Horizontal gene transfer of *Fhb7* from fungus underlies Fusarium Head Blight resistance in wheat

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Dec. 10, 2020

OUTLINES

1. Introduction to Fusarium Head Blight and its effects on Wheat
2. *Th. elongatum* genome assembly and comparative Triticeae genome evolution
3. Map-based cloning of the *Fusarium* resistance gene *Fhb7*
4. Evolutionary history and molecular function of *Fhb7*
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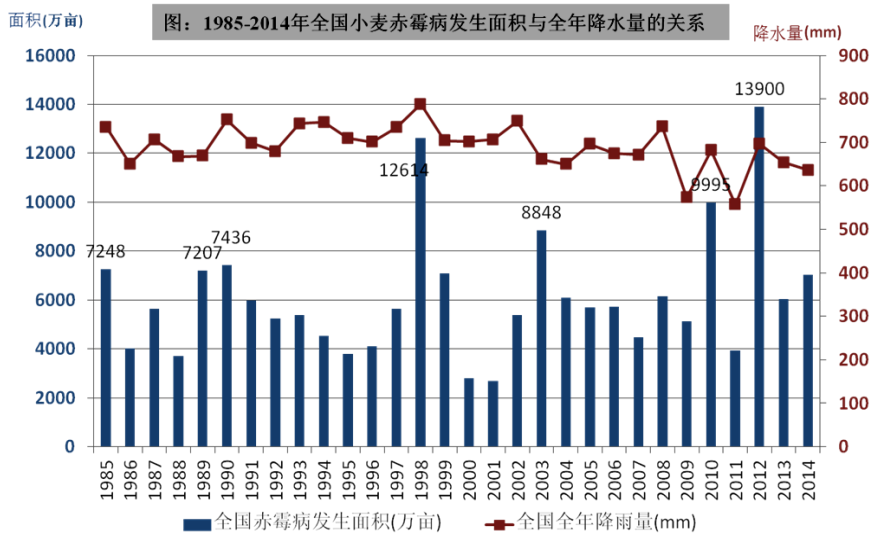
1. Introduction to Fusarium Head Blight and its effect on Wheat



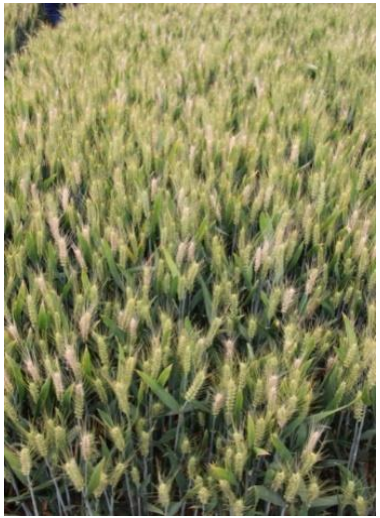


Fig.1 Wheat scab in China (Cheng et al., 2015)

1. Introduction to Fusarium Head Blight and its effect on Wheat

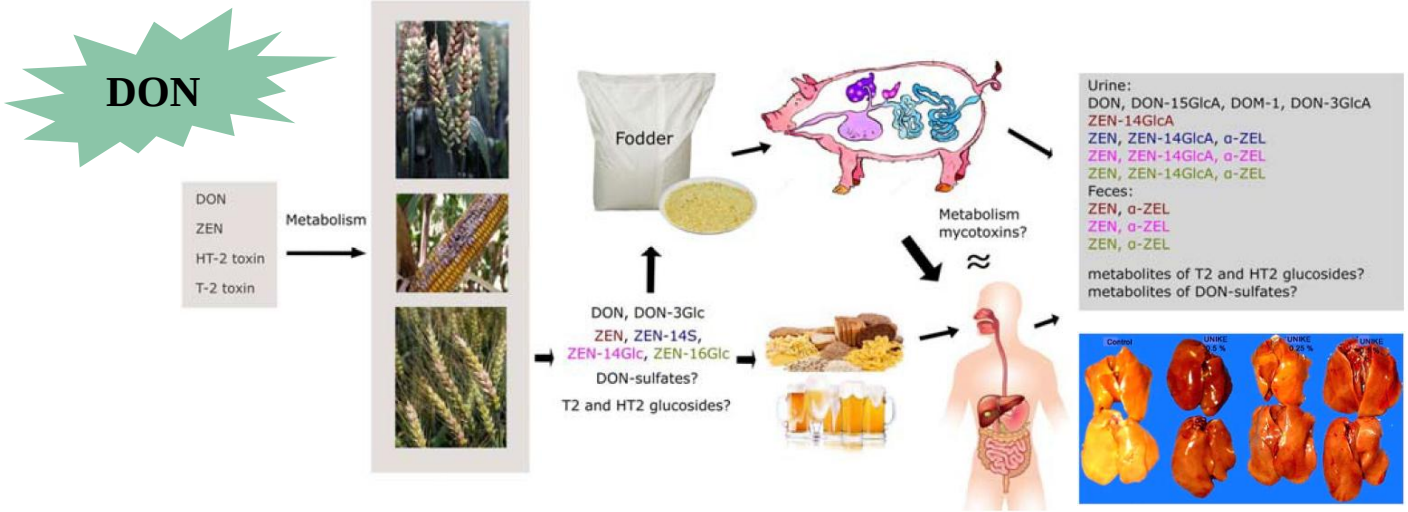
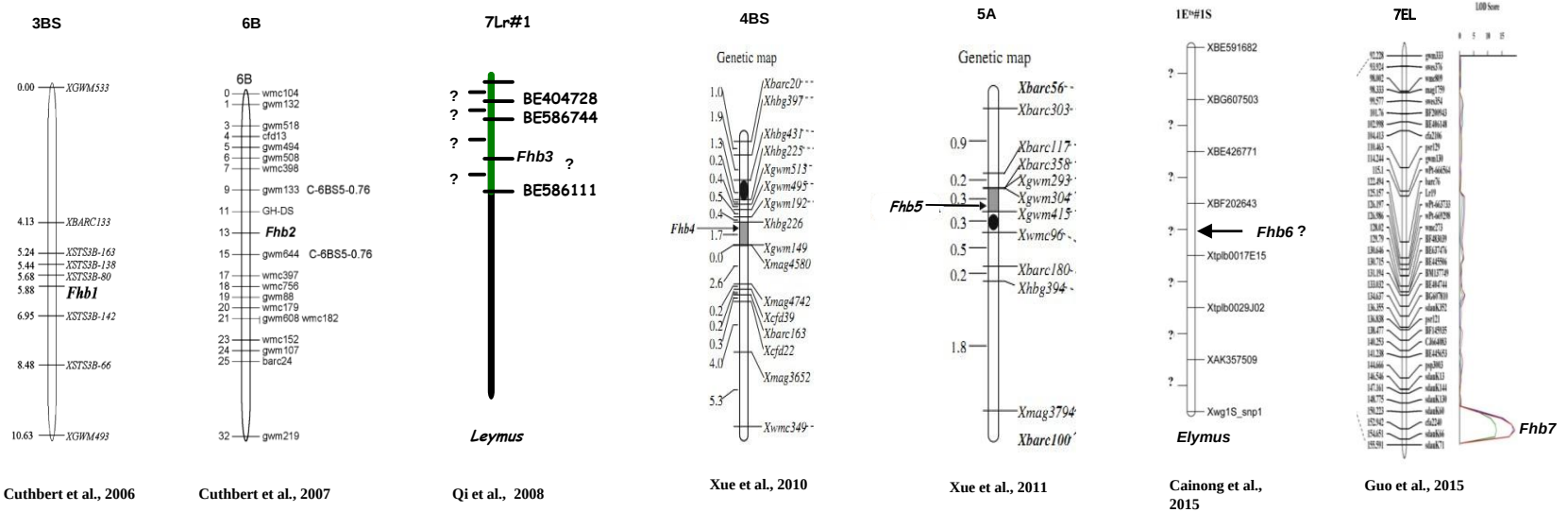


