Host Resistance: A Strategy For Managing Septoria Tritici Blotch of Wheat

Pawan K. Singh[1], X. He[1], S. Dreisigacker[1], M.Vidana[1], G. Azzimonti[2], R.P. Singh[1]

[1]International Maize and Wheat Improvement Center (CIMMYT), Apdo. Postal 6-641, 06600 MEXICO

[2]INIA, Estación La Estanzuela, Ruta 50, Km 11, Mailbox 39173, Colonia, URUGUAY

CIMMYT MR

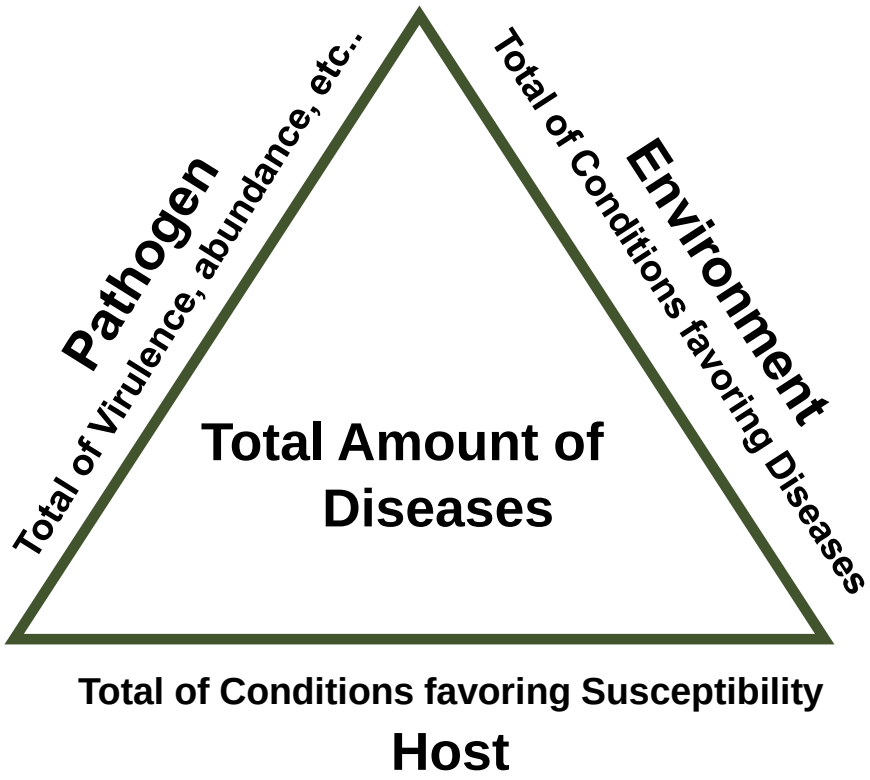
Wheat Production (million metric ton)

Country/Group	2012	2013	2014	2015	2016
1-China	121.0	121.9	126.2	130.2	131.7
2-India	94.9	93.5	95.8	86.5	93.5
3-Russia	37.7	52.1	59.7	61.8	73.3
4-USA	61.7	58.1	55.1	55.8	62.9
5-Canada	27.2	37.5	29.4	27.6	30.5
6-Australia	29.9	22.9	25.3	23.7	22.3
World Produce	672.7	711.0	733.5	736.9	749.5
World Use	684.2	691.2	712.0	709.5	733.9
Exporting Countries: USA, Canada, Russia, Australia, France, Ukraine, Germany					
Importing Countries: Indonesia, Italy, Algeria, Egypt, Japan, Brazil, Morocco					

Source: FAOSTAT

CIMMYT

Conditions for Disease Development

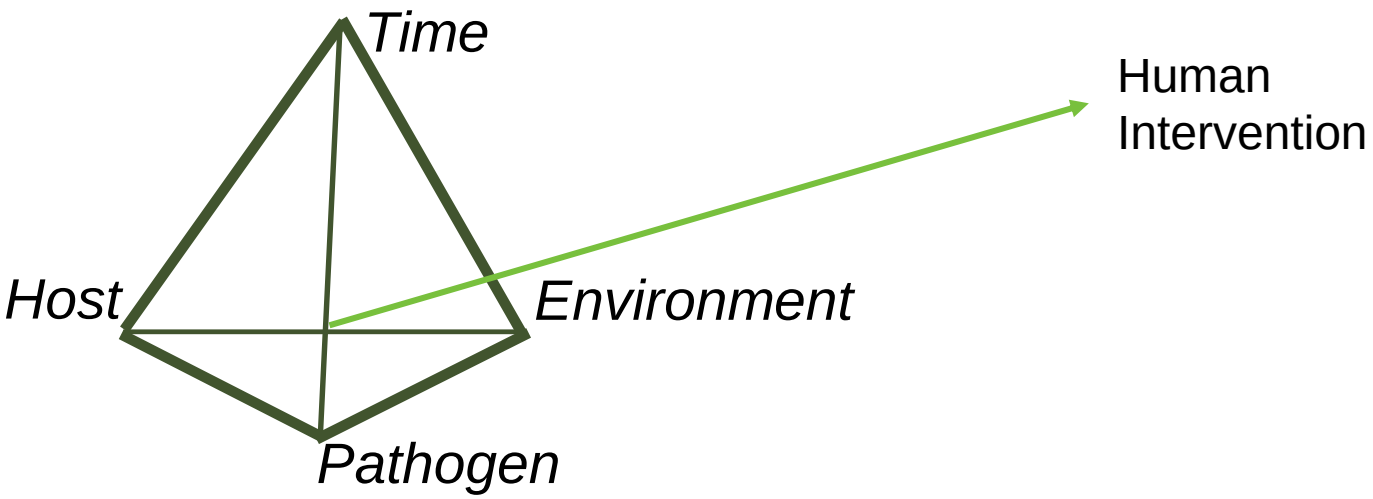


Nearly 200 Wheat diseases and pests are documented and about 50 are considered economically important (Weiss 1987)

Potential grain yield losses due to diseases have been estimated at 18% and actual losses with current disease control at 13% (Oerke 2006)

CIMMYT

Factors Leading to Plant Disease



- A virulent pathogen
- A susceptible variety or host
- A favorable environment (climate, soils etc)
- Appropriate combination of favorable factors at a given time including physiological stage of crop

Strategies for Management of Diseases

- **Host-resistance**

  Resistance to be identified, incorporated & deployed

  Resistance must be effective and durable

- **Agronomic practices**

  Cultural practices, rotation & nutrition management

- **Biological control**

  Understanding of ecology of the plant habitat needed

- **Chemical control**

  Foliar fungicides, seed treatment

Why Host Resistance

- Most practical and economical for all producers
  - Especially for resource poor small farmers
- Technology is easily transferred/disseminated as this is packaged in seed.
- Requires no extra production or management resources
- Environmentally friendly: leaves no harmful residues
- Is compatible with other control strategies:
  - Chemical, cultural and storage practices
- Long term strategy for food safety and security

