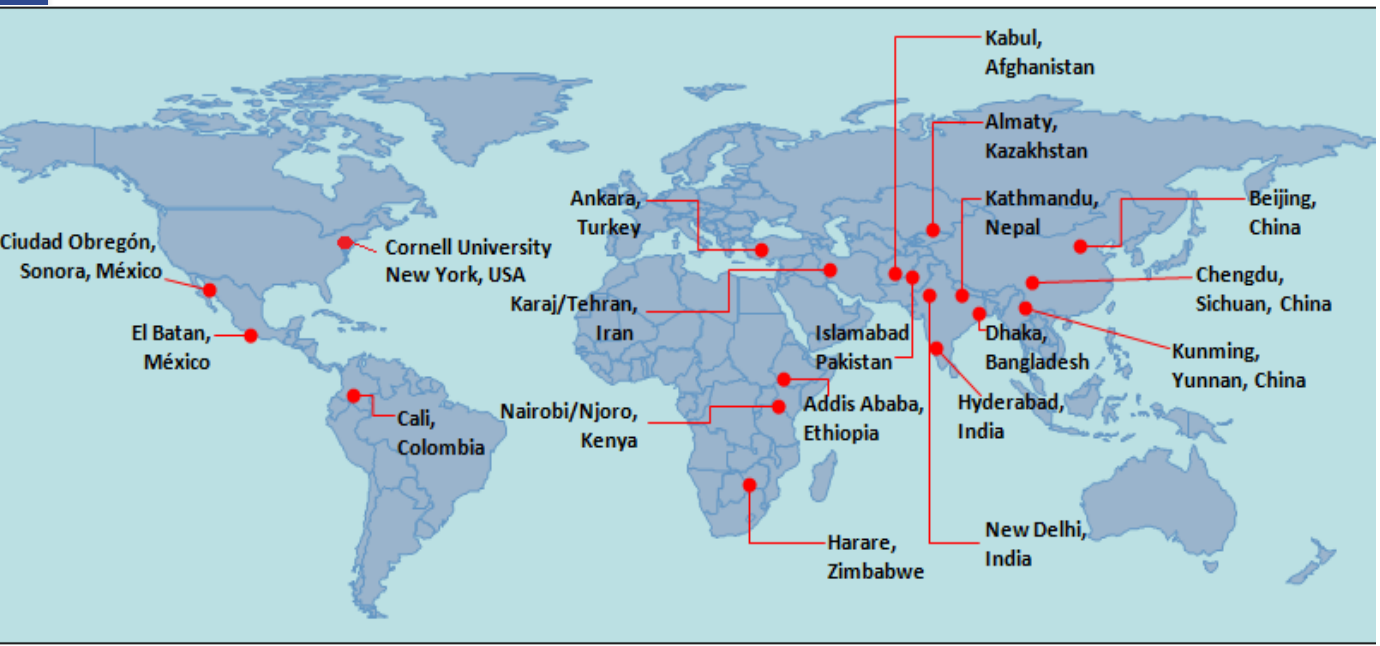
CIMMYT MR

International Maize and Wheat Improvement Center

CIMMYT

- International Maize and Wheat Improvement Center
- Initiator of the Green Revolution Main supplier of maize and wheat germplasm to a global network of co-operators
- One of 15 International Agricultural Research Centers with Headquarters in Mexico
- Employs around 220 Scientists and 900 support staff
- Annual budget 150 million US$ (2016)



19 offices in 17 countries
Works with public and Private sector, ARI, NGOs and Farmer Associations

CIMMYT

Our Mission…

Sustainably increase the productivity of maize and wheat systems to ensure global food security and reduce poverty

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CIMMYT and University Goettingen

Prof. Matin Quaim, CIMMYT Board Member

Prof. Andreas von Tiedemann, Wheat Blast Research

Prof. Ismail Cakmak, CIMMYT Board Member, Zinc Research

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"In the next 50 years we will need to produce as much food as has been consumed over our entire human history."

Megan Clark
CEO of the Commonwealth Scientific and Industrial Research Organization (CSIRO)
Australia

9 billion – the Greatest Challenge
double food production by 2050

Nutritious, accessible, affordable and safe food

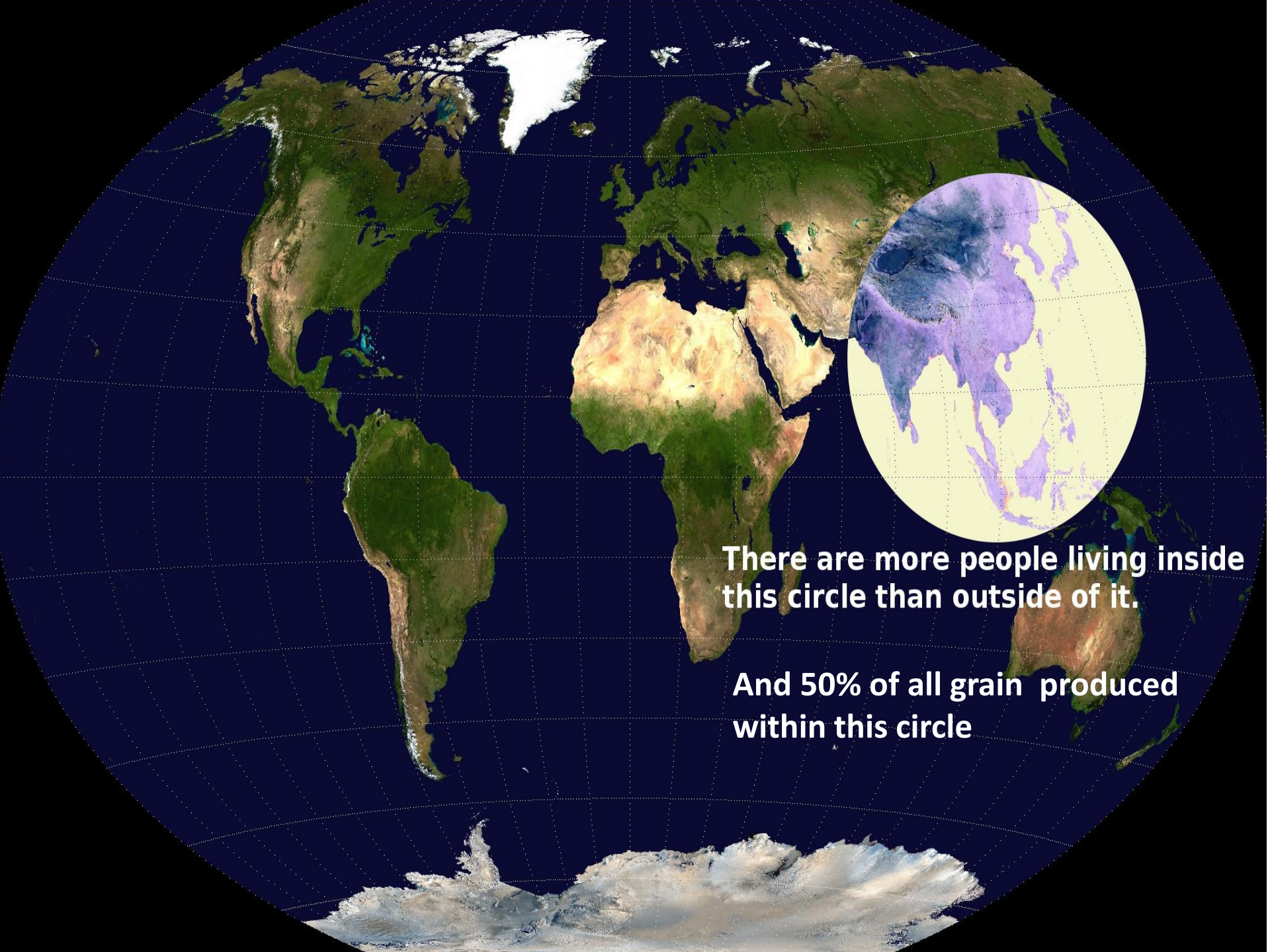
Diet changes with increasing income

9 billion people consume as much food as 12 billion would today (meat => maize / soy beans)

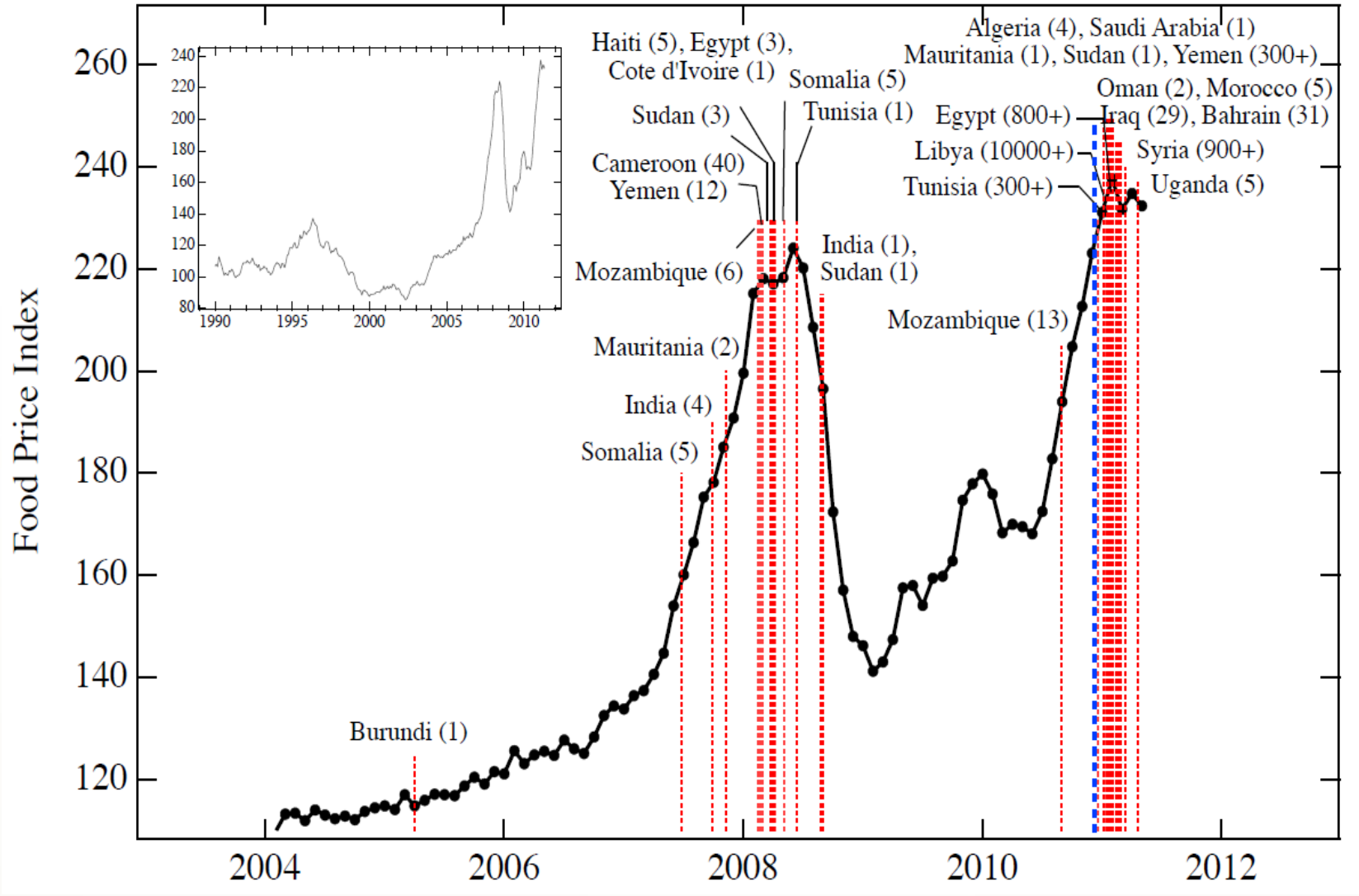
80% of future growth from lands already in use
Limited potential for land expansions

