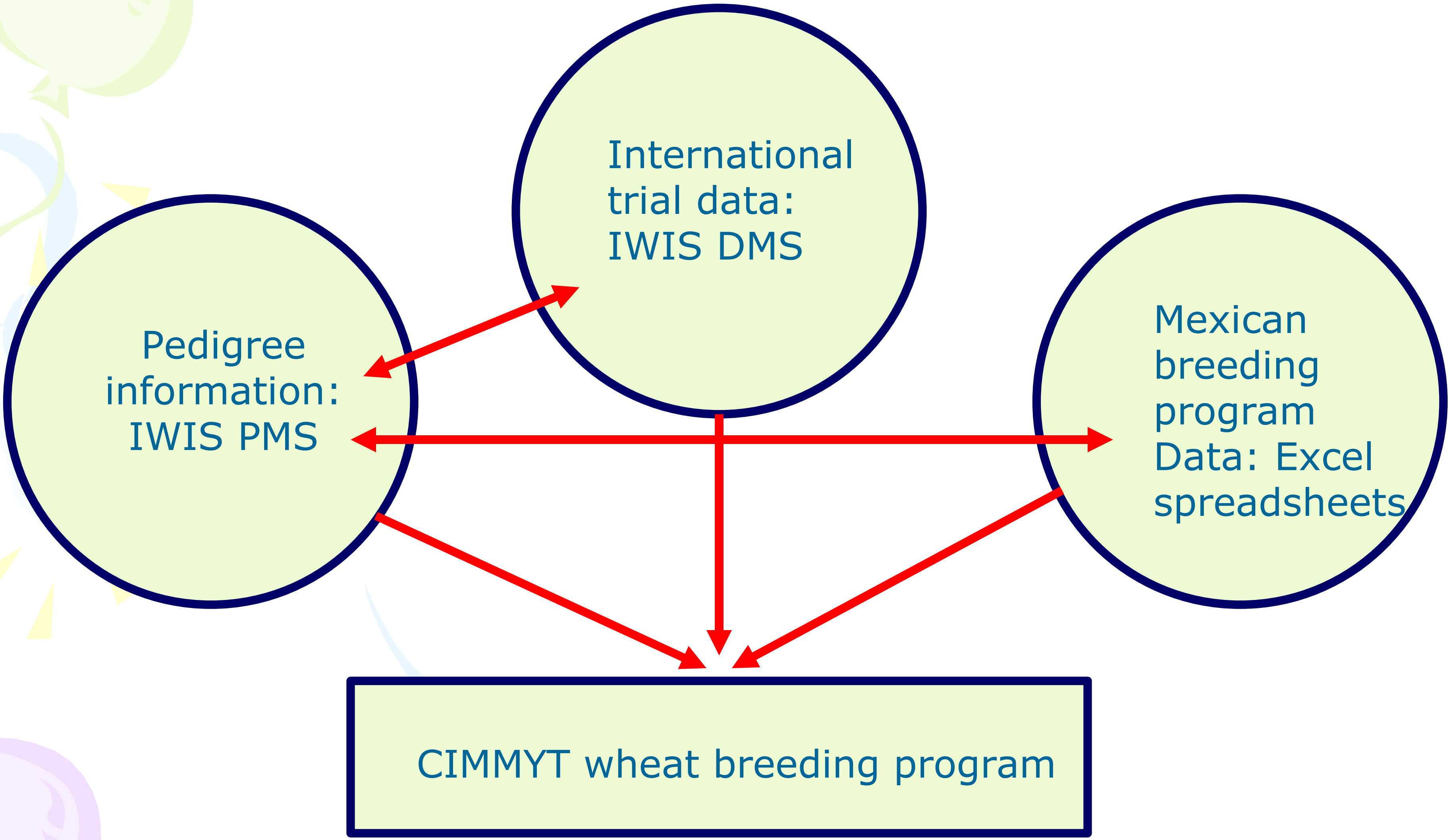
CIMMYT wheat breeding: methods, structure and data

R. Trethowan

CIMMYT

Structure of wheat breeding information at CIMMYT



Pedigree Information

Cross, Cross ID, Selection ID and selection history

CID	SID	Cross	Selection history
2345	0001	KAUZ/SERI M82	CMSA00M0249S-040M-040Y-030M-6Y-0M

Data collected

	Quantitative	Genetic	Qualitative
Yield	x		
Disease	x	x	x
Phenological	x	x	x
Morphological	x	x	x
Quality	x	x	x

Defining wheat growing environments and selecting better parents

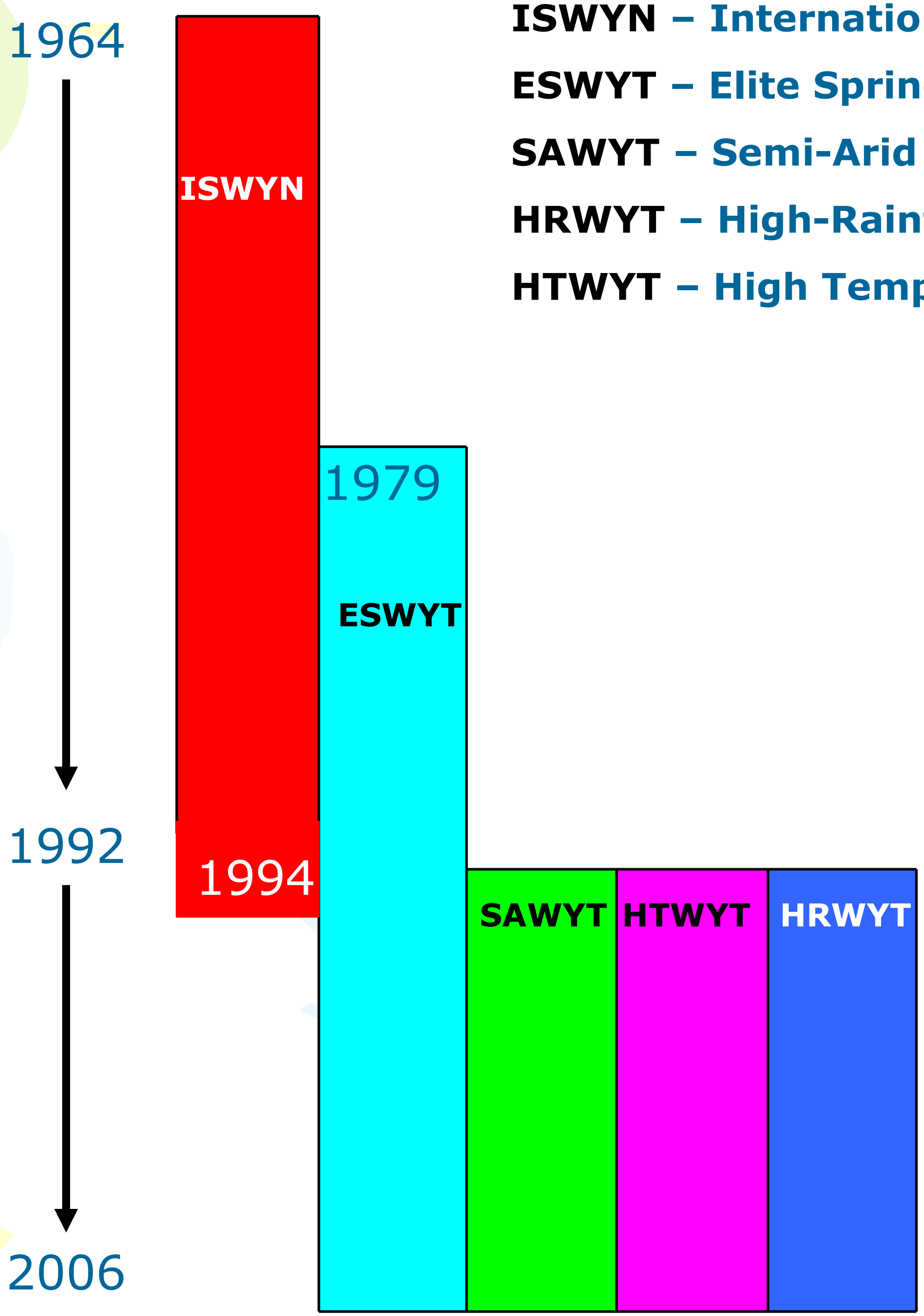
ISWYN – International Spring wheat Yield Nursery