Types of Resistance

Race Specific	Non-Race Specific
Vertical	Horizontal
Qualitative	Quantitative
Hypersensitive	Non-hypersensitive
Complete	Partial
Non-durable	Durable
Seedling	Adult plant type

Regional Priorities for Wheat Diseases

Biotic stress	East Asia	South Asia	West Asia	M-East+ N-Africa	C-Asia+ Caucasus	S-Saharan Africa	L-America + Mexico	Developed countries
Yellow rust	+++	+++	+++	+++	+++	+++	+	+++
Stem rust	+++	+++	+++	+++	+++	+++	+++	+++
Leaf rust	++	+++	+++	+++	+++	++	+++	++
FHB	+++	0	+	+	0	0	++	+++
Septoria	+	0	++	+++	++	++	++	+++
Spot blotch	+	+++	0	0	0	+	++	+
Tan spot	0	+	+	+	+++	0	++	+++
Nematodes	++	++	+++	++	0	+	+	+
Root diseases	++	+	++	++	+	+	+	+
Smuts/bunts	+	+	++	++	+	+	+	+
Wheat blast	0	+	0	0	0	0	++	0
Powdery mildew	++	+	0	0	0	0	+	++

CIMMYT

Blight Diseases of Wheat

- Head Blight Diseases
  - Wheat blast
  - Fusarium head blight
- Leaf Blight Diseases
  - Septoria diseases
    - **Septoria tritici blotch**
    - Stagonospora nodorum blotch
  - Helminthosporium leaf blights
    - Tan spot
    - Spot blotch

CIMMYT

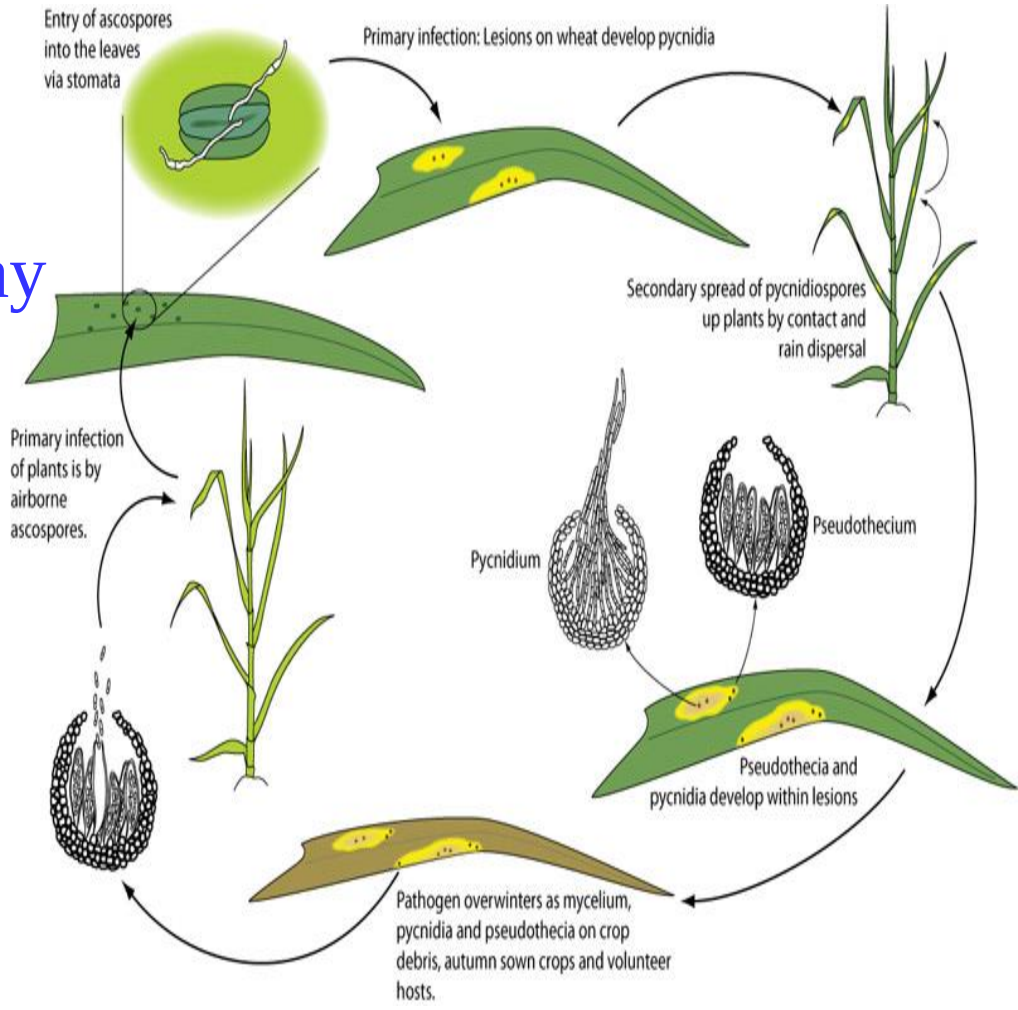
Wheat Diseases at CIMMYT, MEXICO

CIMMYT

Septoria Tritici Blotch

Occurrence:

- Mexico, USA and Canada
- Argentina, Brazil & Uruguay
- Australia and New Zealand
- Europe
- CWANA Region



Screening:

- In Field- Toluca
- In Greenhouse- El Batan

CIMMYT

Septoria Tritici Blotch

- No race structure but highly variable
- Recombination in aggressive strains
  - Mating types known since 1970s
- Resistance to fungicides
- Quantitative and qualitative resistance
  - 21 Major resistance genes identified
  - 89 Meta QTLs identified
- CIMMYT's historical Res. sources
  - Bobwhite, Kavkaz-K4500, Veranopolis Corydon, Catbird, Milan, Murga, and Several Synthetics