Most of production growth in countries where it is consumed

Irrigation expansion crucial to meeting food demand


There are more people living inside this circle than outside of it.
And 50% of all grain produced within this circle

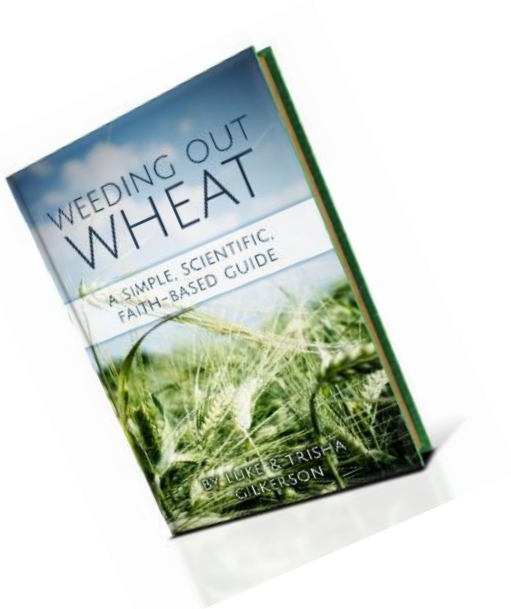
Food Prices Raise – Governments Fall

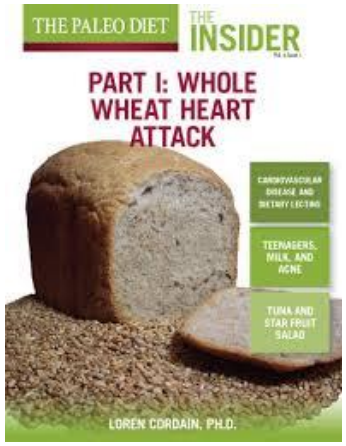


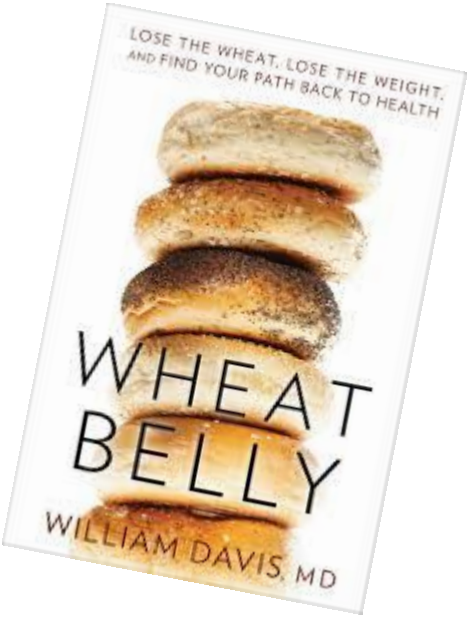
Red dashed vertical lines correspond to beginning dates of "food riots" and protests associated with overall death toll reported in parentheses [26–55]. http://necsi.edu/research/social/food_crises.pdf

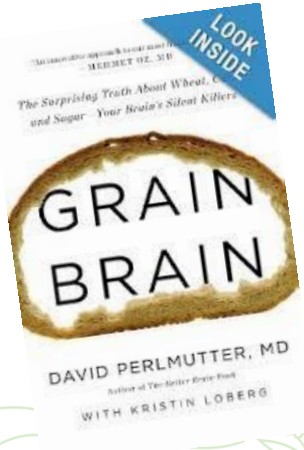
Source: Lagi, K.Z. Bertrand, Y. Bar-Yam, The Food Crises and Political Instability in North Africa and the Middle East. (August 10, 2011)

Wheat – from the staple for global nutrition to the principal problem???









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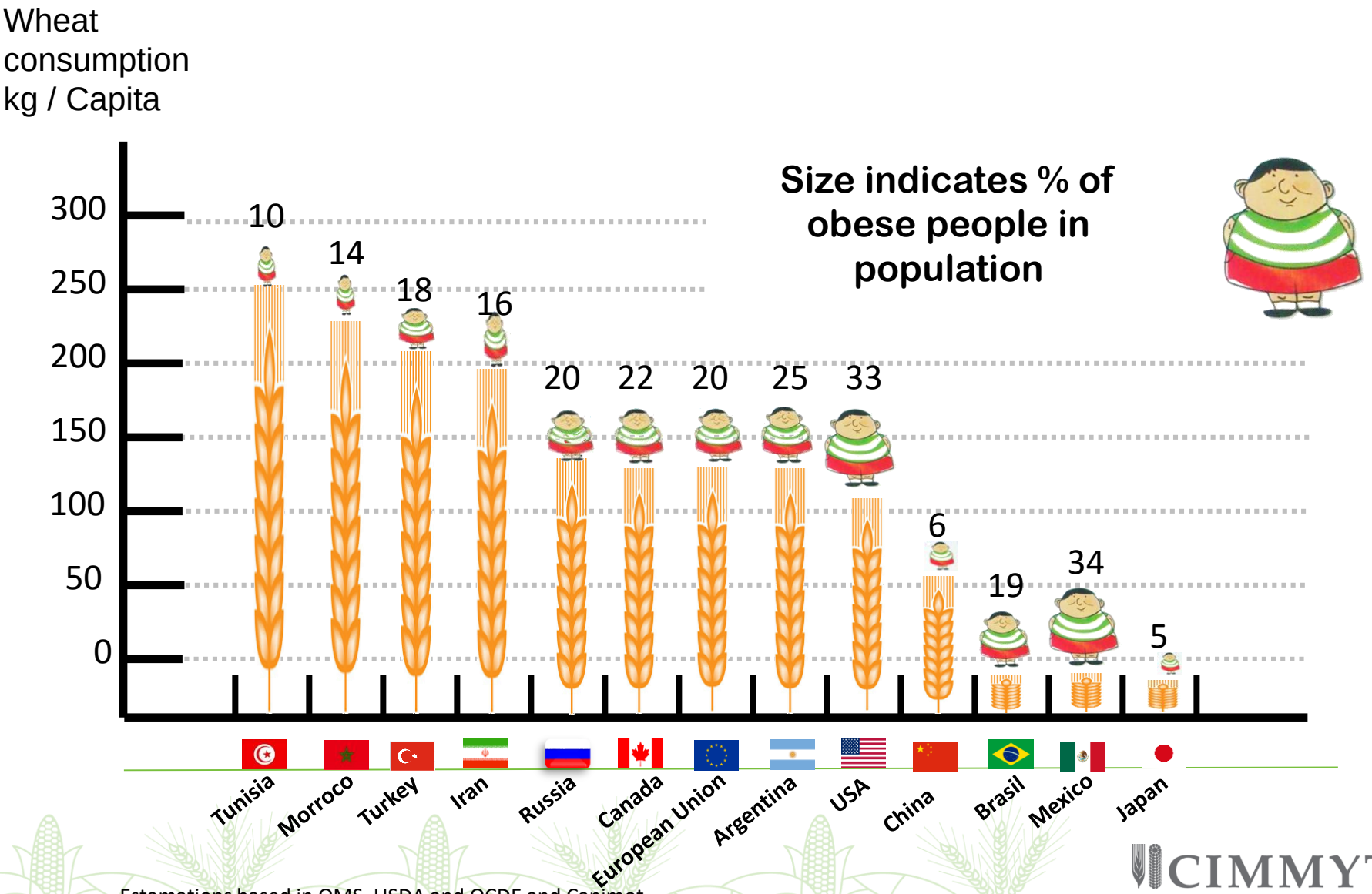
+ Wheat and Obesity



Estamations based in OMS, USDA and OCDE and Canimot

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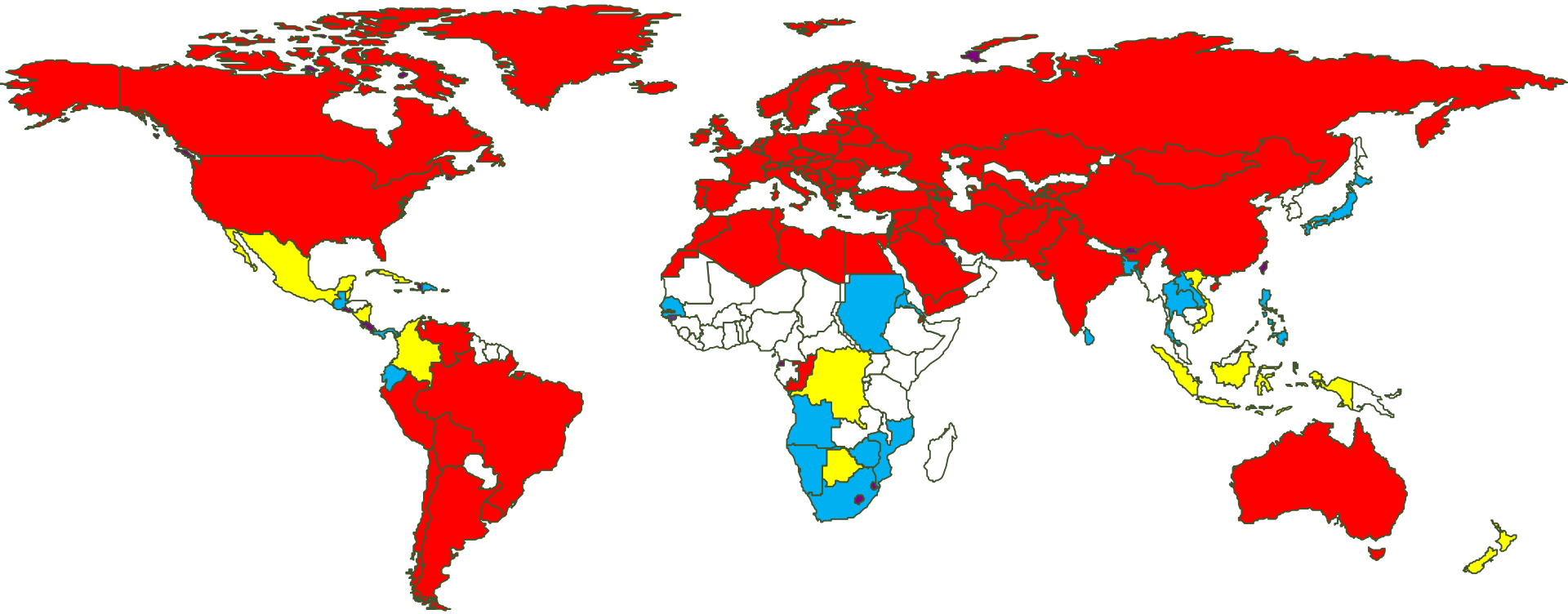
Wheat a cornerstone for global food nutrition

- Globally, most important food crop and covers largerst area all crops
- Provides 20% of all calories and protein
- Staple for 1.2 billion people with less than 2 $ / day
- Major source of fibre and Vitamin B, **Folsäure - pregnancy**
- Average Anti-oxydant activity greater than that of many fruits and vegetables

Wheat is a natural vehicle for providing nutrients to a growing population

Importance of Wheat as Protein Source from Plants

1st 2nd 3rd



Source: FAO 2012

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Countries where wheat provides more than 1/3 of daily calories