ESWYT – Elite Spring Wheat Yield Trial

SAWYT – Semi-Arid Wheat Yield Trial

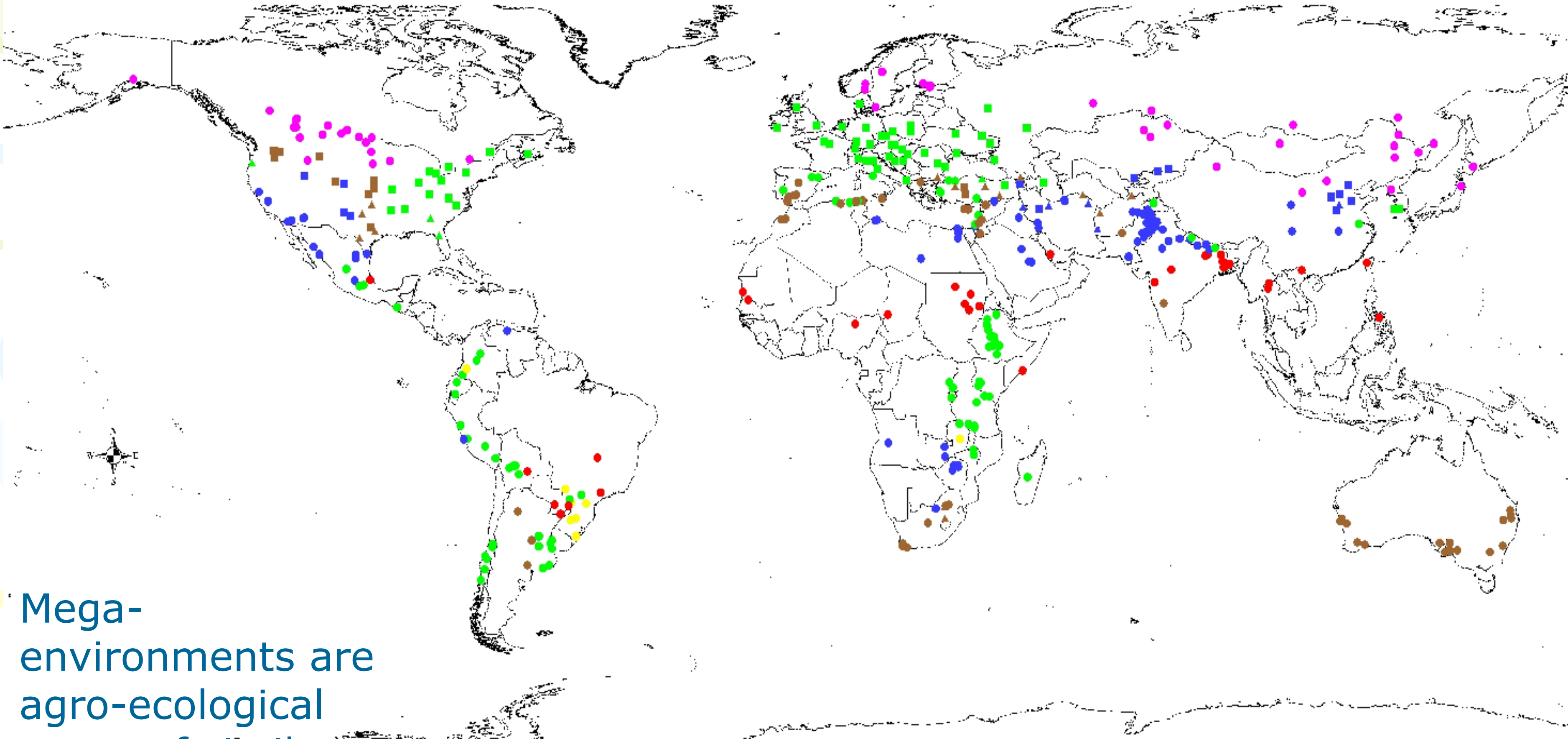
HRWYT – High-Rainfall Wheat Yield Trial

HTWYT – High Temperature Wheat Yield Trial

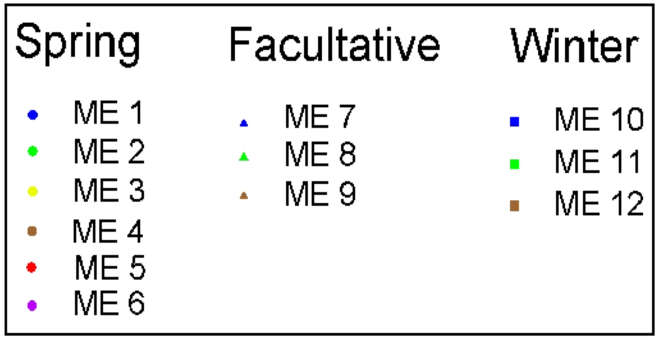


MEGA-ENVIRONMENTS

Wheat Sites Classified by Mega-Environment



Mega-environments are agro-ecological zones of similar adaptation



Source: D. Hodson

JWW 16
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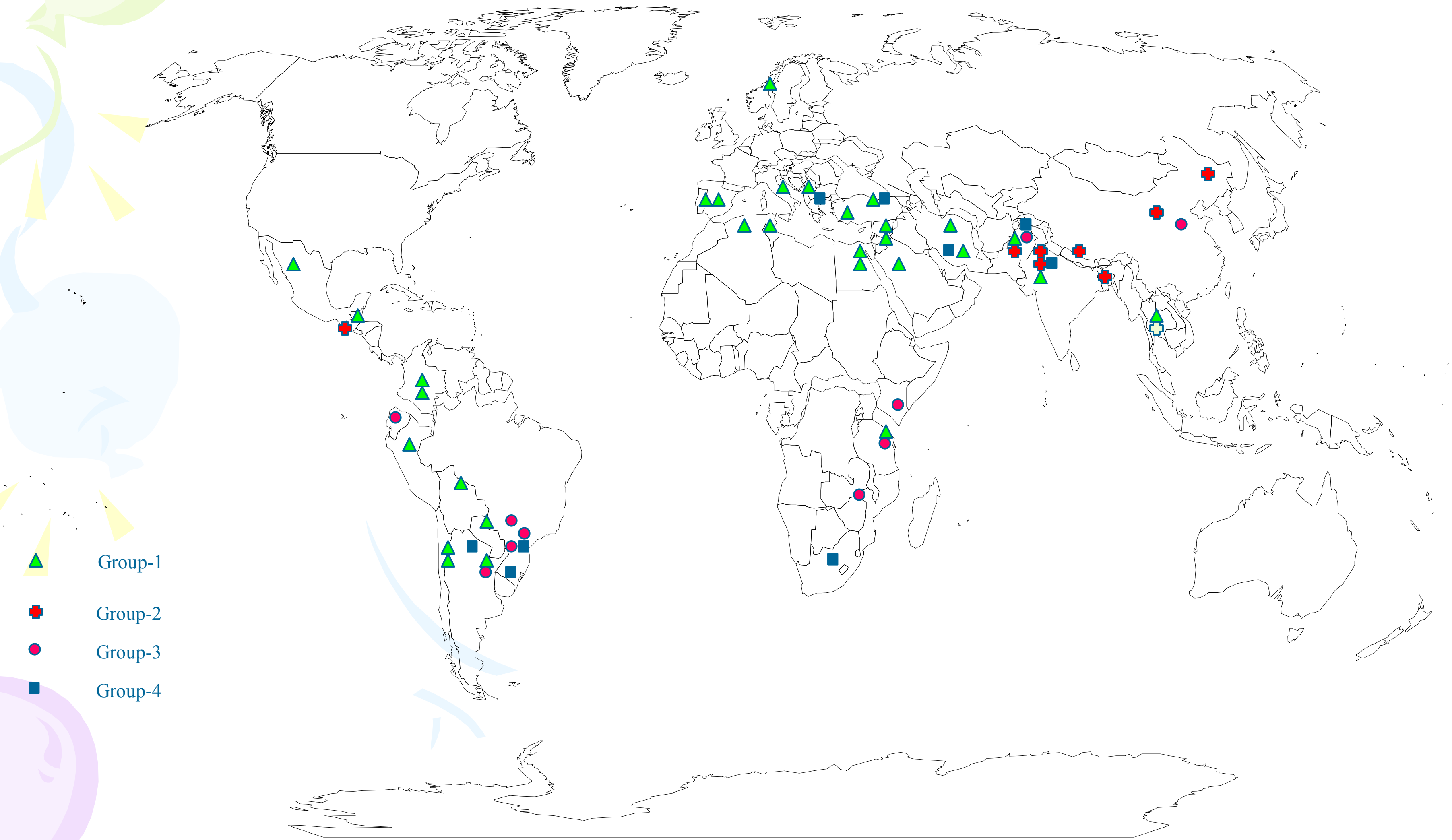
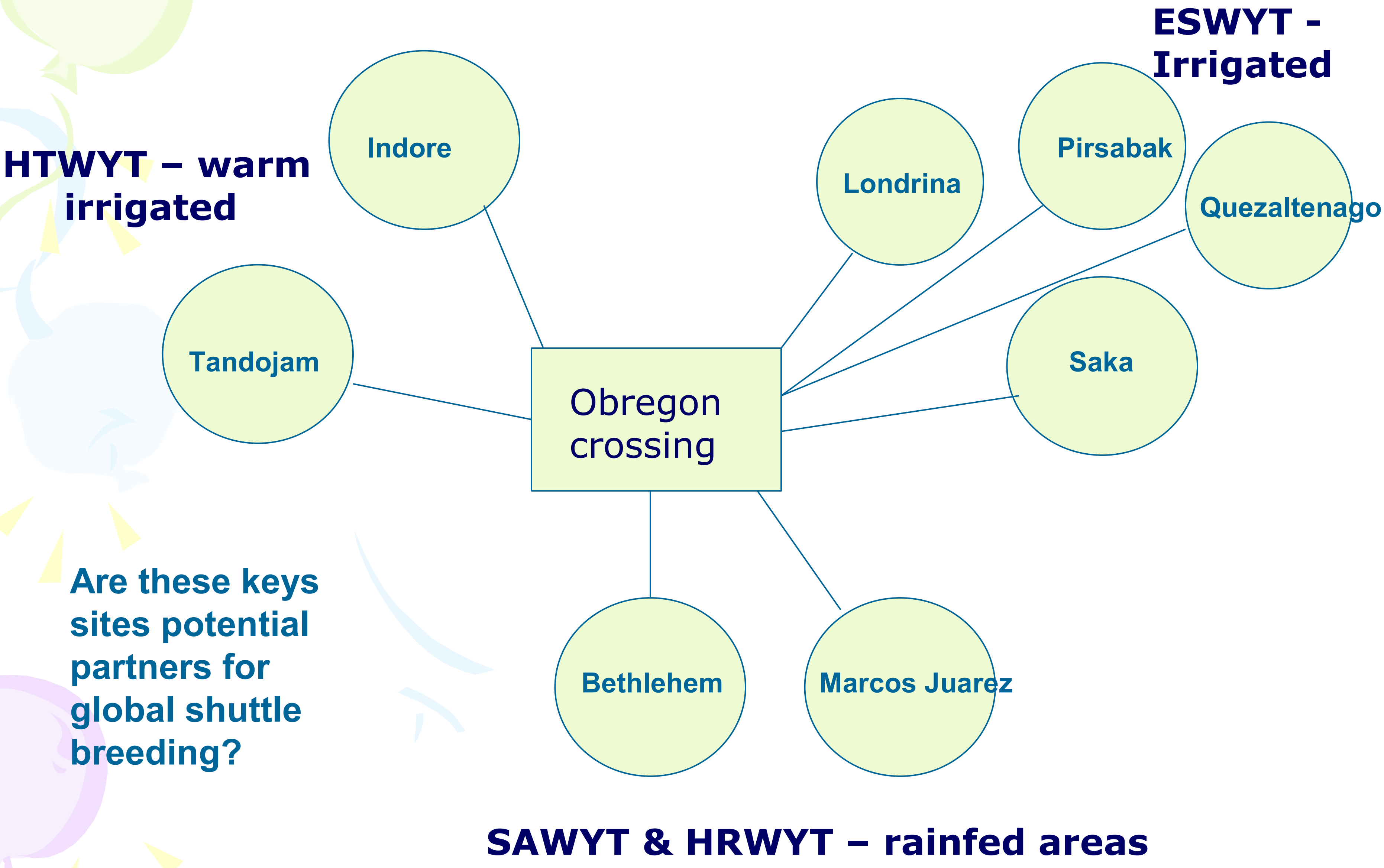
Measuring GxE for yield and selecting parents.

Analysis of 20-years of international bread wheat data



Source: Trethowan et al, 2003

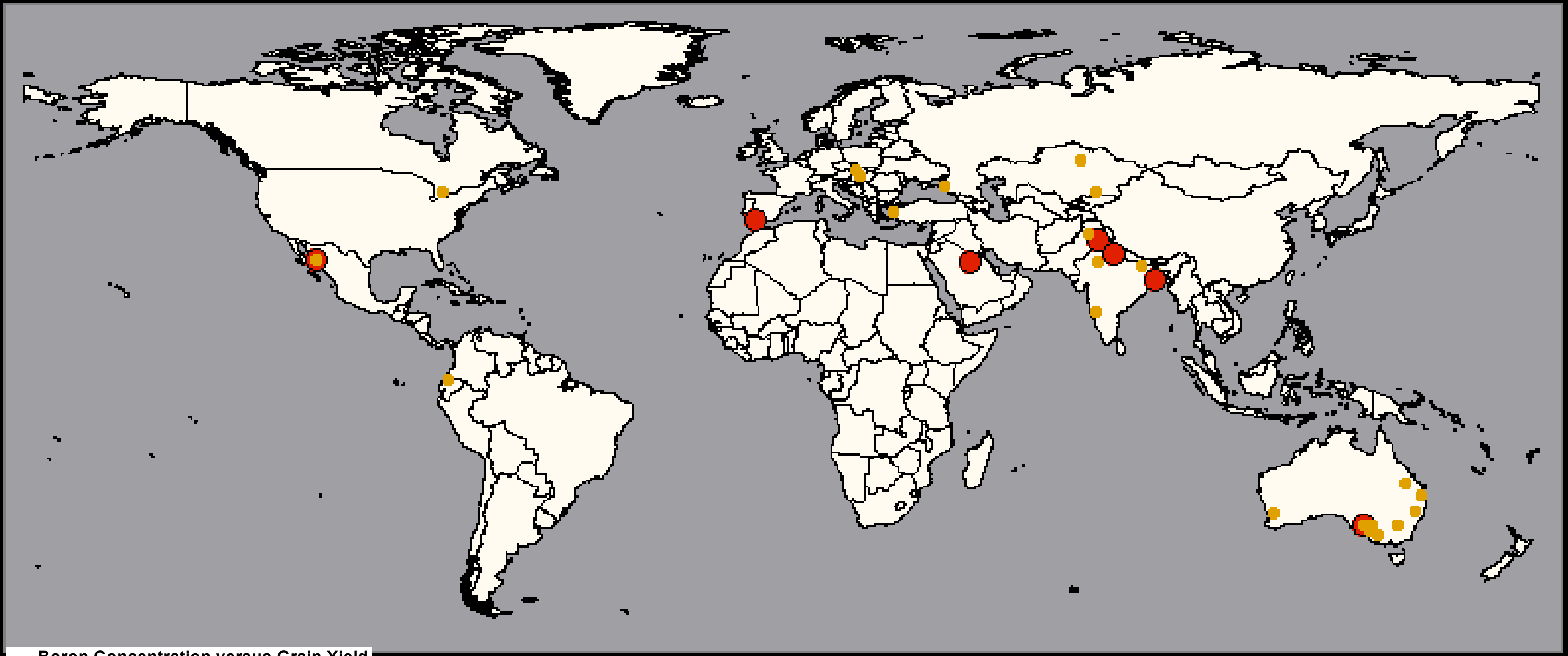
Information from key sites now used to identify parents for crossing in Mexico

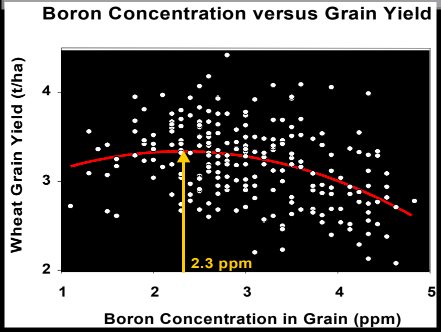


Are these keys sites potential partners for global shuttle breeding?

