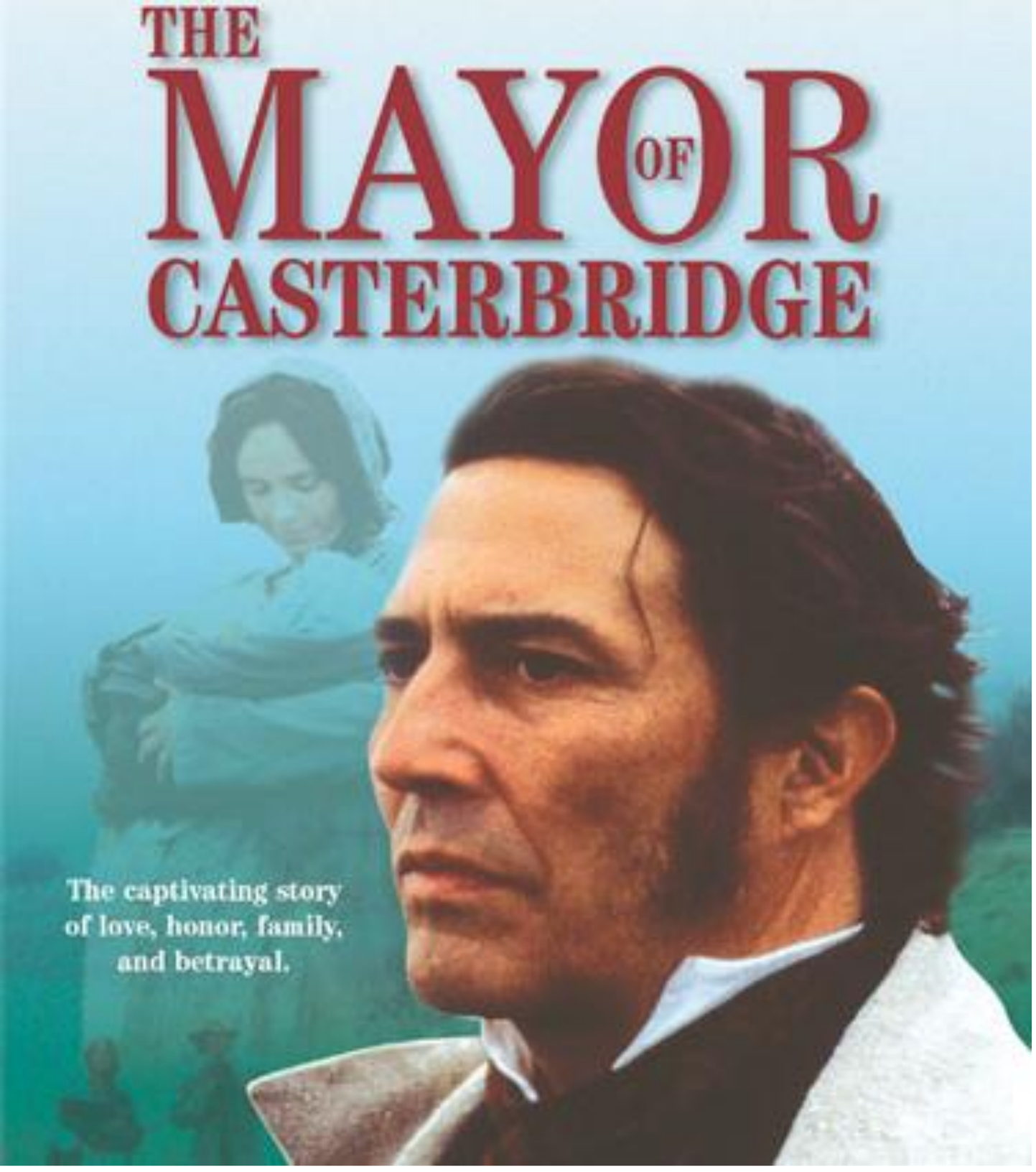
Waking up too early: TaMKK3-A underlies the major 4AL sprouting resistance locus, *Phs-A1*.

Oluwaseyi Shorinola (PhD)

@Oluwheat John Innes Centre



Thomas Hardy (1886)

“Oh, 'tis the [wheat]-factor—he's the man that our millers …deal wi', and he has sold 'em **growed** wheat, … so that the loaves be as flat as toads, and like suet pudden inside.

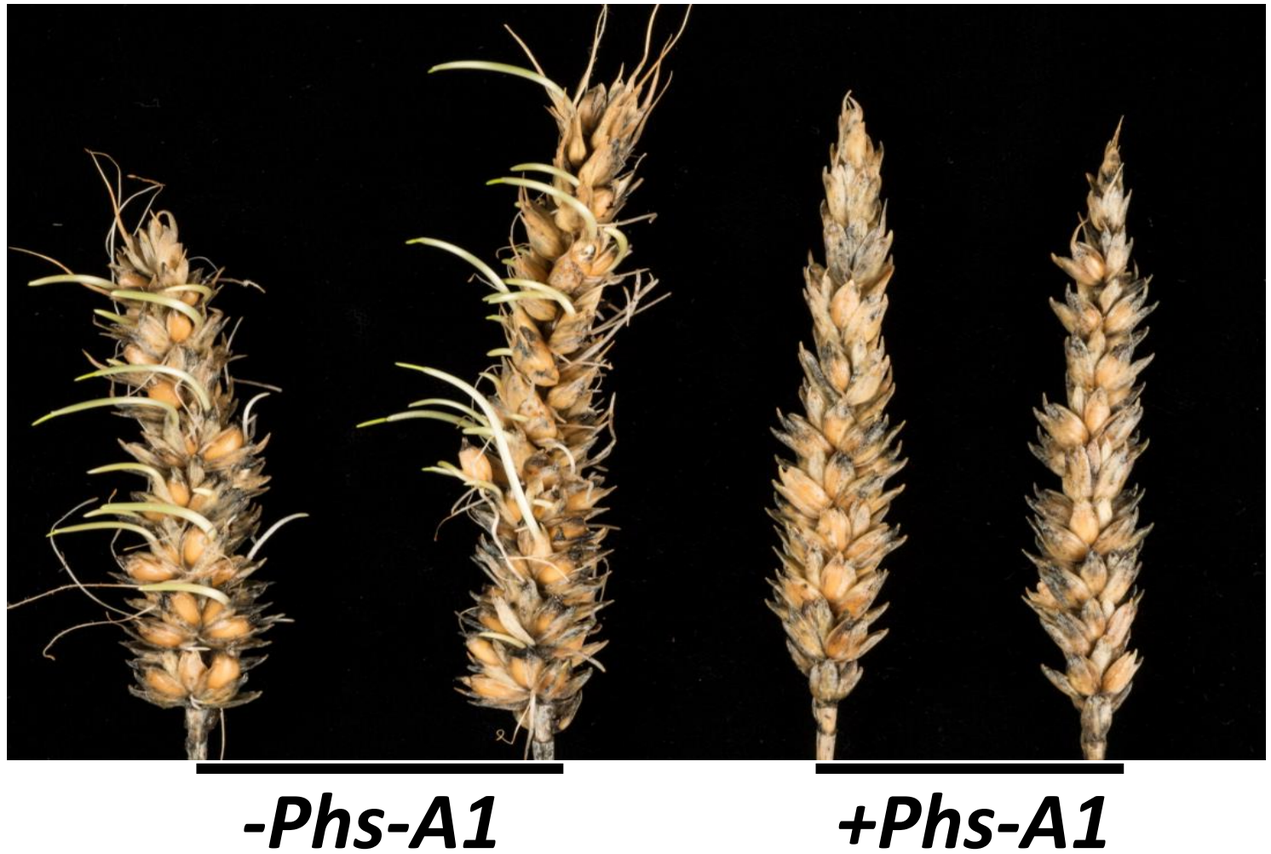
I've been a wife, and I've been a mother, and I never seen such **unprincipled bread** in Casterbridge as this before”