Source: FAO, 2010

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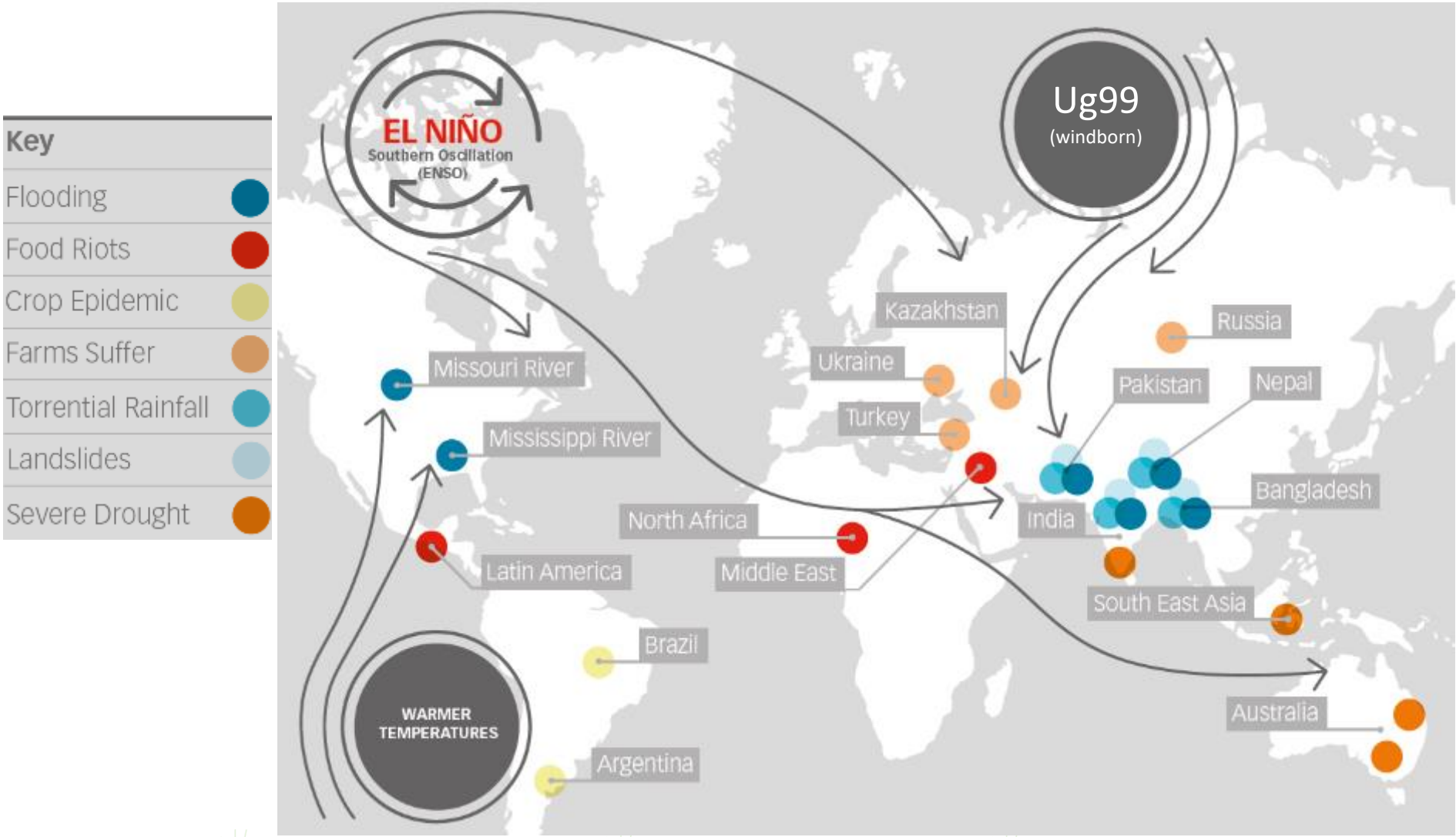
The scenario



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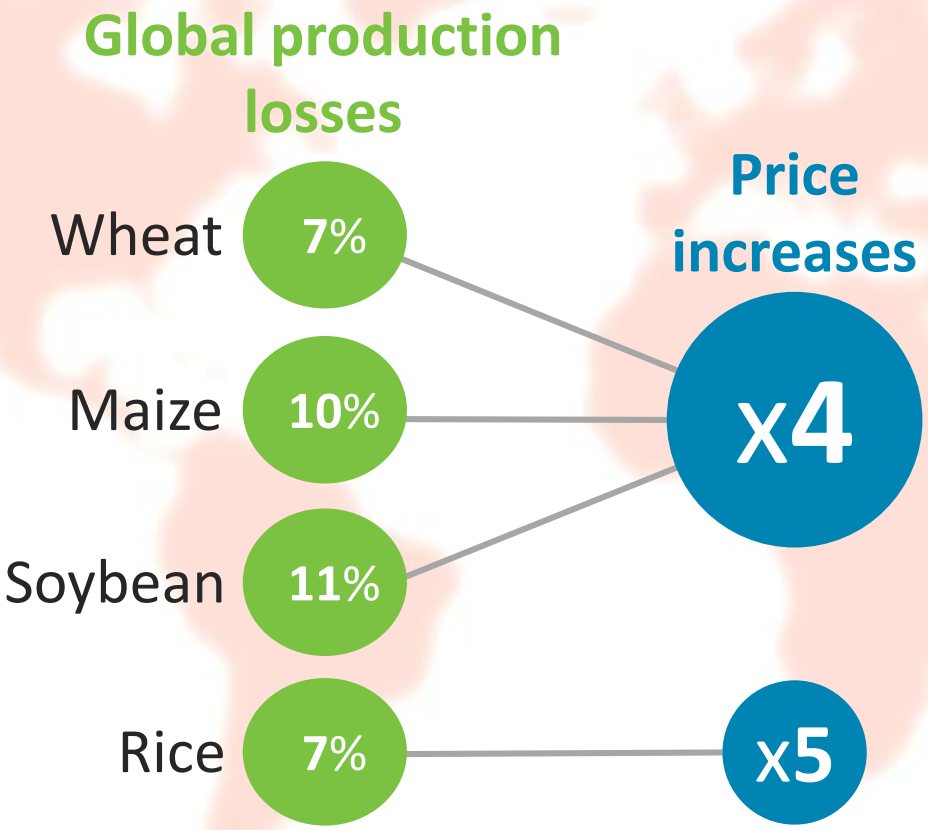
Impacts



Human cost

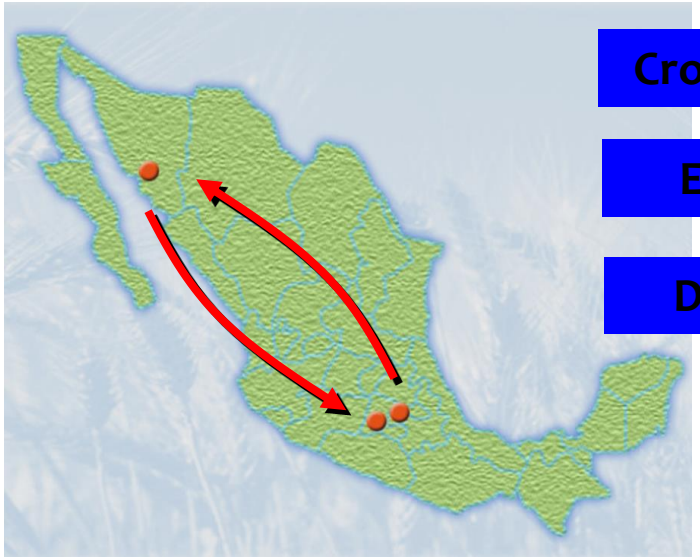
- Humanitarian crisis
- Food riots
- Stock market losses

10% in EU
5% in US


Wheat Improvement at CIMMYT

International Wheat Improvement Network

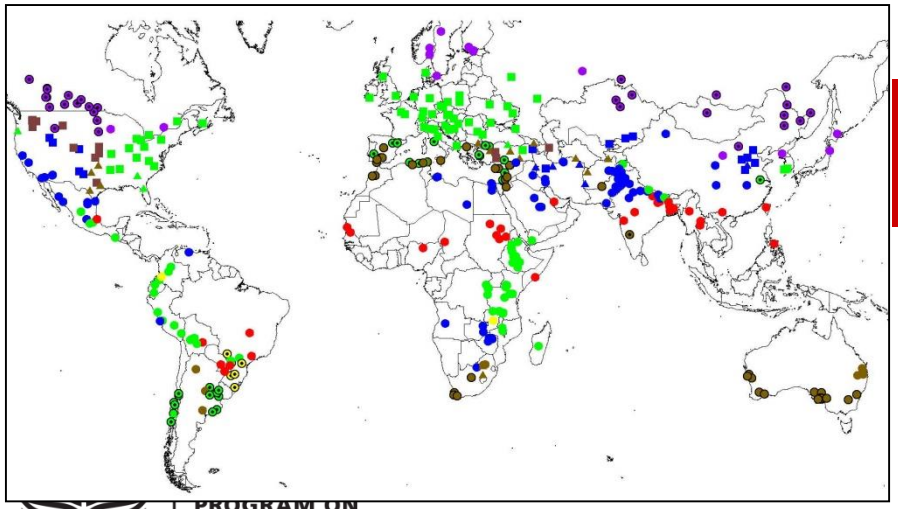
Data collected worldwide, used in centralized program



Crossing

Evaluation in Mexico and hot spot sites worldwide

Distribution of improved germplasm through IWIN



Collection and interpretation of multi-location data

Ca 50% of varieties released worldwide are IWIN related

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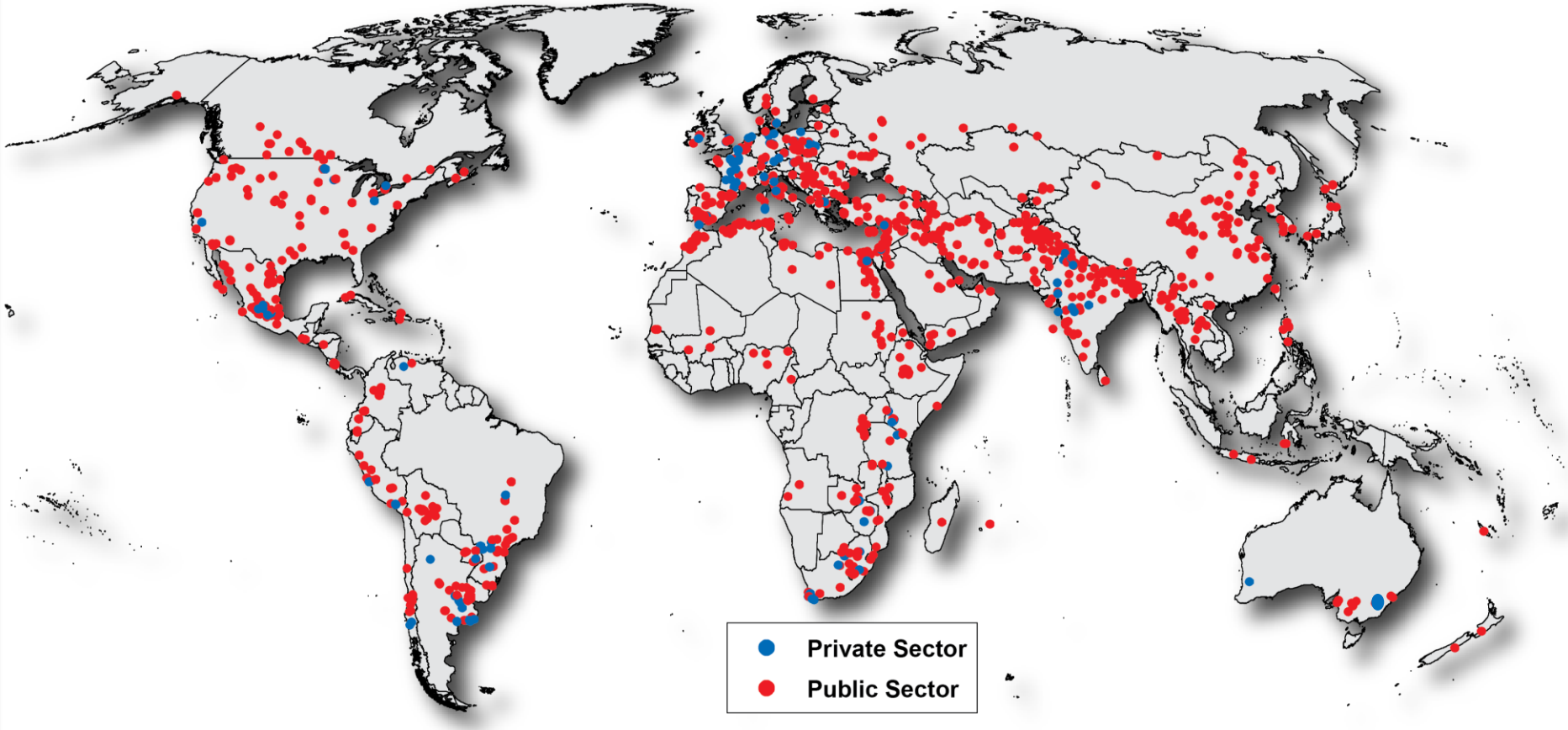
Private and Public sector cooperators in IWIN