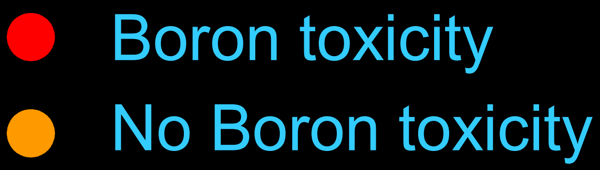
The deployment of differential genotypes for soil borne stresses:

differentiation of locations for boron toxicity

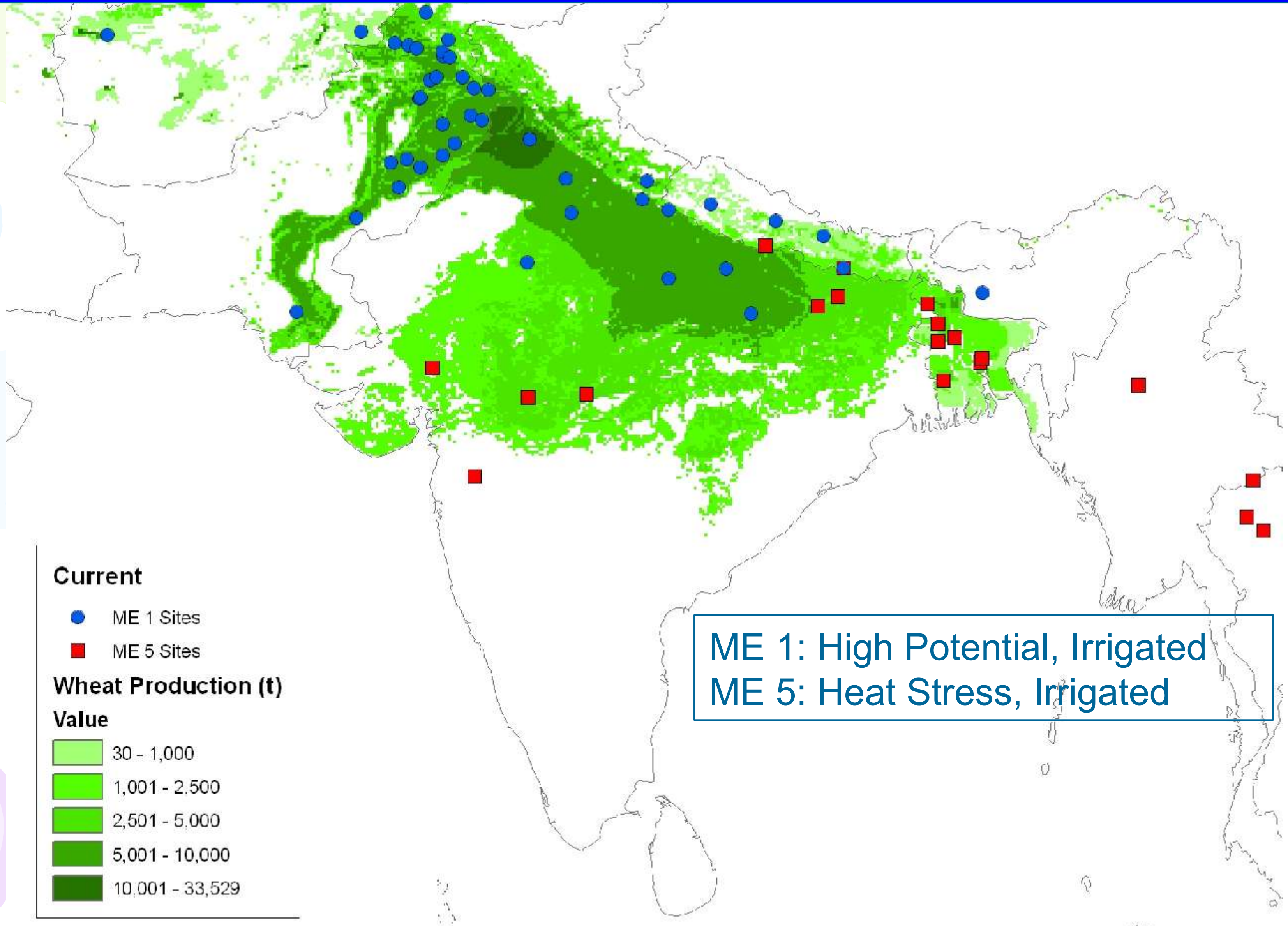




Source: K. Matthews et al

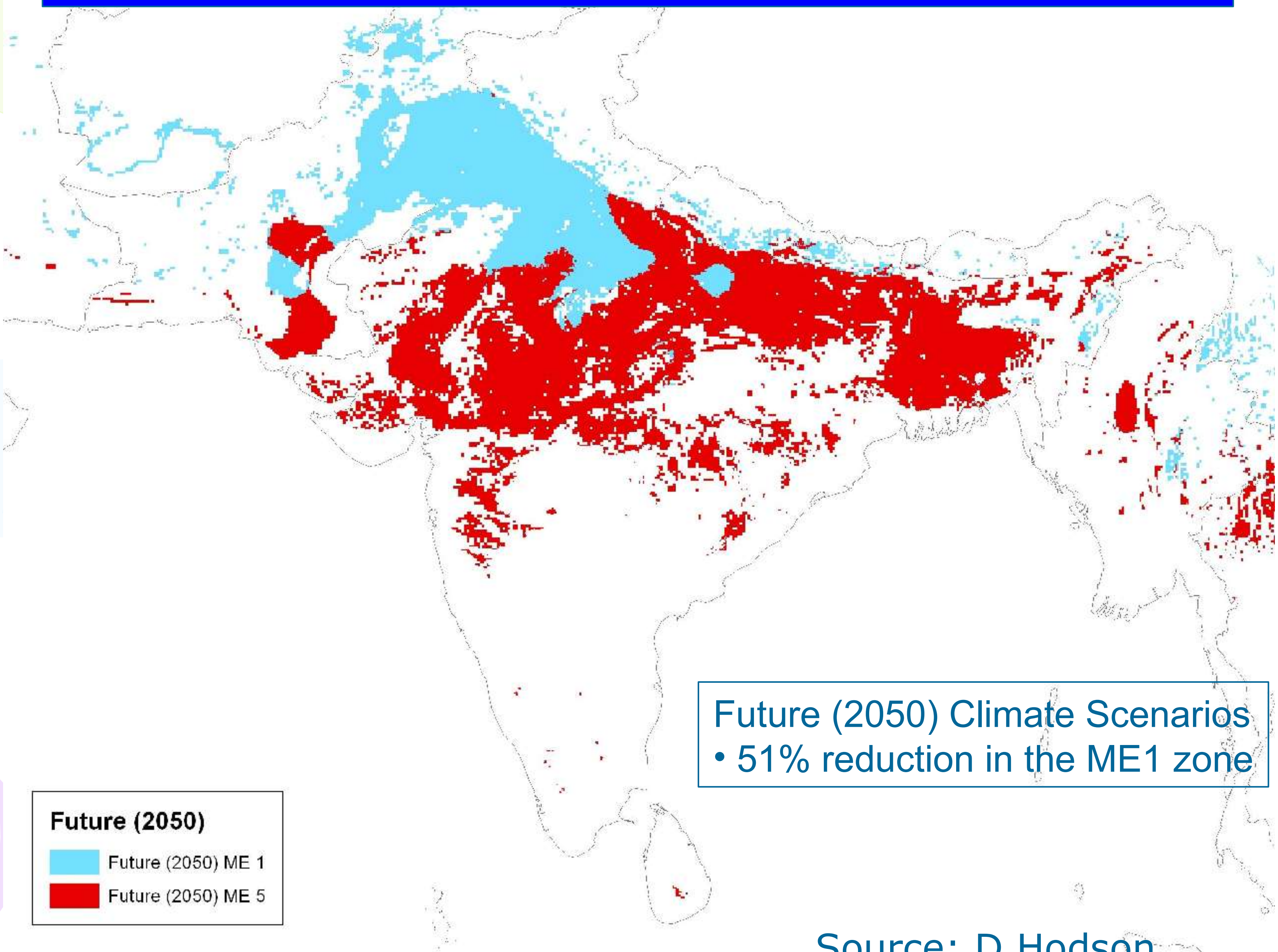


Current Wheat Production and Trial Sites Classified by Mega-environment



Source: D. Hodson

Future Climate Mega-environment Zone Classification – ME 1 & 5



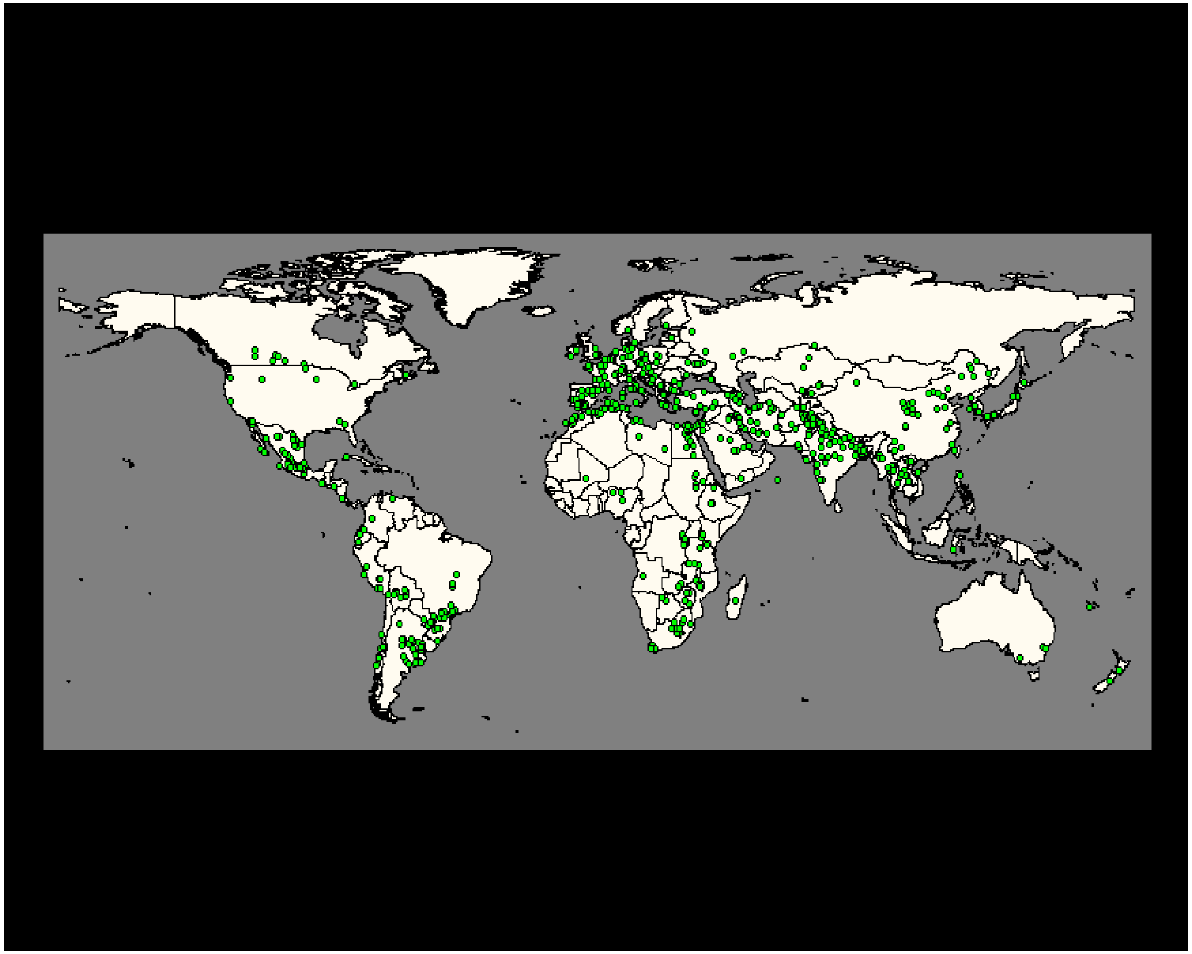
Future (2050) Climate Scenarios

- 51% reduction in the ME1 zone

Source: D Hodson

Use of historical trial data to identify genomic regions and ultimately candidate genes commonly found in germplasm adapted to stress conditions

At CIMMYT, 30 years of trial data are currently being analyzed and genotypes spanning this period are being genotyped



These regions can be used to identify parents and improve selection for stress

Physiological applications in wheat breeding

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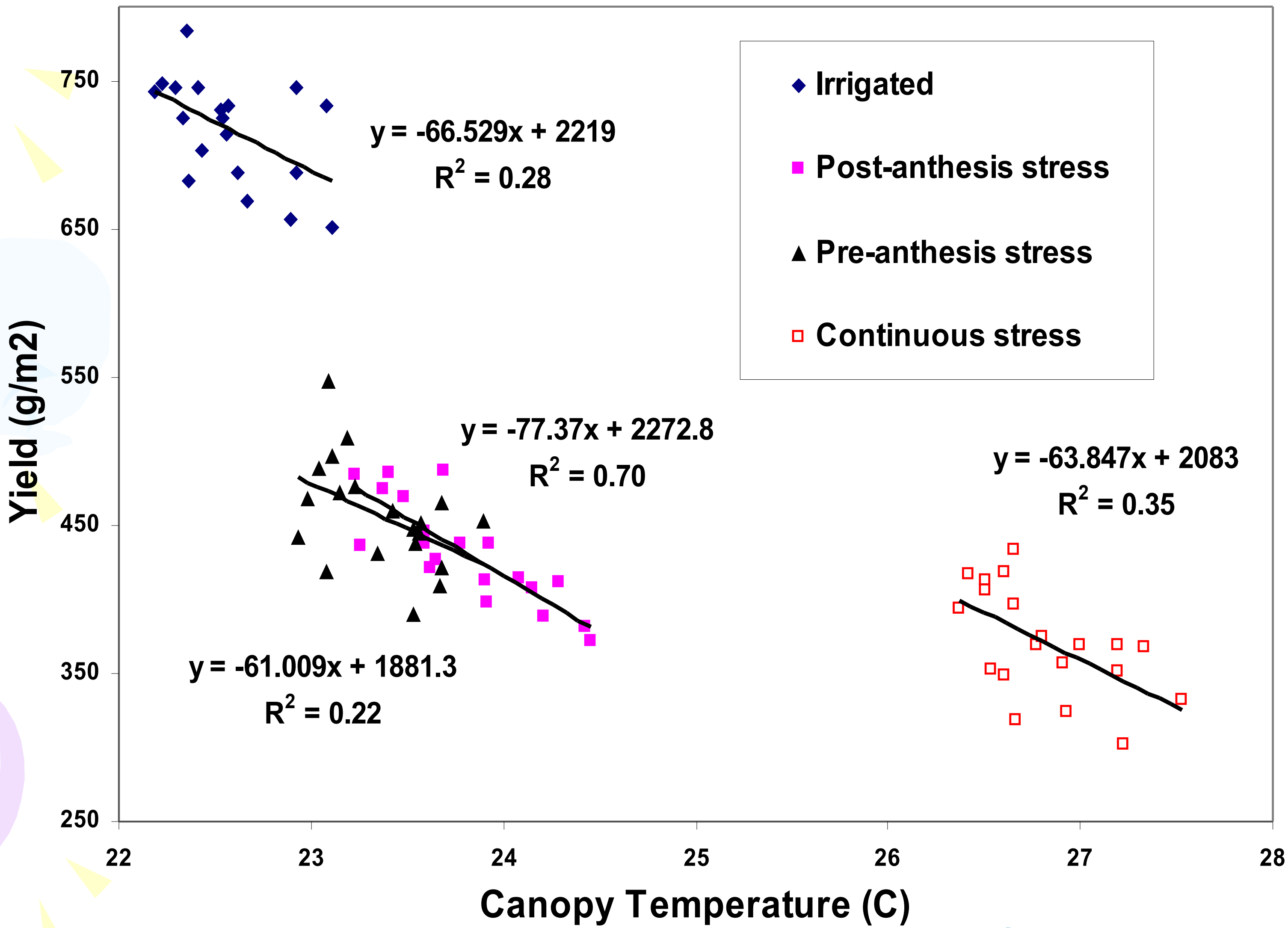
Physiological characterization of crossing materials: combining physiological traits

Pedigree	Yield	Biomass	CT[1]	CT	Carbon isotope	Stem CHO[2]	Water extraction