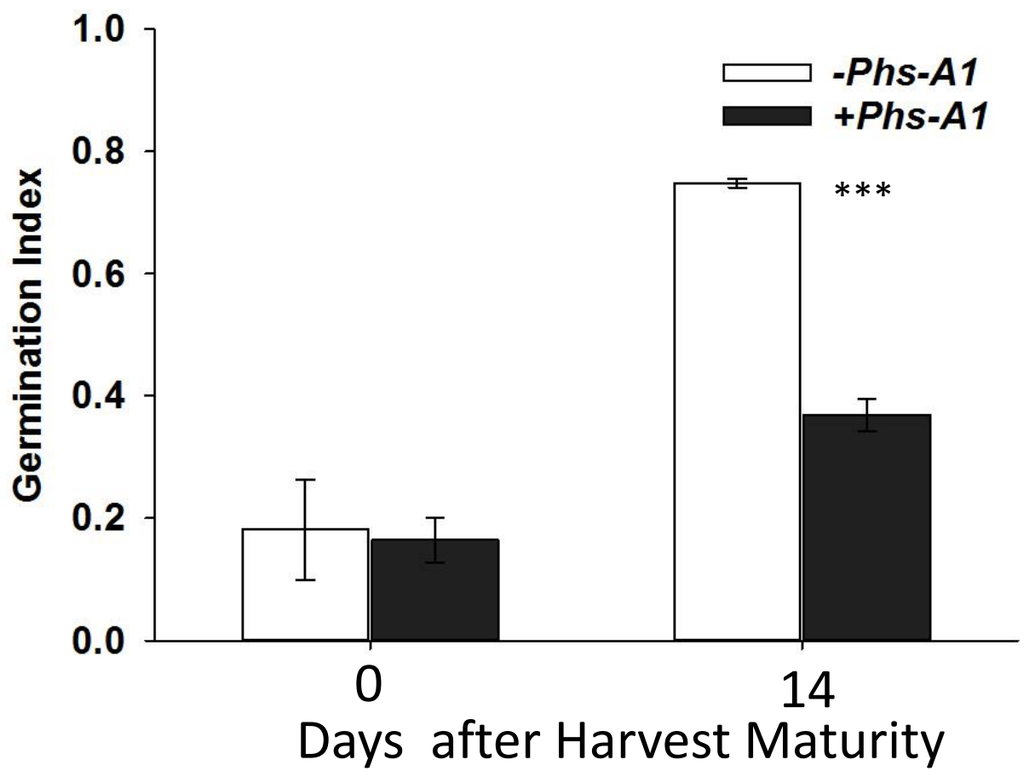
The problem – “growed wheat” and “unprincipled bread”

rvest
g (PHS)

The 4AL *Phs-A1 locus* confers resistance to sprouting

- *Phs-A1* is major locus identified in numerous diverse global germplasm.
- *Phs-A1* delays dormancy loss during seed after-ripening.

