Race non-specific resistance to rusts in CIMMYT spring wheats: Breeding advances

Yellow (stripe) rust
Puccinia striiformis

Brown (leaf) rust
Puccinia triticina

Black (stem) rust
Puccinia graminis

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Types of Resistance

- Monogenic ≈ Race-specific ≈ Major genes ≈ Hypersensitive *(Boom & Bust)*
- Polygenic ≈ Race-nonspecific ≈ Minor genes ≈ Slow rusting/ Partial *(Durable)*

Durable resistance- a proposed working definition by Dubin & Duveiller 2010

Rust resistance that has the following characteristics: Effective in adult plant stage; slow rusting or partial; non-race specific; conferred by genes that have small to intermediate and additive effects with distinct molecular mechanisms of resistance such as ABC Transporter and kinase START domains, or others not yet elucidated, but differing from NB-LRR.

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Slow Rusting Resistance Genes for leaf rust & stripe rust

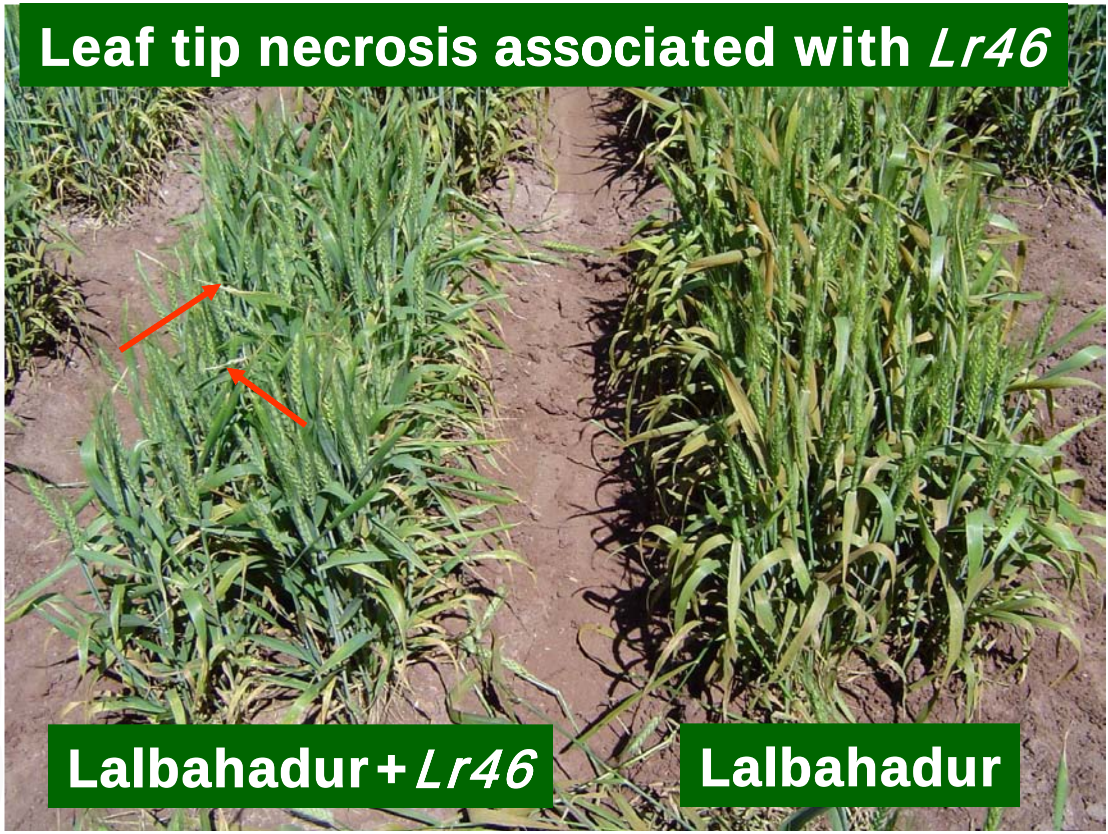
- **The three catalogued genes have pleiotropic effects**

  Lr34/Yr18/Pm38

  Lr46/Yr29/Pm39

  Lr67/Yr46/Pm?

- **All three genes linked to some level of leaf tip necrosis expression**
- **Slow rusting resistance without leaf tip necrosis also known but no gene catalogued**



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Advances in Molecular Mapping of Slow Rusting Resistance Genes

- Several Genomic locations (QTLs) known
- Gene-based markers for relatively larger effect slow rusting genes becoming reality
  - *Gene Lr34/Yr18/Pm38 cloned & shown to be:*

    ABC (ATP Binding Cassette) transporter of PDR (Pleiotropic Drug Resistance) subfamily
  - *Lr34/Yr18 gene sequence based markers in routine use*
  - *Significant progress made towards cloning of Lr46/Yr29/Pm39*
  - *Closely linked SSR markers for Lr67/Yr46 identified*