		anthesis	Veg	Grainfill	Discrim.	at anthesis	by roots
	g/m^2	g/m^2	C°	C°		% stem dry weight	(% available water)
Jun/Gen	338	424	19.2	21.8	-23.1	13.3	84
Weebill 1	348	513	19.3	21.7	-22.5	17.5	83
Synthetic	278	510	19.8	22.6	-22.5	19.1	79
Frame	213	503	20.5	23.2	-21.7	6.8	79
Klein Cacique	247	638	20.1	23.3	-22.6	3.4	82
Prointa Federal	223	572	20.0	22.9	-22.4	11.2	79

[1] canopy temperature; [2] carbohydrate

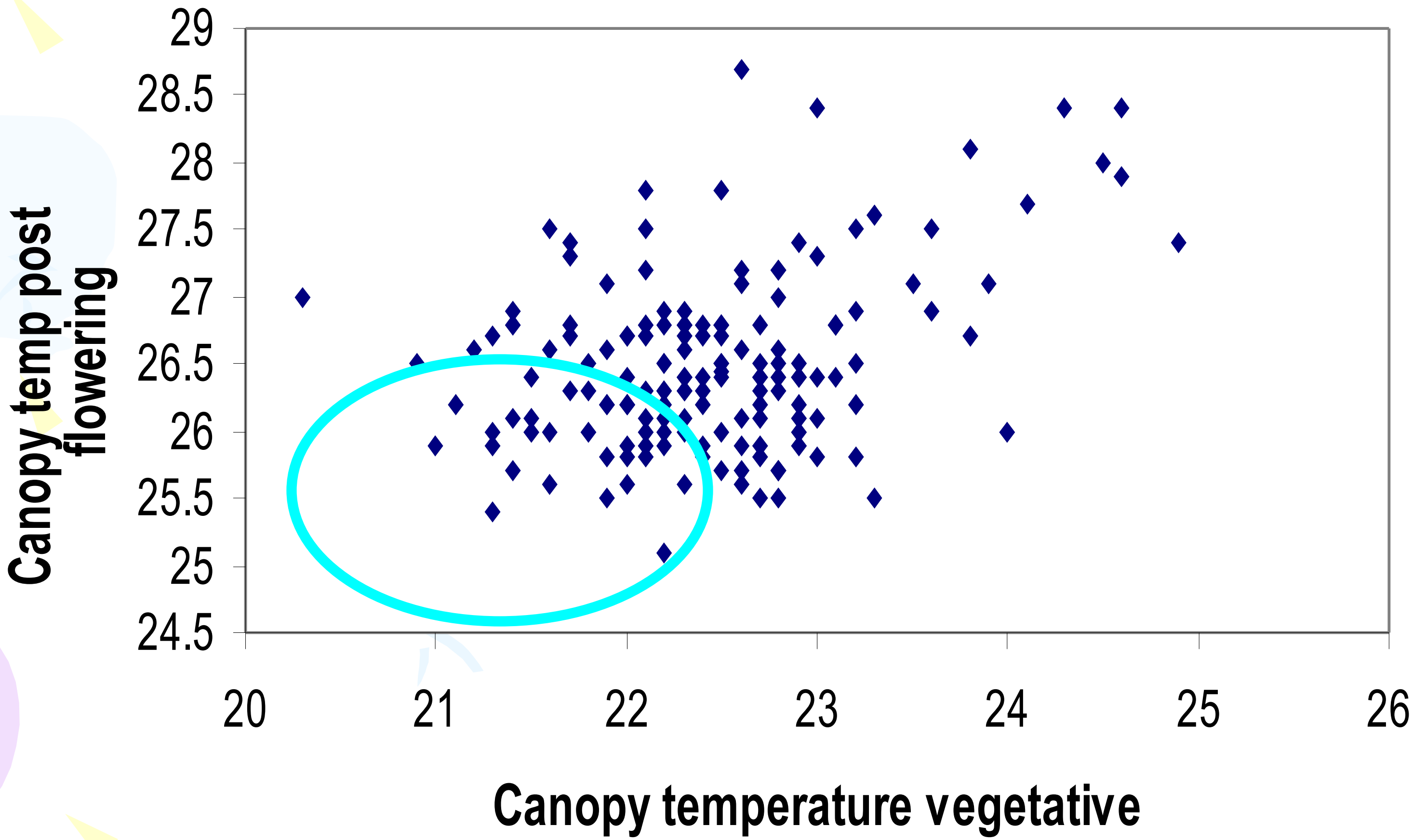
Yield and canopy temperature in grainfilling under different moisture stress scenarios (NW Mexico)



Source: Reynolds et al.

The use of CTD in breeding: F4 bulks under drought stress

Following visual selection, CTD scores used to influence gene frequency



Agronomic applications in wheat breeding

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Improving adaptation to conservation tillage

In the <u>rice-wheat</u> rotations of South Asia Reeves et al. (2001) estimate that adopting zero-tillage on one hectare of land would:

4. Save 1,000,000 litres of irrigation water
5. Save 98 litres of diesel fuel
6. Result in 0.25 tons less CO_2 emission

Farmers traditionally burn crop residues in these systems. Burning 10t/ha of residue will release 13 tons of CO2 into the atmosphere.