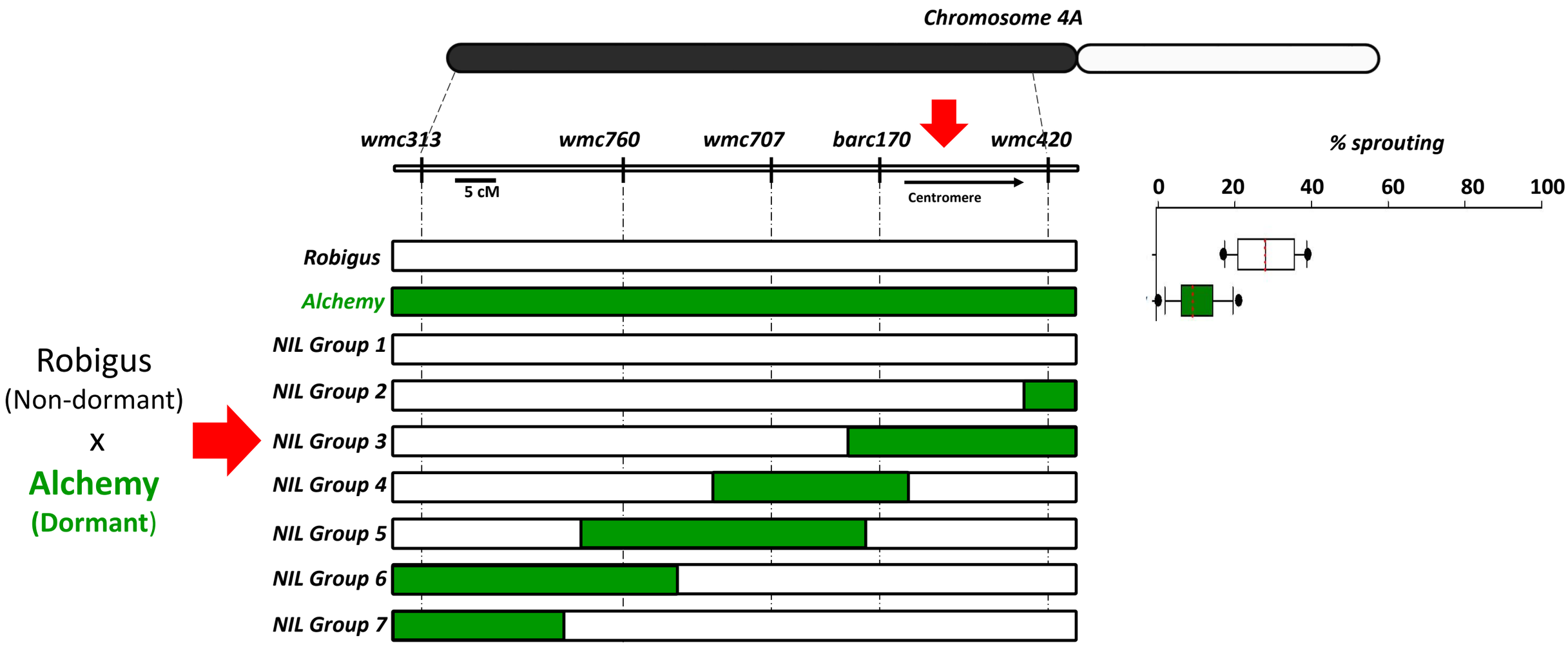




Shorinola *et al* (2016) *JxB 67: 4169-4178*

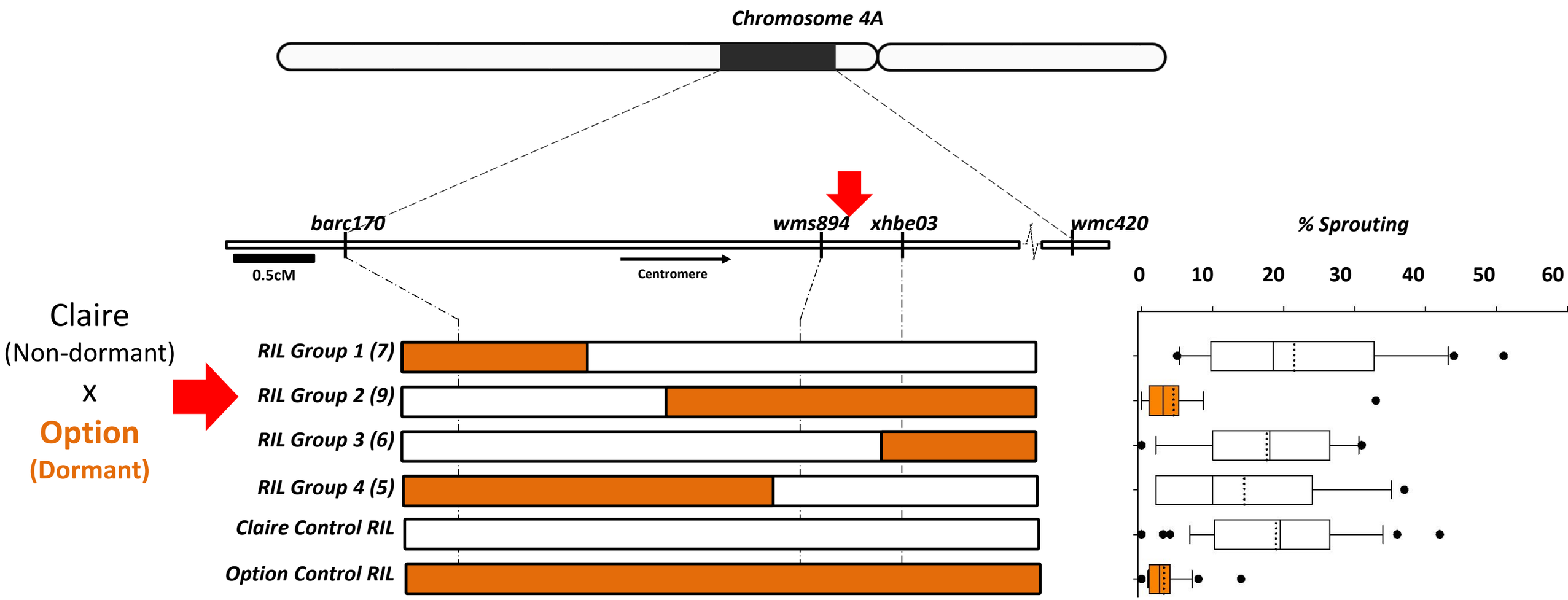
Fine-mapping of *Phs-A1 in bi-parental populations*

- Near isogenic lines (NILs) and recombinant lines (RILs) were developed for fine-mapping of *Phs-A1* from two bi-parental populations.



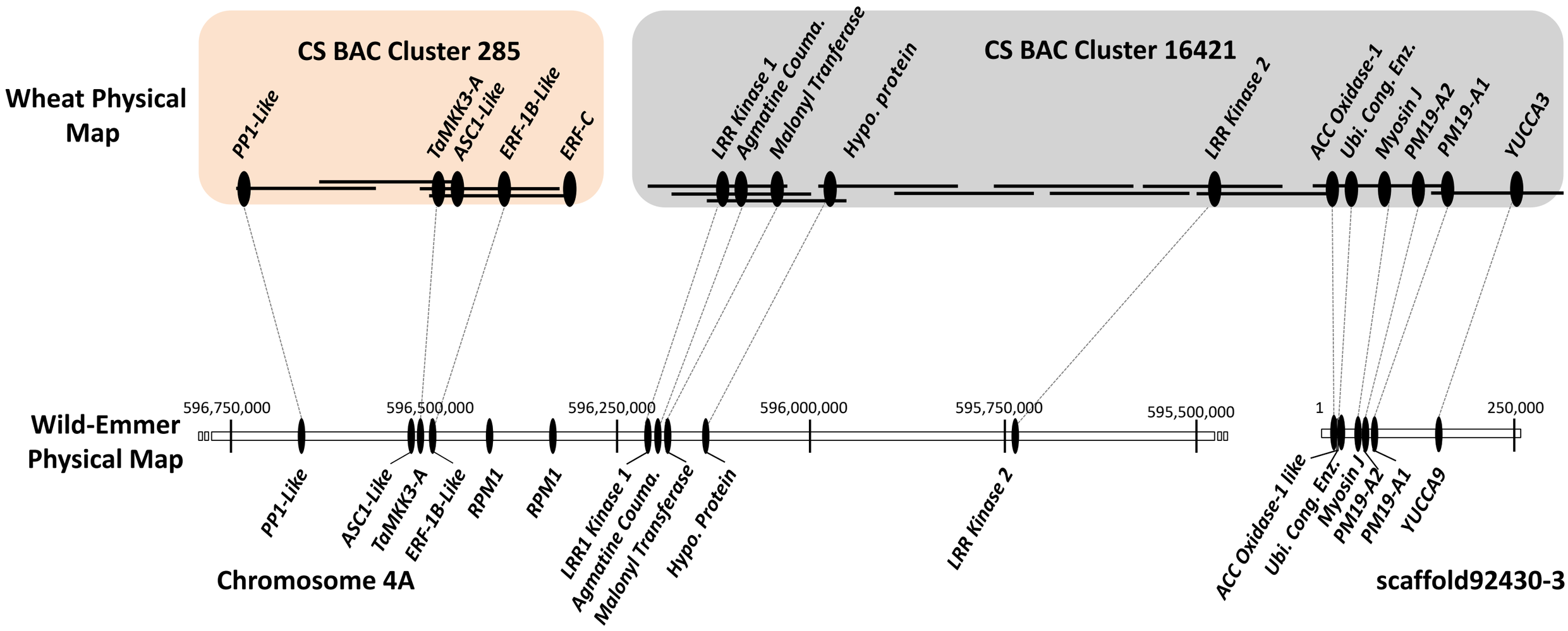
Shorinola *et al* (2016) *JxB 67: 4169-4178*

