Characterization of DON resistance QTL on 3BL and 3DL in a wheat mapping population

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International Maize and Wheat Improvement Center

Mission:

Sustainably increase maize and wheat production to reduce poverty and ensure global food security.

Founded 1966. Headquarters in Mexico.
Offices worldwide. Not-for-profit.

More than 400 global partners.
More productive, resilient maize and wheat varieties and cropping systems.
More than 10,000 researchers trained.

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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

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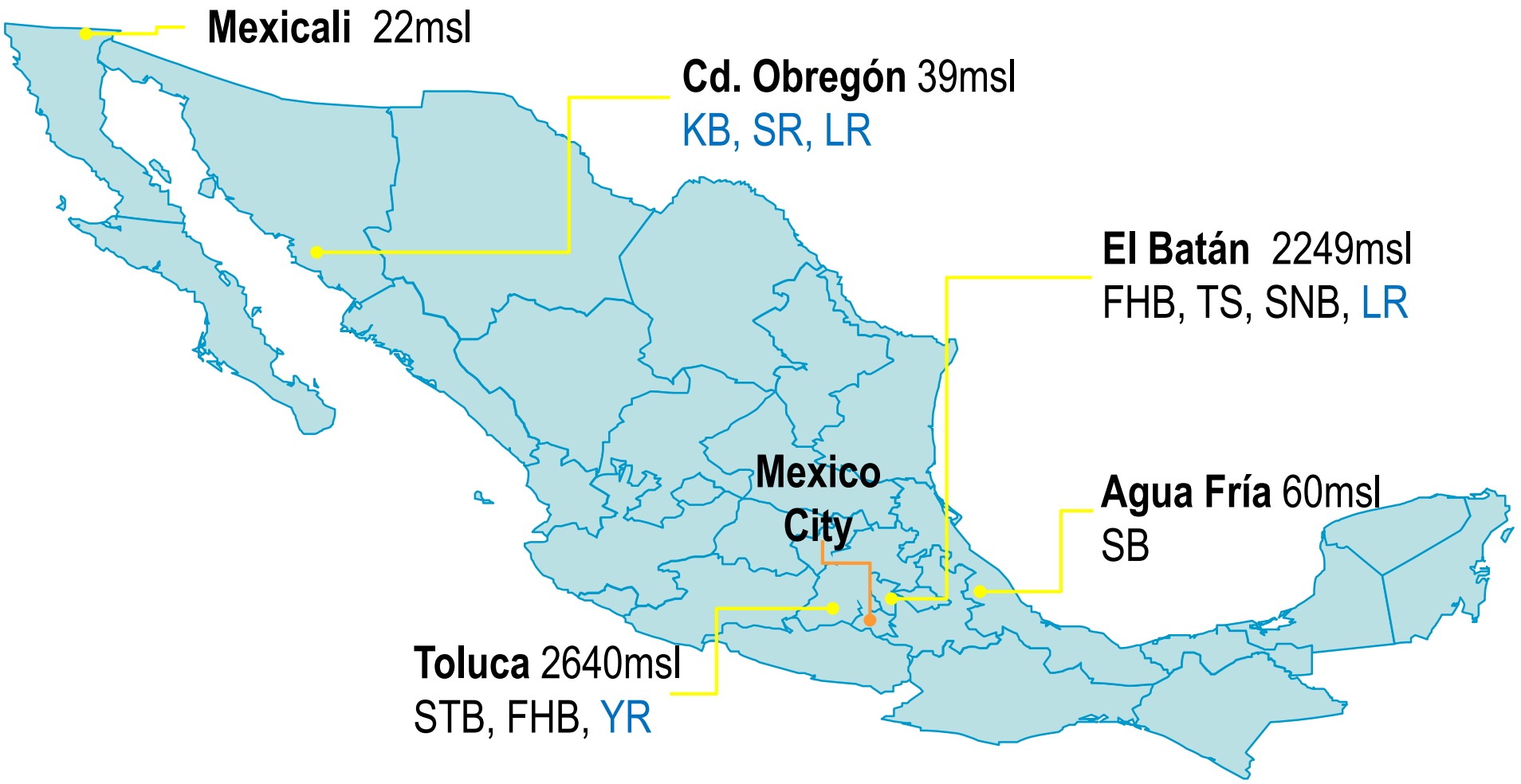
Wheat Diseases at CIMMYT, MEXICO