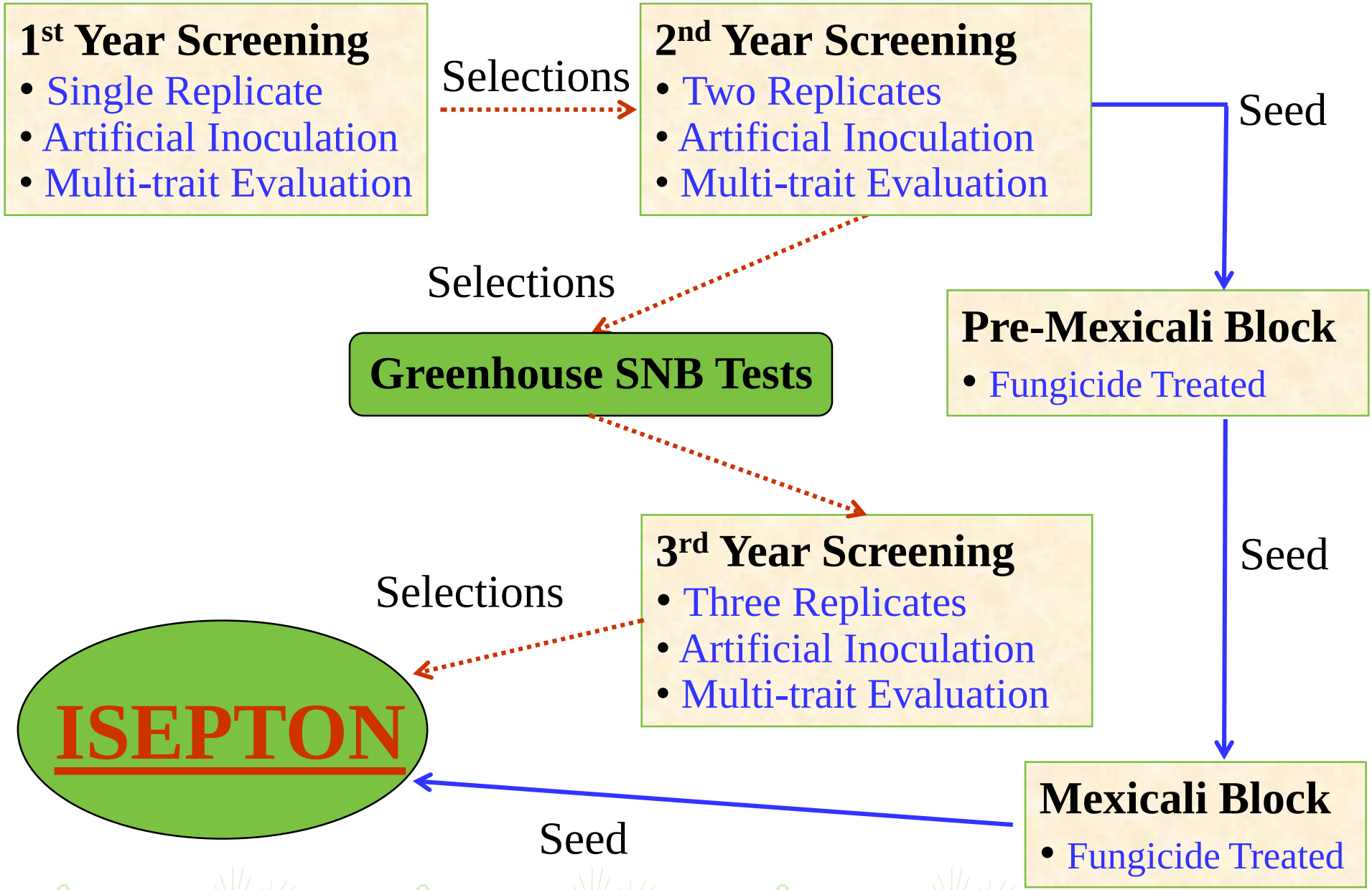
CIMMYT

Septoria Tritici Blotch Research

Selection Criteria's:

- Multiple scoring: At least three at weekly interval
  - Double Digit (00-99)- AUDPC calculated
- Plant phenology:
  - Days to heading
  - Plant height
- 1000-Kernel weight
- Pedigree information
- Multiple-year replicated tests

CIMMYT


1st Year Screening
• Single Replicate
• Artificial Inoculation
• Multi-trait Evaluation
Selections
2nd Year Screening
• Two Replicates
• Artificial Inoculation
• Multi-trait Evaluation
Seed
Selections
Pre-Mexicali Block
• Fungicide Treated
Greenhouse SNB Tests
Seed
3rd Year Screening
• Three Replicates
• Artificial Inoculation
• Multi-trait Evaluation
Selections
ISEPTON
Mexicali Block
• Fungicide Treated
Seed

ISEPTON Development and Distribution

Year	Nursery Name	# Locations Distributed	Number of Entries
1970	1st ISEPTON	15	76
1988	19th ISEPTON	100	104
2009	20th ISEPTON	20	53
2011	21st ISEPTON	74	48
2012	22nd ISEPTON	75	52
2013	23rd ISEPTON	71	52
2014	24th ISEPTON	77	46
2015	25th ISEPTON	52	44
2016	26th ISEPTON	56	52
2017	27th ISEPTON	42	52

Development & Distribution of 27th ISEPTON

2014	Nursery: C49th IBWSN etc (1800 entries, 1 rep)
	Evaluation: AUDPC, Pedigree, Phenology
2015	Nursery: C27th ISEPTON (500 entries, 2 reps)
	Evaluation: AUDPC, Pedigree, Phenology
2016	Nursery: M27th ISEPTON (200 entries, 3 reps)
	Evaluation: AUDPC, Pedigree, Phenology, 1000 Kernel Weight ISEPTON DEVELOPMENT AND GLOBAL DISTRIBUTION
2017	Nursery: 27th ISEPTON (52 entries, 2 reps)
	Evaluation: AUDPC, Pedigree, Phenology, 1000 Kernel Weight
2018	Feedback from international collaborators

Reaction (AUDPC/Day) of Lines from 27thISEPTON

GID	Cross Name	Heading	Height	2017	2016	2015	2014
7045355	BAVIS #1/5/PASTOR/3/URES/JUN//KAUZ/4/WBLL1	67	105	11.4	12.7	12.2	32.1
7077417	NGL//2*WHEAR/SOKOLL	63	105	6.8	32.1	12.1	27.2
7077415	NGL//2*WHEAR/SOKOLL	63	105	7.5	35.4	13.4	27.2
7044796	QUAIU #2/BAVIS #1	63	100	15.7	21.9	13.6	34.6
7077395	MUNAL #1/PREMIO	69	95	8.0	34.4	15.1	29.6
7047645	AMUR*2/3/TRCH/SRTU//KACHU	63	90	24.8	12.7	17.8	32.1
7178836	WBLL1/KUKUNA//TACUPETO F2001/3/PIHA/4/COPIO	65	100	16.0	23.6	17.8	32.1
7077407	BAJ #1/PREMIO	63	90	10.1	20.8	17.2	43.2
7174577	AMUR*2/3/TRCH/SRTU//KACHU	63	95	19.9	19.7	20.2	32.1
7178835	WBLL1/KUKUNA//TACUPETO F2001/3/PIHA/4/COPIO	63	100	13.8	24.6	19.9	36.4
7044811	BECARD #1/BAVIS	65	100	19.0	25.4	18.3	34.6
7077404	BAJ #1/ALTIGO	72	100	16.7	25.1	12.4	43.2
4319982	MURGA (Resistant check)	69	95	8.7	9.5	10.9	NA
4754187	HUIRIVIS #1 (Susceptible check)	72	95	33.2	31.4	41.1	NA