Fig.2 The grain contaminated by mycotoxins imposes health threats to humans and livestock

1. Introduction to Fusarium Head Blight and its effect on Wheat



Cuthbert et al., 2006 | Cuthbert et al., 2007 | Qi et al., 2008 | Xue et al., 2010 | Xue et al., 2011 | Cainong et al., 2015 | Guo et al., 2015

Fig.3 Seven loci resistant to FHB have been designated up to date

1. Introduction to Fusarium Head Blight and its effect on Wheat

Disease	Genes	Chromosomes	Reference
Stem rust	*Sr26*	T6AS.6AL-6Ae#1L	Knott 1961
Stem rust	*Lr24, Sr24*	T3DS.3DL-3Ae#1L	Smith et al.,1968
Leaf rust and Stem rust	*Sr25/Lr19*	$7el_1$	Knott 1968 Xu et al.,2009
Stem rust	*Sr43*	$7el_2$	Liu et al.,2013
Leaf rust	-	1St	Hu et al.,2011
BYDV	*Bdv2*, *Bdv3*	7Ai	Ohm et al.,2009
FHB	*Fhb7*	$7el_2$	Shen et al.,2004 Zhang et al. 2011 Guo et al. 2015
S. nodorum	*SNB*	?	Oliver et al.,2008
Eyespot	-	4Ai#2	Li et al.,2004
WSMV	*Wms1*		Baley et al.,2001

Fig.5 Tall and intermediate wheatgrasses of the *Thinopyrum* genus carry resistant genes to different diseases including FHB

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2. *Th. elongatum* genome assembly and comparative Triticeae genome evolution

Table 1 Summary statistics for *Th. elongatum* genome assembly

	EE	CS-AA	CS-BB	CS-DD
Number of genes	**44,474**	35,345	35,643	34,212
Number of mRNA	44,474	43,697	44,220	42,828
Genes anchored to pseudo-chromosomes	44,144	35,345	35,643	34,212
Average mRNA length (bp)	3,243.46	3,400.47	3,509.61	3,419.13
Average CDS length (bp)	1127.43	1,310.85	1,351.15	1,354.32
Average exon number per gene	4.22	5.36	5.34	5.44
Average intron length (bp)	625	479.50	497.22	464.68

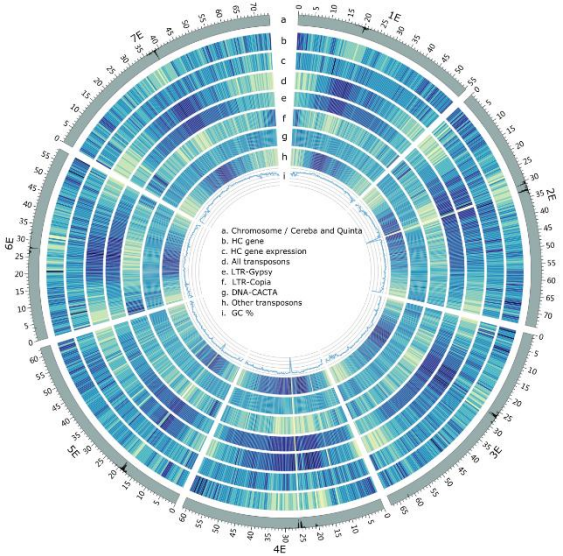


Fig.7 The landscape of *Th. elongatum* genome

2. *Th. elongatum* genome assembly and comparative Triticeae genome evolution

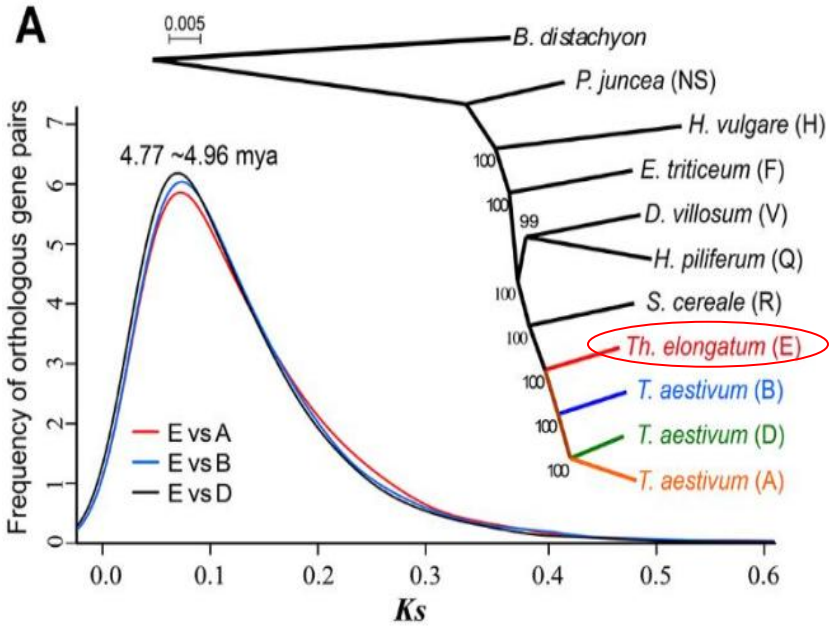


Fig.8 NJ phylogenetic tree of the genomes of *Triticeae* species.