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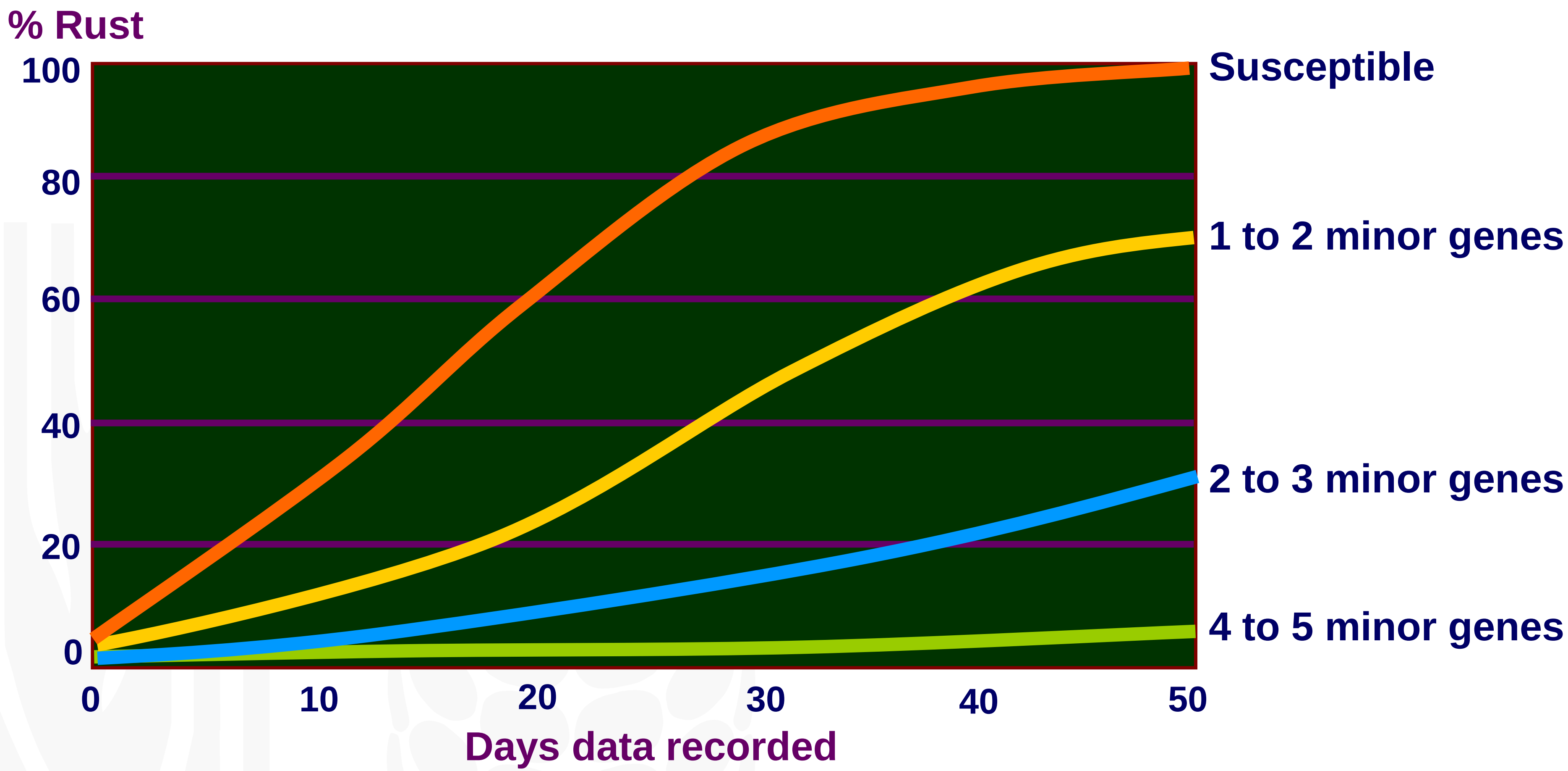
Genetic basis of durable resistance to rust diseases of wheat



- **Relatively few additive genes, each having small to intermediate effects, required for satisfactory disease control**
- **Near-immunity (trace to 5% severity) can be achieved even under high disease pressure by combining 4-5 additive genes**

Challenges to breeding for slow rusting resistance

- A sufficient number of minor genes often not present in a single source genotype
- A source genotype is often poorly adapted
- Segregation of both major and minor genes leading to vertifolia effect
- Crossing, selection schemes and population sizes commonly used not optimum for selecting APR genes
- Inadequate and variable disease pressures in field nurseries
- Reliable molecular markers for several minor genes unavailable
- High costs associated with identifying and utilizing multiple markers

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Advances in breeding for slow rusting resistance to leaf rust and stripe rust at CIMMYT

- 1970s: Wheat lines with intermediate levels of slow rusting resistance selected.
- 1990s: Wheat lines with near-immune level of resistance developed through intercrossing diverse sources of resistance followed by selection of transgressive segregants.
- 2000s: Targeted introgression of resistance into adapted cultivars and genotypes resulting in high-yielding wheats with high levels of resistance.

'Single backcross-selected bulk selection scheme' promotes simultaneous selection of increased yield potential and polygenic resistance

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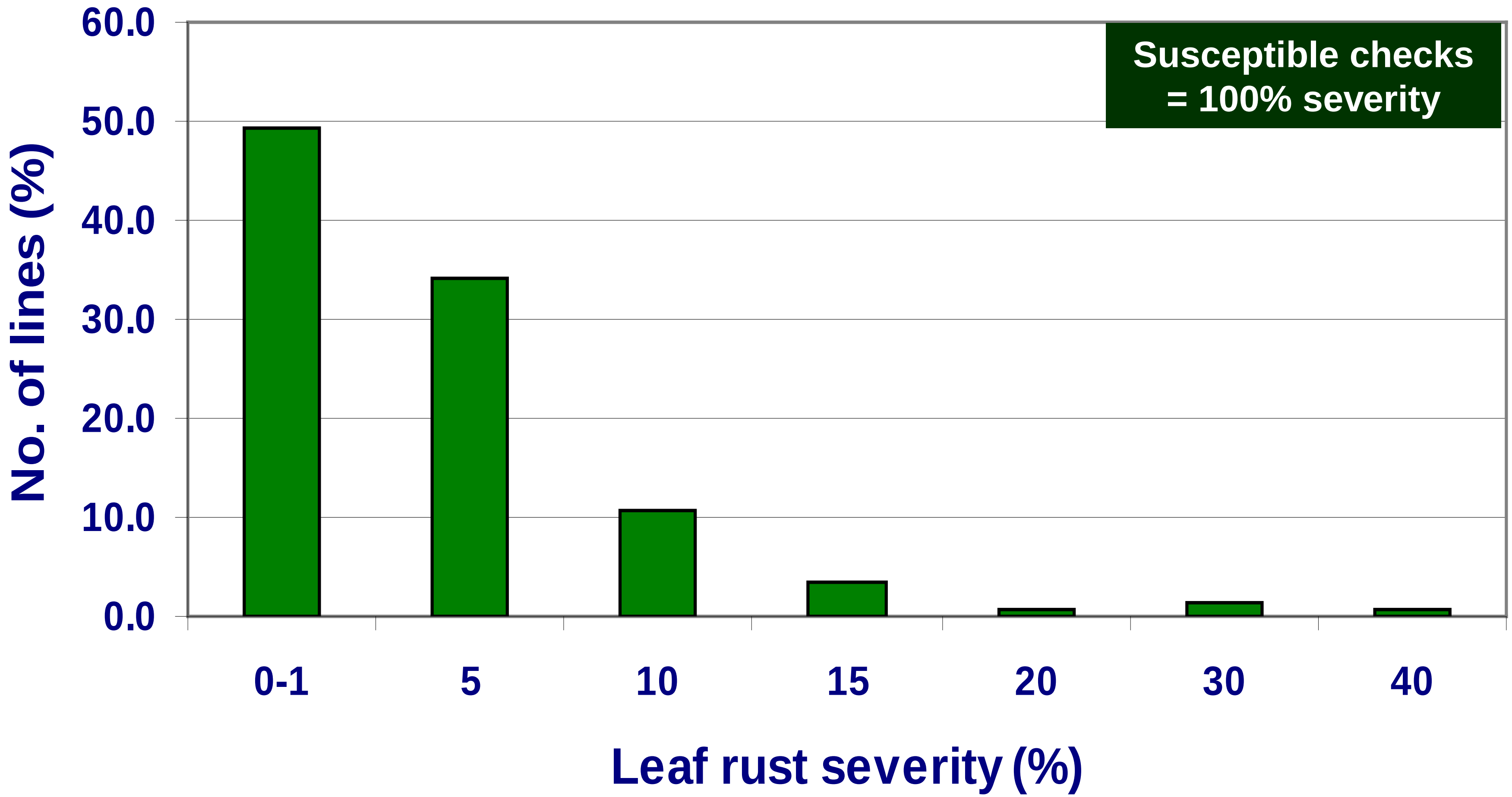
Pyramiding slow rusting genes to achieve near-immunity