Haplotyping of 27th ISEPTON Lines

GID	Cross Name	stb1	stb3	stb4	stb6	stb7	stb8	stb9	stb10	stb12	stb17
7044796	QUAIU #2/BAVIS #1		+			+					+
7044811	BECARD #1/BAVIS									+	+
7045355	BAVIS #1/5/PASTOR/3/URES/JUN//KAUZ/4/WBLL1					+					+
7047612	SAUAL/MUTUS//KINGBIRD #1/3/SAUAL/MUTUS					+					+
7077395	MUNAL #1/PREMIO		+					+			
7077404	BAJ #1/ALTIGO		+	+		+					+
7077407	BAJ #1/PREMIO			+	+						+
7077415	NGL//2*WHEAR/SOKOLL			+			+				
7077417	NGL//2*WHEAR/SOKOLL			+			+				
7170722	ATTILA*2/PBW65//KIRITATI/3/QUELEA			+			+	+		+	
7175897	BAJ #1*2/CIRNO C 2008	+						+			
7176659	SAUAL/3/KAUZ/PASTOR//PBW343/4/KINGBIRD #1	+				+			+		+
7177666	YAYE/4/WAXWING/3/PFAU/WEAVER//BRAMBLING/5/KACHU/SAUAL			+					+		
7177772	HEILO//MILAN/MUNIA/3/2*WHEAR/SOKOLL					+	+	+			
7178554	BAVIS #1/5/W15.92/4/PASTOR//HXL7573/2*BAU/3/WBLL1									+	+
7178555	BAVIS #1/5/W15.92/4/PASTOR//HXL7573/2*BAU/3/WBLL1								+	+	+
7178641	BAVIS#1*2/4/PASTOR//HXL7573/2*BAU/3/SOKOLL/WBLL1	+						+			
7178734	MUNAL #1*2//SOKOLL/WBLL1		+			+	+				+
4319982	MURGA (Resistant check)			+		+					
4754187	HUIRIVIS #1 (Susceptible check)			+							

23rd ISEPTON Lines Reaction Across Locations

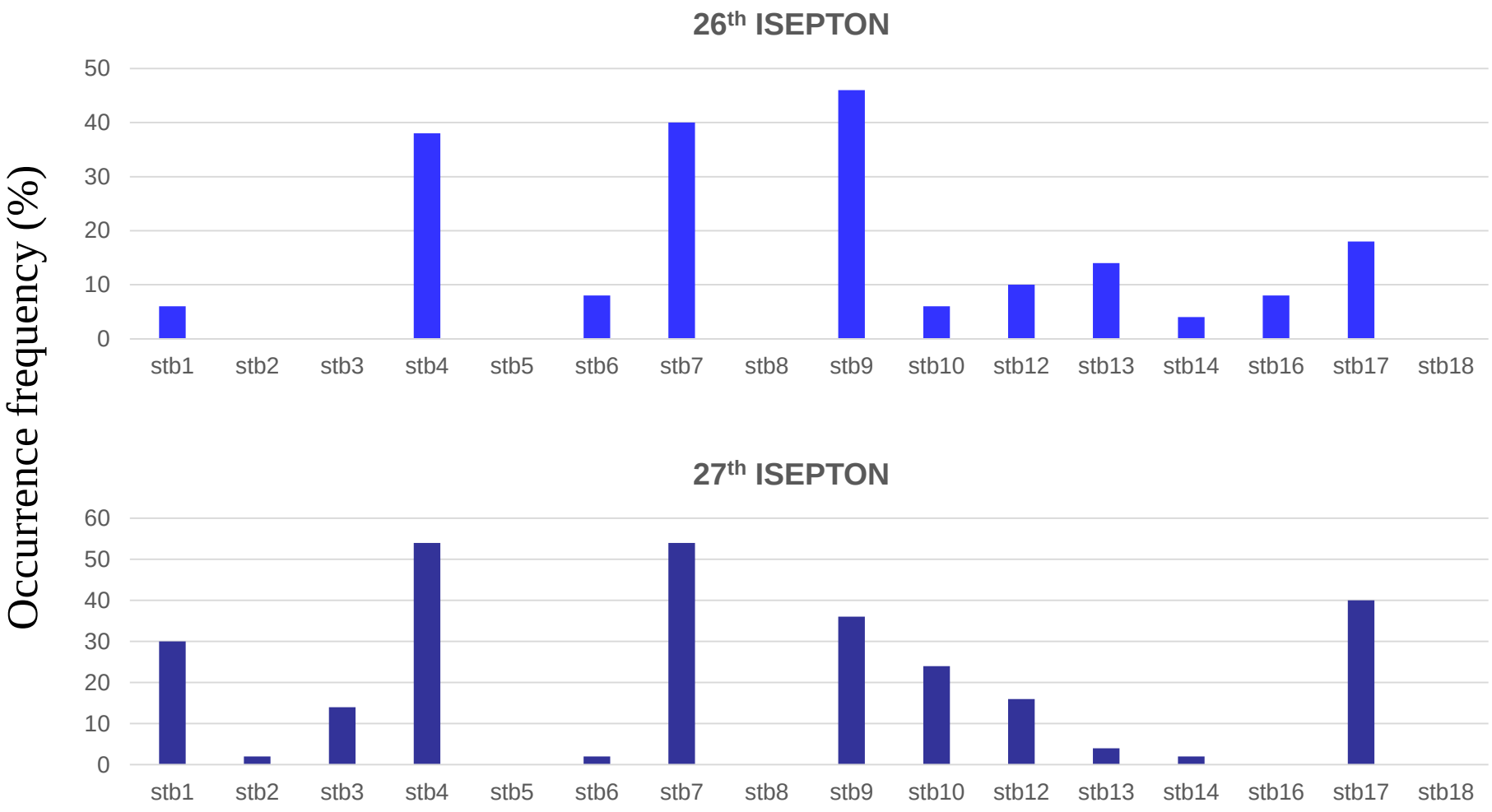
GID	Cross Name	Romania	Algeria	Turkey		Ethiopia		Iran		Mexico
		Fundulea	Elkhroub	Sakary	Trakya	Holetta	Kulumsa	Dezfoul	Gorgan	Toluca
6176024	ROLF07*2/4/CROC_1/AE.SQU.(205)//BORL95/3/2*MILAN	3	1	2	4.9	4.9	4.9	8.6	-	26.6
6176402	SAUAL/4/CROC_1/AE.SQU.(205)//BORL95/3/2*MILAN/5/SAUAL	2	2	3	4.9	4.9	4.9	24.7	17.3	5.9
6176106	OASIS/SKAUZ//4*BCN*2/3/PASTOR*2/5/MUNIA/CHTO/3/PFAU/BOW//VEE#9/4/CHEN/AE. SQU./TAUS//BCN	3	1	4	2.5	8.6	4.9	37.0	17.3	8.9
6278780	KRONSTAD F2004/VORB	4	2	1	7.4	4.9	4.9	17.3	34.6	9.2
6174904	ALTAR84/AE.SQU.(221)//3*BORL95/3/URES/JUN//KAUZ/4/WBLL1/5/MUTUS	3	1	3	4.9	4.9	4.9	17.3	30.9	13.8
6176052	VALK	4	2	3	14.8	4.9	4.9	8.6	-	25.0
6176308	ATTILA*2/PBW65*2//MURGA	2	2	3	11.1	4.9	17.3	6.2	30.9	5.9
6176403	SAUAL/4/CROC_1/AE.SQU.(205)//BORL95/3/2*MILAN/5/SAUAL	3	2	3	4.9	4.9	4.9	55.6	17.3	6.5
6176296	ATTILA*2/PBW65*2//MURGA	3	2	2	29.6	8.6	6.2	6.2	24.7	5.9
6280390	VORB/6/CPI8/GEDIZ/3/GOO//ALB/CRA/4/AE.SQU.(208)/5/2*WESTOIA/7/CPI8/GEDIZ/3/GOO//ALB/CRA/4/AE.SQU.(208)/5/2*WESTONIA	2	2	1	14.8	4.9	4.9	25.9	17.3	27.4
5999816	VORB/4/D67.2/PARANA66.270//AE.SQU.(320)/3/CUNNINGHAM	3	2	2	4.9	4.9	12.3	11.1	37.0	12.7
5999776	BABAX/LR42//BABAX/3/VORB	3	2	2	43.2	4.9	4.9	7.4	17.3	12.1
6176361	WBLL1/FRET2//PASTOR*2/3/MURGA	3	2	3	14.8	4.9	4.9	18.5	12.3	16.9
6278973	PASTOR//HXL7573/2*BAU/3/CACUKE	4	1	4	37.0	4.9	4.9	6.2	25.9	11.2
4319982	MURGA (Resistance check)	3	3	1	4.9	1.2	6.2	11.1	24.7	15.0
4754187	HUIRIVIS #1 (Susceptible check)	7	2	4	18.5	43.2	22.2	51.9	51.9	25.4