Phs-A1 is further delimited to a sub-cM interval



Shorinola *et al* (2016) *JxB 67: 4169-4178*

Physical mapping of *Phs-A1* interval



Dr Miroslav Valarik

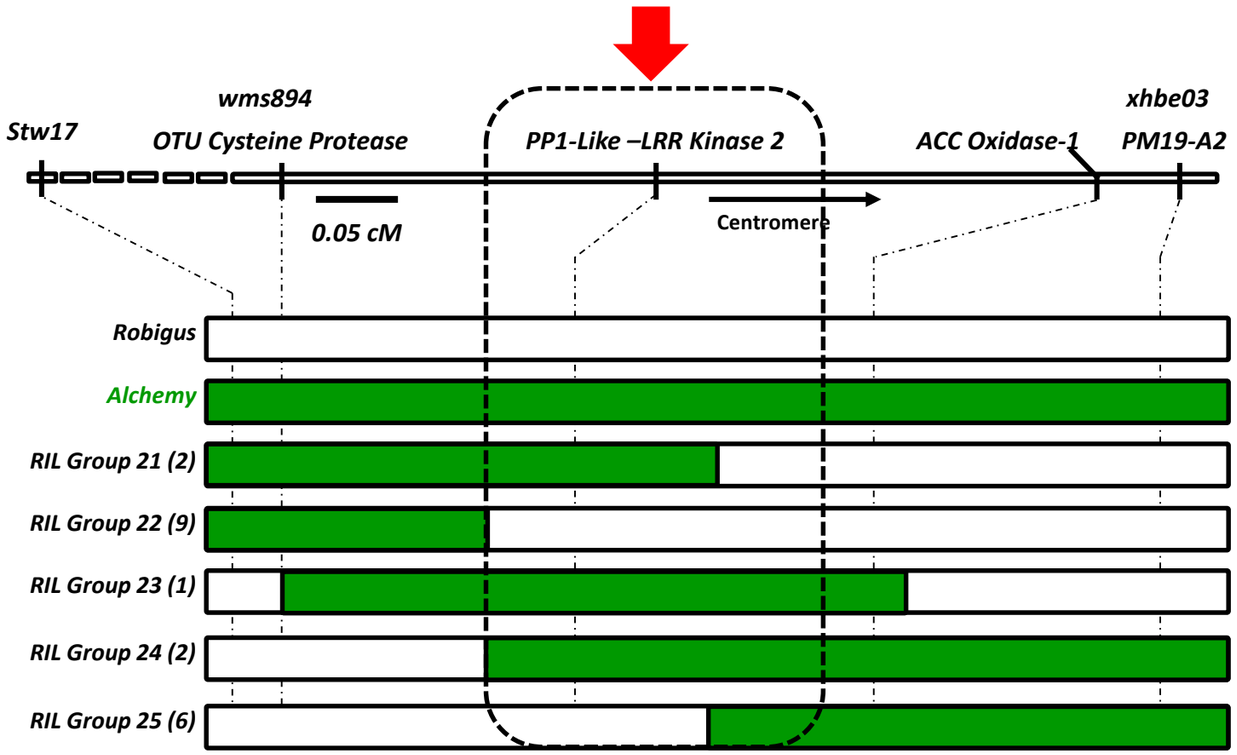
Dr Bara Klocova

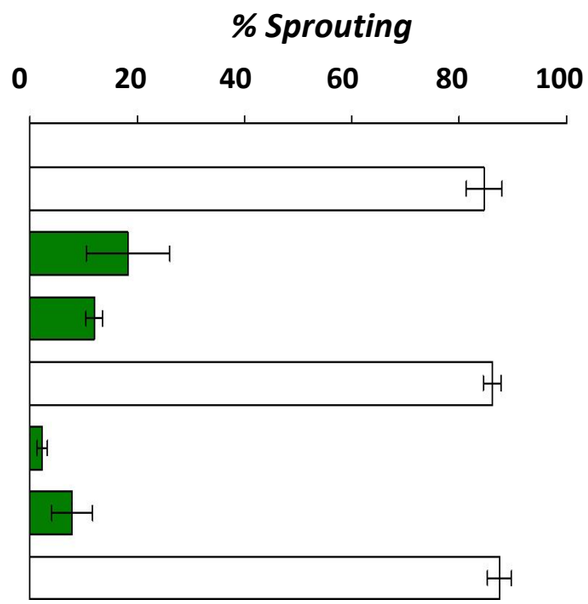
Dr Assaf Distefeld

Shorinola *et al.* (2017) *bioRxiv*

High resolution fine-mapping of the *Phs-A1* locus

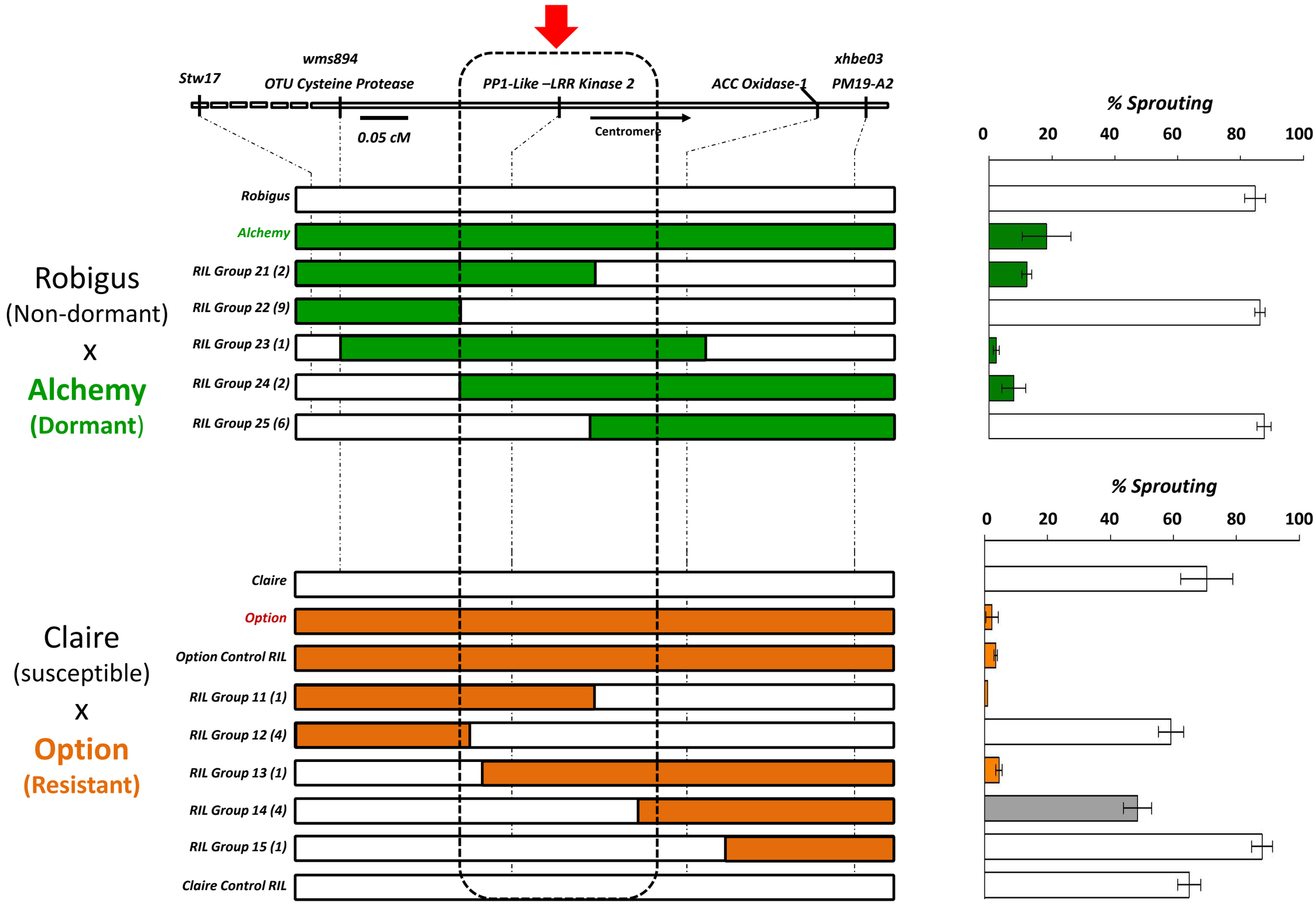
Robigus
(Non-dormant)
x
Alchemy
(Dormant)