Selection under uniform epidemics in field conditions is the best available method at present and the near future

Adult plant leaf rust responses of 360 seedling susceptible new elite entries in El Batan, Mexico 2009



High frequency of near-immune APR to leaf rust in new wheat germplasm

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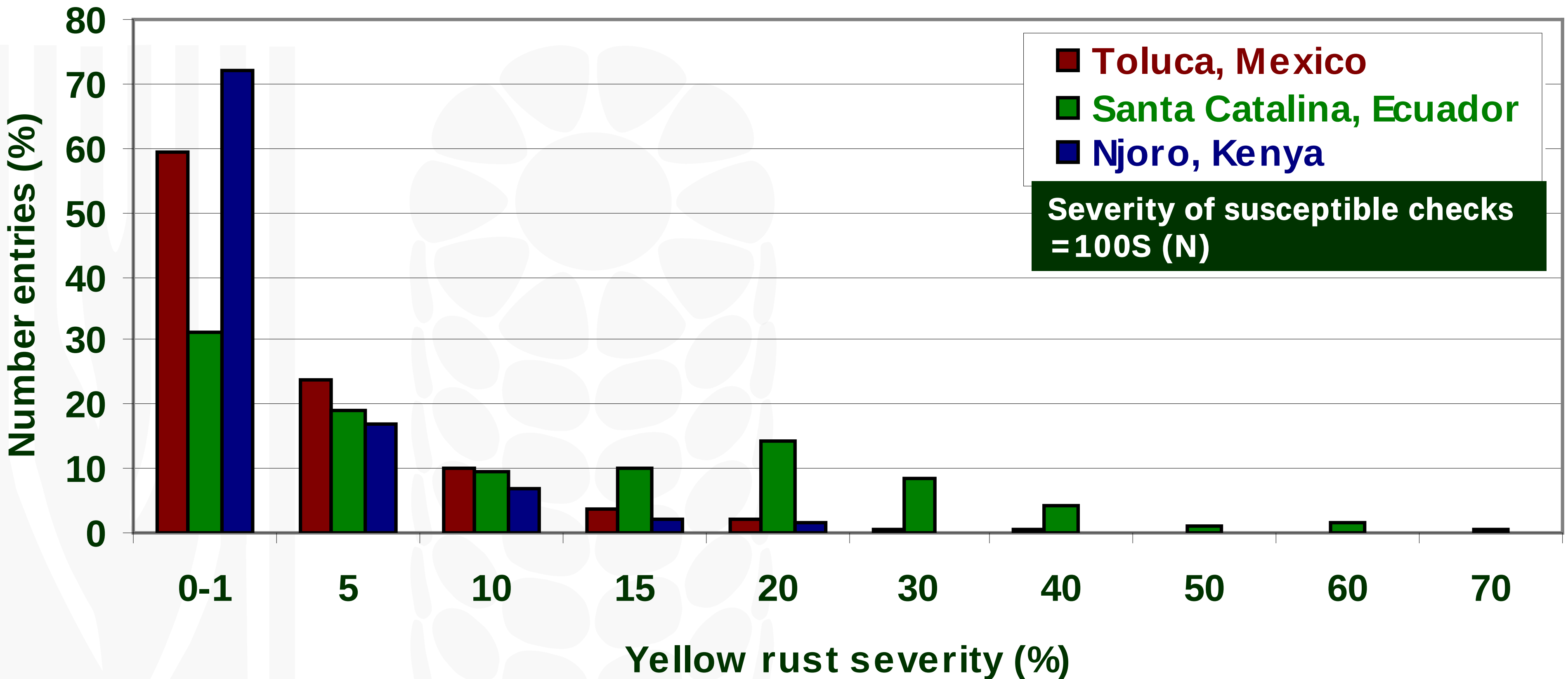
Variation in resistance to yellow rust in 504 new elite entries tested during 2009



Based on pedigrees, resistance in about 60% lines likely due to multiple APR genes (further studies needed for confirmation)

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Methodology used for identifying adult plant resistance to Ug99 in current wheat materials

- Field evaluation of advanced breeding lines in Kenya/Ethiopia
- Greenhouse seedling tests for susceptibility to Ug99 at USDA-ARS Lab. in St. Paul, Minnesota, US
- Characterization of pseudo-black chaff phenotype and application of *Sr2* molecular marker
- *Identified APR Sources:* Kingbird, Kiritati, Juchi, Pavon, Parula, Picaflor, Danphe, Chonte

Njoro, Kenya 2008

Kingbird-the best semidwarf source of APR

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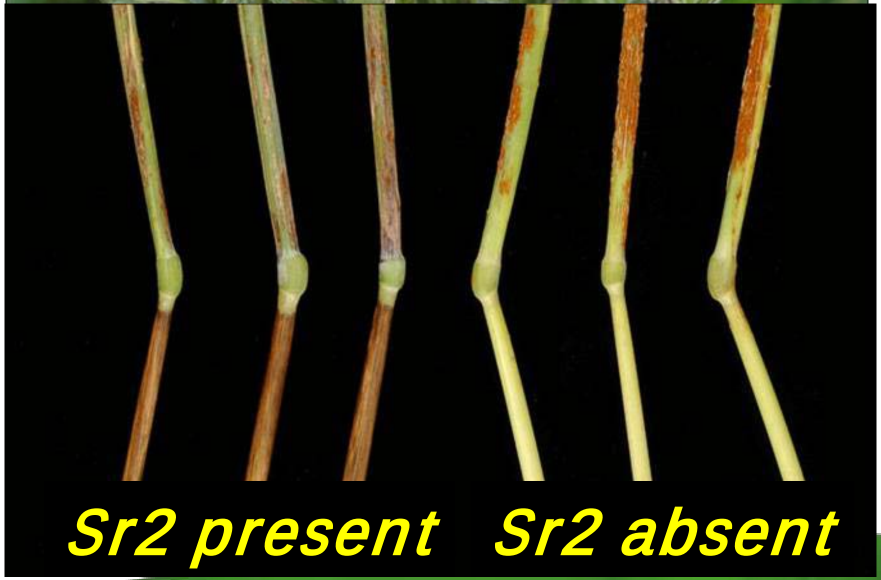
Durable adult-plant resistance to stem rust