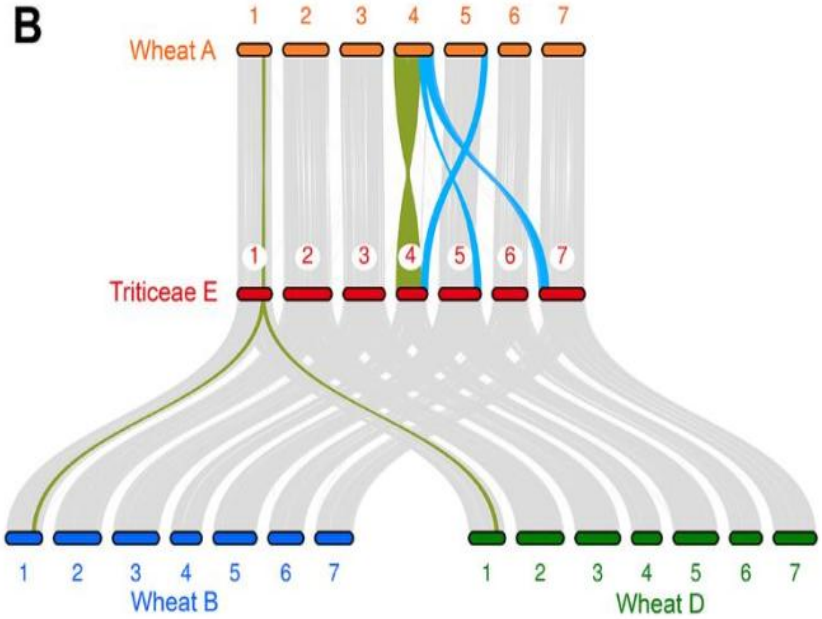
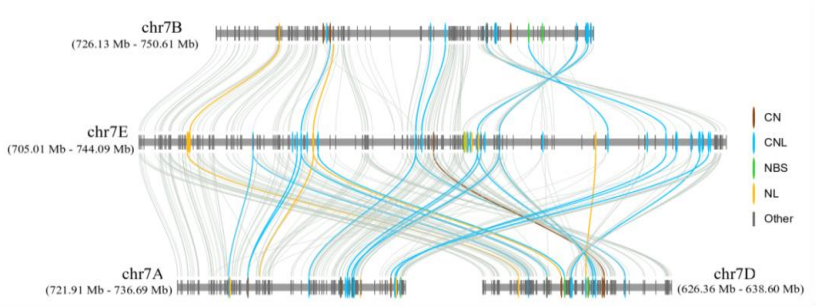


Fig.9 Syntenic blocks between the E genome and the three wheat sub-genomes

2. *Th. elongatum* genome assembly and comparative Triticeae genome evolution



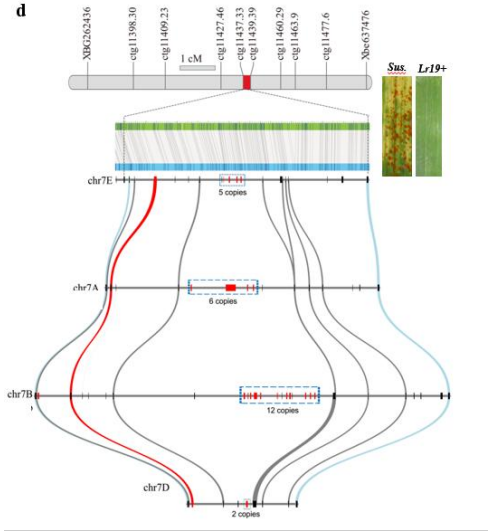


Fig.10 Micro-synteny of Chr. 7 distal region between the *T. elongatum* and *T. aestivum* sub-genomes

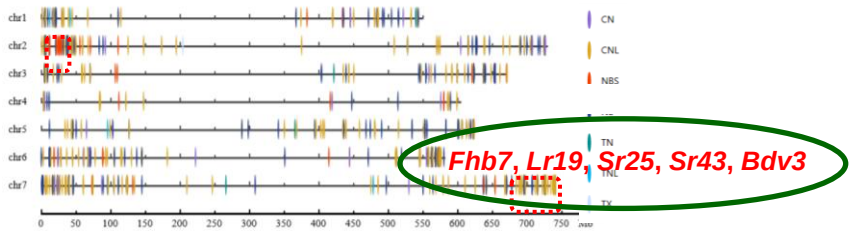


Fig.11 Chromosome distribution of predicted RGAs in the *T. elongatum* genome

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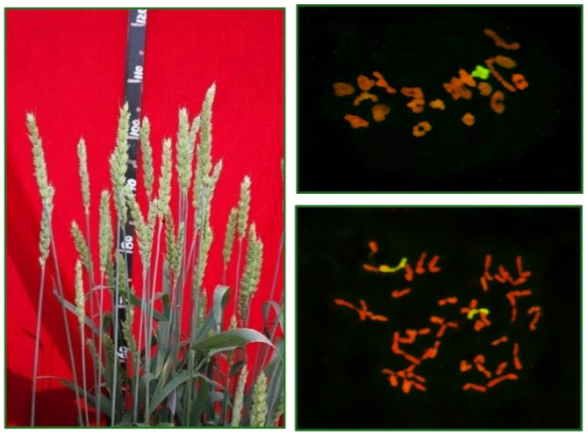
3. Map-based cloning of the Fusarium resistance gene *Fhb7*