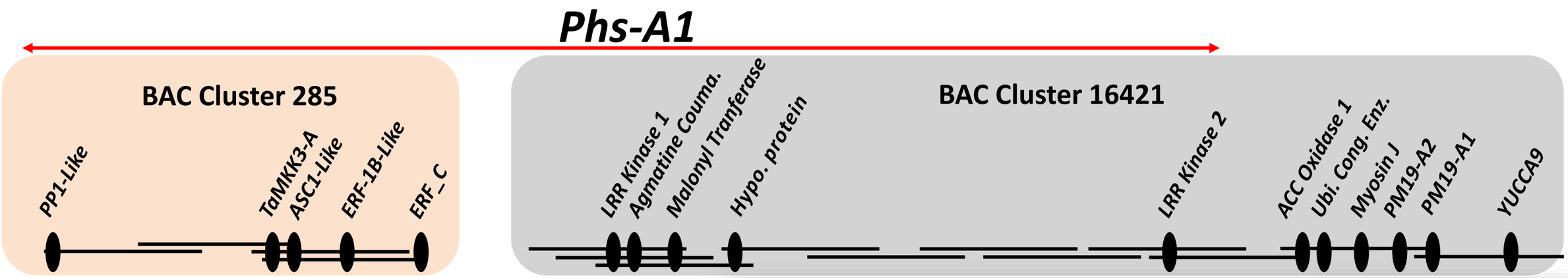
Shorinola *et al* (2016) *JxB 67: 4169-4178*

High resolution fine-mapping of the *Phs-A1* locus



Shorinola *et al* (2016) *JxB 67: 4169-4178*

Causal gene for the *Phs-A1* locus



Barrero *et al. Genome Biology* (2015) 16:93
DOI 10.1186/s13059-015-0665-6

Genome Biology

RESEARCH Open Access

Transcriptomic analysis of wheat near-isogenic lines identifies *PM19-A1* and *A2* as candidates for a major dormancy QTL

Jose M. Barrero[1*†], Colin Cavanagh[1,7†], Klara L. Verbyla[2], Josquin F.G. Tibbits[5], Arunas P. Verbyla[3], B. Emma Huang[4], Garry M. Rosewarne[1,8], Stuart Stephen[1], Penghao Wang[1], Alex Whan[1], Philippe Rigault[6], Matthew J. Hayden[5] and Frank Gubler[1]

Current Biology

Cell PRESS

Volume 26, Issue 6, 21 March 2016, Pages 782–787

Report

A Causal Gene for Seed Dormancy on Wheat Chromosome 4A Encodes a MAP Kinase Kinase

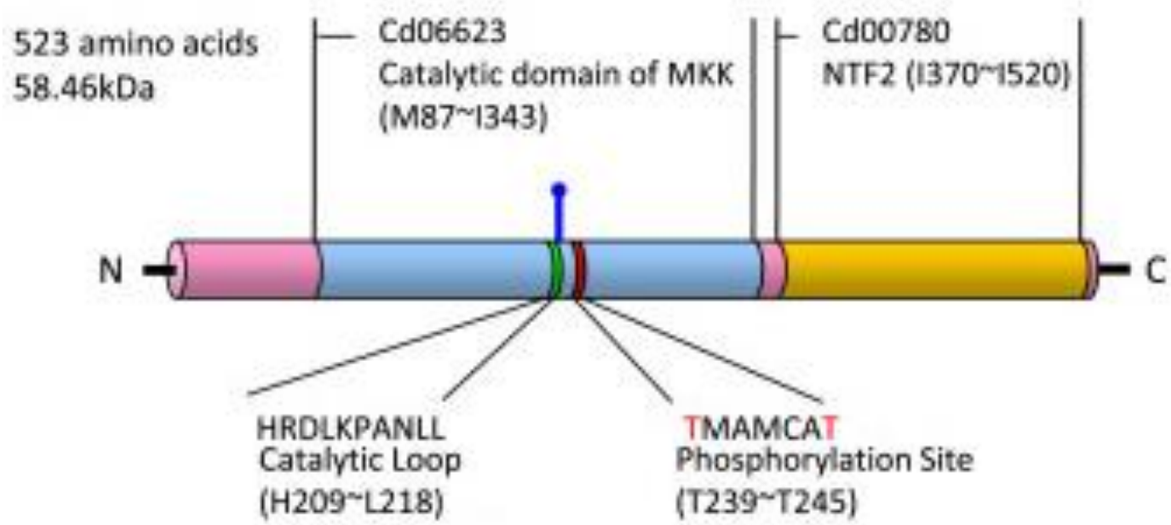
Atsushi Torada[1, 4], Michiya Koike[1, 4], Taiichi Ogawa[2], Yu Takenouchi[1], Kazuki Tadamura[1], Jianzhong Wu[2], Takashi Matsumoto[2], Kanako Kawaura[3], Yasunari Ogihara[3]