Romania: linear scale 0-9, Algeria, Turkey_S: linear scale 1-5, Mexico_T: AUDCP/day,Others: disease severity 0-100%

CIMMYT

Gene	Linked Markers	Chromosome	Source of Resistance (Stage)
Stb1	Barc74	5BL	Bulgaria 88, Oasis F86 (S, A)
Stb2	Wmc230	1BS	Veranapolis, Nova Prata (A)
Stb3	Wmc83	7AS	Israel 493 (A)
Stb4	Gwm111	7DS	Tadinia, Tadoma (S, A)
Stb5	Gwm44	7DS	CS Synthetic 6X, Bezostaya-1 (S, A)
Stb6	Gwm369	3AS	Flame, Shafir, Flame, Arina (S, A)
Stb7	Wmc313	4AL	Estanzuela Federal (S)
Stb8	Gwm577,Gwm146	7BL	M6 Synthetic W7984, Opata M85 (A)
Stb9	Wmc317	2BL	Courtot (S)
Stb10	Wms848	1D	Kavkaz-K4500 L.6.A.4 (S)
Stb11	Barc008	1BS	TE 9111 (S)
Stb12	Wmc219	4AL	Estanzuela Federal, KVK-K4500L (S)
Stb13	Wmc396	7BL	Salamouni (S)
Stb14	Wmc500, Wmc623	3BS	Salamouni (S)
Stb15	Xpsr904	6AS	Arina, Riband (S)
Stb16	Wmc494	3DL	M3 Synthetic W7976 (S, A)
Stb17	Hbg247	5AL	M3 Synthetic W7976 (A)
Stb18	Gpw5176, Gpw3087	6DS	Balance (S, A)
StbSm3	Barc321	3AS	Salamouni (S)
StbWW	Barc119b	1BS	WW1842, WW2449, WW2415 (S)
TmStb1	Barc174	$7A^{m}S$	MDR043 (*T. monococcum*) (S)

Frequency of Stb genes in ISEPTON



False positive results may be expected since only one of the flanking markers was used in haplotyping except for *Stb14* and *Stb18*, where both flanking markers were applied

CIMMYT

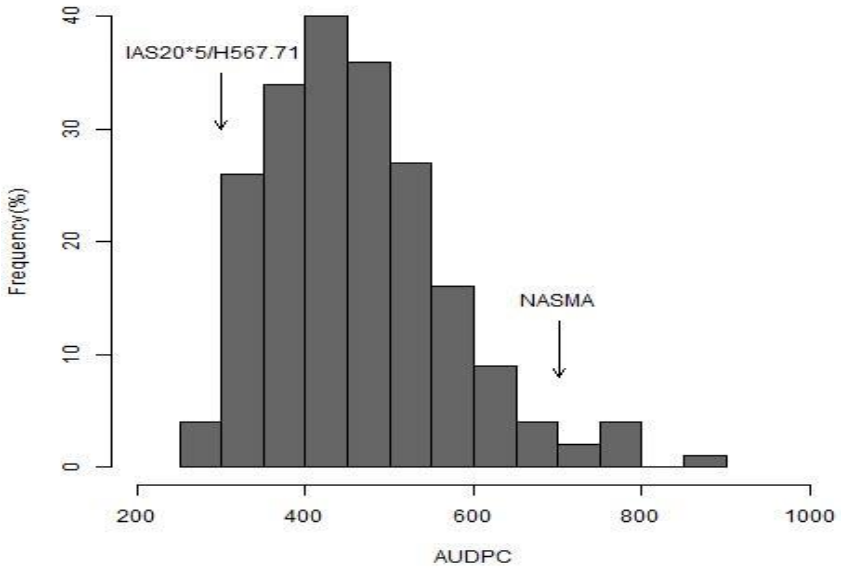
Genetic and Mapping Studies for STB Resistance

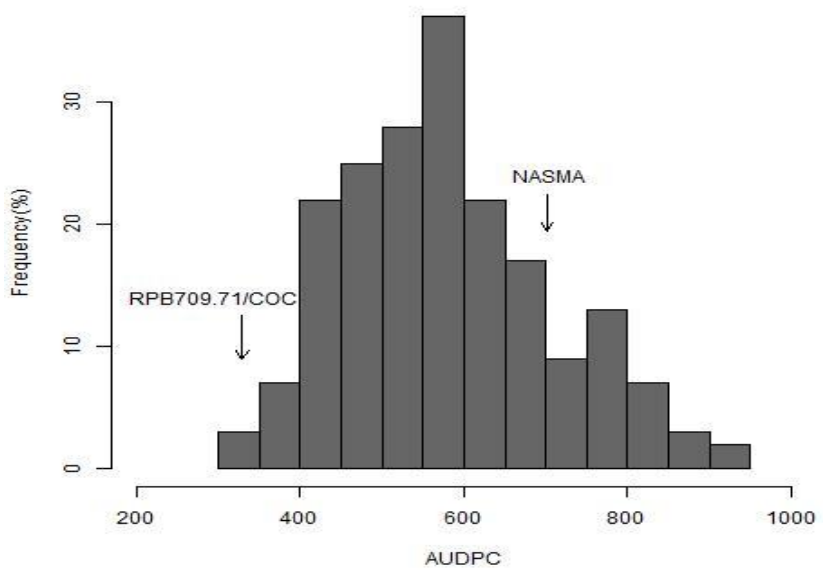
Cross	Phenotype	Markers	Analysis
NASMA x IAS20*5/H567.71	2-year: Toluca & Boximo	SSR, SNP	DONE
NASMA x RPB709.71/COC	2-year: Toluca & Boximo	SSR, SNP	DONE
*BLOUK#1 x WHEAR/KUKUNA/3 /C80.1/3*BATAVIA//2*WBLL1*	*3-year: Toluca*	*GBS*	*In Progress*
BLOUK#1 x CHIBIA//PRLII/ CM65531/3/SKAUZ/BAV92	*3-year: Toluca*	*GBS*	*In Progress*
HUIRIVIS#1 x MUTUS	*3-year: Toluca*	*GBS*	*In Progress*
HUIRIVIS#1 x MURGA	3-year: Toluca	GBS	Preliminary Results