Thatcher-*Thinopyrum* substitution lines: $7el_1$（7D）*et al.*

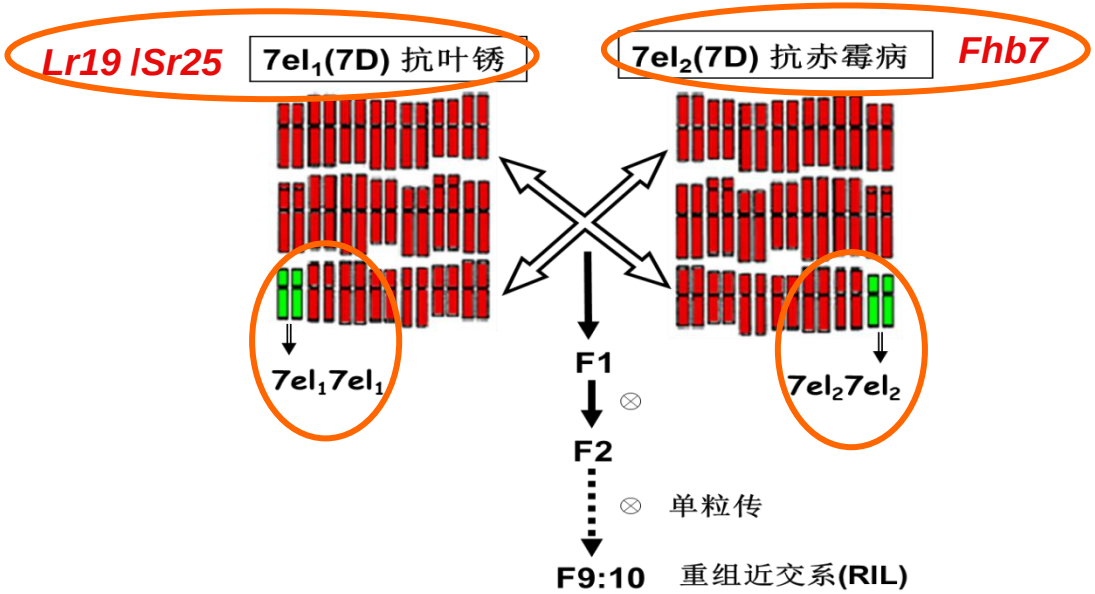


Fig.12 Recombinant Inbred Line (RIL) population is constructed using these two substitution lines, 7el1(7D) and 7el2(7D), as parents

3. Map-based cloning of the Fusarium resistance gene *Fhb7*

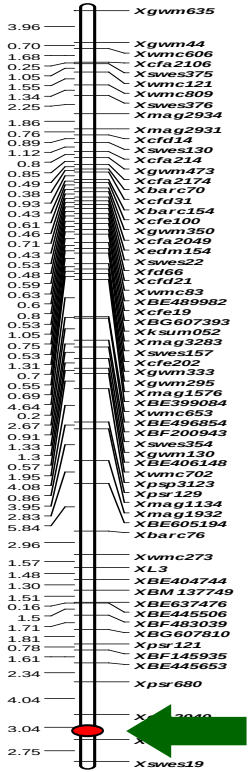
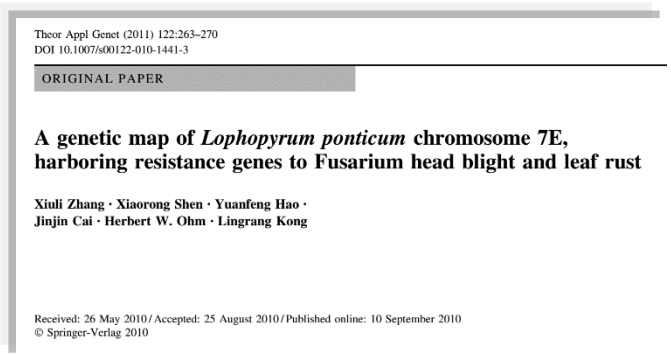


Fig.6 *Fhb7* on Chr. 7E



Theor Appl Genet (2011) 122:263–270
DOI 10.1007/s00122-010-1441-3

ORIGINAL PAPER

A genetic map of *Lophopyrum ponticum* chromosome 7E, harboring resistance genes to Fusarium head blight and leaf rust

Xiuli Zhang · Xiaorong Shen · Yuanfeng Hao · Jinjin Cai · Herbert W. Ohm · Lingrang Kong

Received: 26 May 2010 / Accepted: 25 August 2010 / Published online: 10 September 2010
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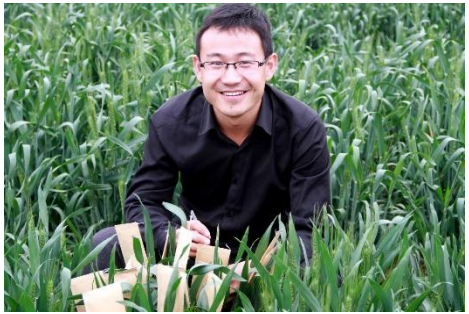
Xiuli Zhang @ NWFU

TAG，2011



Jun Guo @ SAAS

Theor Appl Genet
DOI 10.1007/s00122-015-2586-x

CrossMark

ORIGINAL ARTICLE

High-density mapping of the major FHB resistance gene *Fhb7* derived from *Thinopyrum ponticum* and its pyramiding with *Fhb1* by marker-assisted selection

Jun Guo[1] · Xiuli Zhang[2] · Yanlin Hou[3] · Jinjin Cai[1] · Xiaorong Shen[4] · Tingting Zhou[1] · Huihui Xu[1] · Herbert W. Ohm[4] · Hongwei Wang[1] · Anfei Li[1] · Fangpu Han[3] · Honggang Wang[1] · Lingrang Kong[1]

Received: 3 April 2015 / Accepted: 16 July 2015
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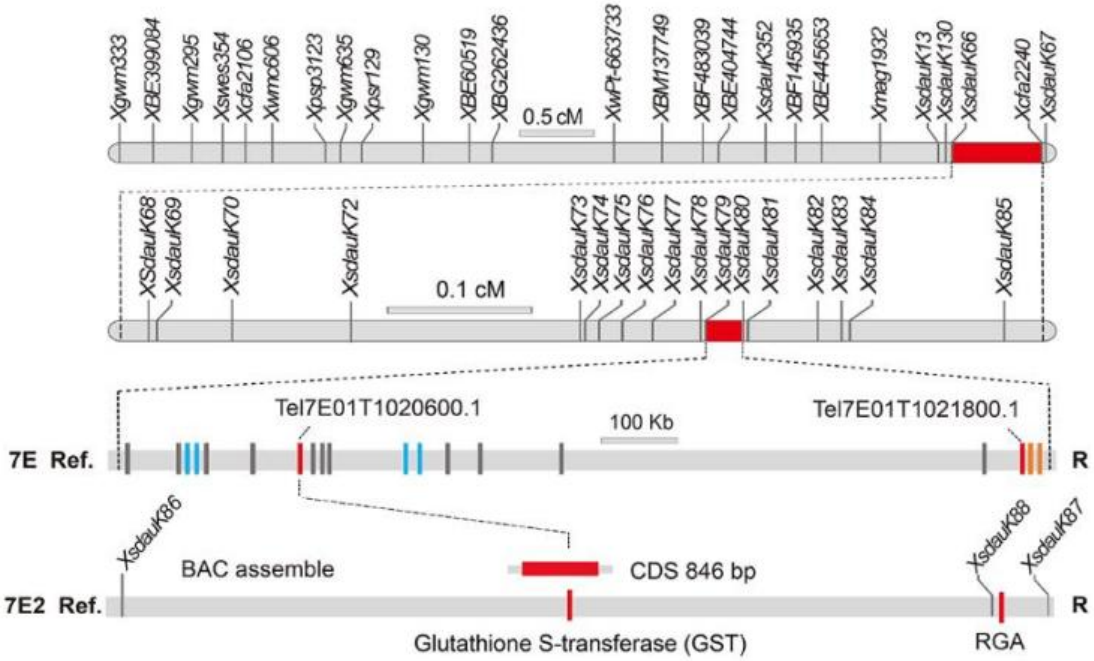
Designated as *Fhb7*