Sr2-Complex
(*Sr2* and other minor genes)

- *Sr2* transferred to wheat from 'Yaroslav' emmer in 1920s by McFadden
- *Sr2* is linked to pseudo-black chaff
- *Sr2* confers only moderate levels of resistance (about 30% reduction in disease severity)
- Adequate resistance achieved when *Sr2* combined with other unknown genes
- Essential to reduce/curtail the evolution of Ug99 in East Africa and other high risk areas



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Mapping of Adult Plant Resistance to Stem Rust

-- A major focus in BGRI
-- 15 mapping populations developed and phenotyped
-- SSR mapping of three populations underway in collaboration with Syngenta supported by Syngenta Foundation
-- Other populations being assigned to graduate students
-- Preliminary DArT mapping results now available for some populations

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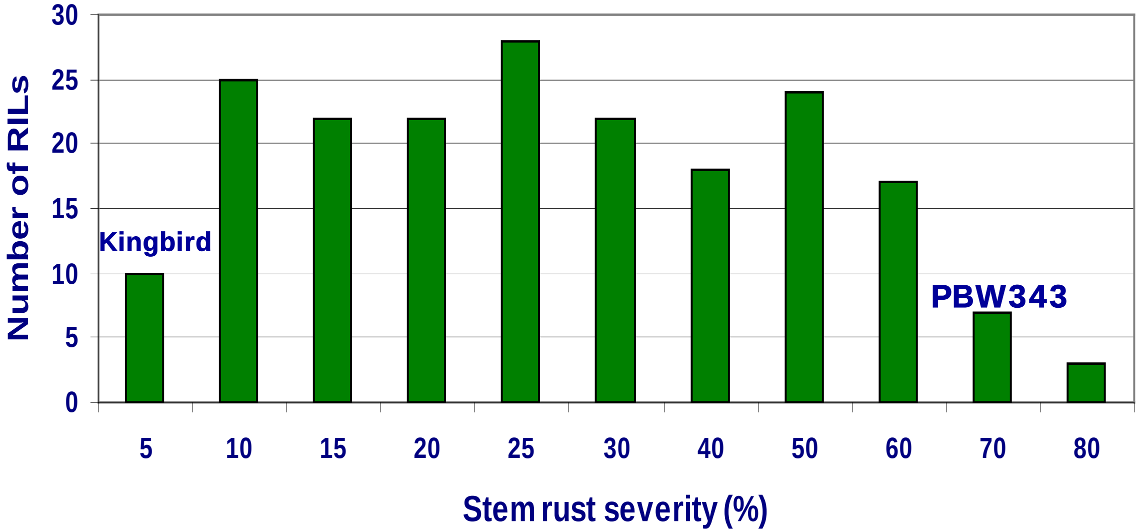
PBW343 x Kingbird RIL mapping population



No. of polymorphic DArT markers	736
No. of informative DArT markers	420

Chromosome	Position	Left marker	Right marker	Est. Add.	LOD	PVE(%)
3B	540	wPt-3921	wPt-1162	10.9	13.3	42.3
4A	188	wPt-0162	wPt-3398	- 5.5	1.8	15.8
5A	40	wPt-4262	wPt-1038	7.0	2.1	25.5
5B	278	wPt-8163	wPt-4736	- 5.9	3.6	12.3
7A	56	wPt-0205	wPt-8670	- 5.0	3.4	8.8

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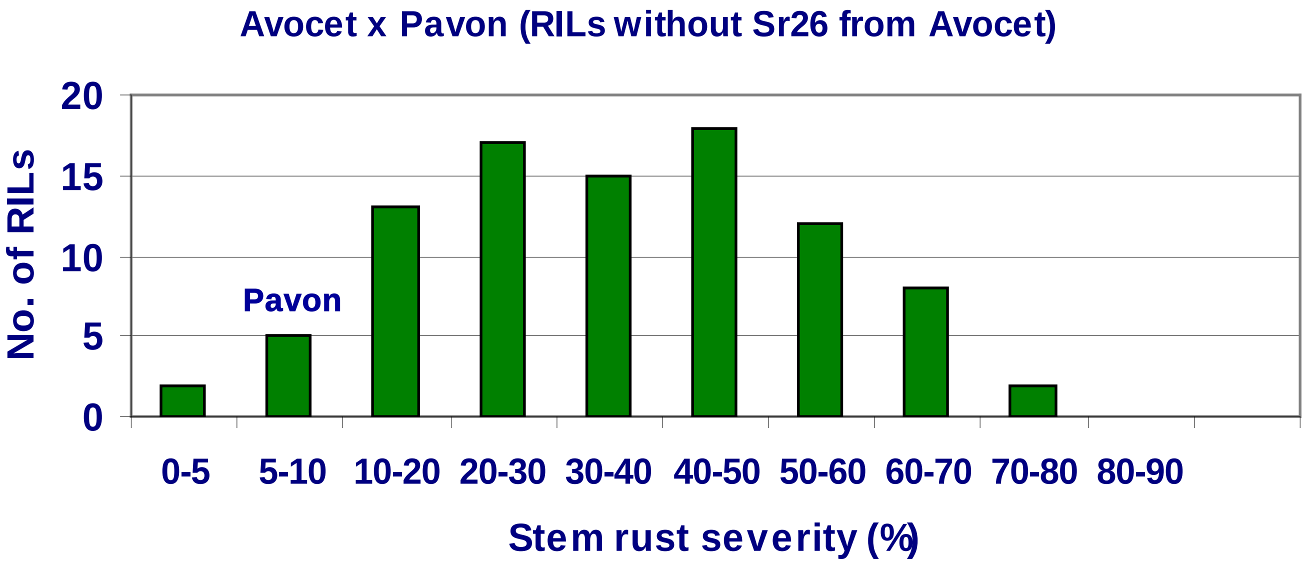