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Fusarium head blight (FHB) & deoxynivalenol (DON)

- FHB is a major fungal disease with global importance, causing more concern on food safety than yield reduction, due to its ability to produce mycotoxins represented by DON
- Due to climate change, adoption of conservation agricultural practices and maize-wheat rotation, FHB is spreading to non-traditional epidemic regions, like the Yellow and Huai river valleys in China, Oklahoma, Montana and Idaho in USA, Alberta and Saskatchewan in Canada etc.
- Legislation has been set up in many countries and organizations to control the highest allowable DON content in food and feed; but contamination with DON higher than the threshold has often been reported, e.g. 70% of the wheat samples from Jiangsu, China, tested in 2010 showed DON content higher than the standard (1 ppm)

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Resistance Mechanisms for FHB and DON

- Several resistance mechanisms have been proposed, but the below ones are the most frequently researched:
  - Type I for initial infection of FHB
  - Type II for pathogen spread within the spike tissues
  - Type III for DON content on grains
  - Type IV for kernel infection rate
- In most studies, Types III and IV were associated with Types I and II, thus many researchers take the former simply as consequence of the latter
- Under this assumption, only FHB is measured in most breeding programs, due to its low cost and ease of scoring, assuming low FHB leads to low DON content, although exceptions often happen

Hint for the Independence of Type III Resistance

- Low correlation between FHB and DON reported from time to time, and even results for no or negative correlation have been reported
- Late infection that leads DON contamination on grains without visible FHB symptom
- The recently cloned *PFT* gene at *Fhb1* locus turned out to be ineffective against DON, suggesting a DON detoxification gene in close linkage with *PFT*, considering *Fhb1* is well known for Type III resistance
- In oat, it has been well established that DON content is independent of FHB symptom that is seen only in extremely susceptible varieties

QTL for Type III Resistance in Published Studies

- QTL mapping for DON has been available in limited number of studies, due to the additional expense and the assumption that DON is dependent on FHB
- In a Meta-analysis, Liu et al. (2009) summarized QTL for different FHB resistance components and found that only 25 out of 209 QTL were associated with Types III, and none of them was independent from Type I and/or Type II
- A few studies showed QTL exclusively for DON; but mostly they were minor QTL and/or not repeatable

QTL Mapping in a CIMMYT line IAS20*5/H567.71

- IAS20 is a Brazilian FHB resistant cultivar, and its pedigree is COLONIAS//FRONTANA/KENYA-58
- A RIL population derived from NASMA and IAS20*5/H567.71 was used, containing 197 entries
- Field trials were performed in 2010, 2013, 2014 and 2017 in El Batan, Mexico
- Phenotyping was conducted for FHB index, FDK, DON, as well as PH and DH
- Genotyping was done with 15K SNP markers and some SSRs and SNPs