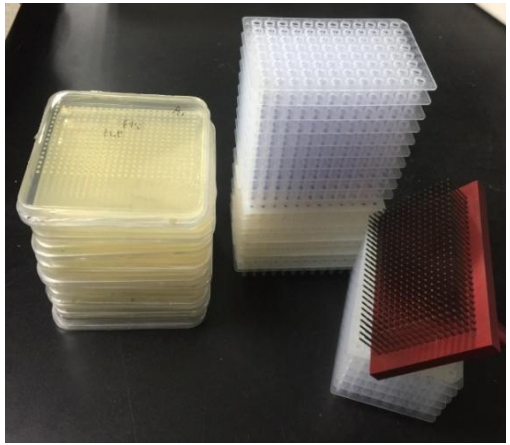
3. Map-based cloning of the Fusarium resistance gene *Fhb7*

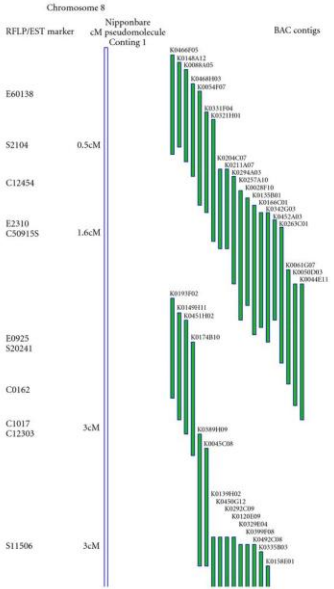


（**245 kb**）

Fig.17 Map-based cloning of *Fhb7* at the distal region of Chr. 7E

3. Map-based cloning of the Fusarium resistance gene *Fhb7*

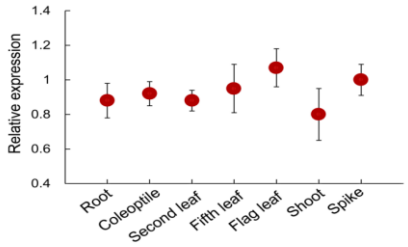




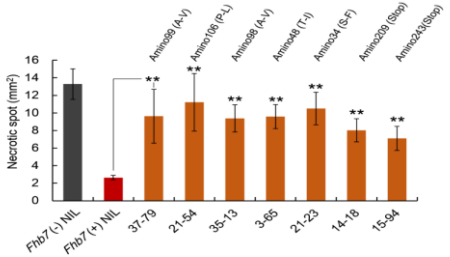
Chr. Walking

Fig.18 BAC (bacterial artificial chromosome) clones containing target gene were identified from the resistant donor

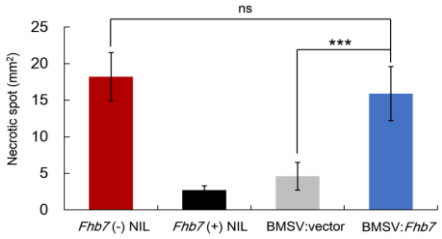
3. Map-based cloning of the Fusarium resistance gene *Fhb7*



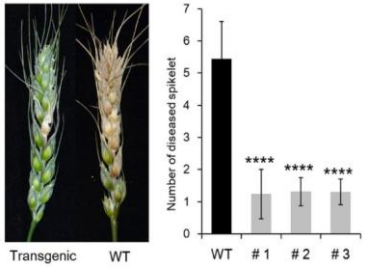
Tissue specific expression of *Fhb7*



Functional validation of *Fhb7* by EMS mutants



FHB was evaluated by VIGS



FHB was evaluated for wild-type and transgenic wheat

Fig.19 Map-based cloning of *Fhb7* at the distal region of Chr. 7E

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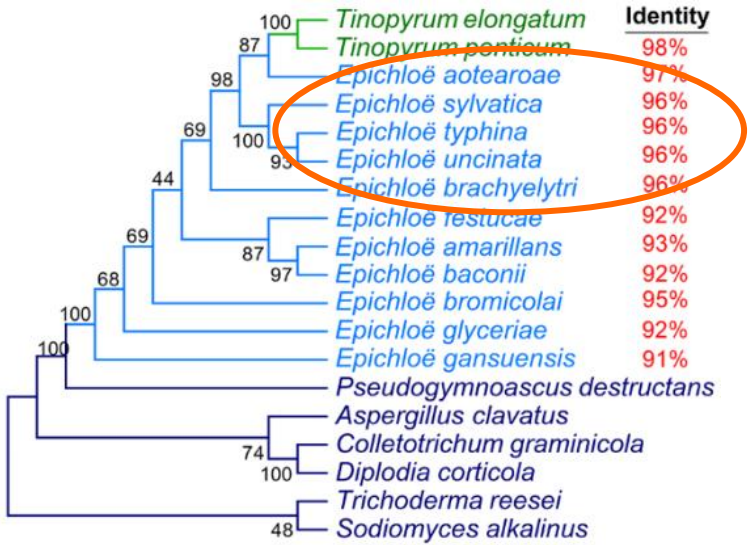


Fig.20 ML phylogenentic tree of the closest homologs of *Fhb7* from plants and fungi