CIMMYT

STB Resistance in CIMMYT Sources

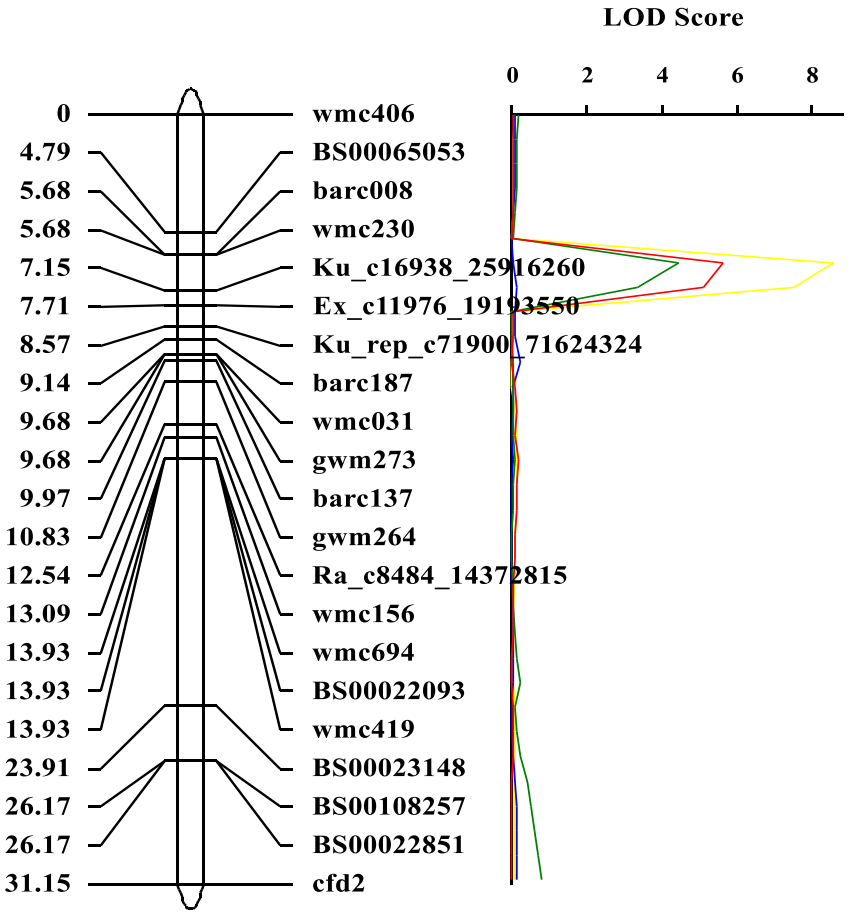
Mean and range of AUDPC for STB for Susceptible: NASMA and Resistant: IAS20*5/H567.71 & RPB709.71/COC and their RILs								
Location	Year	NASMA	IAS20*5/H567.71	RPB709.71/COC	Population mean (NASMA × IAS20*5/H567)	Population mean (NASMA × RPB709.71/COC)	Population range (NASMA × IAS20*5/H567.71)	Population range (NASMA × RPB709.71/COC)
Boximo	2010	445.1	250.6	188.0	271.9	329.8	112.3 - 713.0	155.6 - 587.7
	2011	885.8	309.9	418.2	576.7	818.8	217.6 - 1330.6	388.0 - 1397.5
Toluca	2010	650.3	304.6	267.9	367.8	424.3	242.0 - 650.3	259.3 - 734.6
	2011	828.4	333.3	442.0	524.4	616.6	324.1 - 914.8	355.6 - 1023.5





NASMA × IAS20*5/H567.71 RIL Population

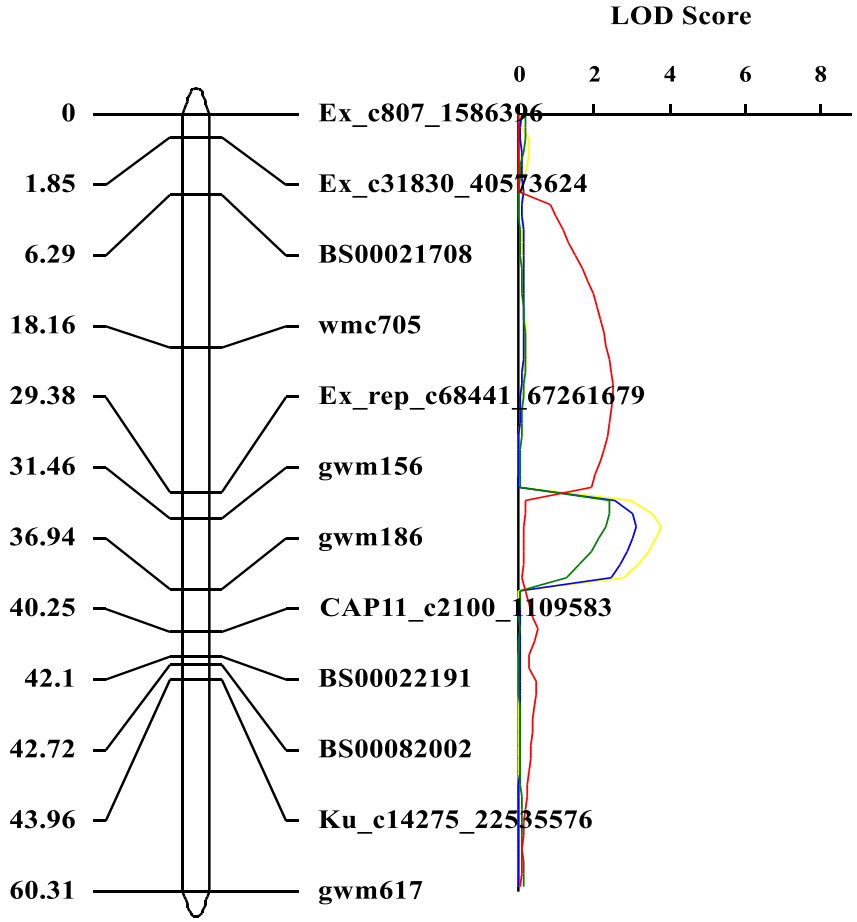
Genetic distance on chromosome 1BS in cM