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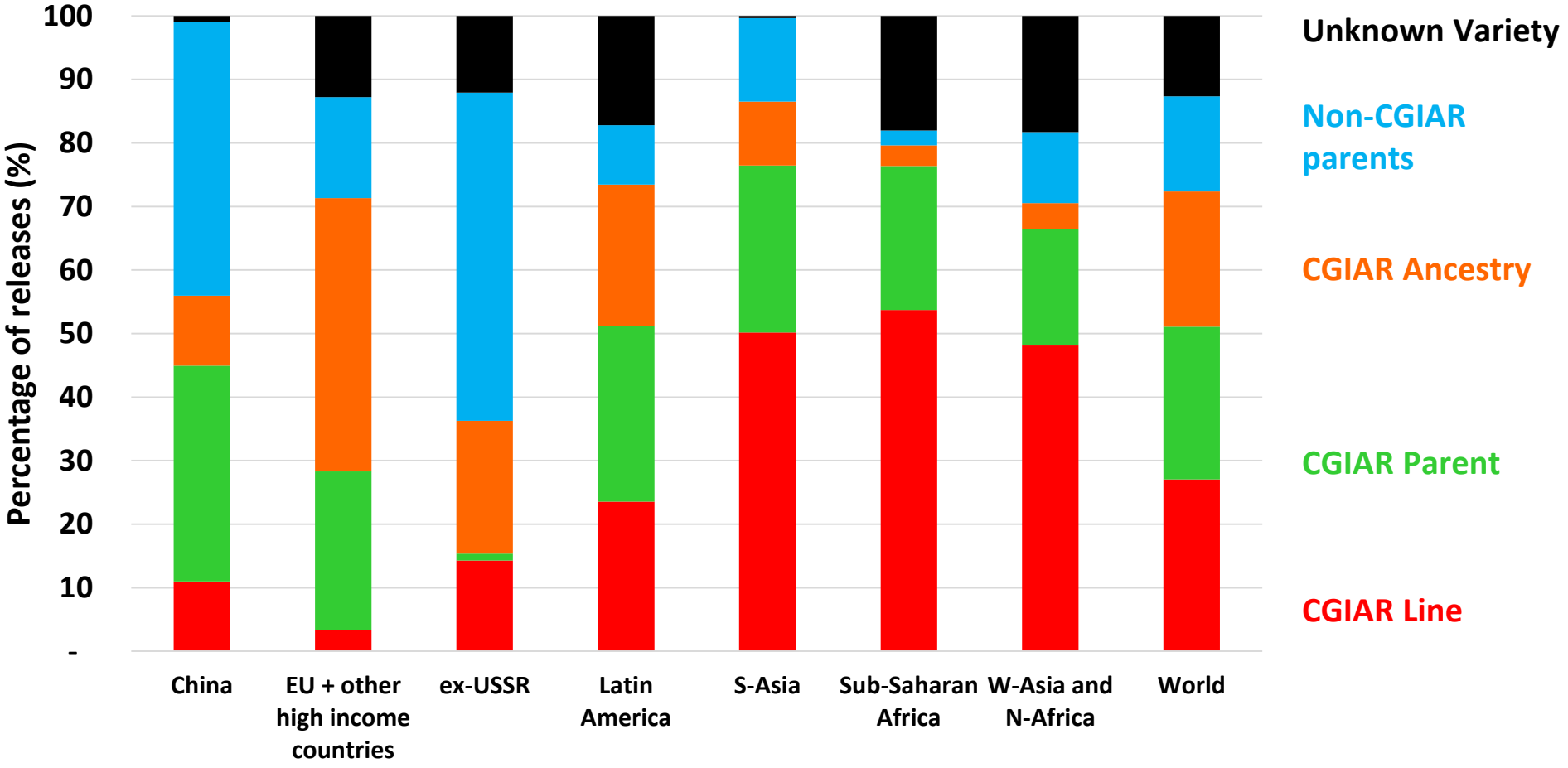
Spring bread wheat releases 1994-2014



Bread Wheat Breeding Priorities

Core traits

- High and stable yield potential
- Durable resistance to Rusts-Stem (Ug99), Stripe and Leaf
- Water use efficiency/Drought tolerance
- Heat tolerance
- Appropriate end-use quality
- Enhanced Zn and Fe content for nutrition (South Asia)

Key diseases in specific mega-environments

- Durable resistance to diseases and pests
  - Septoria leaf blight (ME2)
  - Spot Blotch (ME5)
  - Tan Spot (ME4)
  - Fusarium – head scab and myco-toxins (ME2/4/5)
  - Karnal bunt (ME1)
  - Root rots and nematodes (ME4)

Packaging multiple traits together is essential under climate change scenario to benefit wheat farmers

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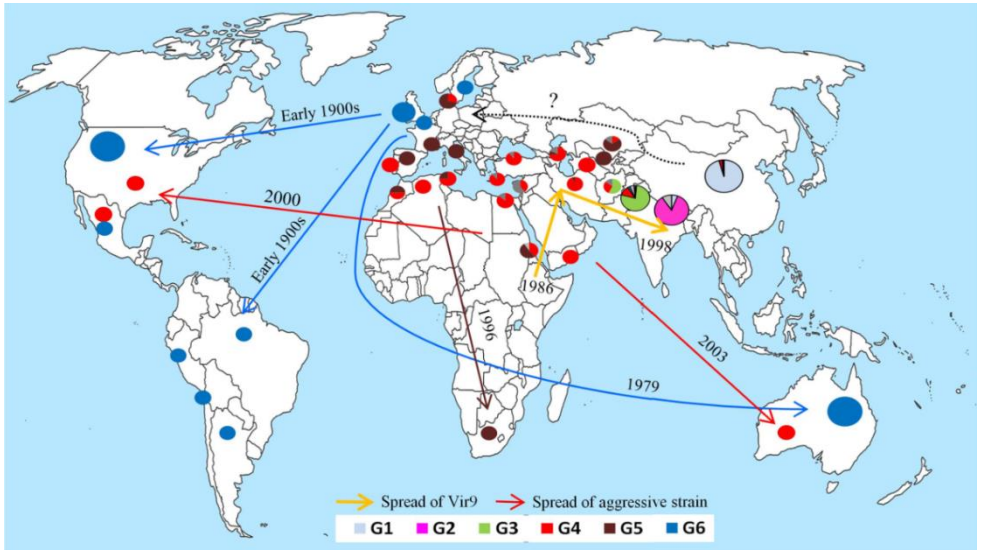
Spread of aggressive *Puccinia striiformis* (yellow rust) races Pst1/Pst2 adapted to higher temperature



- Early infection initiation
- Faster disease build up
- Disease progression even when temperatures are warmer
- New areas of adaptation
- Faster evolution for new virulences
- Reduced effectiveness of resistance
- East Africa origin of this race group
  (Walter et al. 2016. Ecology & Evolution)

Countries with red dots with confirmed presence of Pst1/Pst2 race group

Source: Ali et al. (2014) PLoS Pathog 10(1): e1003903. doi:10.1371/journal.ppat.1003903

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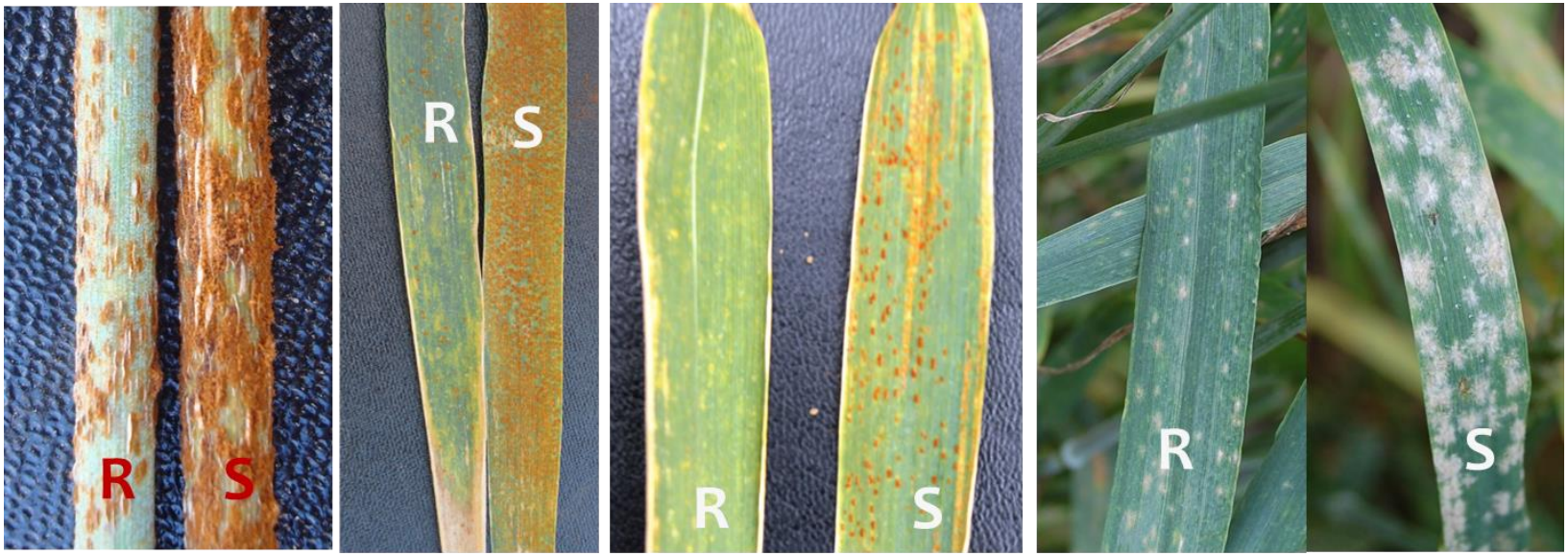
Slow Rusting Adult Plant Resistance and Pleiotropic Effects