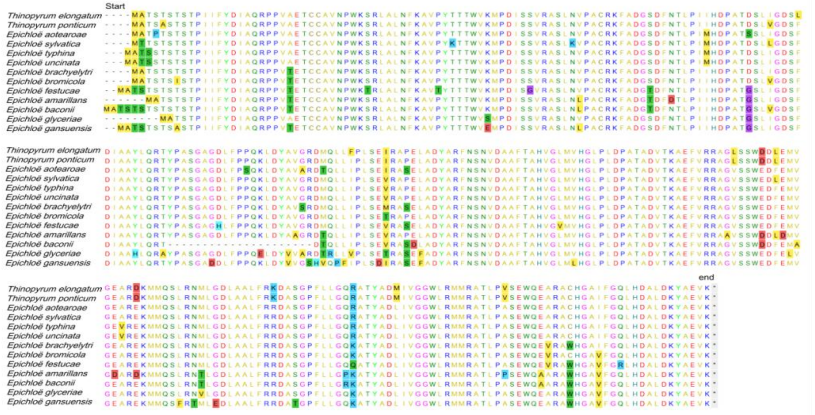
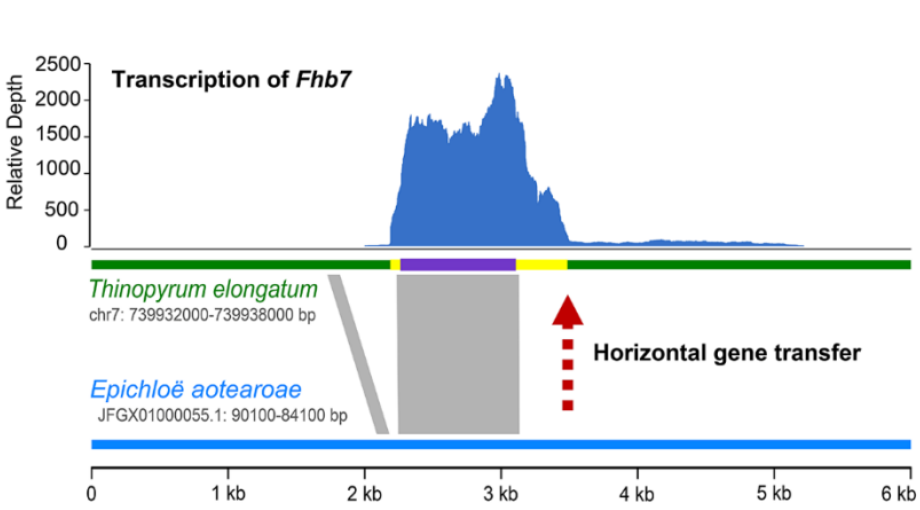


Fig.21 Alignments of *Fhb7* homologs in *Thinopyrum* and *Epichloë* species

4. Evolutionary history and molecular function of *Fhb7*



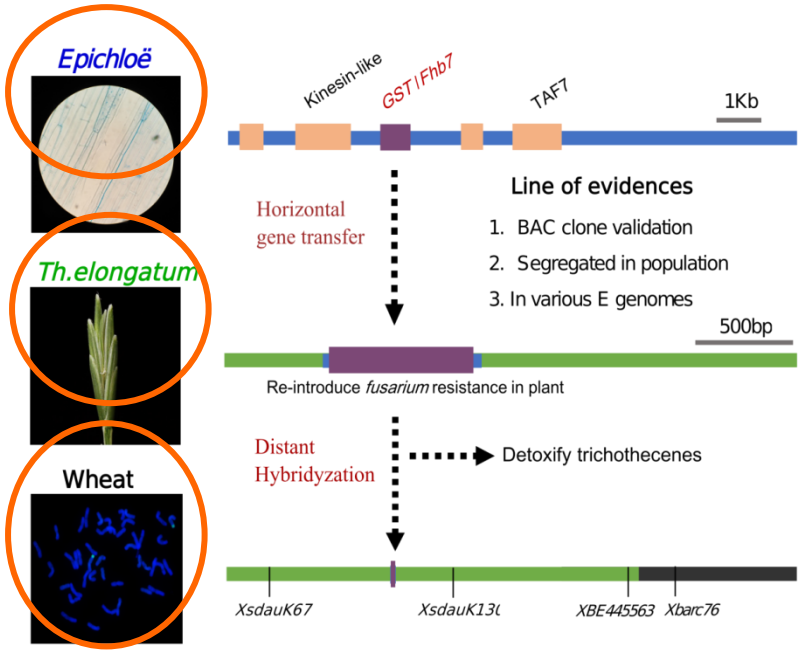
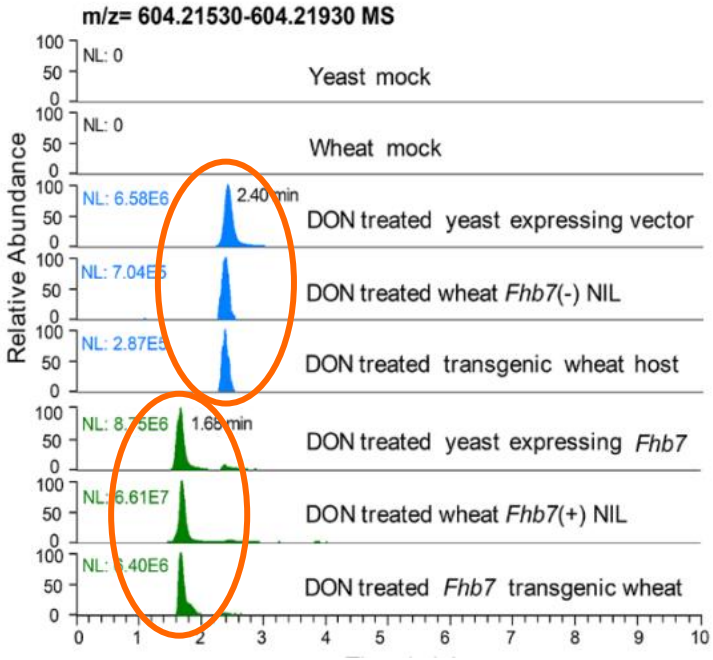
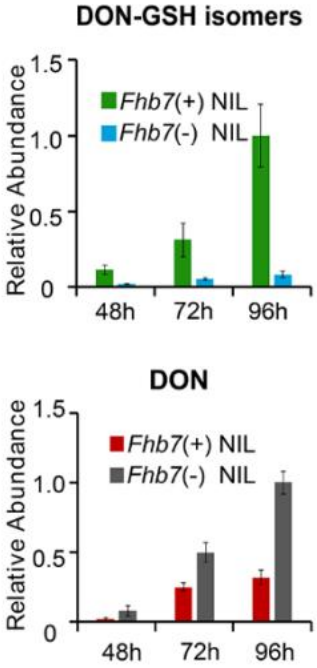