In rainfed environments zero-tillage provides better water infiltration and reduced runoff

Source: Fernando Delgado

Improving the emergence & establishment of wheat

- Substitution of *Rht 1* & *2* for alternate GA sensitive dwarfing sources

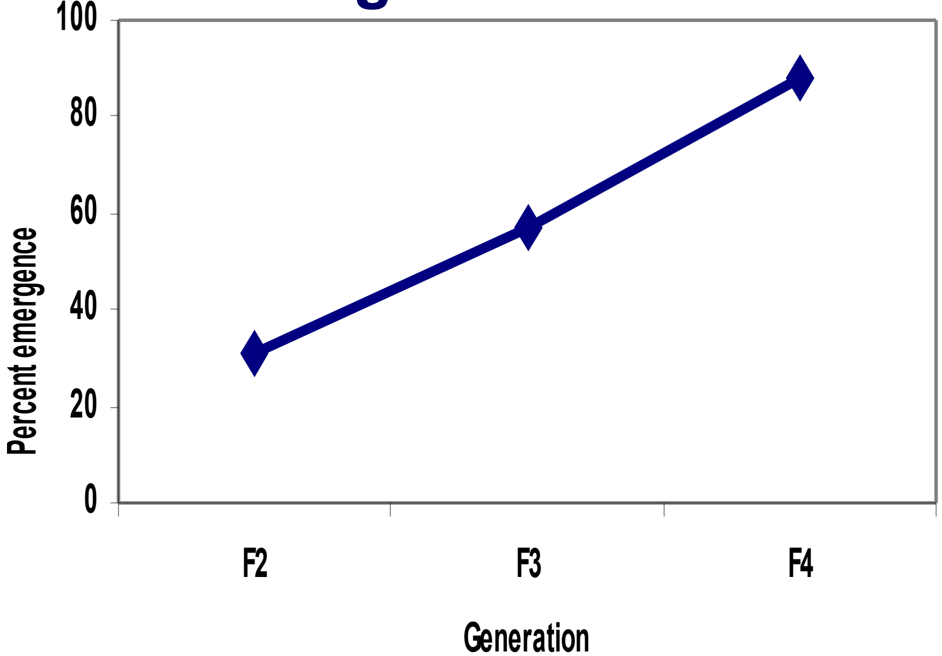
- Significantly better emergence from depth

- Improved early vigor (inferences for WUE and weed growth)

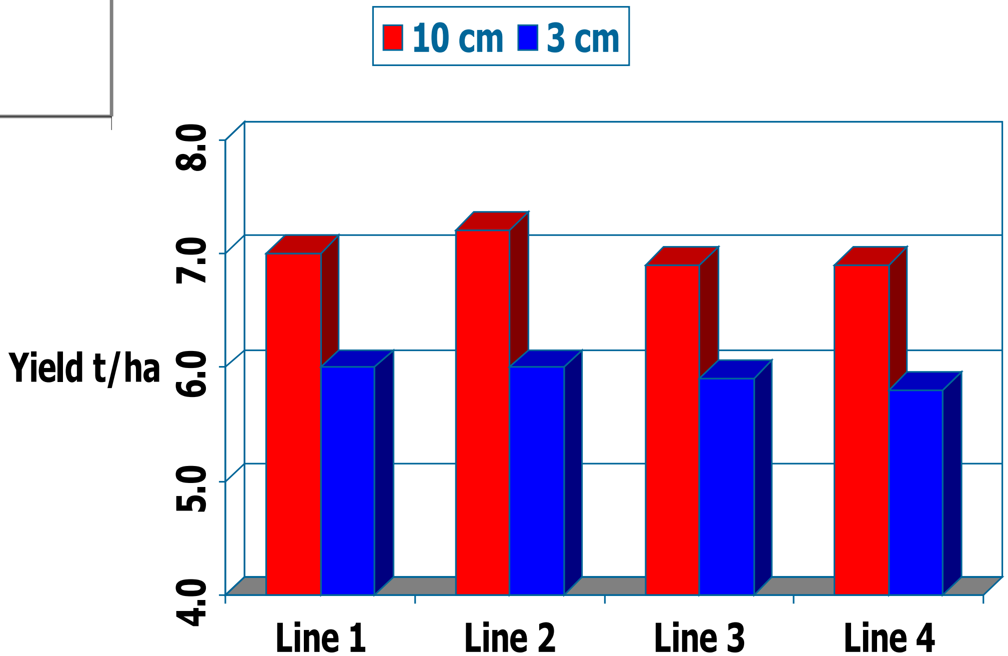
- Faster emergence at normal sowing depths

- No yield penalty when sown at normal sowing depths

Percentage emergence at 10cm planting depth in three consecutive generations



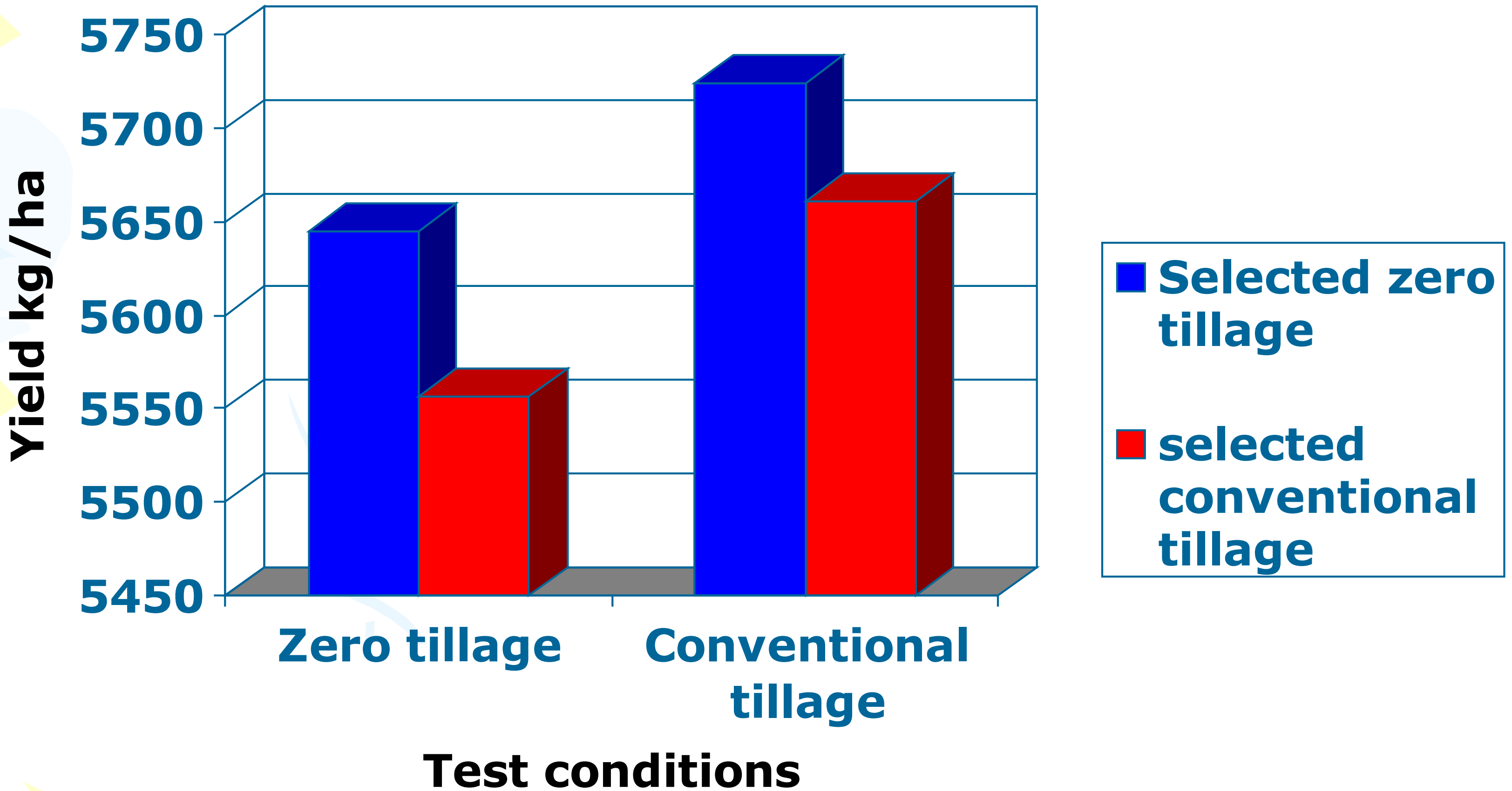
The yield of lines developed using deep sowing when sown at two depths (intermediate stress)



Implications of breeding for adaptation to conservation tillage

- **New diseases (tan spot, root rots etc)**
- **More challenging seed bed**
- **Herbicide use and weeds**
  - **Issues of herbicide resistance (*Phalaris minor*)**
- **Changes in nitrogen management**
  - **N used less efficiently under zero-tillage**
- **Tillage x cultivar interaction**
- **Different CA practices regionally**

Comparison of lines bred under zero tillage with those developed under conventional tillage



Source: Trethowan & Sayre, 2005

Molecular marker applications

Molecular markers used to create gene profiles of key parental materials to improve the efficiency of crossing

	GBSS Null 4A	Glu1BX	PinA	PinB	Rht status	Lr34	Sr24
Krichauff//2*Pastor	+	-	Pina-D1b	Pinb-D1a	1	-	+
Wyalkatchem	+	+	Pina-D1a	Pinb-D1b	2	-	-
Klein Escorpion	+	-	Pina-D1b	Pinb-D1a	1	+	-
Buck Guapo	-	+	Pina-D1a	Pinb-D1b	2	-	-
Fundacep 37	-	-	Pina-D1b	Pinb-D1a	1	-	+
68.111/RGB//Ward/3/FGO/4/Rabi/5/AE.SQ(629)/6/2*Carnamah	-	-	Pina-D1b	Pinb-D1a	Null	+	

Improve water use efficiency through better root health

Cultivar intolerance to root diseases or micronutrient imbalances often mistaken for susceptibility to drought

Resistance and tolerance to:

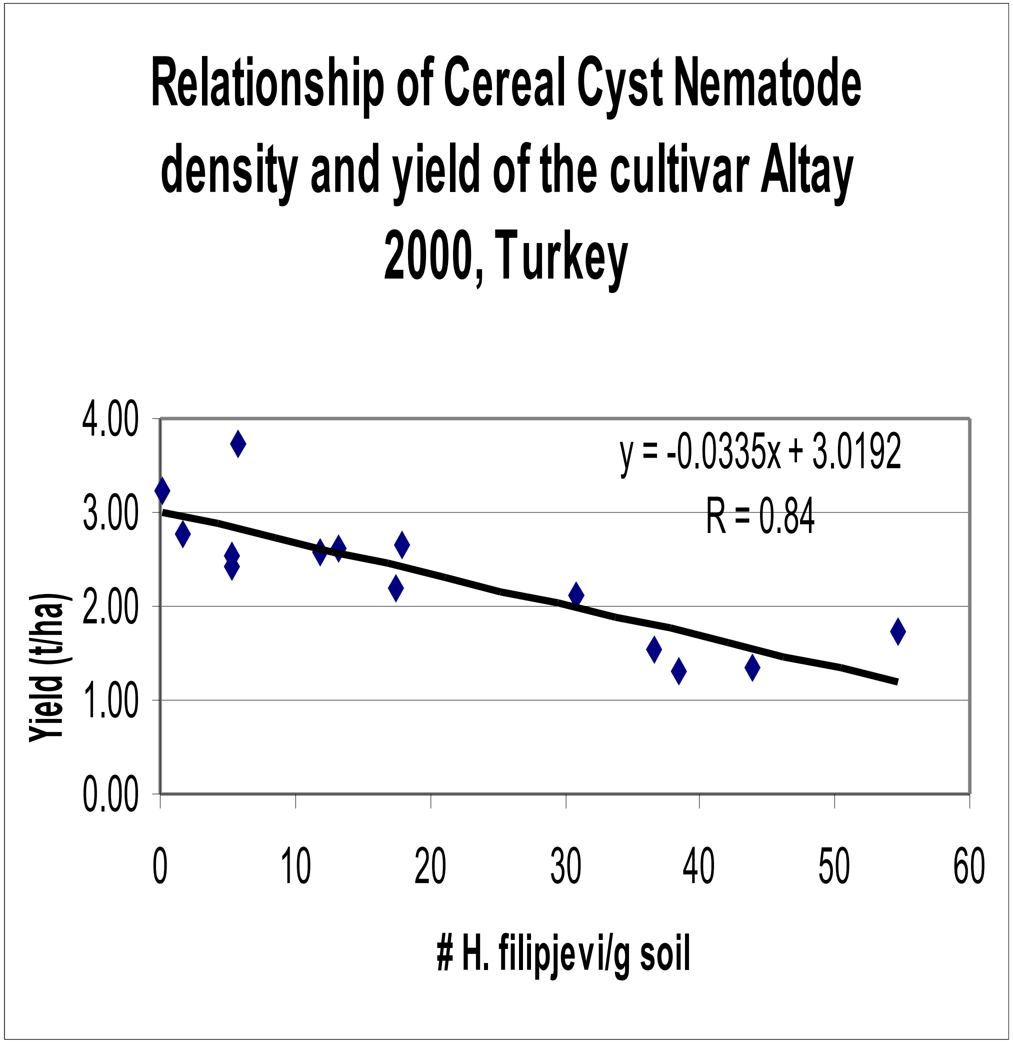
- nematodes
- root rots
- Micronutrient imbalances