PVE=11.5%

Stb11

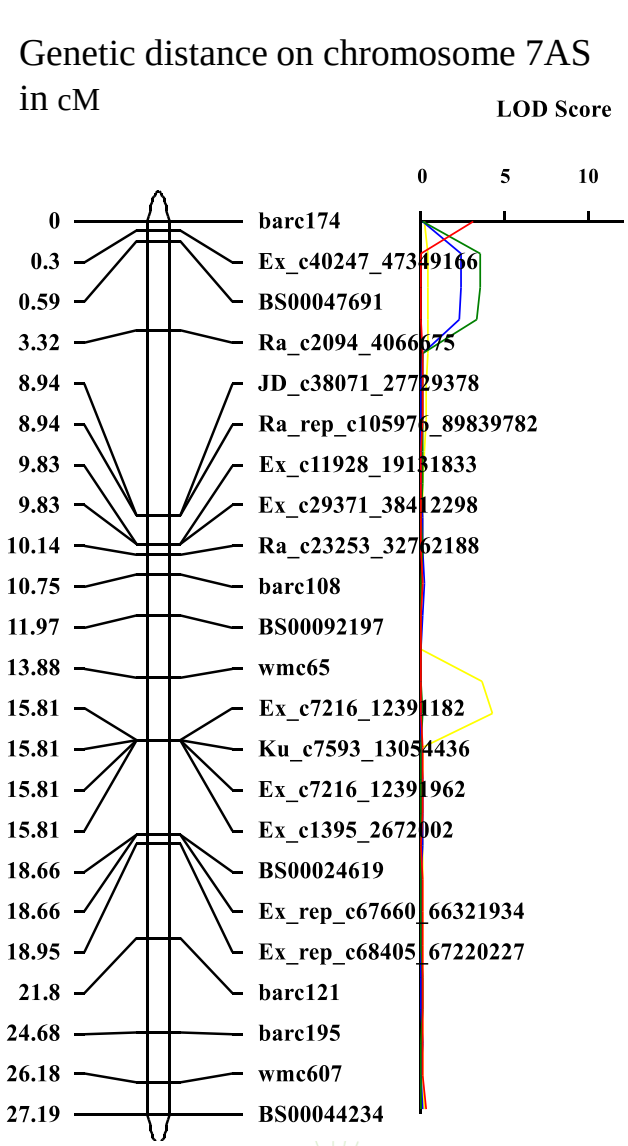
Genetic distance on chromosome 5AL in cM



PVE=5.4%

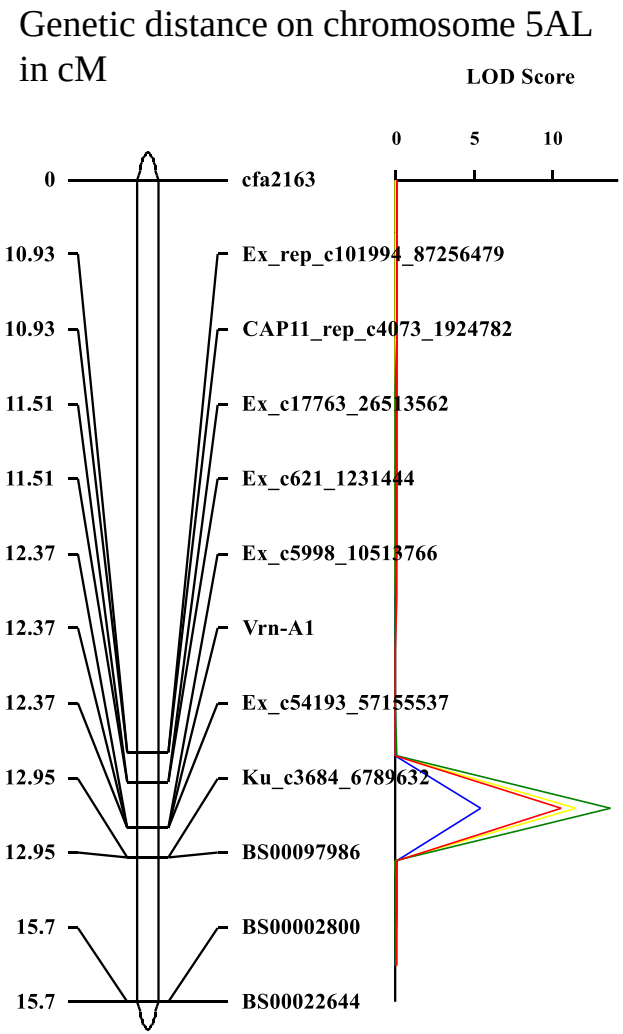
CIMMYT

NASMA × RPB709.71/COC RIL Population

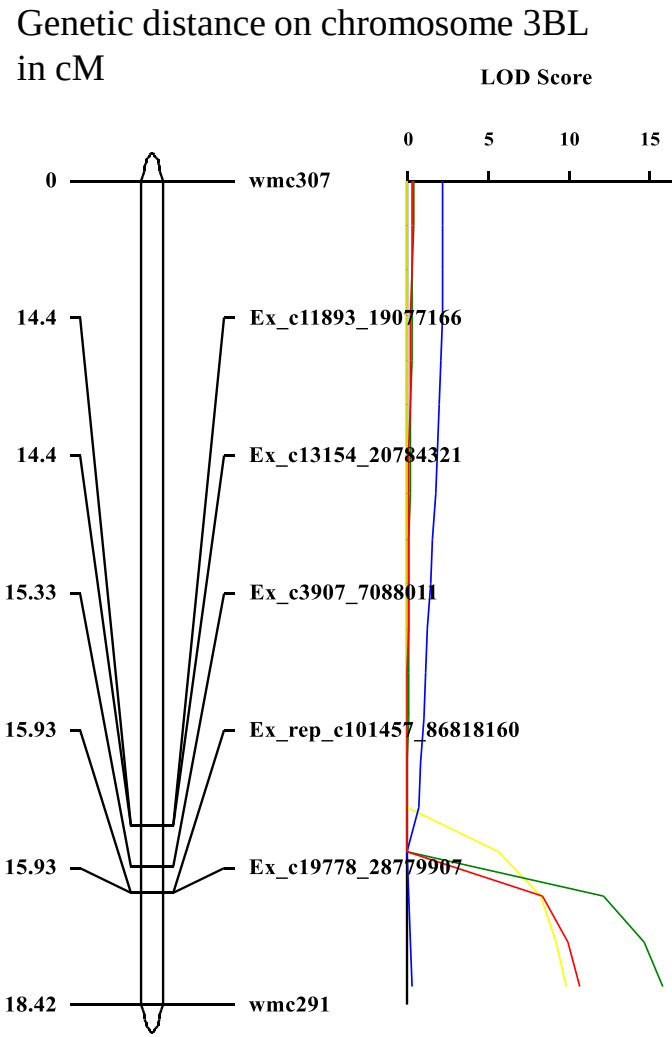


PVE=5.1%

Stb3



PVE=18.5%



PVE=22.7%

CIMMYT

Preliminary Analysis of Huirivis#1/Murga

The mapping population comprises 300 individuals, which was evaluated in La Estanzuela, Uruguay, in 2016, and in Toluca, Mexico in 2017