Stem rust **Leaf rust** **Leaf & Stripe rust** **Powdery mildew**
(Obregon, Mexico) **(Cobbitty, Australia)** **(Vollebekk, Norway)**

Lr34 [Syn. = *Yr18=Sr57=Pm38 =Ltn1=Sb1= Bdv1*] cloned*
Lr46 [Syn.= *Yr29=Sr58=Pm39=Ltn2=Ts?*]
Lr67 [Syn.= *Yr46=Sr55=Pm46=Ltn3*] cloned*
Sr2 / [Syn.= Yr30=Lr27=Pm]

- * **novel resistance mechanism - pleiotropic genes encode hexose transporter**

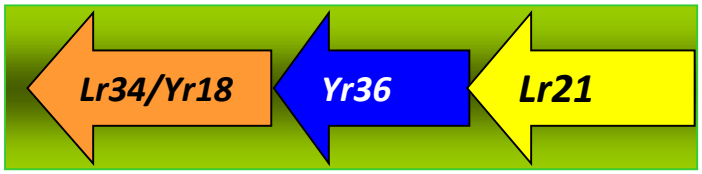
Moore et al. 2015. Nature Genetics 47:1494-1498

CSIRO and Sydney Uni CIMMYT

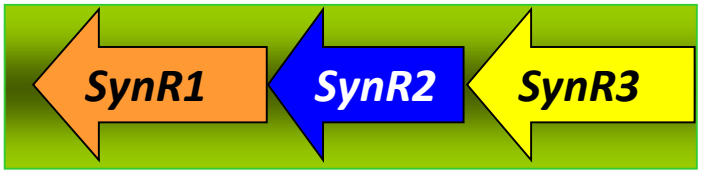
Future: GM intervention to achieve resistance durability

Gene Cassettes- multiple resistance genes inherited as a single unit

simplifying breeding and enhancing resistance durability



Natural gene cassette
(currently developed)



Synthetic gene cassette
(future possibility)

- **Natural gene cassettes currently in the pipeline at CSIRO**
  Lr34/Yr18/Sr57 +Lr67/Yr46/Sr55 +Lr21 +Yr36

- **Scientific/Commercialisation Challenges**
  - **Cloning many resistance genes for diversity**
  - **Technology for insertion of large DNA "packages"**
  - **Synthetic R genes?**
  - **Cisgenic vs Transgenic crops**

Source: GRDC Triple Rust Initiative

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Wheat blast caused by *Magnaporthe oryzae:* A reality and new challenge for wheat research

Etienne Duveiller[1], David Hodson[2] and Andreas von Tiedemann[3]

International Wheat Conference, St Petersburg 2010

Preliminary maps show that climatic areas favorable for wheat blast exist on other continents, if the presence of inoculum coincides with susceptible cultivars. Regions where the disease may occur include parts of East Africa (Ethiopia) and South Asia (Bangladesh, eastern India).

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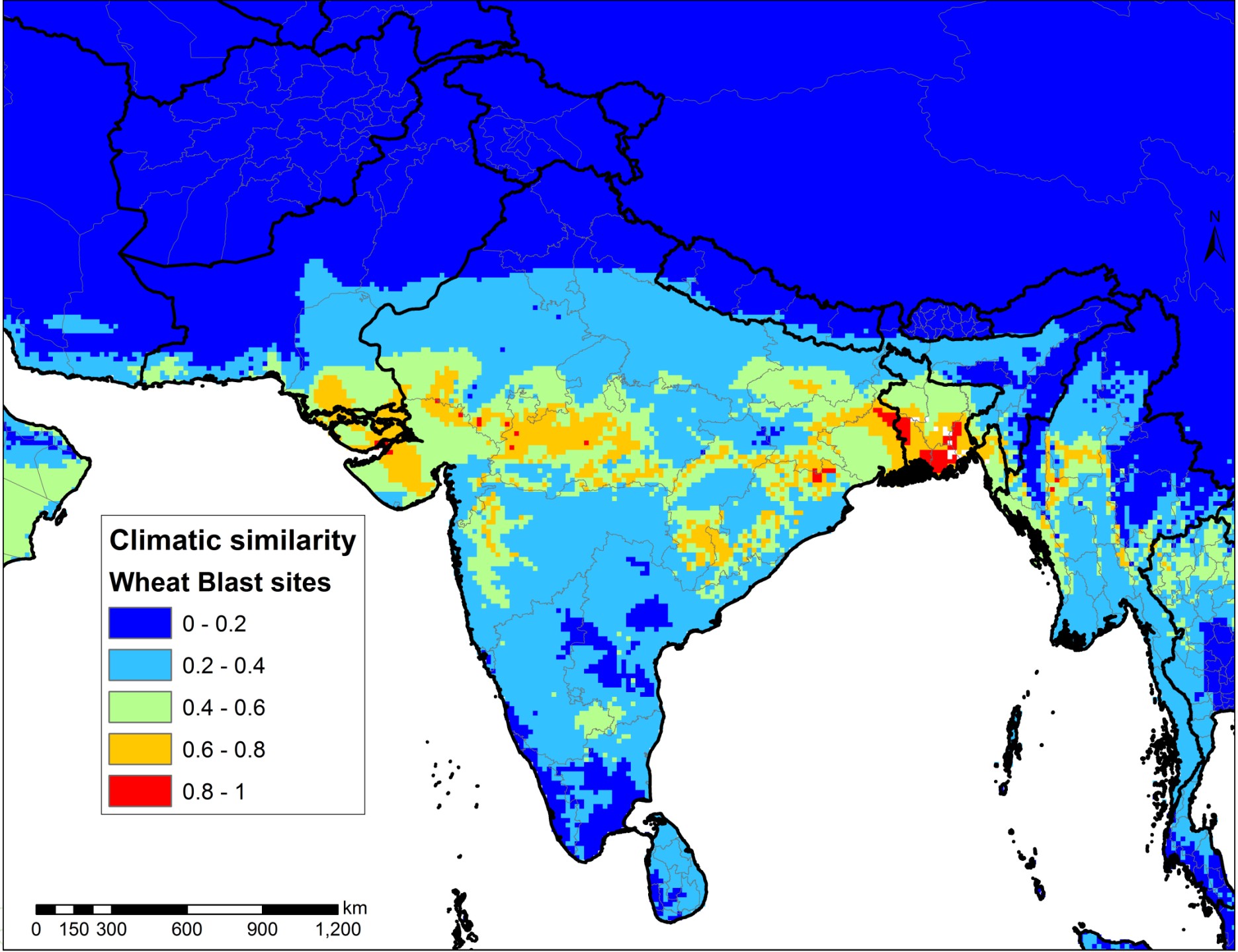

Climatic similarity
Wheat Blast sites
0 - 0.2
0.2 - 0.4
0.4 - 0.6
0.6 - 0.8
0.8 - 1
N
0 150 300 600 900 1,200
km

Source: Dr Malik, Bangaldesh

PHOTO: STAR

A blast disease affected wheat seed production field under Bangladesh Agricultural Development Corporation in Meherpur is getting burnt as the authorities decided to destroy the plants to prevent use of seriously defective seeds and spread of the disease further. Following detection of the disease by a team of experts from Wheat Research Centre in Dinajpur, a large number of farmers in Meherpur have also started burning their wheat fields as preparation to cultivate paddy or jute there in the next season.

Wheat Blast

- Seedborne disease
- Disease develops very fast – less than a week from first symptoms to major losses
- Most cultivars susceptible – resistance from Trit. ventricosa
- Fungicides partially effective under medium to low disease pressure.
- Pathogen has developed resistance against some fungicides
- Wheat growing areas at risk with similar climate as in Brazil and Bolivia - South Asia, South China, African low lands
- Global Wheat Blast Consortium has been formed

Agriculture and Water and Heat

WEEKLY | NEWS IDEAS INNOVATION | THE BEST JOBS IN SCIENCE

NewScientist

25 February 2006

It takes **20,000 litres** of water to grow 1 kilo of coffee,

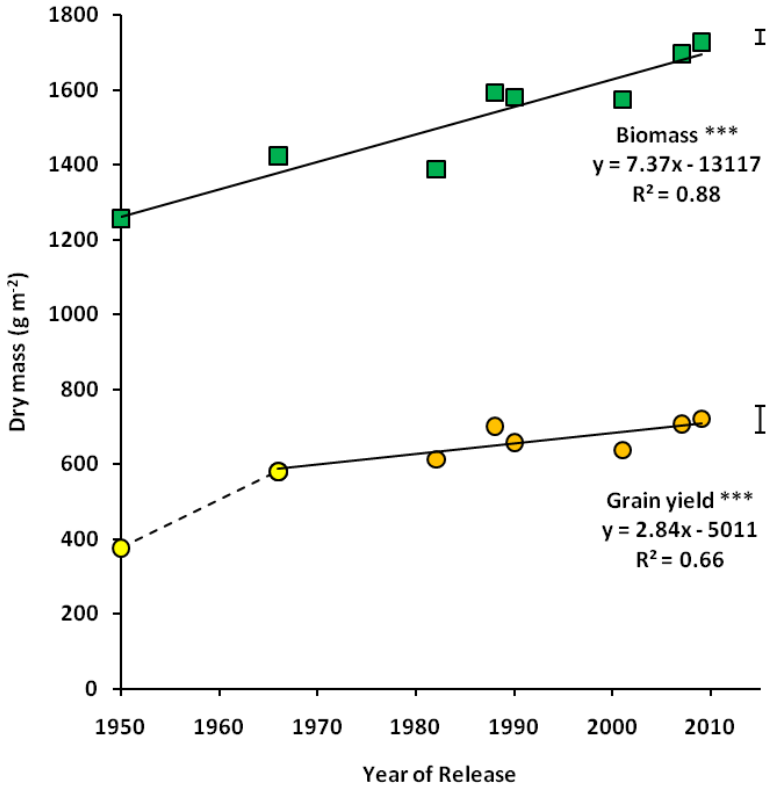
11,000 litres of water to

make a quarter pounder, and **5000 litres** of water to make 1 kilo of cheese

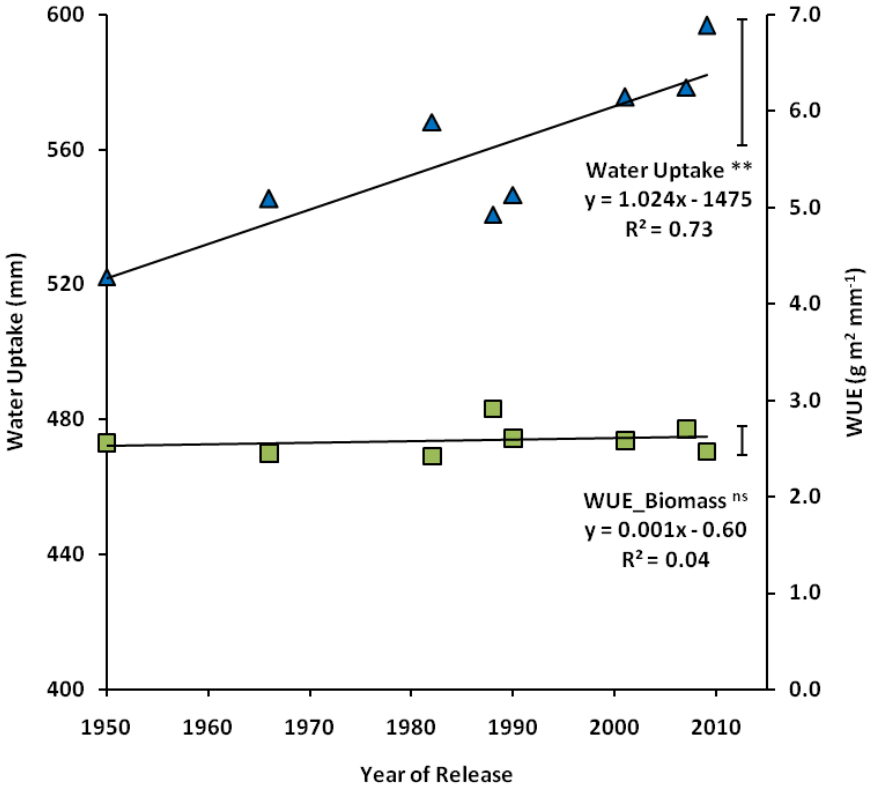
No wonder the Earth is running dry...