Molecular markers for root health traits economically and biologically feasible

Impact of nematodes on yield in rainfed environments

- Temik + Temik

Response of the cultivar Bezostaya to nematicide



Source: J. Nicol

The yield of genotypes developed using MAS for improved root health in northwestern Mexico in two environments

Pedigree	Target gene[1]	Yield in reduced irrigation as % of source parent[2]	Yield in drought as % of the source parent[2]
CROC_1/AE.SQUARROSA (205)//KAUZ/3/SILVERSTAR	*Cre 1*	107.0	125.3 *
CROC_1/AE.SQUARROSA (205)//KAUZ/3/SILVERSTAR	*Cre1*	118.6 *	116.3 *
CNDO/R143//ENTE/MEXI_2/3/AEGILOPS SQUARROSA (TAUS)/4/WEAVER/5/2*FRAME	*Bo1*	114.1 *	167.6 *
CNDO/R143//ENTE/MEXI_2/3/AEGILOPS SQUARROSA (TAUS)/4/WEAVER/5/2*FRAME	*Bo1*	113.4 *	166.3 *
KRICHAUFF/2*PASTOR	*Rln 1,Bo1*	120.1 *	133.2 *
KRICHAUFF/2*PASTOR	*Rln 1,Bo1*	127.4 *	125.7 *

[1] *Cre 1*, *Bo1* and *Rln 1* confer resistance to cereal cyst nematode, tolerance to boron toxicity and resistance to root lesion nematode, respectively.

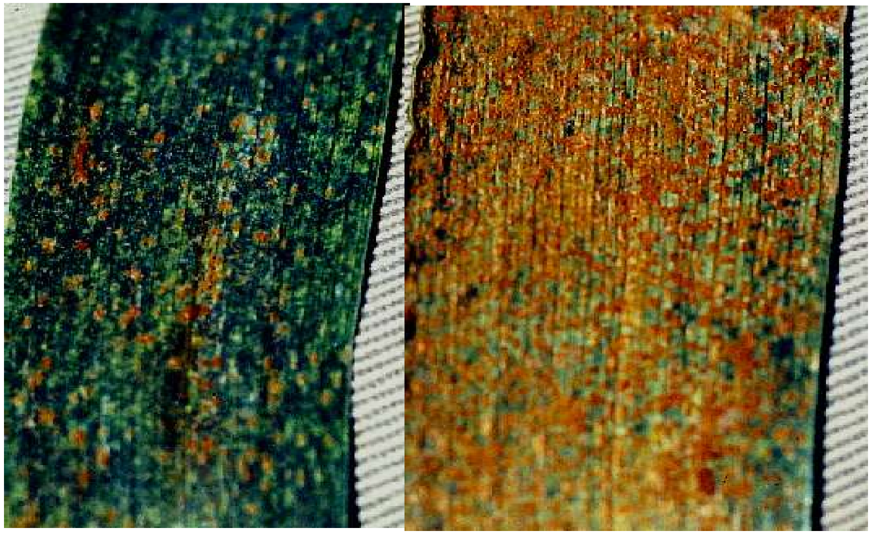
[2] The source parents are Silverstar, Frame and Krichauff. Reduced irrigation represents two applied irrigations and drought one applied irrigation.

* significantly different from the recurrent or adapted parent at $P<0.05$

Improved rust resistance: underpinning race specific resistance

Race specific resistance

Durable resistance – effect of Lr46



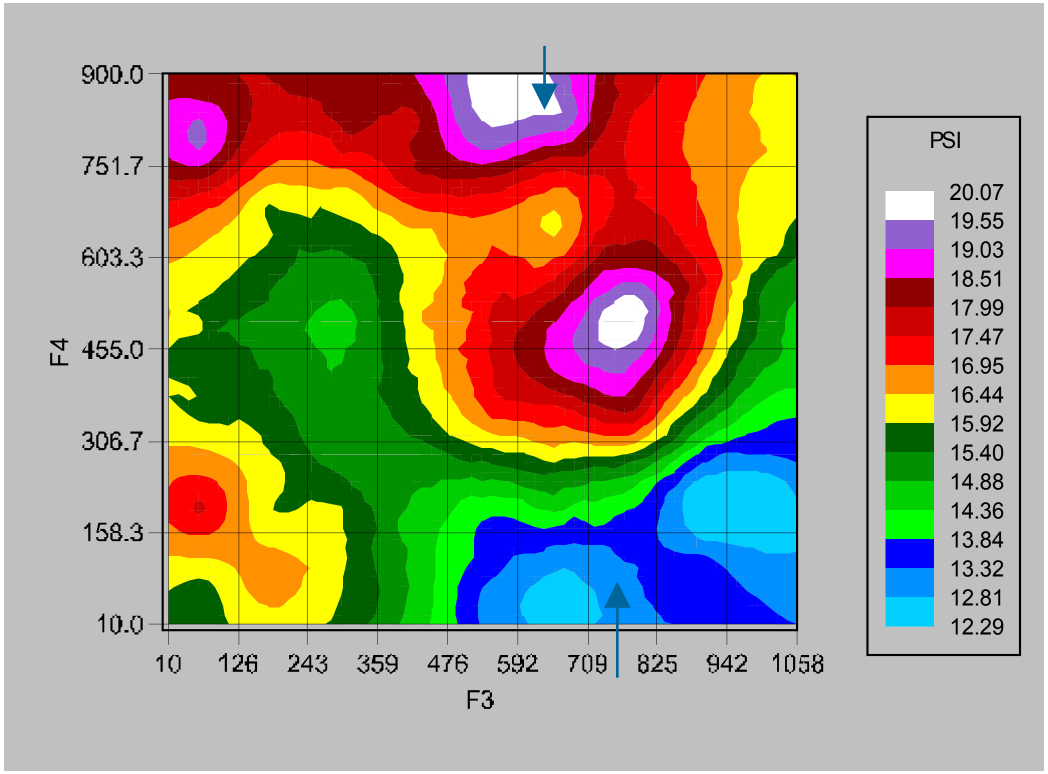
Molecular markers for the components of both race specific and durable resistance make pyramiding these genes possible

Defining and developing effective selection/screening environments

Determining a drought phenotype is dependant on a well characterized evaluation site

Uniform plots under drought stress, Ciudad Obregon, Mexico

Sodicity map at 30-60cm, Ciudad Obregon, Mexico



Drought screening with gravity irrigation in Mexico

By anthesis there is considerable drought stress and clear differentiation among genotypes for stress response

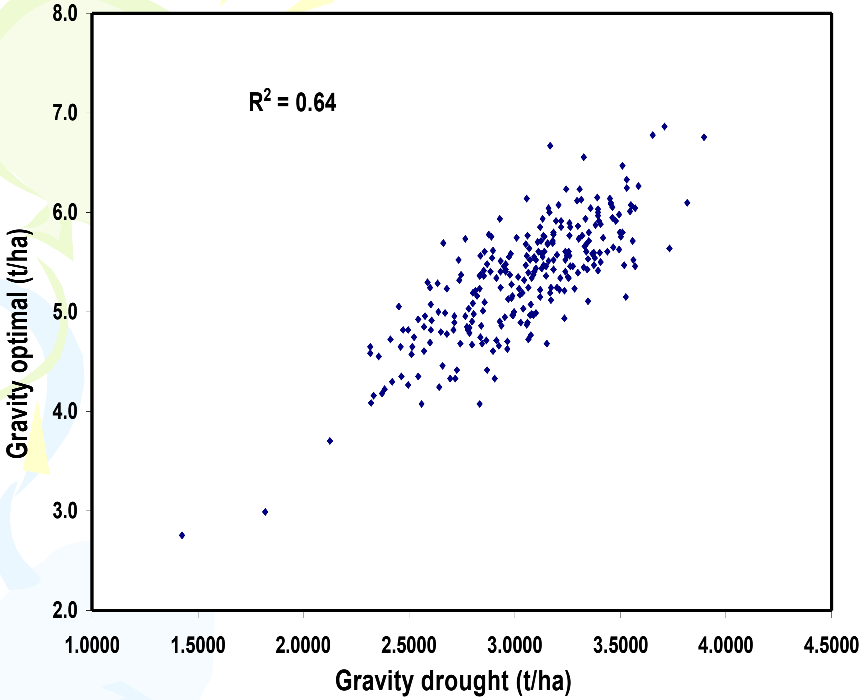
Raised beds are gravity irrigated 2 weeks before planting: trials are then sown on a receding moisture profile

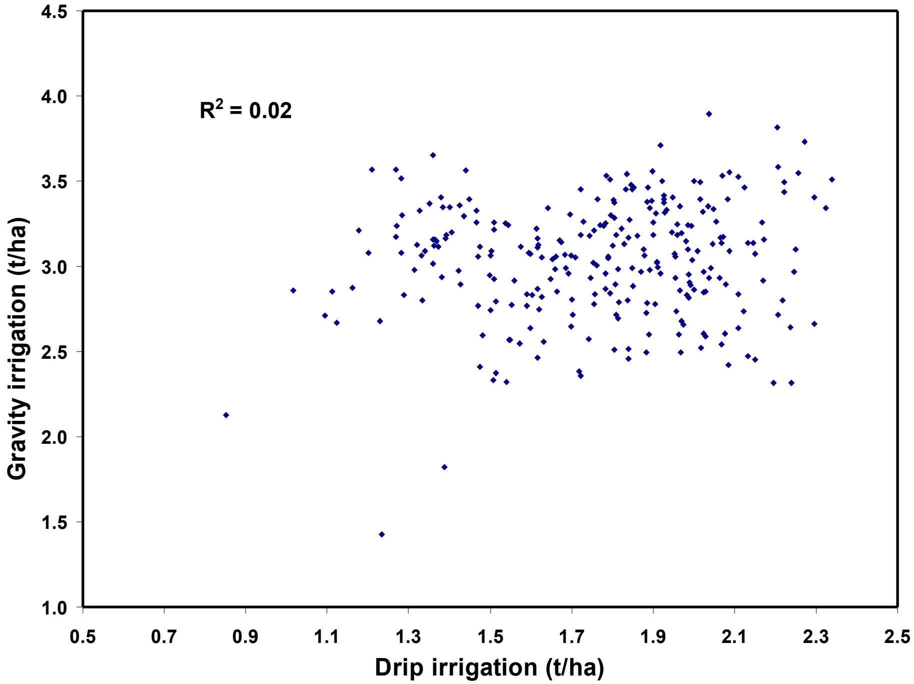
Little stress in the early stages of development