No. of polymorphic DArT markers	510
No. of informative DArT markers	359

Chromosome	Position	Left marker	Right marker	Estd. Add.	LOD	PVE(%)
1B	278	wPt-1560	wPt-7486	10.4	6.0	23.8
3B	52	wPt-8093	wPt-7212	12.1	13.7	59.3
3B	310	wPt-11050	wPt-11452	3.7	2.2	5.9
3D	46	wPt-2689	wPt-10291	10.2	7.7	22.3
4B	66	wPt-2525	wPt-0391	- 4.4	2.9	8.0
5A	8	wPt-6048	wPt-4249	- 5.4	2.9	6.3

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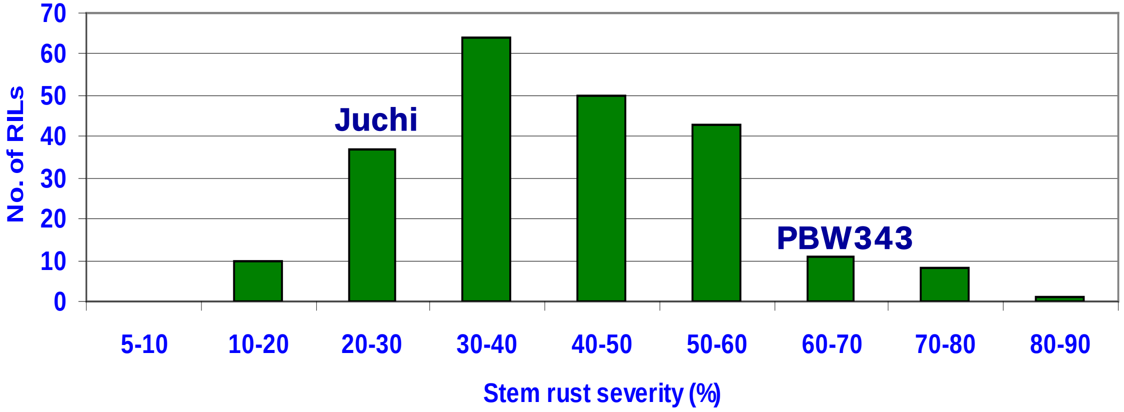
PBW 343 x Juchi RIL population



No. of polymorphic DArT markers	734
No. of informative DArT markers	371

Chromosome	Position	Left marker	Right marker	Est. Add.	LOD	PVE(%)
1A	6	wPt-3698	wPt-8172	4.7	3.3	7.6
1D	174	wPt-1263	wPt-3636	4.4	2.9	6.5
2B	288	wPt-6643	wPt-2266	7.1	6.1	15.4
3A	172	wPt-5476	wPt-1482	7.9	4.7	20.2
3B	134	wPt-1940	wPt-5390	4.6	5.3	11.6
4A	340	wPt-3398	wPt-9251	-4.8	2.9	7.6
5B	408	wPt-6597	wPt-0750	-9.3	9.8	27.6
6B	6	wPt-5211	wPt-9881	-4.6	3.0	7.0
7B	20	wPt-666614	wPt-3723	5.1	2.4	15.1

Distribution and testing of existing Ug99 resistant materials

- 1st to 4th Stem Rust Resistance Screening Nurseries (2006 through 2009)
- Yield testing of high-yielding entries with moderate levels of APR through 2nd, 3rd and 4th Elite Bread Wheat Yield Trials
- Higher frequency of resistant lines in recent Elite Spring Wheat Yield Trials

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Resistance to Ug99 group of races in CIMMYT nurseries

Resistance Category	31stESWYT		4thSRRSN	
	Entries (No.)	Entries (%)	Entries (No.)	Entries (%)
Adult-plant:				
R-MR	15	32.6	20	27.4
MR	7	15.2	29	39.7
MR-MS	11	23.9	-	-
MS-S	3	6.5	-	-
Race-specific:				
Sr25	5	10.9	12	16.4
SrTmp	2	4.3	10	13.7
SrHUW234	2	4.3	1	1.4
SrUnknown	1	2.2	1	1.4

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Grain yield performance of eight Ug99 resistant entries 4thEBWYT, India, 2008-2009

		Across India (10 sites)		Across NWPZ (6 sites)		Stem rust
Entry	Cross	kg/ha	% Check	kg/ha	% Check	Resist.
501	LOCAL CHECKS	3460	100	3746	100	
502	MUNAL #1 (CIMMYT CHECK)	3828	111	4234	113	APR-MR
529	WHEAR/SOKOLL	3959	114	4444	119	*Sr25*
527	NELOKI#1	3937	114	4371	117	APR-MR
516	BECARD	3857	111	4317	115	APR-MR
510	PBW343*2/KUKUNA//PBW343*2/KUKUNA	3823	110	4127	110	APR-MR
526	PRL/2*PASTOR//PBW343*2/KUKUNA/3/ROELFS	3808	110	4159	111	APR-MR
525	PFAU/SERI.1B//AMAD*2/3/PBW343*2/KUKUNA	3758	109	4193	112	APR-MR
	LSD (P =0.05)	199		256		
	CV (%)	8.8		3.2		