Increased deep water extraction of modern wheat cultivars drives biomass production.

Yield and biomass significantly increase with year of release since 1950.



Productivity driven by increased water harvest. Efficiency of crop water use unchanged.



Pask, AJD and MP Reynolds. 2013. Breeding for yield potential has increased deep water extraction capacity in irrigated wheat. Crop Science, vol. 53.

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Traits with potential for improving wheat performance

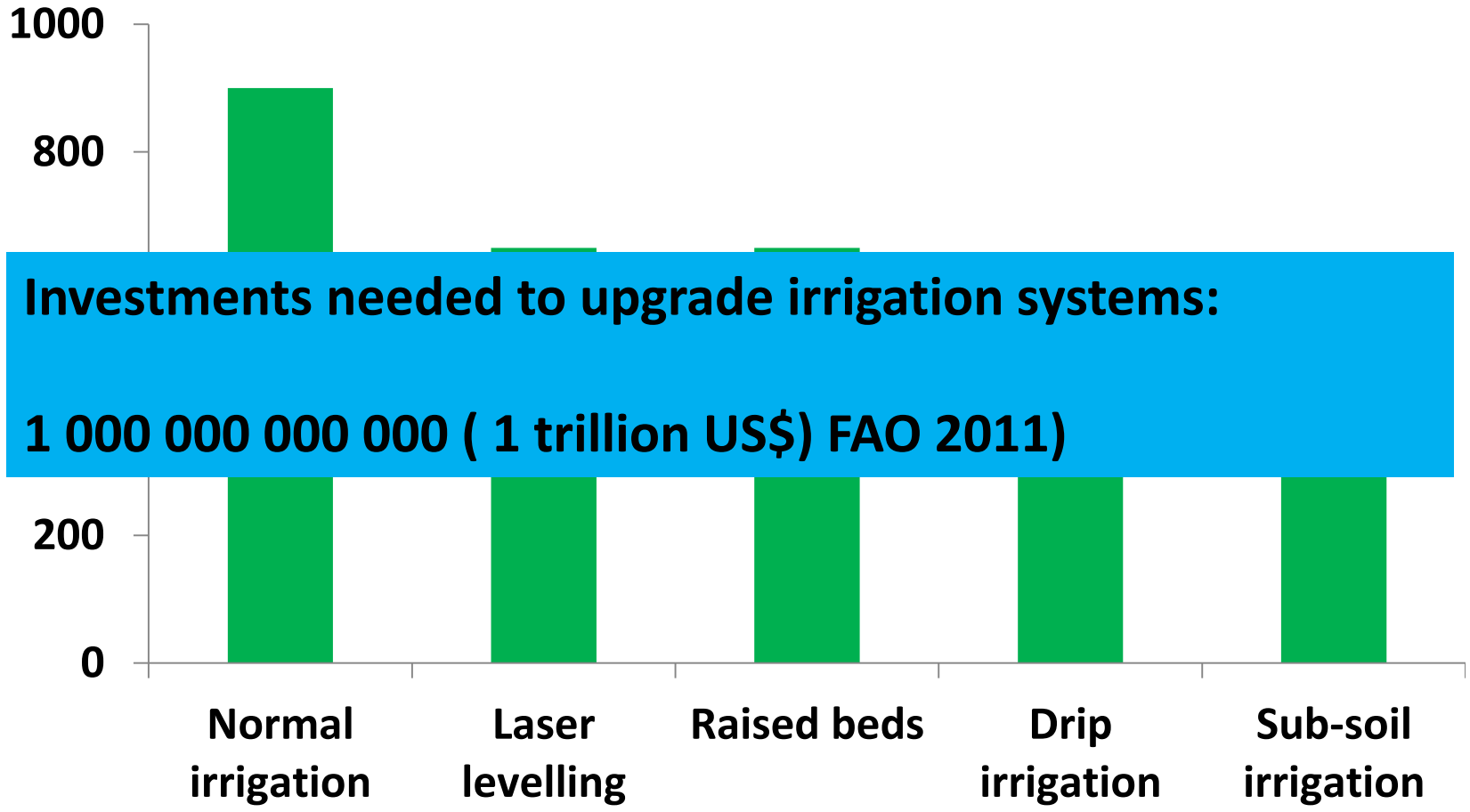
Trait	Ease of screening	Heritability	Chromosomal location of genes
Phenology	Simple	High	2A, 2B, 2D, 3A, 3B, 5A, 5B, 5D, 6A, 6B, 7A, 7B
Early vigour	Simple	High	2D, 4B, 4D, 5A
Leaf rolling	Simple	High	Unknown
Restricted-tillering	Simple	High	1A
Canopy temperature	Simple	Moderate	1B, 2B, 3B, 4A
Coleoptile length	Simple	Moderate	2B, 2D, 4A, 4B, 4D, 5D, 6B
Glaucousness	Simple	Moderate	2B, 2D
Photosynthetic capacity	Simple	Moderate	1B, 1D, 2D, 3B, 4A, 4B, 4D, 5B, 6B, 7A, 7B
Carbon isotope discrimination (leaf)	Difficult	High	1B, 1D, 2D, 3B, 4A, 4B, 4D, 5A, 7A, 7B
Carbon isotope discrimination (grain)	Difficult	High	1D, 2A, 2D, 4B, 4D, 6D, 7B
Harvest index	Difficult	High	2B, 2D, 4B, 4D
Osmotic adjustment	Difficult	Moderate	7A
Staygreen	Difficult	Moderate	2B, 2D
Stem carbohydrates	Difficult	Moderate	1A, 2B, 2D, 3B, 4B, 5B, 6B, 7A, 7B
Root biomass	Difficult	Low	1B
Stomatal conductance	Difficult	Low	1B, 2A, 2B, 2D, 4A, 4B, 4D, 7A, 7B

Adapted from Reynolds, Manes, Rebetzke, (2012)

Airborne Remote Sensing Yield, Biomass

Trial		Yield (g/m^2)	Biomass (g/m^2)
CIMCOG_H_1	NDVI UAV	0.77	0.79
	NDVI GROUND	0.63	0.58
CIMCOG_H_2	NDVI UAV	0.79	0.72
	NDVI GROUND	0.74	0.64
SEED_SEL	NDVI UAV	0.67	-
	NDVI GROUND	0.43	-
DIVERSITY SET	NDVI UAV	0.64	0.76
	NDVI GROUND	0.63	0.66
FIGS	NDVI UAV	0.60	0.69
	NDVI GROUND	0.58	0.66

Water (liter) needed to produce 1 kg wheat with various irrigation systems



Source: Compiled by H.J. Braun form various sources

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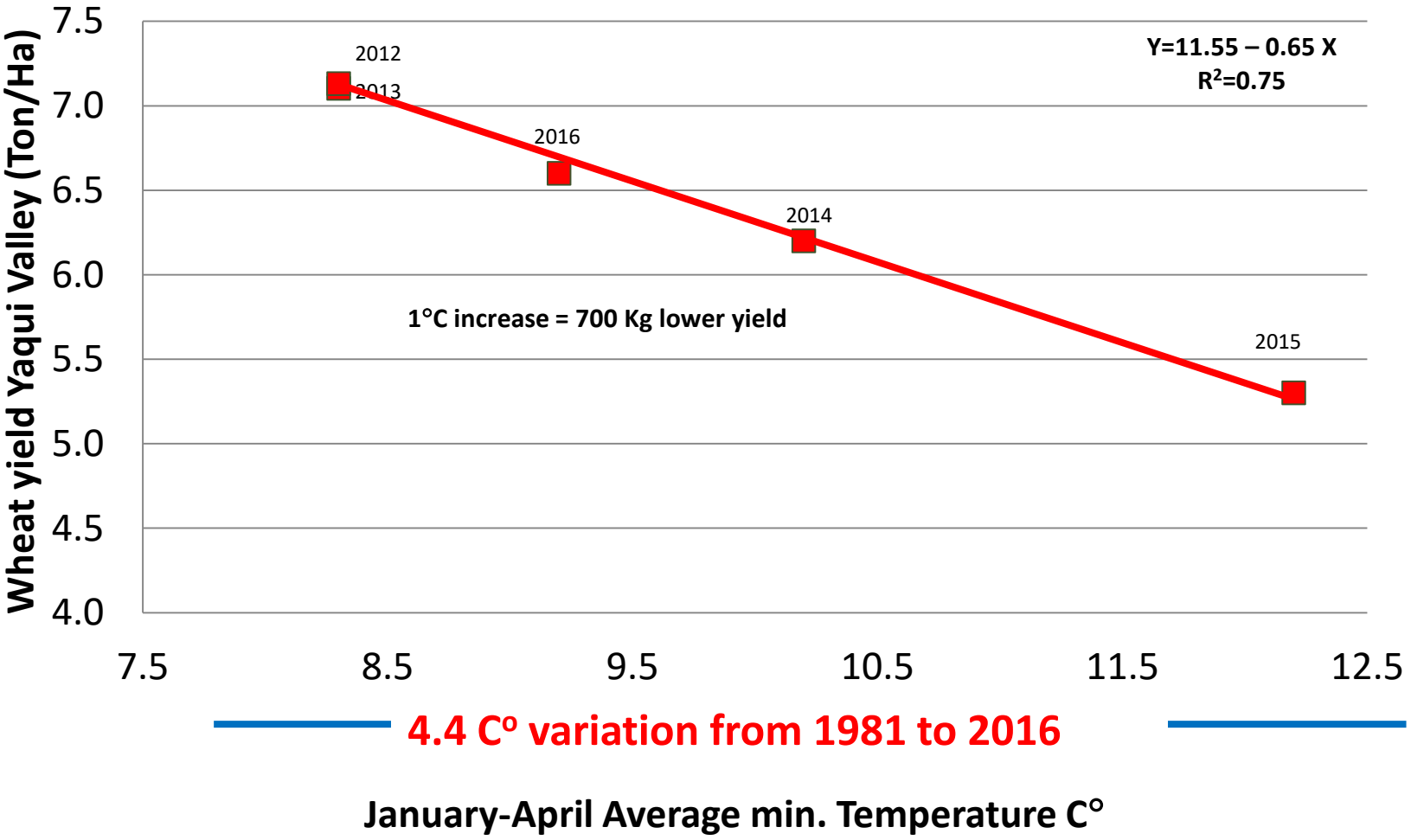
Response of wheat to increasing night temperature