Dr Jose Barrero

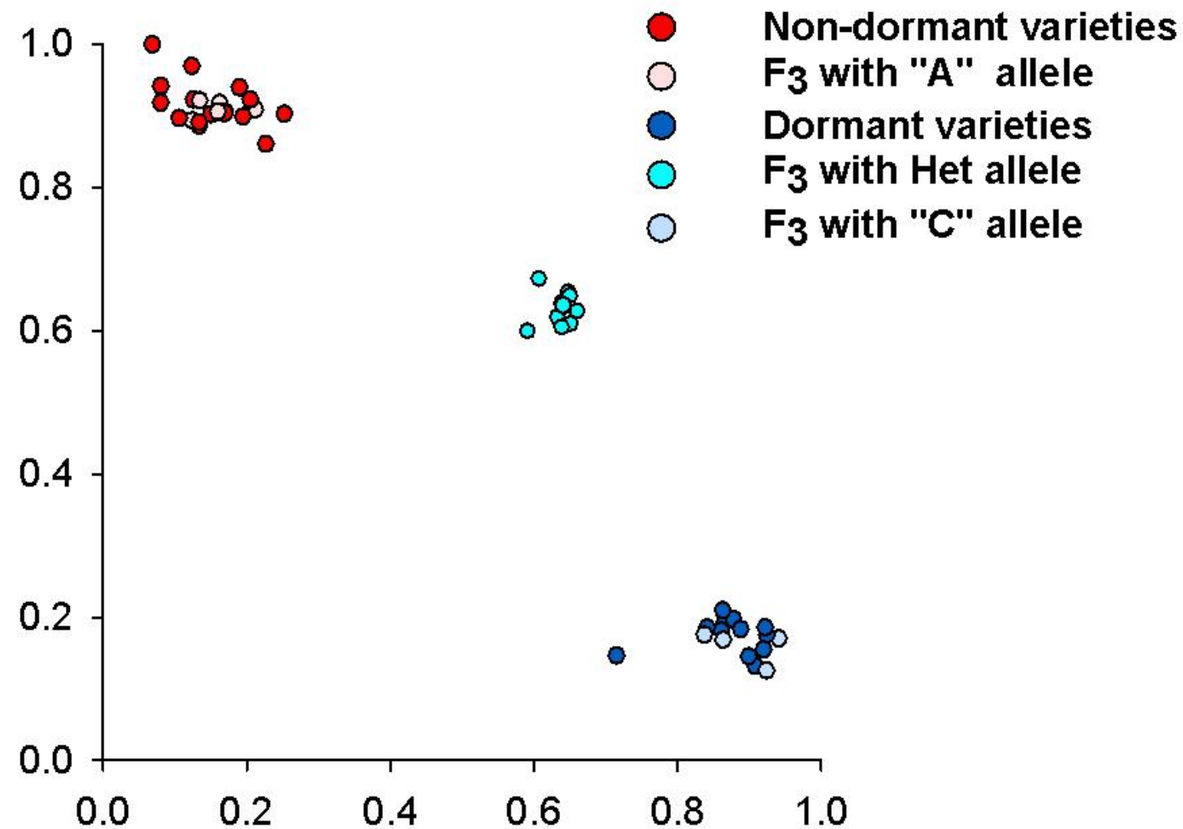
Shorinola *et al.* (2017) *bioRxiv*

A mutation in *TaMKK3-A* is associated with *Phs-A1* effect

Amino acid substitution in the catalytic domain caused by a C>A mutation results is associated with *Phs-A1* effect.



Torada *et al* (2016) *Curr Biol* 26 (6):782-787



Shorinola *et al.* (2017) *bioRxiv*

TaMKK3-A mutation is associated with *Phs-A1* effect

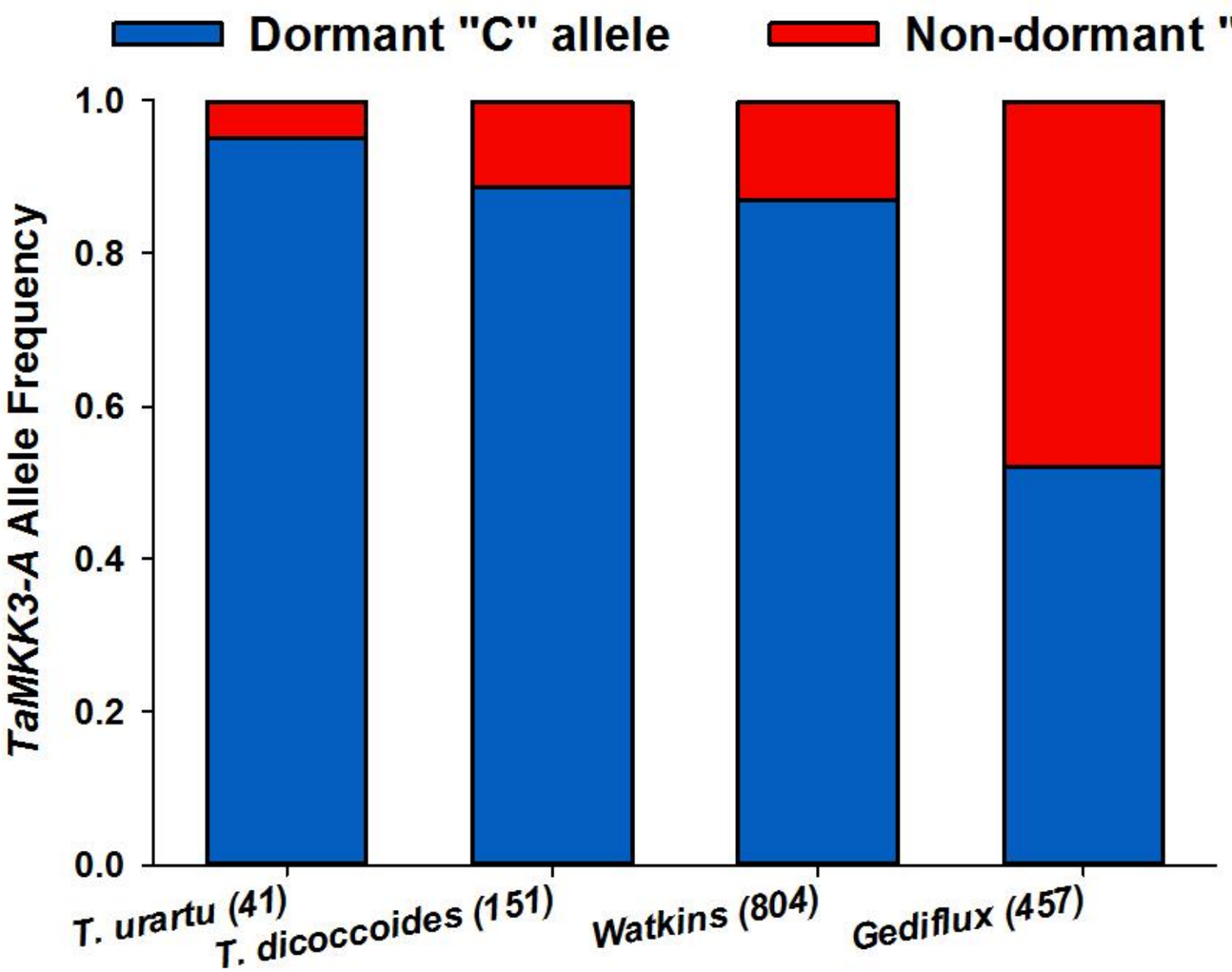
In collaboration with

Dr Jose Barrero and Dr Atsushi Torada

		TaMKK3-A C>A mutation	*PM19-A1 promoter InDel*	
UK	**Robigus**	**A**	***Deletion***	**Non-dormant**
UK	**Alchemy**	**C**	***Insertion***	**Dormant**
UK	**Claire**	**A**	***Deletion***	
UK	**Option**	**C**	***Insertion***	
Australia				
Japan				

Shorinola *et al.* (2017) *bioRxiv.*

TaMKK3-A allele distribution in global germplasm



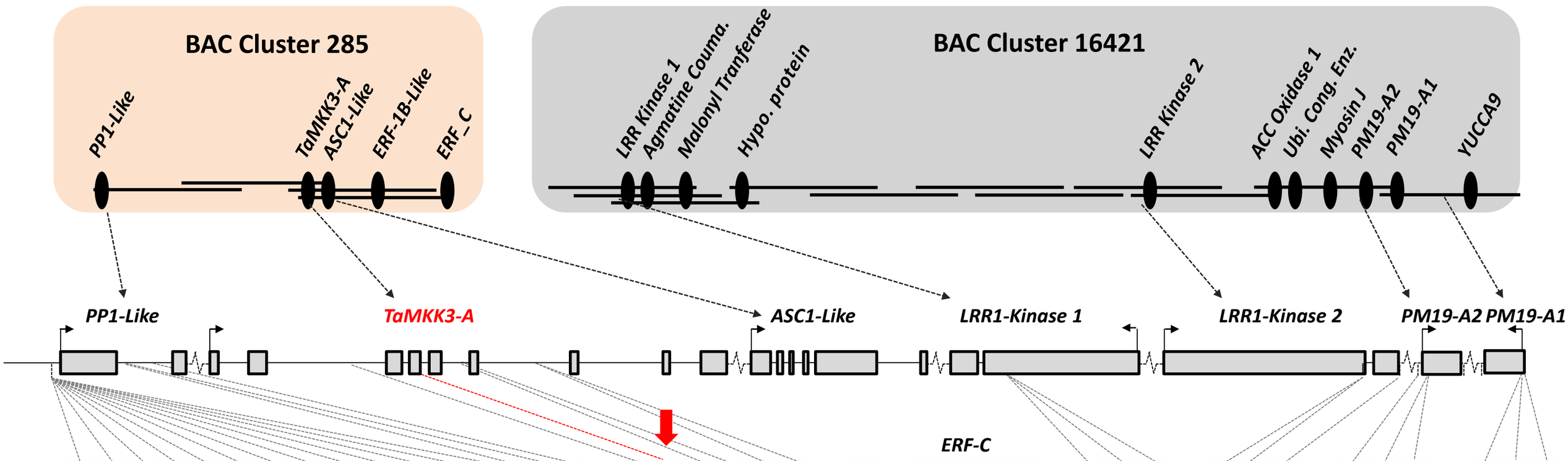
Germplasm	Description
Triticum urartu	Diploid progenitor of bread wheat
T. diccocoides	Tetraploid progenitor of bread wheat
Watkins	Global landraces before 1930
Gediflux	European germplasm 1945-2000