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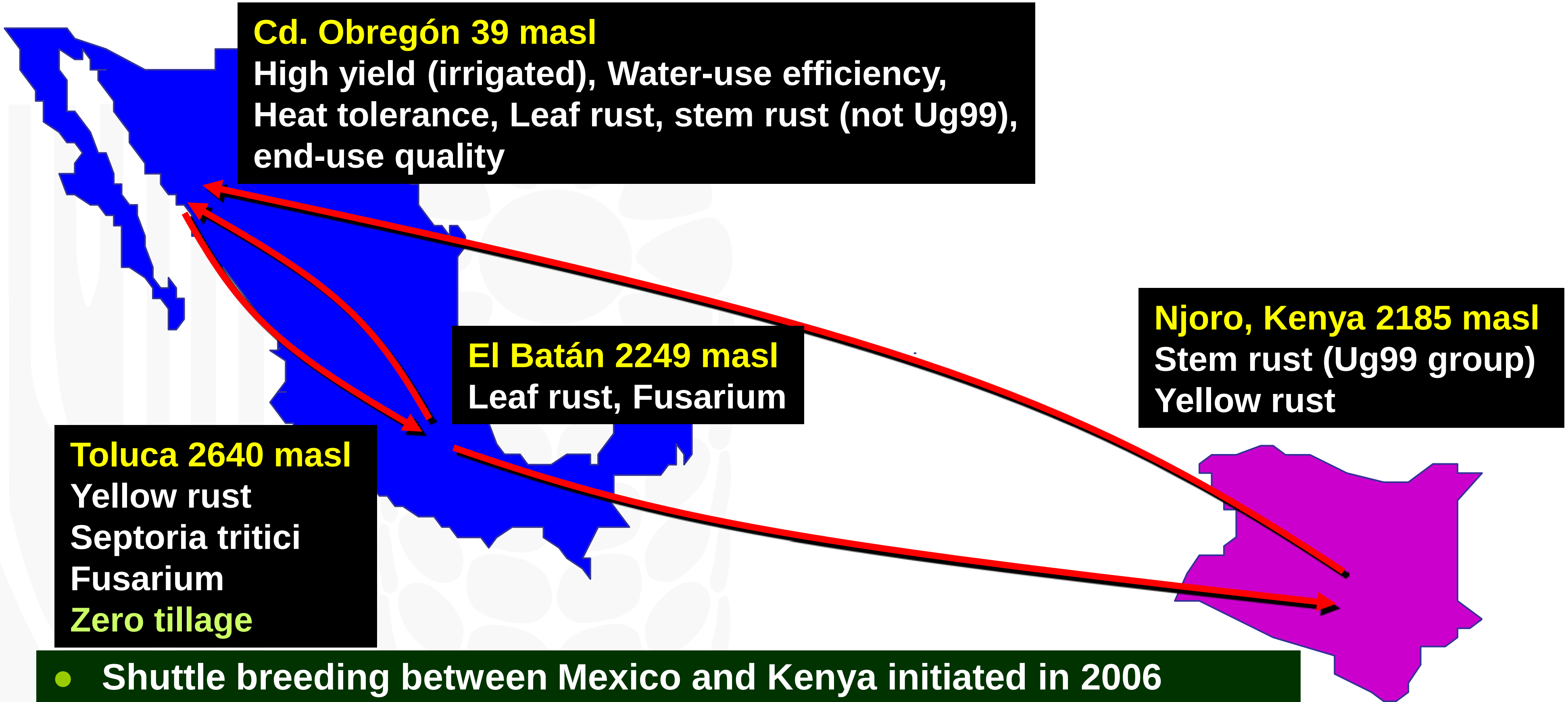
Breeding for durable, adult-plant resistance at CIMMYT

Mexico (Cd. Obregon-Toluca/El Batan)- Kenya International Shuttle Breeding: a five-year breeding cycle)



- Shuttle breeding between Mexico and Kenya initiated in 2006
- >1000 F3/F4 populations undergo Mexico-Kenya shuttle
- High yielding lines with APR identified

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Status of the 2008 Mexico-Kenya shuttle breeding populations for incorporating stem rust resistance with high yield potential and other traits

	Cd. Obregon 2008-2009		Toluca & El Batan 2009		Cd. Obregon 2009-2010
Populations	Populations (No.)	Plants/ Cross retained	Advanced lines (No.)	Lines retained (%)	Lines in yield trials (No.)
F5/F6 (Mexico shuttle)	499	14.5	7237	18	1302
F5/F6 (Mexico-Kenya shuttle)	290	19.7	5703	18.5	1053
F5/F6 Populations from other crosses	*766*	*14.1*	*10815*	*24*	*2601*
Total	1555	15.3	23755	20.9	4956

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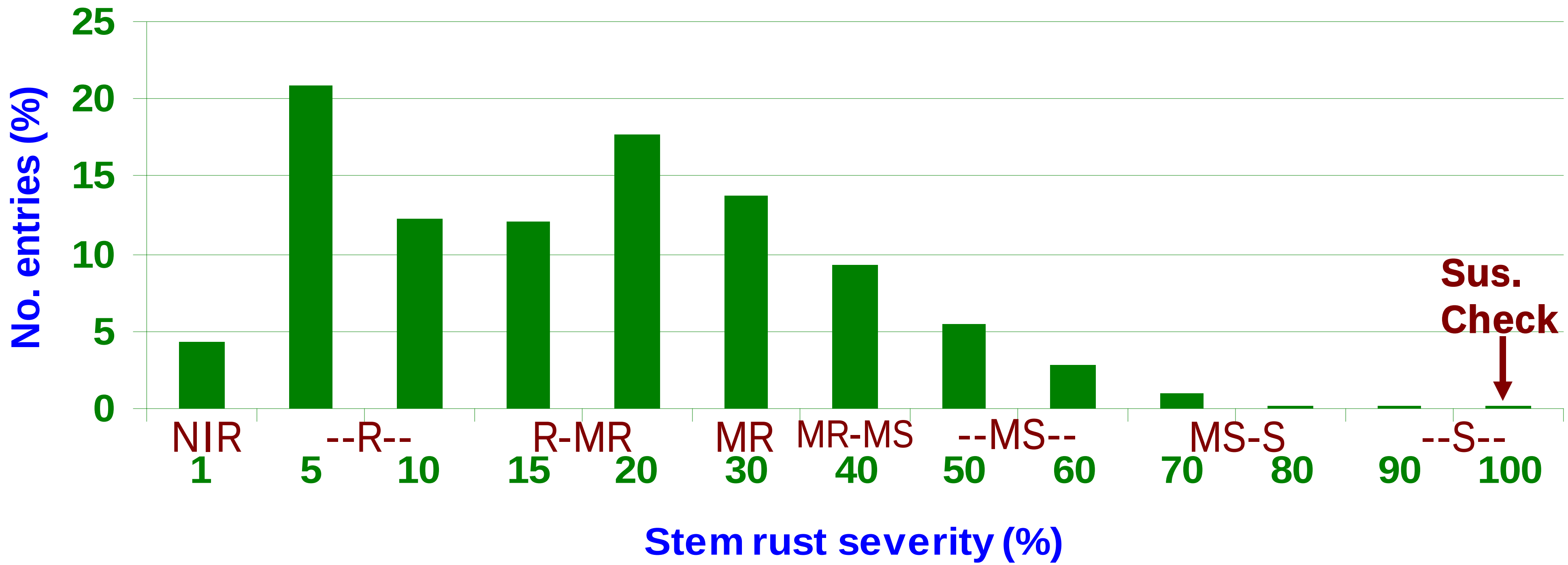
Stem rust severities of 761 Mexico-Kenya shuttle derived lines that do not carry race-specific resistance (Kenya 2010)