Source: H.-J. Braun and I. Ortiz-Monasterio, CIMMYT

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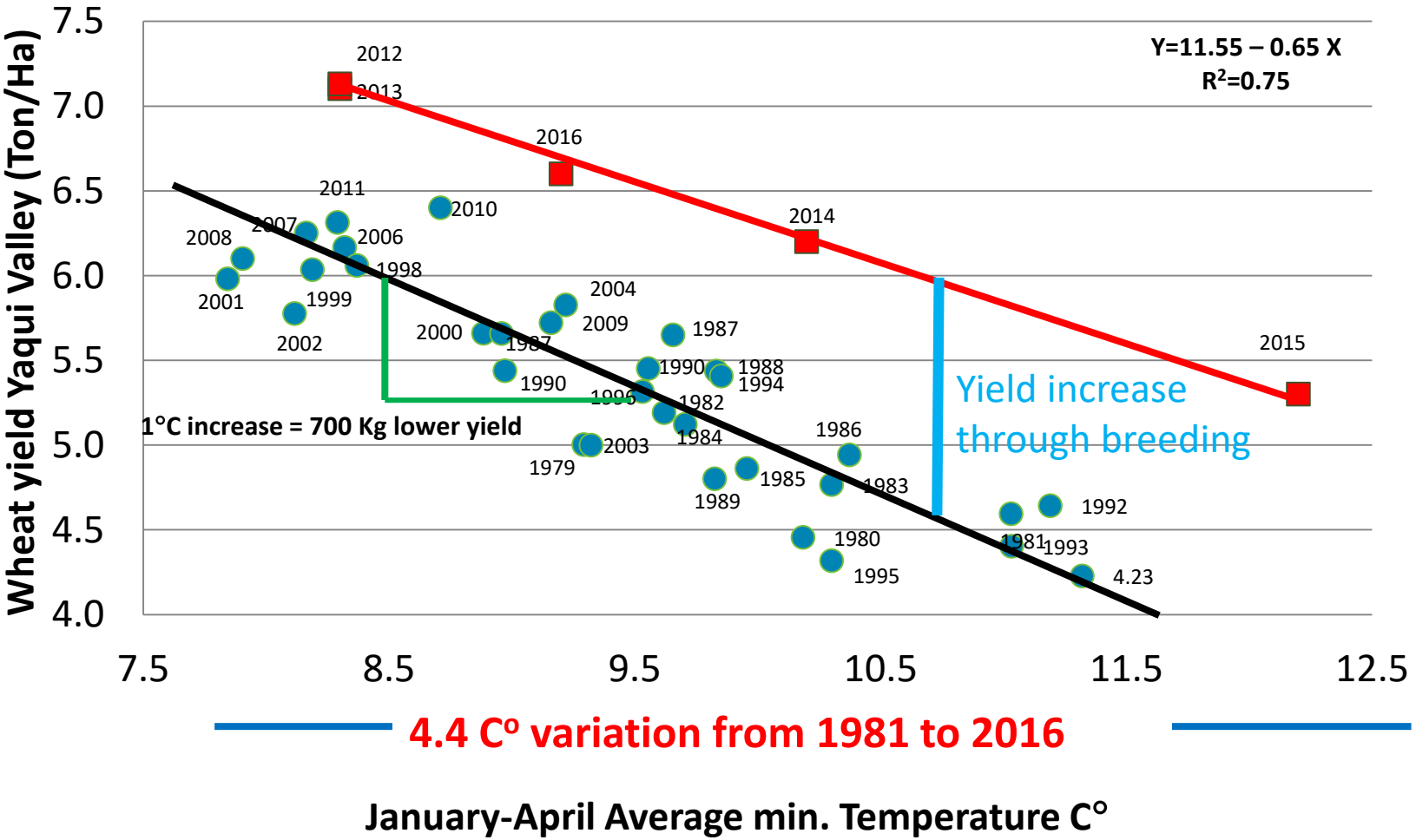
Adapting to Climate Change: Heat Tolerant Wheats prove their Value in Farmers' Fields in Mexico



Source: H.-J. Braun and I. Ortiz-Monasterio, CIMMYT

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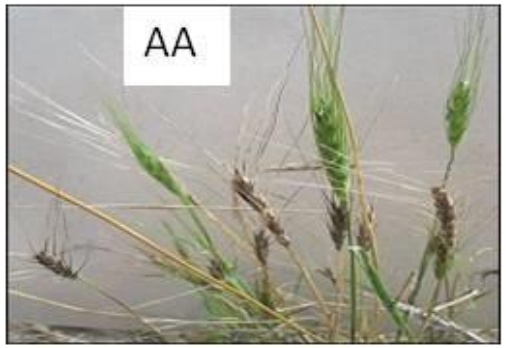
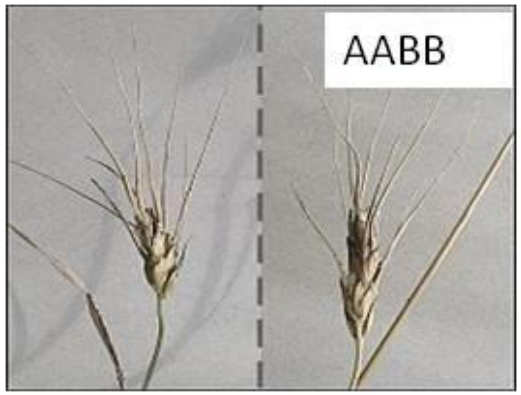
Wheat Genetic Resources





70,000 Wheat Genetic Resources Screened Under Drought and Heat, Sonora, Mexico, 2011-2013

CIMMYT Genebank holds

140 000 Wheat and wheat relative accessions

28 000 Maize Accessions

CIMMYT's Synthetic Wheat Program

X

=

T. durum
AABB

T. tauschii
DD

Hexaploid synthetic
AABBDD

Introgression of new DD genomes has brought in traits such as yield and resistance to FHS, Septoria, Spot Blotch, Rusts, Hessian Fly, Russian Wheat Aphid and drought tolerance.

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Synthetic hexaploid wheats

Variation found for a large range of traits

- Rusts
- Septoria tritici
- Fusarium Head Blight
- Spot Blotch
- Drought tolerance
- Grain quality

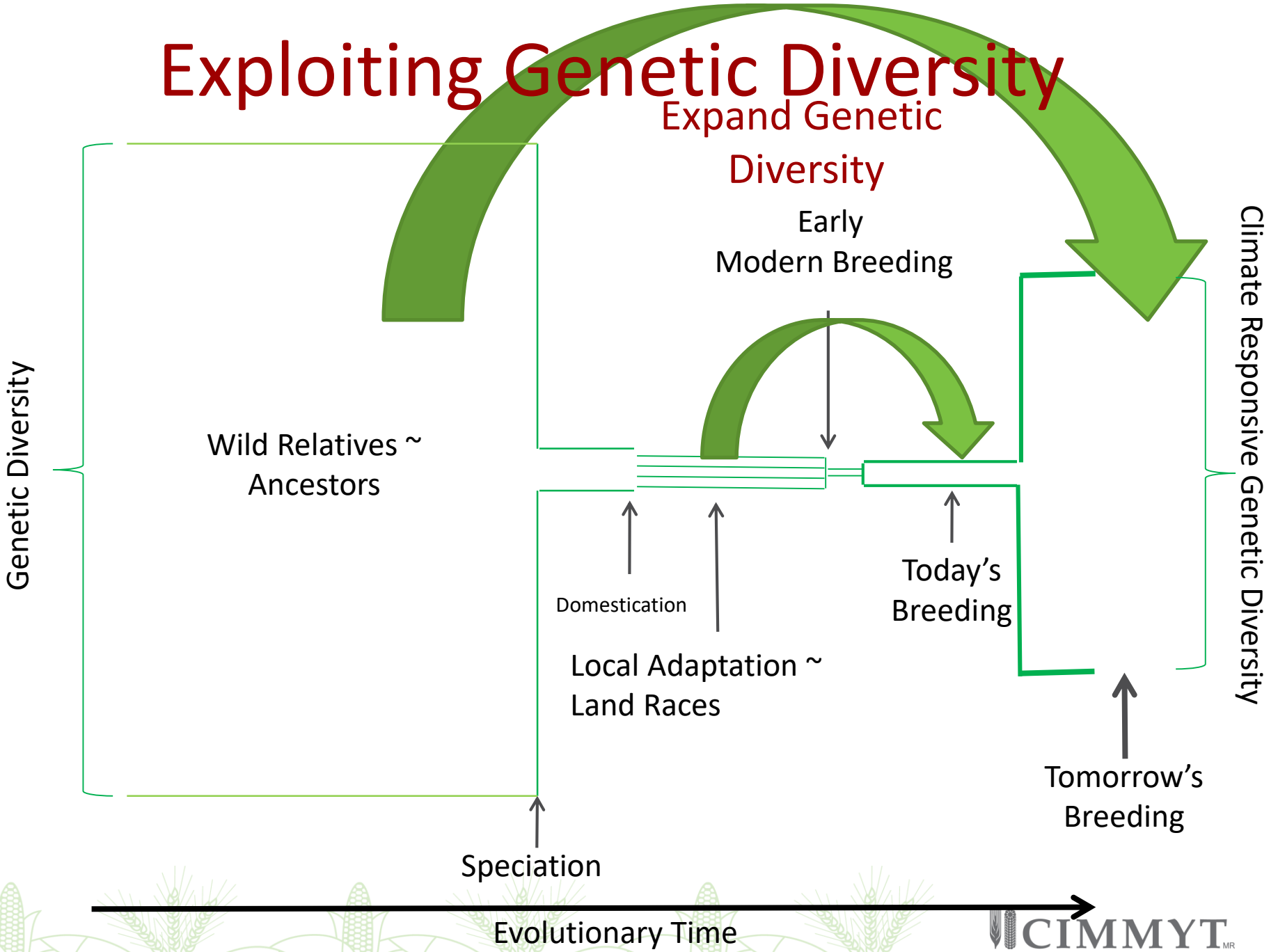
Hessian Fly
Sunn Pest
Russina Wheat Apid
Soil Borne Diseases
Water logging
New ppd alleles