FHB screening nursery at El Batan, Mexico

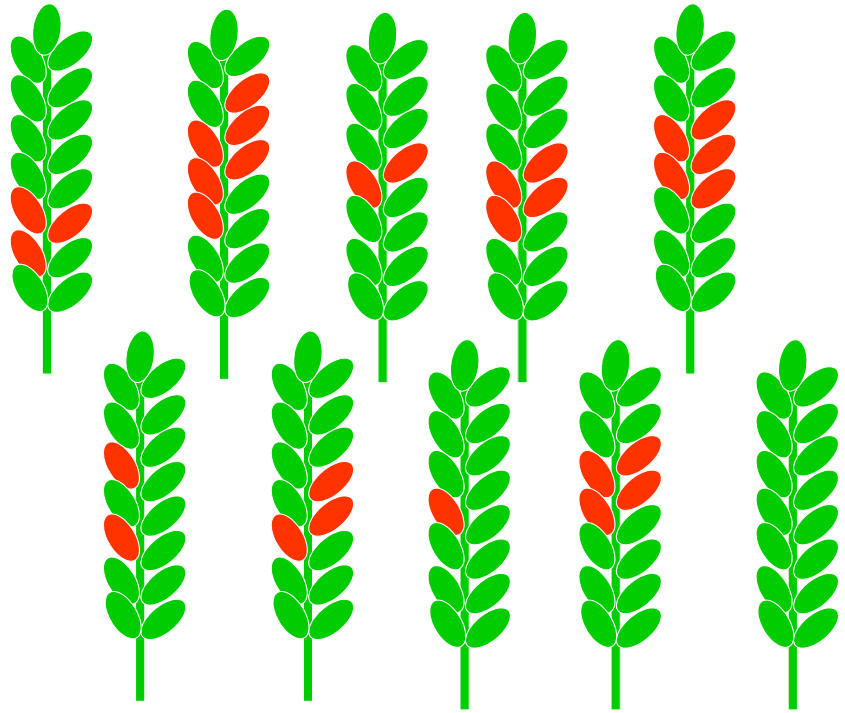
- Move fields from Toluca to Batan (2006)
- Logistic efficiency
- Enhanced capacity (2 ha/10,000 plots)

Maize-wheat rotation with CA practices

Automated programmable misting system

Precision spray inoculation technique

FHB screening nursery at El Batan, Mexico



FHB Index = Incidence x Severity /100

Example: Incidence: 90.0%
Severity: 20.8%
FHB index: 18.7%

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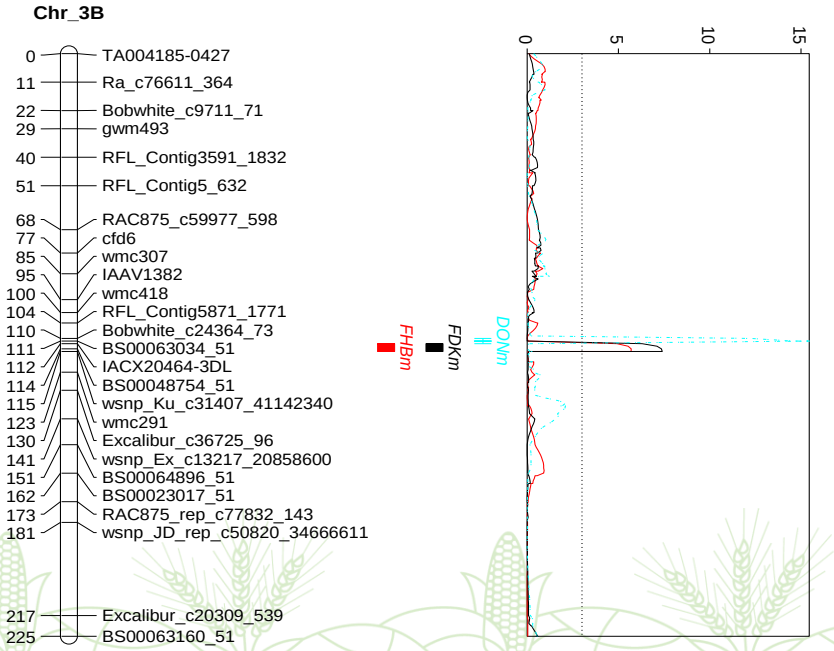
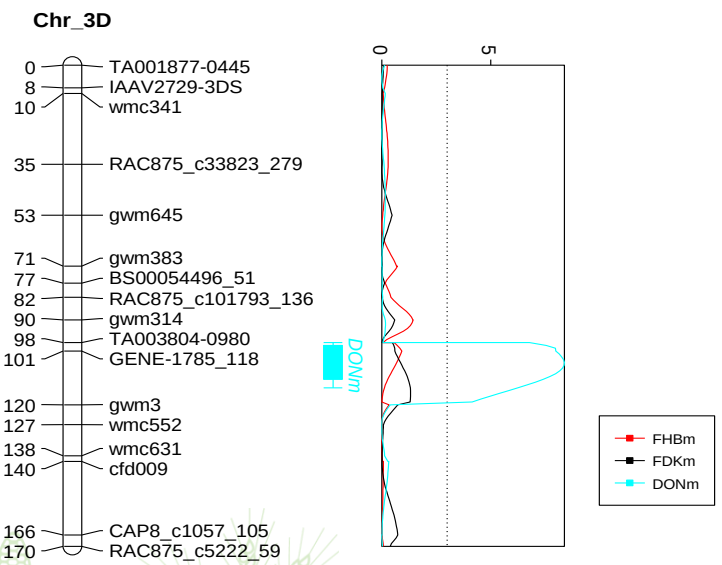
QTL mapping in a CIMMYT line IAS20*5/H567.71