Fig.22 Horizontal gene transfer of *Fhb7* from fungus to *Thinopyrum*

4. Evolutionary history and molecular function of *Fhb7*





① *Fhb7*-expressing yeast

② *Fhb7* transgenic wheat

③ NILs of *Fhb7*

Fig.26 Extracted ion chromatograms (EICs) at m/z 604.2173 revealing the presence of two DON-glutathione adducts

4. Evolutionary history and molecular function of *Fhb7*

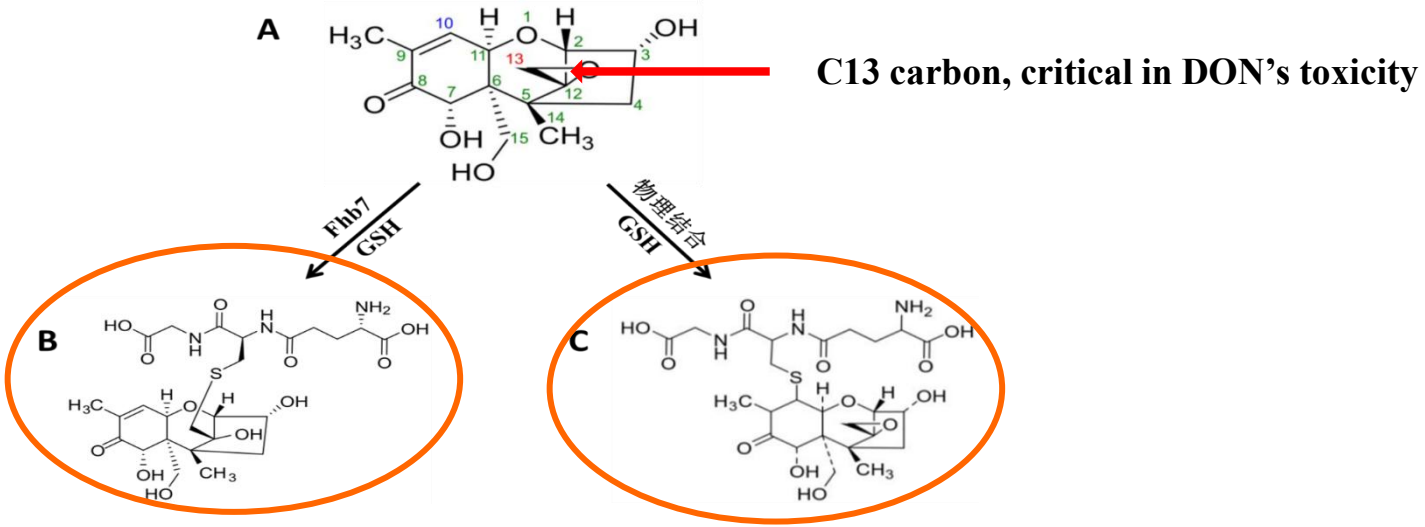
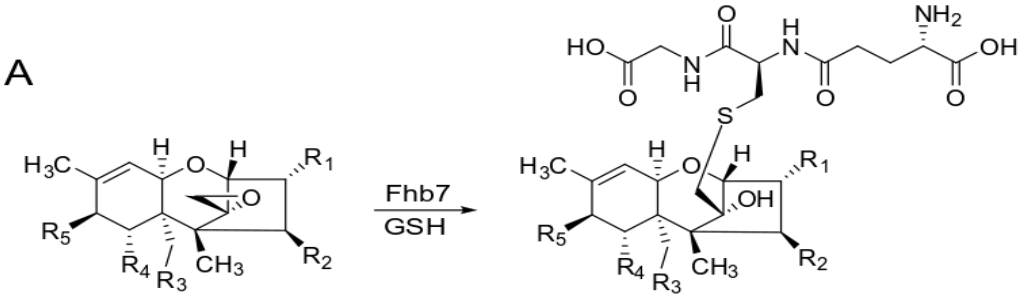


Fig.27 Molecular structure of the de-epoxidated DON-glutathione adduct catalyzed by the *Fhb7*

4. Evolutionary history and molecular function of *Fhb7*

A



B

Trichothecene	Abbrev.	R1	R2	R3	R4	R5
Deoxynivalenol	DON	OH	H	OH	OH	=O
3-Acetyl-deoxynivalenol	3-ADON	$OCOCH_3$	H	OH	OH	=O
15-Acetyl-deoxynivalenol	15-ADON	OH	H	$OCOCH_3$	OH	=O
Nivalenol	NIV	OH	OH	OH	OH	=O
Fusarenon X	Fus-X	OH	$OCOCH_3$	OH	OH	=O
T-2 Toxin	T-2	OH	OCOCH3	$OCOCH_3$	H	$OCOCH_2CH(CH_3)_2$
HT-2 Toxin	HT-2	OH	OH	$OCOCH_3$	H	$OCOCH_2CH(CH_3)_2$
Diacetoxyscirpenol	DAS	OH	$OCOCH_3$	$OCOCH_3$	H	H

Fig.28 Illustration of the GSH adducts of trichothecenes catalyzed by *Fhb7*

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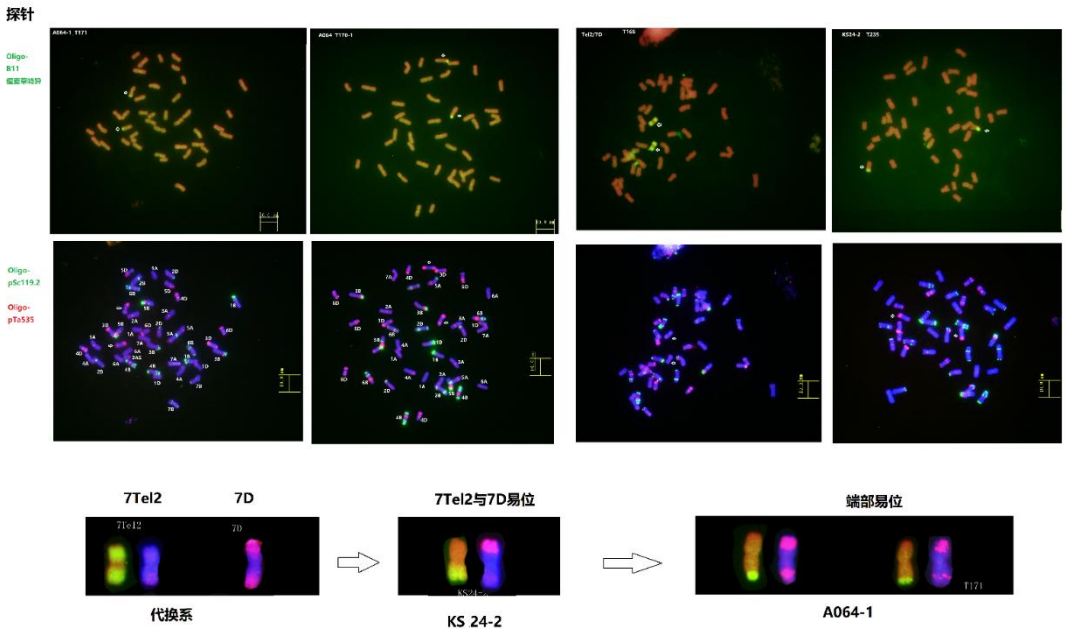