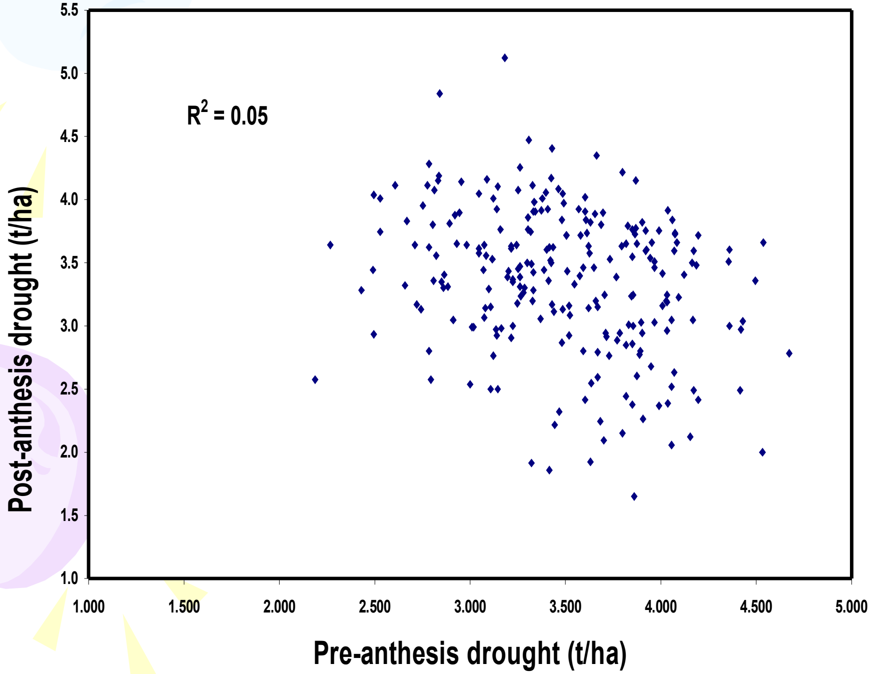
Drip Irrigation to Generate Moisture Stress in NW Mexico

Stress is monitored and irrigation applied as required

Sowing into dry soil: germinated with 40mm of water



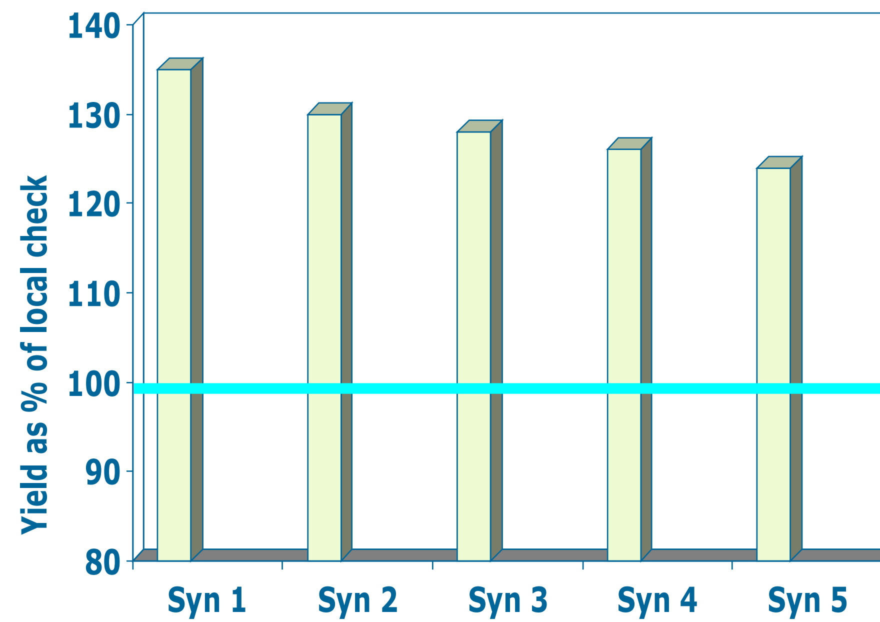




The relationships among different irrigation regimes in Mexico for yield

Screening under terminal heat stress to identify heat tolerant lines

Yield of synthetic derivatives sown late and subjected to terminal heat stress compared to the local check cultivar



Associations among stress environments in Mexico and international test sites

Stress Generated in Mexico	International sites clustering without significant cross over
Continuous drought (furrow)	Brazil; Spain; Algeria; Bolivia; Pakistan
Continuous drought (drip)	S. Arabia; Argentina; S. Africa; Egypt; Canada
Terminal drought (furrow) & no stress (drip)	Iran; Bangladesh; S. Arabia; Spain; Afghanistan
Terminal drought (drip)	No sites
Pre-anthesis drought (drip)	Nepal; Brazil; Pakistan; Iran; Canada
Terminal heat & drought (furrow)	Zimbabwe; Iran; Pakistan
No stress (Furrow)	No sites