Chr.	Position	Left marker	Right marker	FHB index				FDK			DON content			R source	Traits associated
				2010	2013	2014	2017	2013	2014	2017	2013	2014	2017		
1BL	66.3-71.6	wmc419	BS00064032_51									**4.4**		I	
2AL	86.9-98.7	WEC_4379619	BS00039406_51					**7.4**						I	
2DL	15.7-18.9	tplb0021c10_951	GENE-0638_732								**5.4**			N	
3BL	109.6-119.0	BW_c24364_73	Ex_c27120_789	**8.7**	**4.8**	**4.4**	**8.6**	**7.5**	**12.3**	**13.6**	**15.8**	**20**	**23.9**	I	
3DL	89.4-119.7	TA003804-0980	gwm3								**10.5**	**15.3**	**10.3**	I	
4BS	44.1-46.3	Rht-B1	BS00021984_51		**5.5**									N	PH
4DS	0-10.7	Rht-D1	barc105	**9.5**	**12.7**	**9.2**	7.7	4.9		3.9				I	PH
5AL	147.6-147.9	WEC_5013188	Vrn-A1	3.9	**21.2**	**21.7**								I	DH, PH
5BL	92.1-92.4	BS00022673_51	R_c539_1789		**4.8**	3.4	3.9							N	DH
7AC	115.6-119.8	WERC_70021470	Ku_c97425_164						**7.5**					N	
Accumulated percentage of variation explained				22.1	49.0	38.7	22.0	19.8	19.8	22.9	26.3	39.7	34.2		