Shorinola *et al.* (2017) *bioRxiv*

Fourteen haplotypes around the *Phs-A1* locus in global germplasm

- Using newly available wheat haplotype resource: "A haplotype map of allohexaploid wheat .."

Jordan et al. (2015). *Genome Biol* 16:48.



H_1	C	C	T	C	G	G	C	C	G	C	A	T	T	T	T	G	G	A	G	A	C	G	G	C	C	T	A	C	C	G	A	T	G	C	G	A	A	T	T
H_2	C	C	T	C	G	G	C	C	G	C	A	T	T	T	T	G	G	A	G	A	C	G	G	C	C	T	A	C	C	G	A	T	G	G	G	A	A	T	T
H_3	C	C	T	C	G	G	C	C	G	C	A	T	T	T	T	G	G	A	G	A	C	G	G	T	C	T	A	C	C	G	A	T	G	G	G	A	A	T	T
H_4	C	C	T	C	G	G	C	C	G	C	A	T	T	T	T	G	G	C	G	A	C	G	G	C	C	T	A	C	C	G	A	T	G	G	G	A	A	T	T
H_5	C	C	T	C	G	G	C	C	G	C	A	T	T	T	T	G	G	C	G	A	C	G	G	C	c	T	A	C	T	T	G	C	A	G	G	G	C	C	G
H_6	C	C	T	C	G	G	C	C	G	C	A	T	t	T	T	G	G	C	G	A	C	G	G	C	c	T	A	C	C	G	G	C	A	G	G	A	A	T	T
H_7	C	C	T	C	G	G	C	C	G	C	A	T	T	T	T	G	G	C	G	A	C	G	G	C	C	T	A	C	C	G	G	C	A	G	G	G	C	C	G
H_8	C	C	T	C	G	G	C	C	G	C	A	T	T	T	T	G	G	A	G	A	C	G	G	T	C	T	A	A	T	T	G	C	A	G	G	G	C	C	G
H_9	C	C	T	C	G	G	C	C	G	C	A	T	T	T	T	G	G	C	G	A	C	G	G	C	C	T	A	C	C	G	A	T	G	G	G	A	C	C	G
H_10	C	T	C	C	G	T	C	T	G	C	C	C	C	T	C	G	A	C	A	G	C	A	A	C	C	A	G	C	C	G	G	C	A	G	G	G	C	C	G
H_11	C	T	C	C	G	T	C	T	G	C	C	C	C	T	C	G	A	c	A	G	C	A	A	C	C	A	G	C	C	G	G	C	A	G	G	A	A	T	T
H_12	C	T	C	C	G	T	C	T	G	C	C	C	C	T	C	G	A	C	A	G	C	A	A	C	C	A	G	C	C	G	G	C	A	G	T	G	C	C	G
H_13	C	T	C	C	G	T	C	T	G	C	C	C	C	T	c	G	A	C	A	G	C	A	A	C	C	A	G	C	C	G	G	C	A	G	T	G	C	T	T
H_14	T	C	C	G	A	T	T	T	A	T	C	C	C	C	C	A	A	C	A	G	G	A	G	C	T	A	G	A	T	T	G	C	A	G	G	G	C	C	G

Shorinola *et al.* (2017) *bioRxiv*

Fourteen haplotypes around the *Phs-A1* locus in global germplasm

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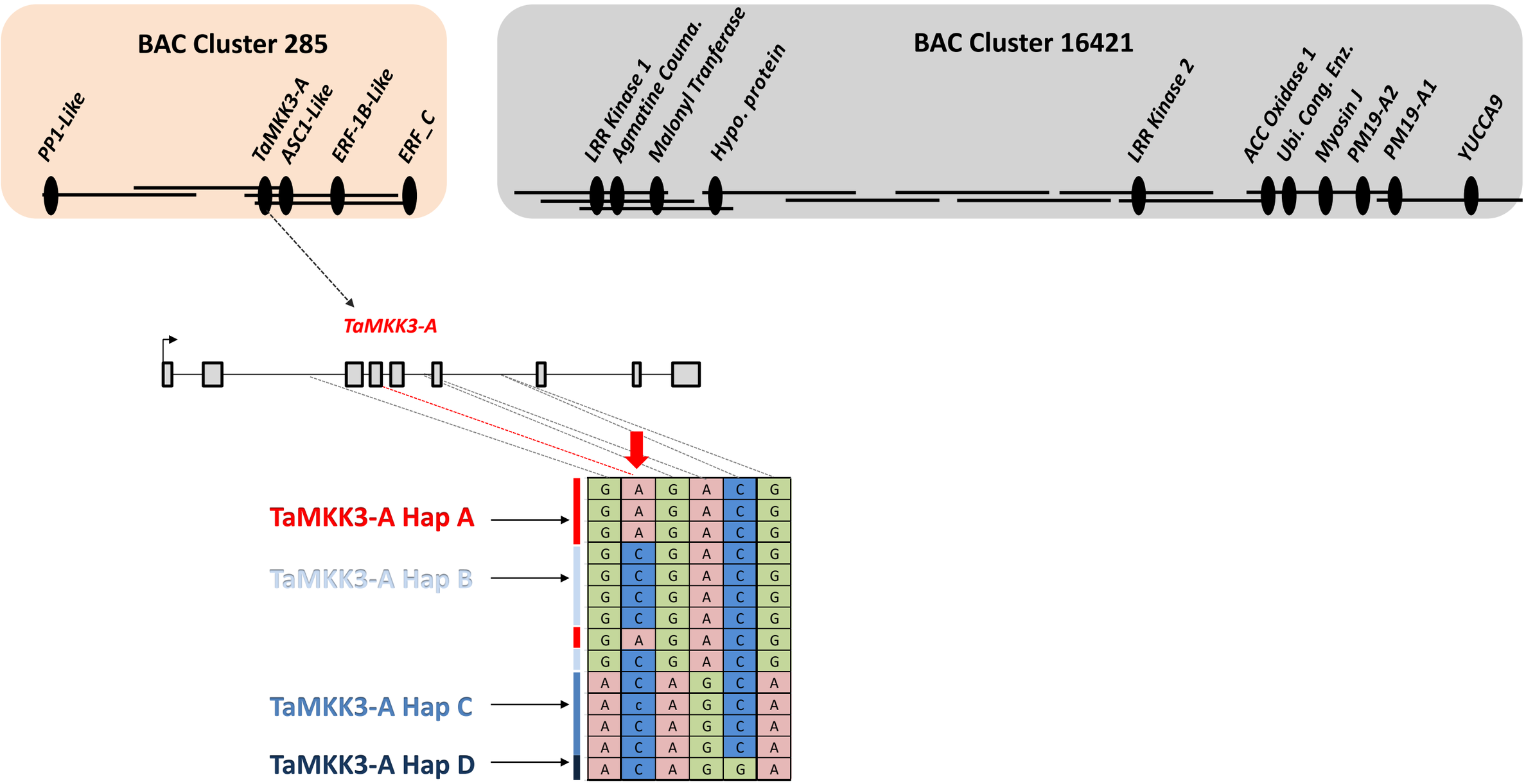
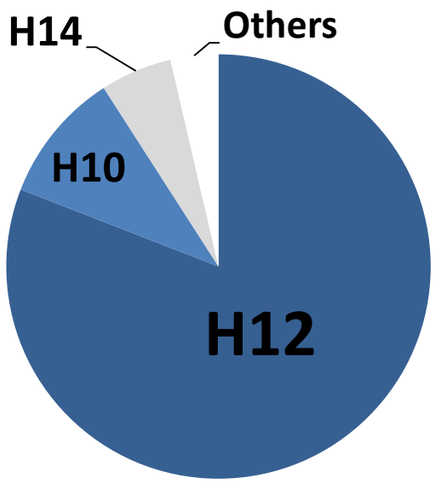
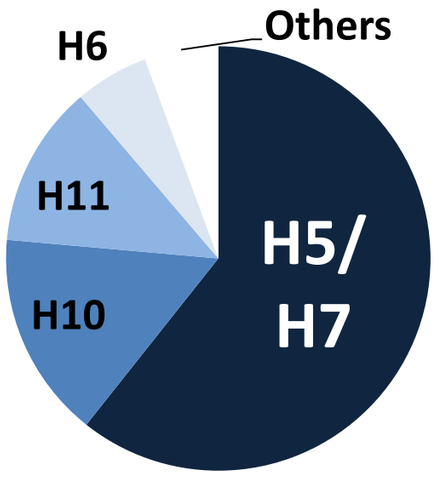