In Uruguay, QTL were found on chromosomes 2B, 2D, 3D and 5D

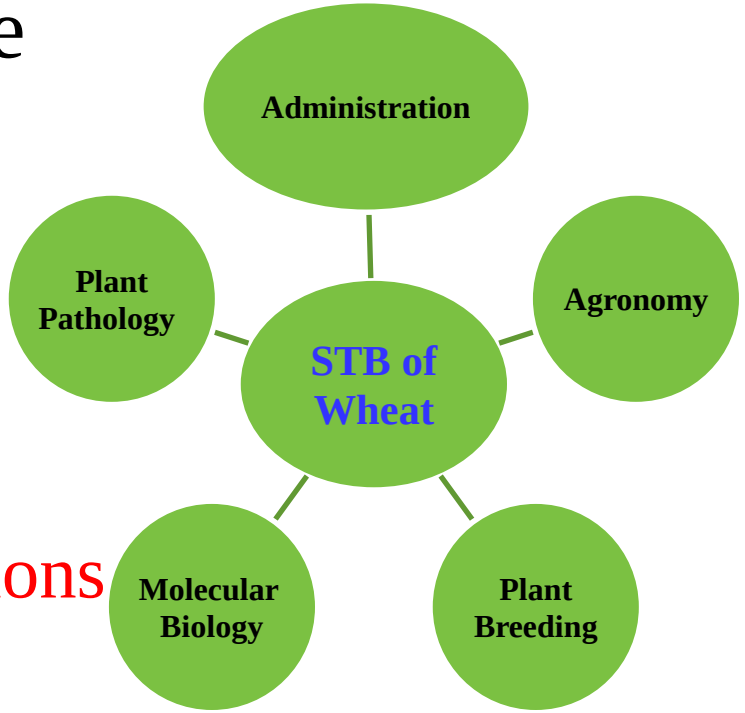
In Mexico, QTL were found on chromosomes 2A, 2D, and 5B

Apart from the QTL on 2D, none of the above QTL was shared between Uruguay and Mexico

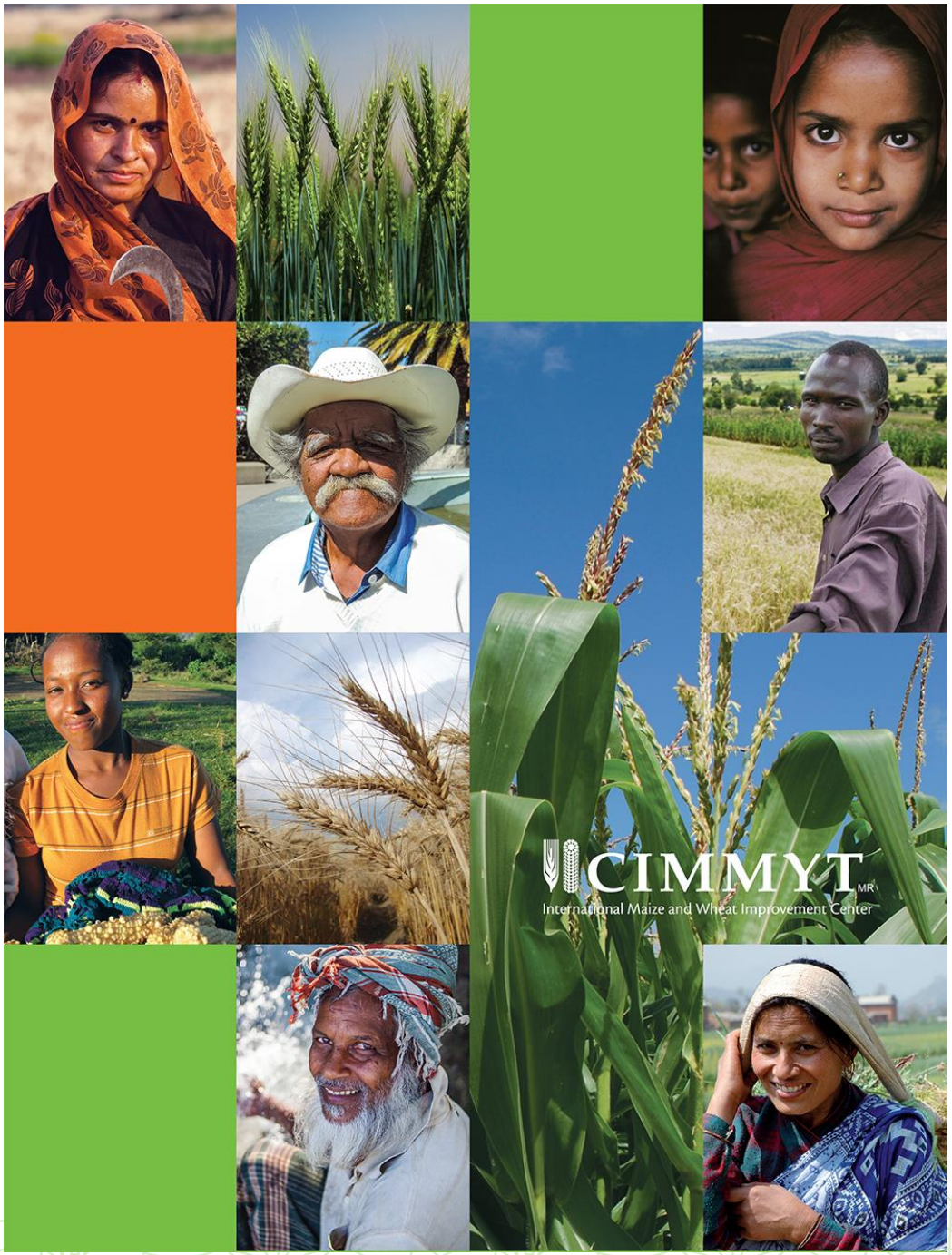
The 2D QTL (likely *Stb16*) showed major effect in Mexico (PVE 65.5%), but much less effect in Uruguay (PVE 11.9%)

Conclusions

- High level of resistance in CIMMYT germplasm
- Resistance is broad genetic base
  - Diverse germplasm
  - Rigorous breeding efforts
  - Multi-location testing
  - Shuttle breeding
  - Major and minor gene combinations



Multidisciplinary Approach ⟹ Mitigate Threat of STB Disease



Thank you for your interest!

CIMMYT MR