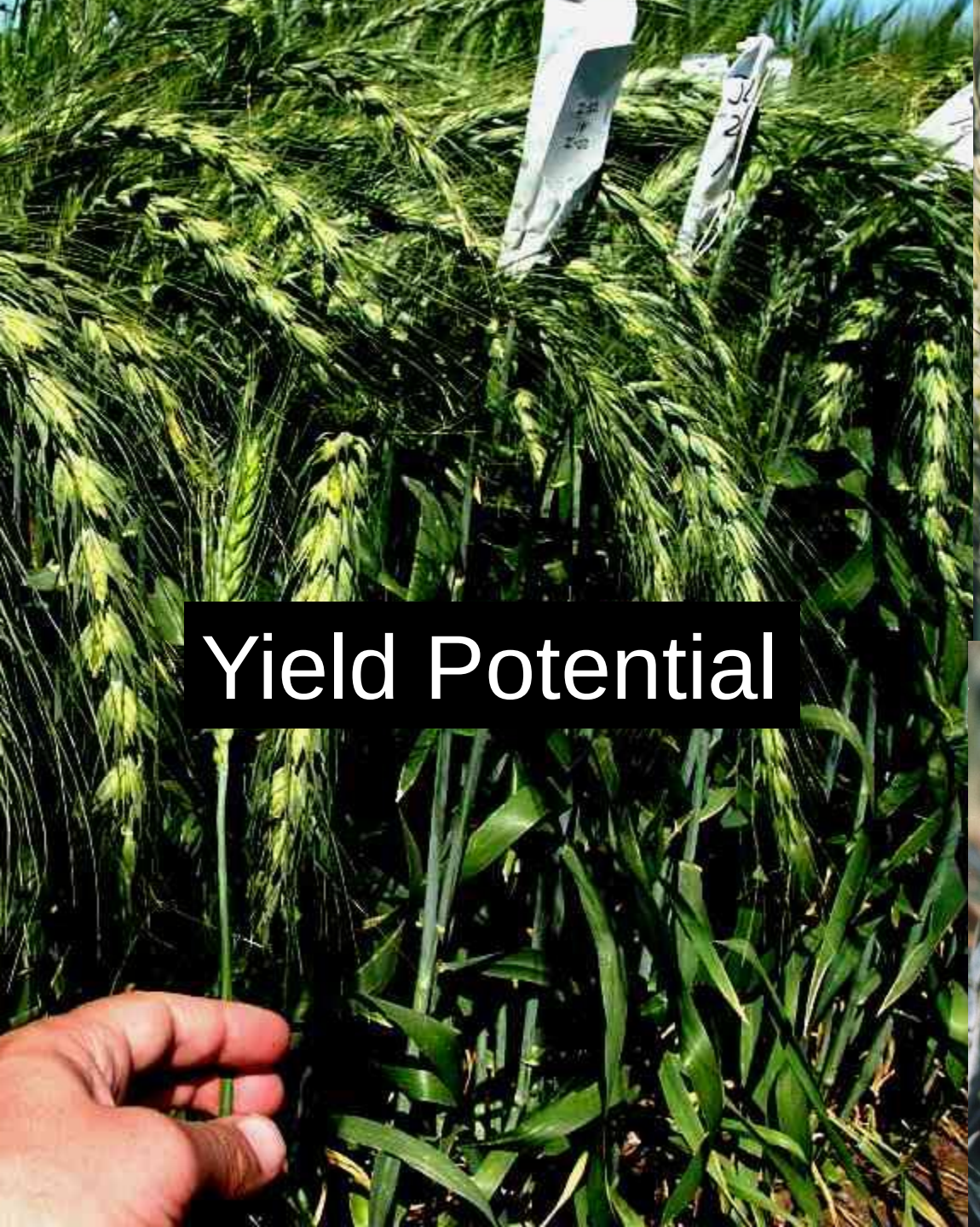
- Used in breeding at CIMMYT and distributed globally
  => then noticed increased yield potential; CIMMYT NIAB

8 synthetic derived varieties released in China, Spain and Ecuador

Little genetic analysis initially

Exploiting Genetic Diversity





Yield Potential

Raising Wheat Productivity by 70% by 2050

• Sharing germplasm and knowledge	50??	Rassmusen, 1996
• Agro-ecological attainable yield gap	75%	Bruinsman 2009
• Agronomy – yield gap	50%	Fischer et al, 2014
• Weeds/ Diseases / Pests	28%	Oerke 2006
• Post Harvest Losses in LDC	20%	?? Limited info
• Breeding / Physiology	50%	Reynolds et al, 2010
• Transgenics / Cisgenics	??	

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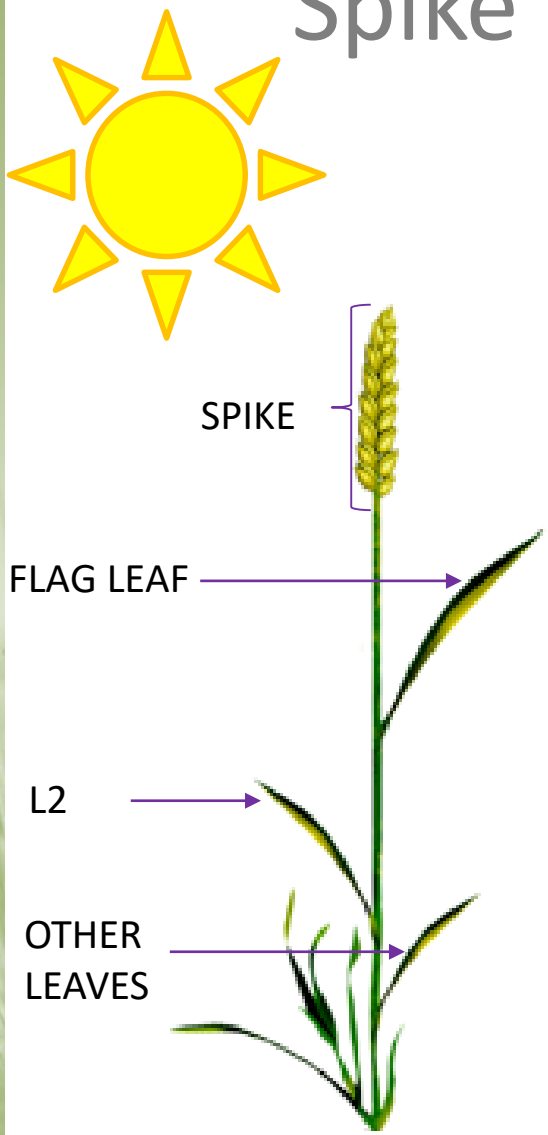
Spike Photosynthesis…



Light Intercepted A+7 (%)
2 year data, 30 gen, 3 reps

22 – 41 % (28 %)
17 – 40 % (28 %)
7 – 33 % (25 %)
4 – 34 % (10 %)

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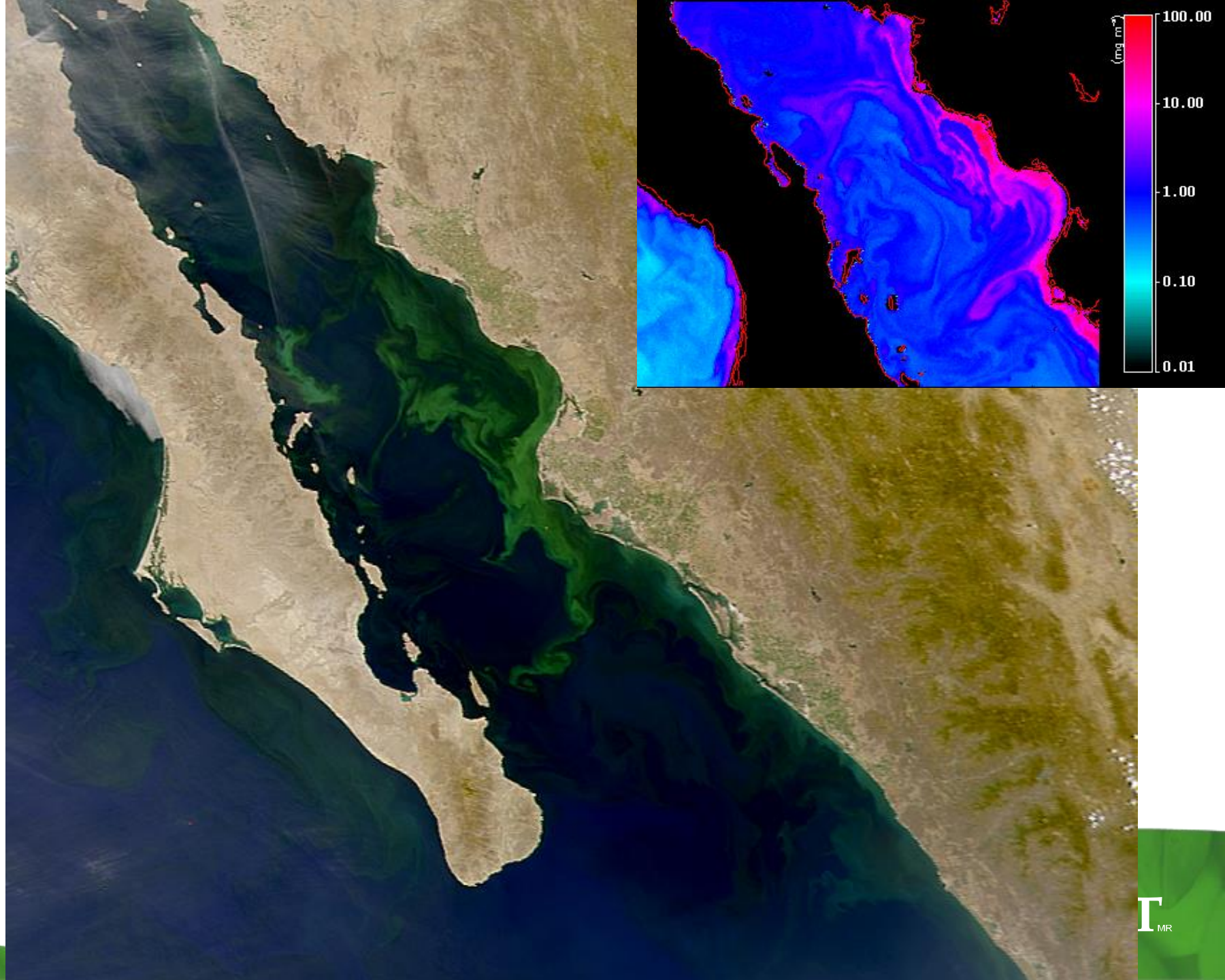

(mg m³)
100.00
10.00
1.00
0.10
0.01

Increase N-use efficiency

- Wheat uses more N than any other crop(19%) (IFA, 2007)
- China, India and Pakistan apply 50% of all N used for wheat (IFA, 2007)
- NUE in LDC only 1/3 i.e. 2 of 3 kg N applied do not end up in plants but in water or air

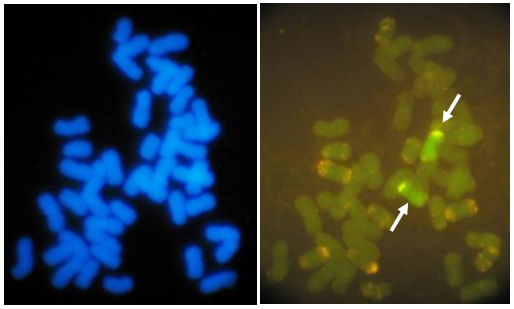
BNI from *L. racemosus*

Roots produce exudates that inhibit nitrification (90% remains in stable NH_4 form after 60 days)

L. racemosus chromosomes have been transferred to wheat (CS) and are now transferred to elite lines

- Bioassay by Dr Subbarao at JIRCAS Tsukuba found addition of Lr#n expressed BNI at about 80% of *L. racemosus* level

Stock	racemosus chromosome	Homol gp in wheat	BNI[a]
L. racemosus			31.55
Chinese Spring			6.39
DALr#n	Lr#n	3 and 7	24.57
DALr#J	Lr#J	7	13.47
DALr#I	Lr#I	5	13.02
DALr#k	Lr#k	6	5.5
DALr#F	Lr#F	4	4.12
DALr#H	Lr#H	3	3.65



A B

Two Lr#n *L. racemosus* chromosomes in wheat detected by florescence *in situ* hybridization with probe of *L. racemosus* genomic DNA (green color)

CIMMYT





Soil loss, an unfolding global disaster

- **30% of the world's arable land lost to erosion or pollution in the last 40 years.**
- **Erosion rates from ploughed fields averages 10-100 times greater than rates of soil formation.**
- **It takes about 100 years to form 0.5cm of topsoil under normal agricultural conditions.**

University of Sheffield's Grantham Centre for Sustainable Futures, 2016

CIMMYT

To a hungry person,
God appears in the form of Bread

Mahadma Gandhi

CIMMYT Academy

www.cimmyt.org
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¡gracias!

তোমাকে ধন্যবাদ

شكرا

kiitos

감사합니다

takk

danke

با تشکر از شما

धन्यवाद

na-ekele unu

merci

obrigado

teşekkür ederim

dank u

thank you

asante sana

ありがとう

Ameseginalehu

ขอขอบคุณคุณ

谢谢

tak

спасибо

grazie

dankie

shukran

merci

salamat

謝謝

આભાર

tack