Introducing and tracking new genetic variation for key traits

Continued expansion of the genetic base of the major cereals

+

AB

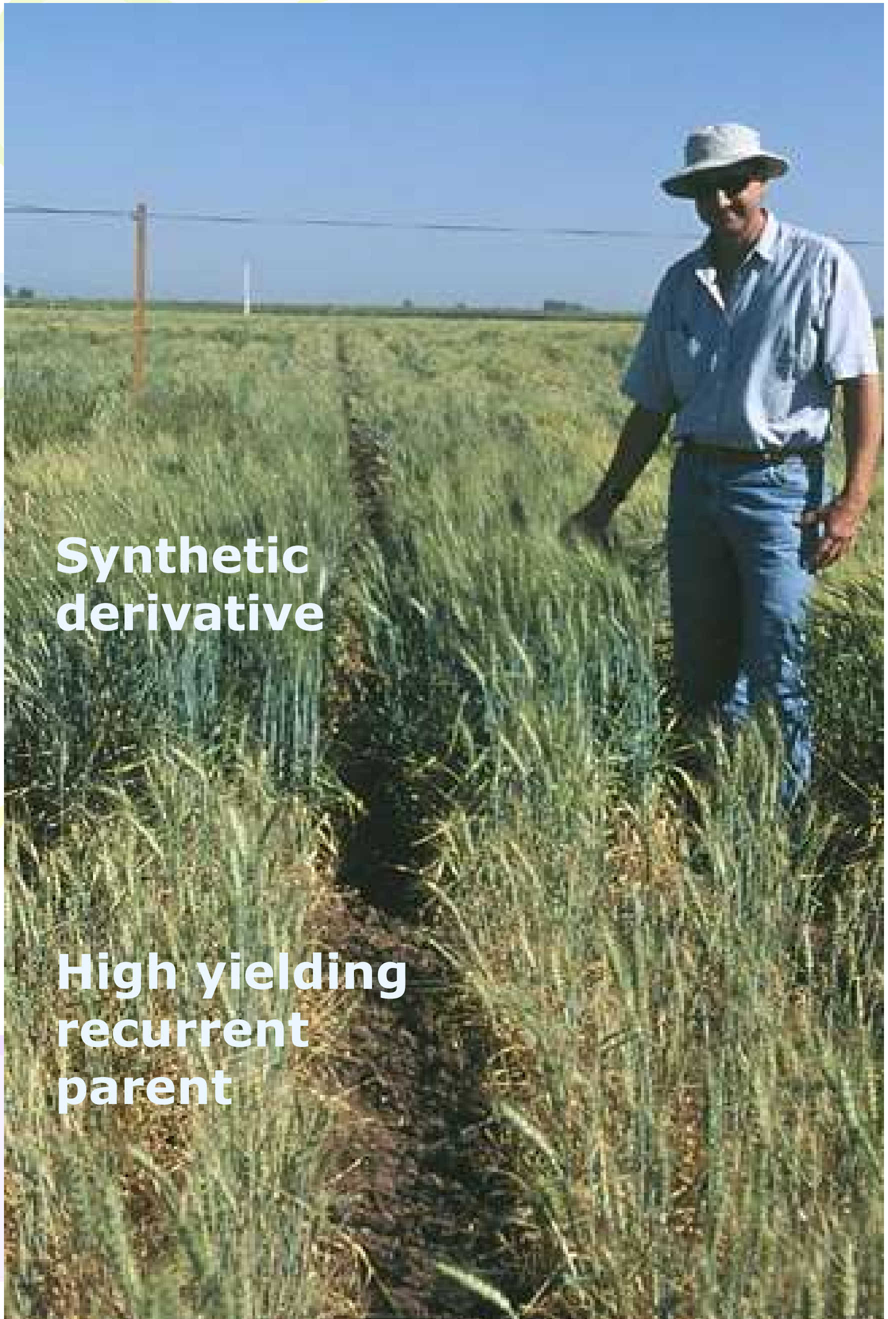
T. durum

D

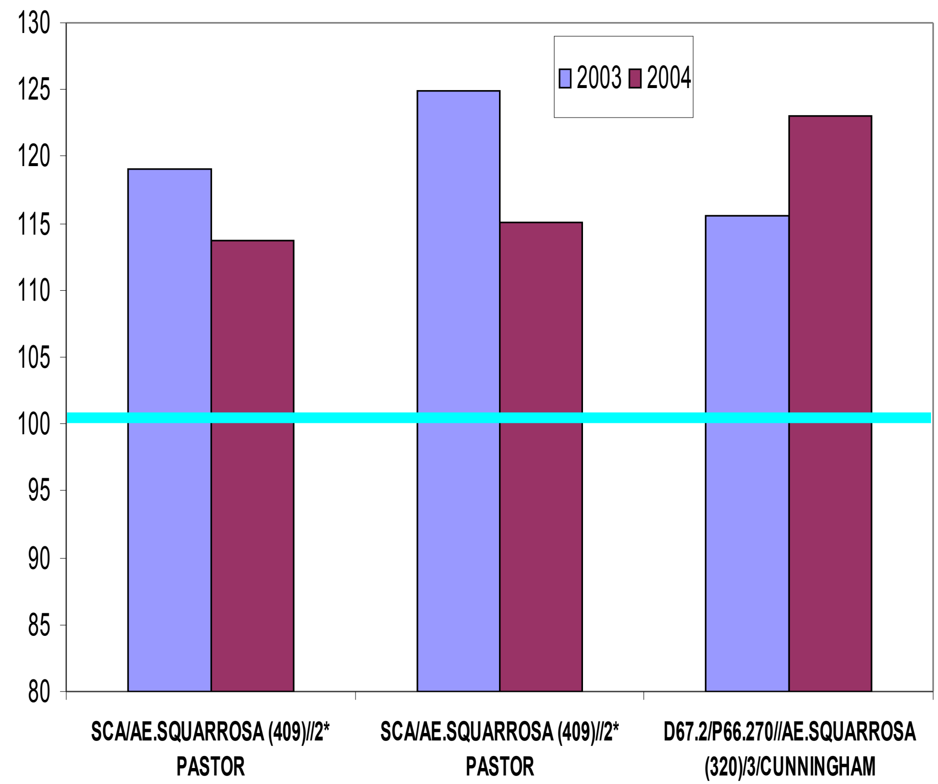
T. tauschii

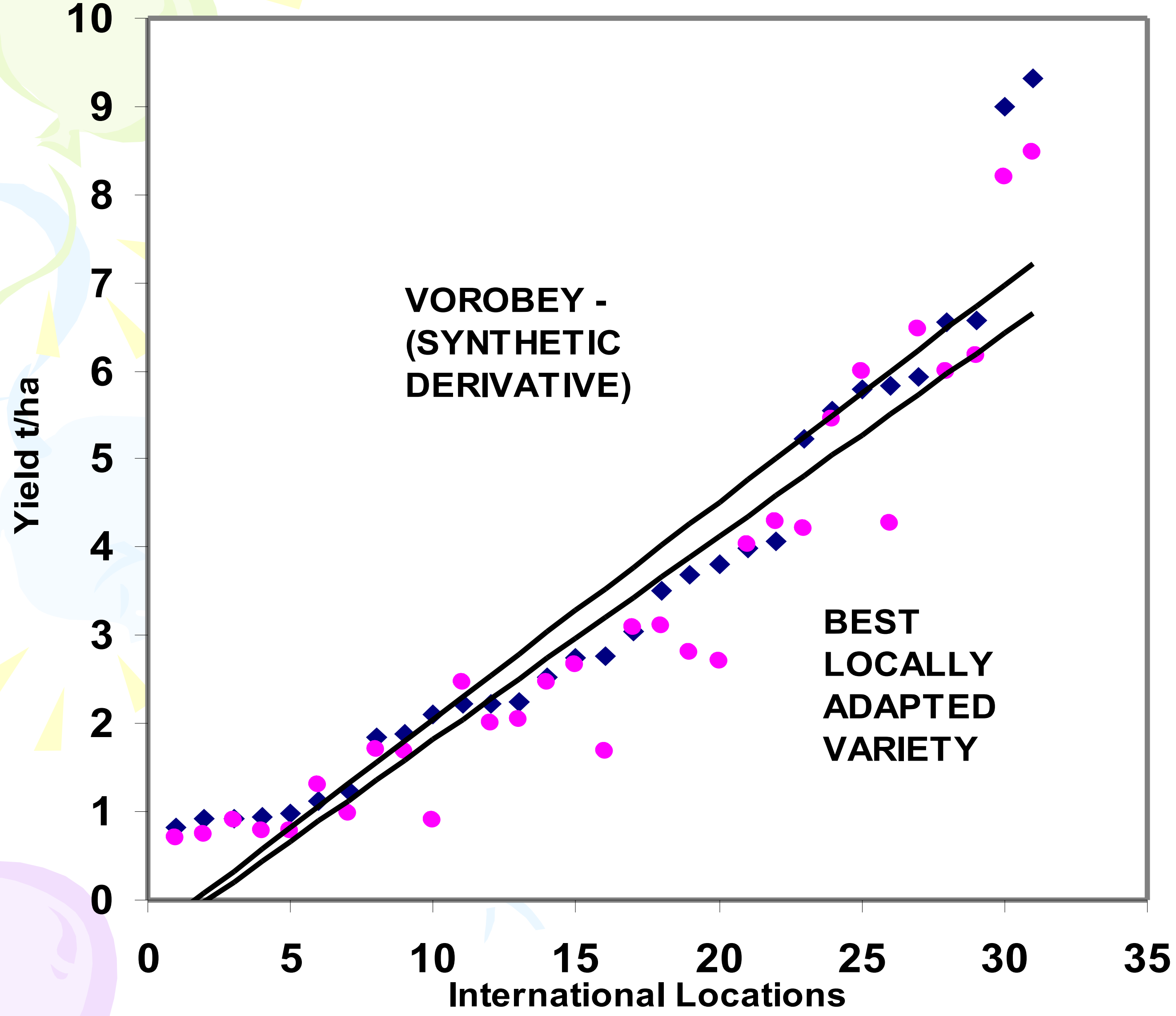
ABD

- Continued exploitation of hexaploid synthetics
- Development of synthetic hexaploids based on wild tetraploids



Yield of synthetic derivatives expressed as % of the recurrent parent over two years under drought stress





THE YIELD PERFORMANCE OF A SYNTHEIC DERIVATIVE COMPARED TO THE BEST LOCALLY ADAPTED LINE: 11th SAWYT

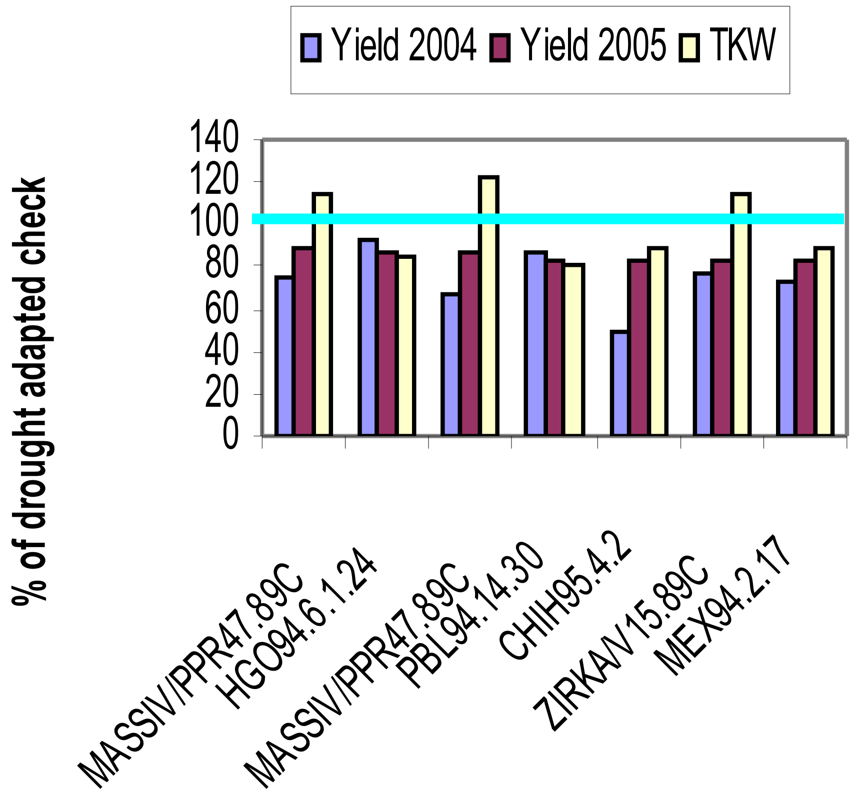
New synthetic wheats derived by crossing wild tetraploids with *Aegilops tauschii* contribute new variability for stress tolerance

Yield of *T. dicoccum* based synthetic derivatives compared to their recurrent parents under drought stress

	Yield t/ha	% of recurrent parent
T.dicoccumPI225332// Ae. sq(895)//3*Weebill 1	2.623	146 a
T.dicoccumPI94625// Ae. sq(373)//3*Pastor	2.830	161 a
Pastor	1.756	100 b
Weebill 1	1.792	100 b

Means followed by different letters significant at P<0.05

Landraces sourced from drier areas can be a source of genetic variability for drought tolerance

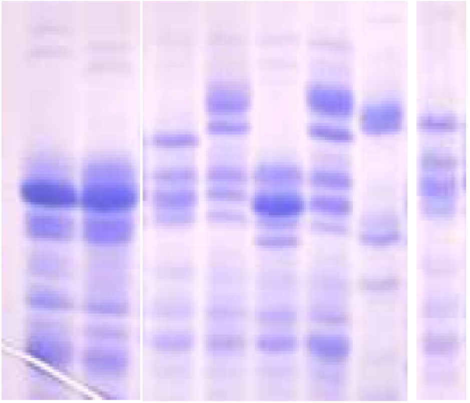


Introduction of transgenes into wheat: transformation with DREB1A

- DREB1A (from Arabidopsis) reduces drought stress symptoms in wheat in the greenhouse
- Field results under drought stress in Mexico are not encouraging

Source: A. Pellegrineschi & M. Reynolds

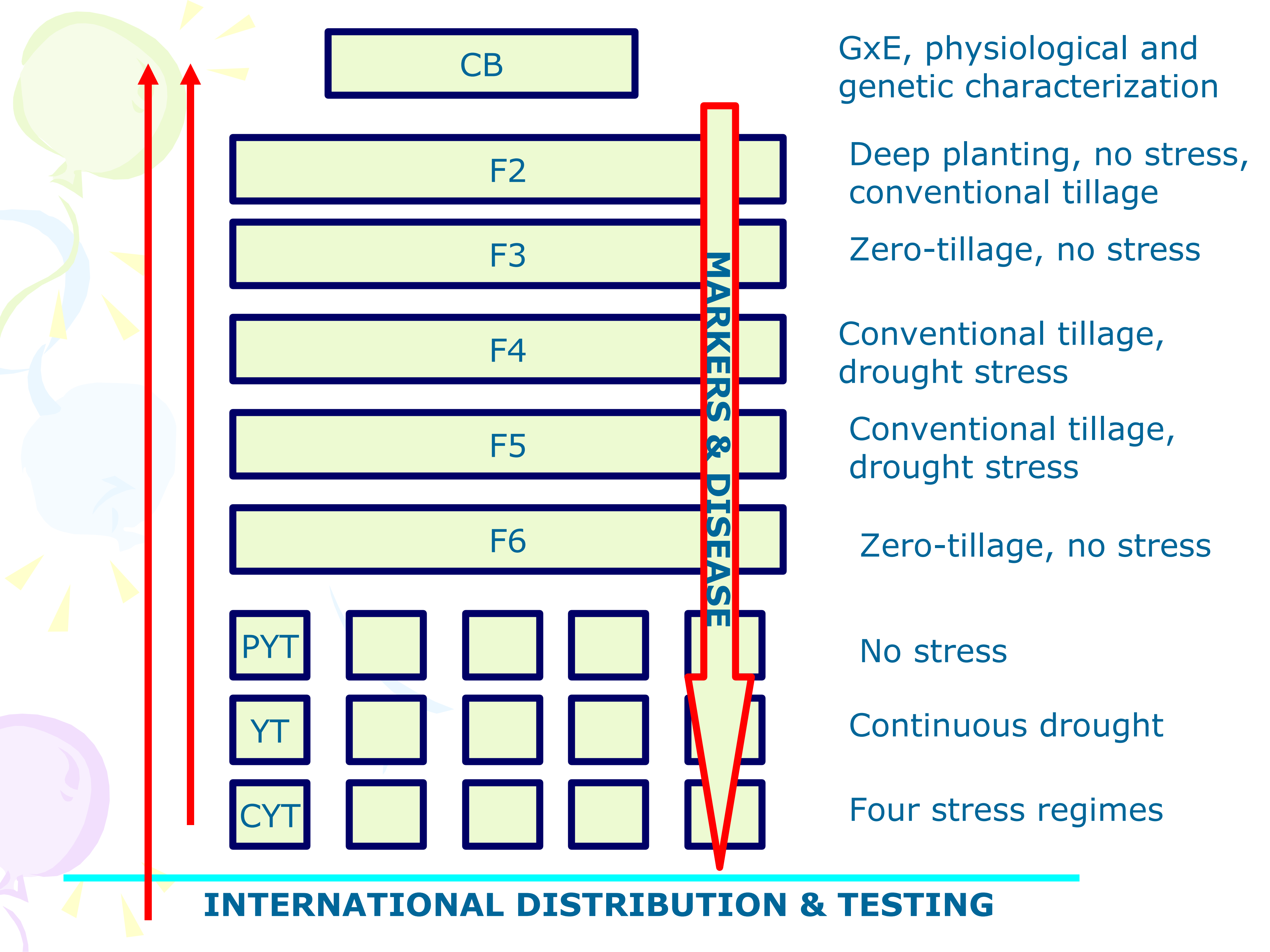
Industrial and nutritional quality



Physical data – P%, Hardness, SDS, dough rheology, bake scores

Genetic information: High and low MWG, Pin genes, GSBS etc.

Micronutrient concentration of newly developed wheat genotypes



CB
GxE, physiological and genetic characterization
F2
Deep planting, no stress, conventional tillage
F3
Zero-tillage, no stress
F4
Conventional tillage, drought stress
F5
Conventional tillage, drought stress
F6
Zero-tillage, no stress
MARKERS & DISEASE
PYT
No stress
YT
Continuous drought
CYT
Four stress regimes
INTERNATIONAL DISTRIBUTION & TESTING