- High frequency of APR in shuttle materials
- Transgressive segregants with NIR (near-immune resistance)

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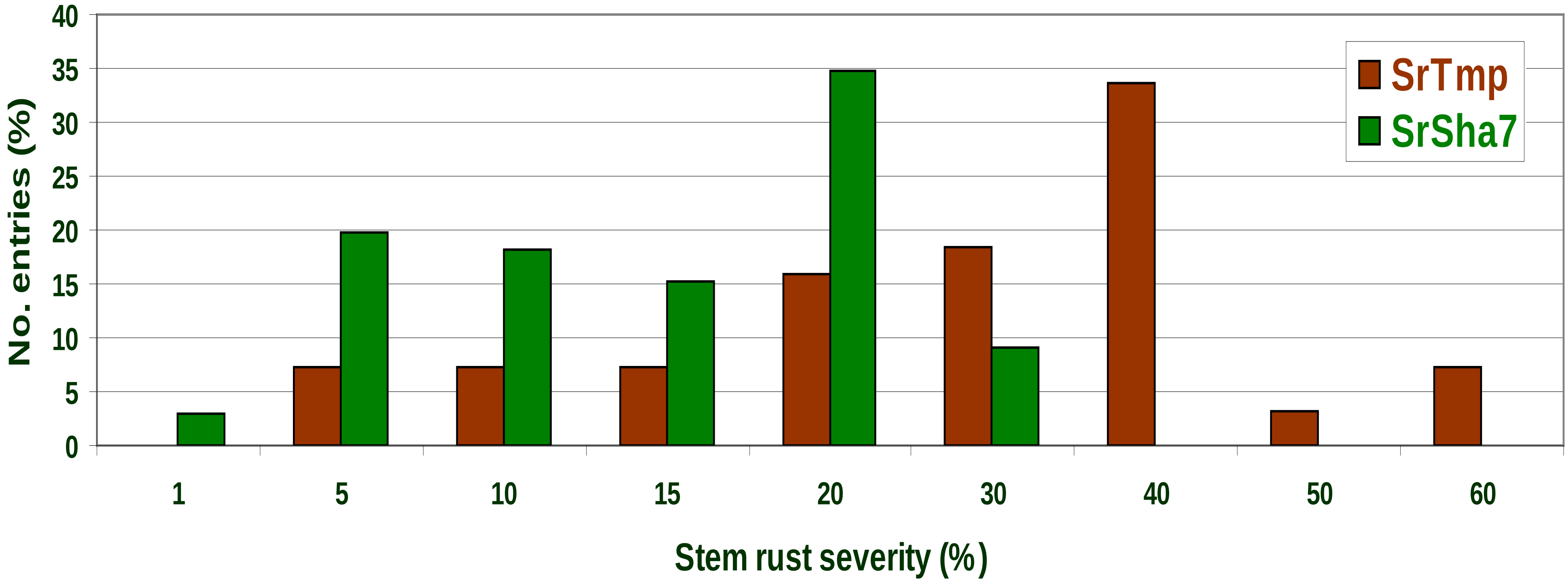
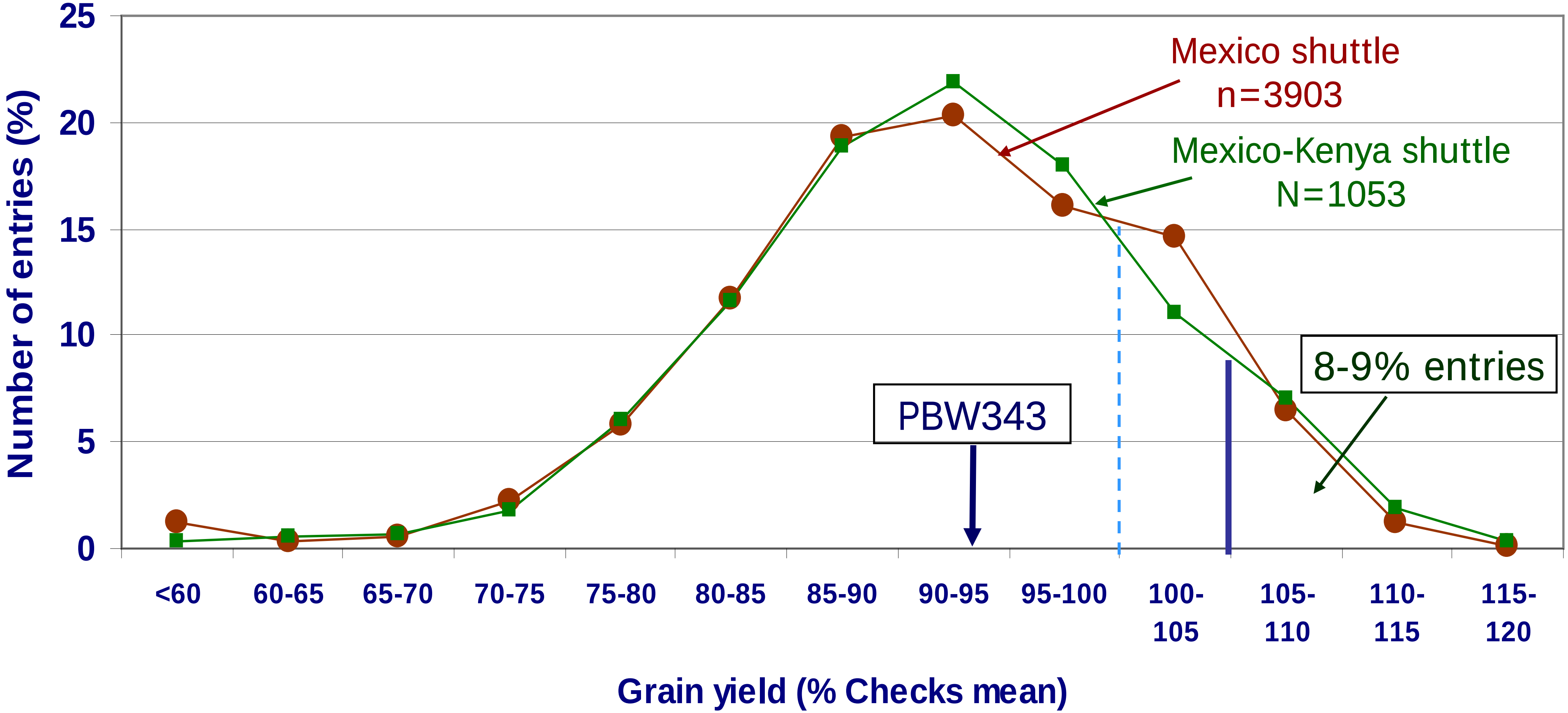
Stem rust severities of *SrTmp* (n=125) and *SrSha7* (n=66) possessing wheat lines in Kenya 2010