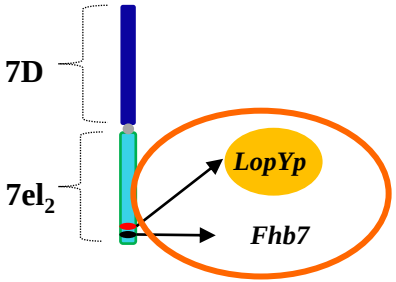


Fig. 33 The linkage with distance of about 18 Mb between *Fhb7* and yellow pigment (*Yp*)

（Unpublished data）

4. Application of *Fhb7* in Fusarium resistance breeding

LiangXing99 SN2-16 carrying Fhb7

Fig.35 The recombinants lines carrying *Fhb7* exhibited resistance to FHB using single floret inoculation

（Unpublished data）

4. Application of *Fhb7* in Fusarium resistance breeding

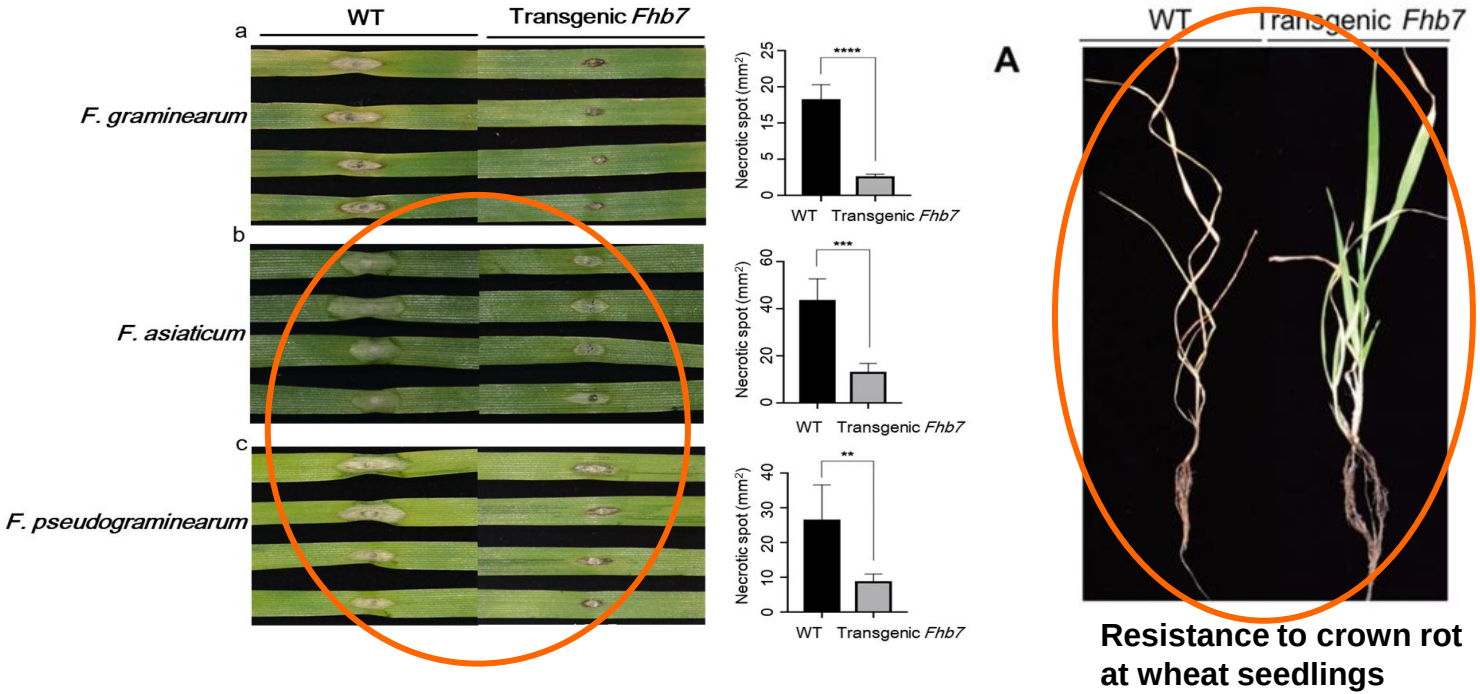


Fig.31 Images of *Fusarium* infected spikes (left panel) and crown rot (right panel) of 'LX99' NILs contrasting in *Fhb7*

4. Application of *Fhb7* in Fusarium resistance breeding

Fig.32 The cultivar carrying *Fhb7* exhibits crown rot resistance in the field in Taian, Shandong this year

Summary of studies on *Fhb7* derived from wheatgrass

(i) A high-quality assembly of *Thinopyrum elongatum*;

(ii) *Fhb7* cloning supported by cytogenetic stocks, mutational genomics, and functional validation using virus-induced gene silencing (VIGS) and transgenics;

(iii) Demonstration of biochemical function of *Fhb7* and a novel mechanism of fungal disease resistance;

(iv) Field trials to demonstrate that there is no hit on wheat yield in stocks carrying *Fhb7*;

(v) *Fhb7* arose in plants through horizontal gene transfer (HGT) from a fungal endophyte.

Deep thanks to my supervisor Prof. Herbert Ohm and colleagues at Purdue University

W. Lafayette, 2004

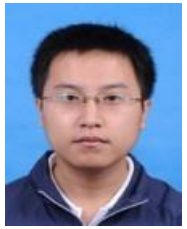
Taian, Shandong, 2009

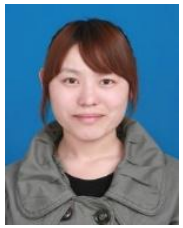
Wheat Genetic Improvement and Genomics Lab


Prof. Af Li


Prof. HW Wang


Dr. X Ma


Dr. SL Sun


Dr. XQ Wang


Dr. Y Zhao

Website for my lab：http://konglab.sdau.edu.cn





Thank you!

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