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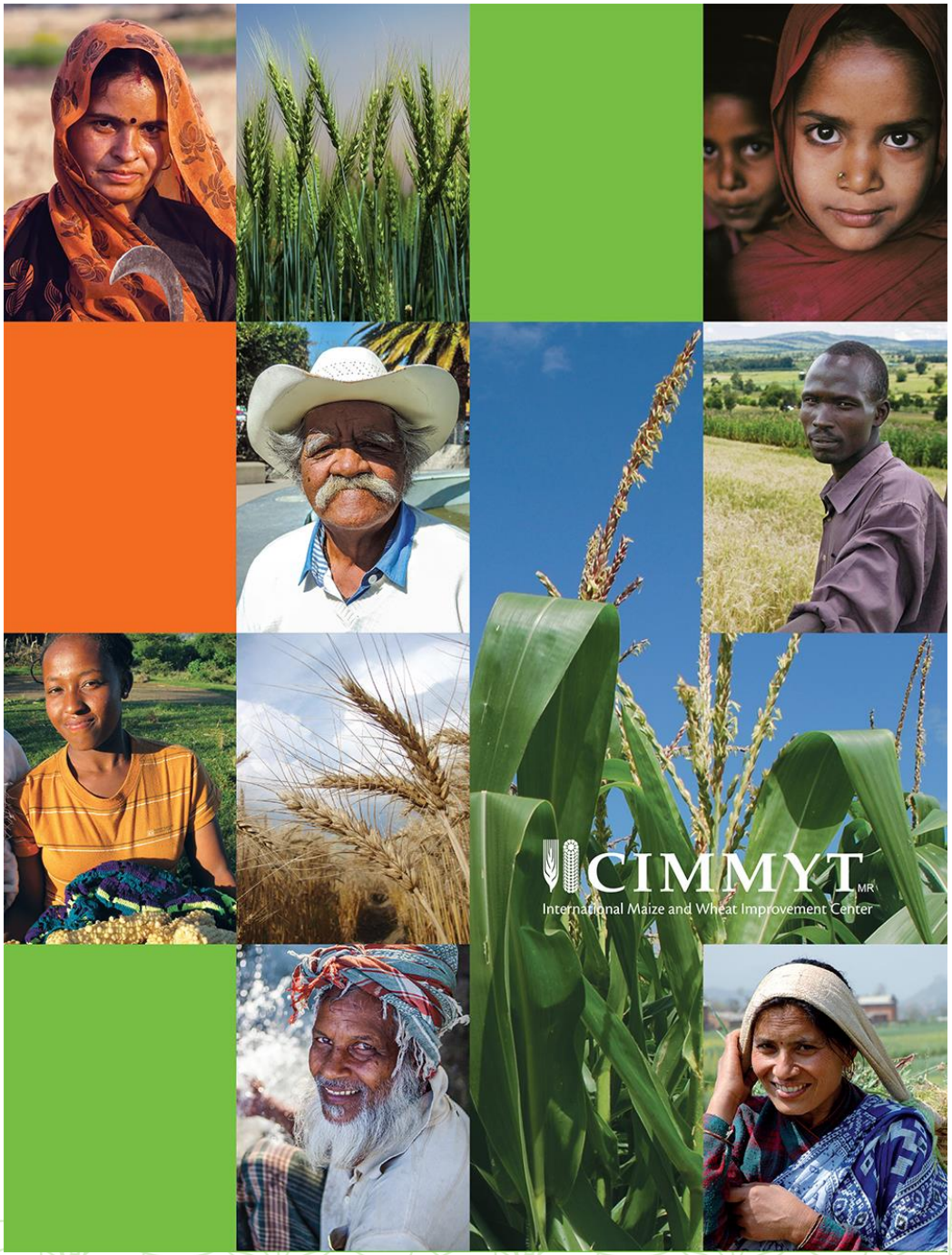
QTL Mapping in a CIMMYT line IAS20*5/H567.71

- SNP markers flanking the 3BL and 3DL QTL have been transformed into KASP markers for their utilization in MAS
- Additional KASPs on the 3DL QTL region are being tested in order to fill the gap and identify closer markers
- Based on map comparisons, the 3BL QTL is not the well-known 3BSc/3BLc QTL originally found in Wuhan1 and most likely to be a new QTL, while the 3DL QTL has not been reported previously
- Based on haplotyping results of the progenitor lines of IAS20*5/H567.71, resistant source of the 3BL QTL is Frontana, and that of the 3DL is Kenya58
- The concept of Type III resistance was initially proposed based on the fact that Frontana has an ability to detoxify DON (Miller et al. 1985), and the identification of the 3BL QTL may provide an evidence for the phenomenon

Moving Forward With The Project

- Both the 3BL and 3DL QTL showed major and stable effects on Type III resistance (detoxification), which may be of interest not only to breeders but also to grain industry
- Fine mapping of both QTL are being planned
- Developing diagnostic markers for the two Type III QTL and investigate their occurrence in CIMMYT germplasm.
- Combining Type I (2DLc from Soru#1, Mayoor etc.), Type II (*Fhb1/Sr2* recombinants) and Type III (3BL and 3DL from IAS20) in CIMMYT genetic background, and screen for lines with holistic resistance via markers, field evaluation, laboratory experiments (DON analysis)



Thank you for your interest!

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