APR genes enhance the expression of moderately effective race-specific genes

Grain yield performance comparison: Mexico Shuttle vs. Mexico-Kenya Shuttle Breeding, Cd. Obregon 2009-2010



No effect of selection in Kenya on grain yield performance

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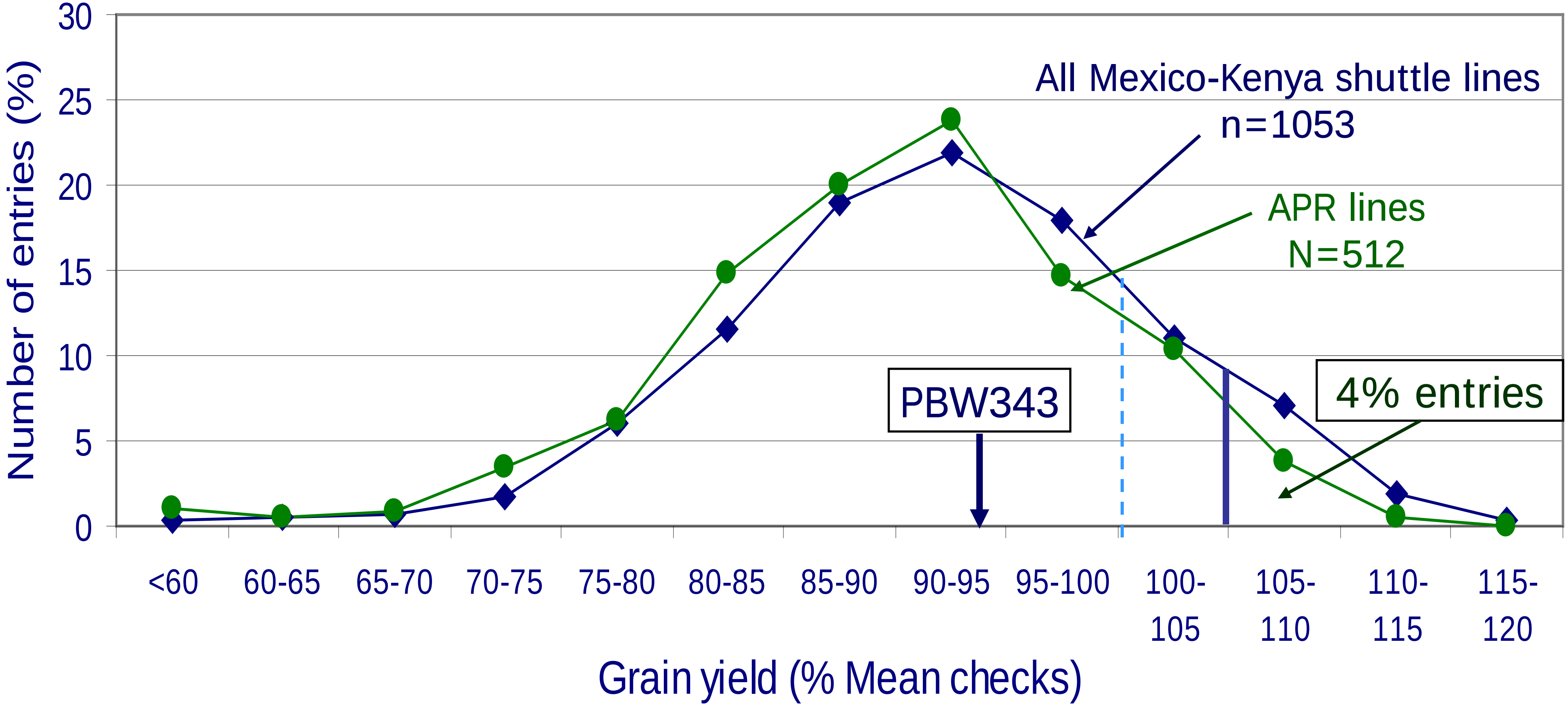
Grain yield performance comparison: All Mexico-Kenya Shuttle Breeding lines vs. APR lines (NIR, R & R-MR category), Cd. Obregon 2009-2010



- **High grain yield potential and multigenic APR can be combined**
- **Large population sizes to recover rare lines with high yield & high level of APR**

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Status of the 2009 Mexico-Kenya shuttle breeding populations for incorporating stem rust resistance with high yield potential and other traits

Populations	Toluca 2009	Cd. Obregon 2009-2010	Cd. Obregon 2009-2010	Toluca & El Batan 2010
	Populations (No.)	Adv. Lines (No.)	Populations (No.)	Adv. lines (No.)
F5 (Mexico shuttle)	700	18248	-	6583
F6 (Mexico shuttle)	-	-	593	13840
F5/F6 (Mexico-Kenya shuttle)	-	-	989	10843
Total	700	18248	1582	31266

• About 10 thousand lines expected for yield evaluation at Cd. Obregon and stem rust characterization at Njoro during 2010-2011 crop season
• Our capacity: 5 thousand in 3-rep trials or 7.5 thousand in 2-rep trials

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Conclusions

- Simultaneous progress in selecting grain yield potential and high levels of multigenic APR possible
- 'Selected bulk' selection of F3/F4 or F4/F5 at Njoro, Kenya did not affect grain yield performance in Mexico
- Higher rate of genetic progress is expected in the future because most crosses will involve high-yielding, APR parents
- Utilization of durable APR in Asia, Middle East, Africa and Latin America is at present the preferred strategy to curtail/reduce the evolution of new races
- Deployment of new higher yielding, rust resistant germplasm should lead to enhanced productivity and food security

Acknowledging agencies supporting bread wheat improvement & rust research

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- **DRRW Project**
- **CSISA Project**
- **Harvest Plus Project**

Syngenta Foundation

Farmers' organizations:

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GRDC, Australia
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ICAR, India
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SDC, Switzerland
ACIAR, Australia

Thank you

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