Shorinola *et al.* (2017) *bioRxiv*

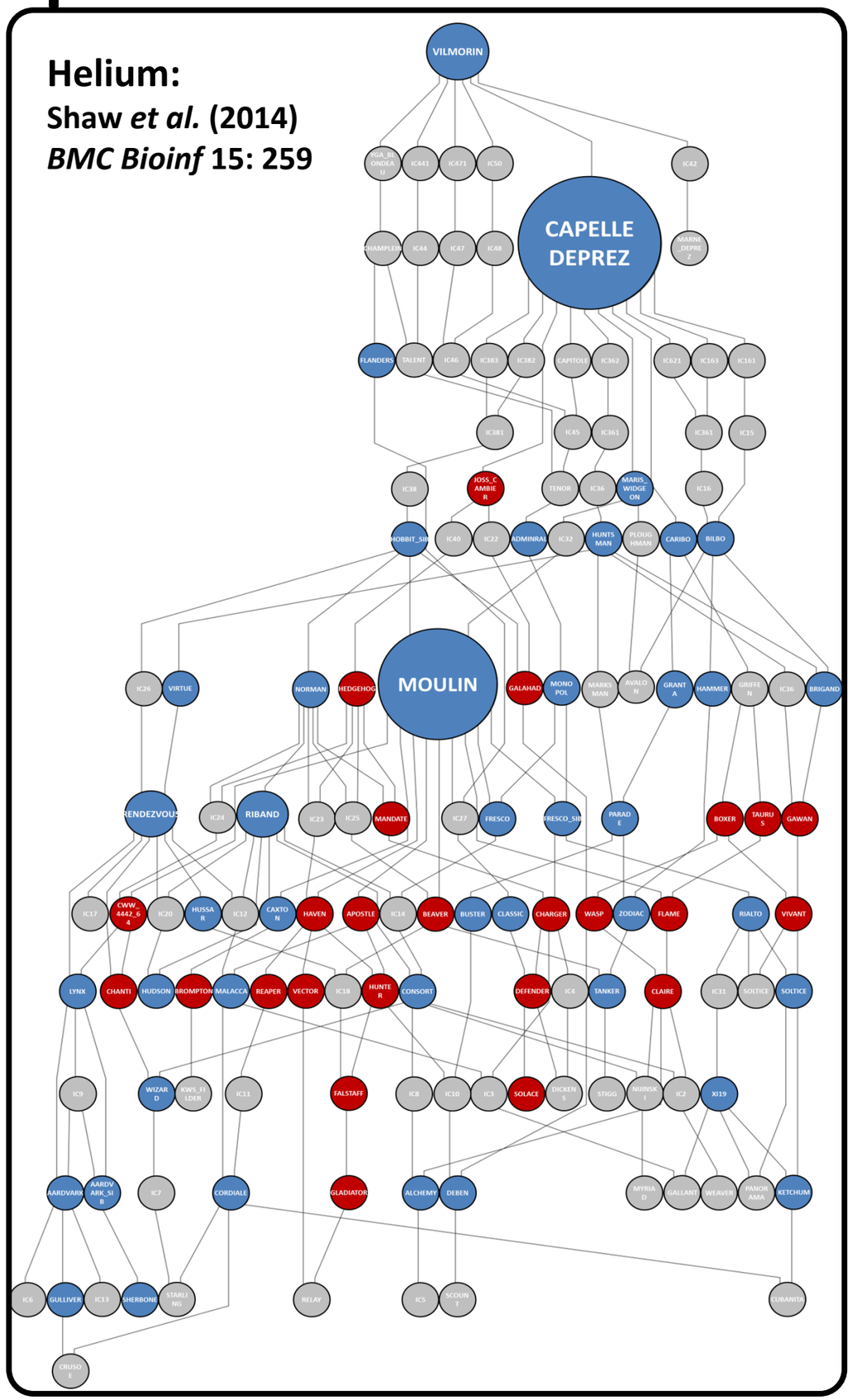
Implication for PHS breeding

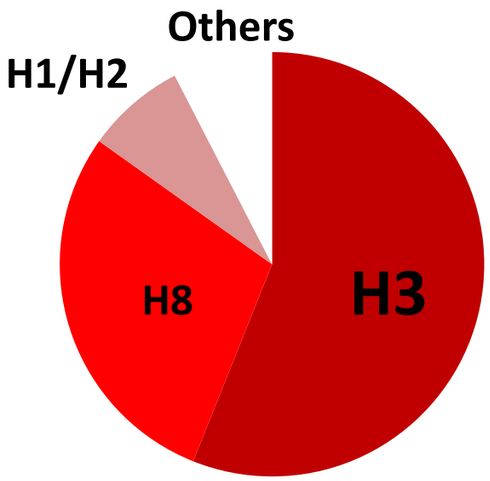


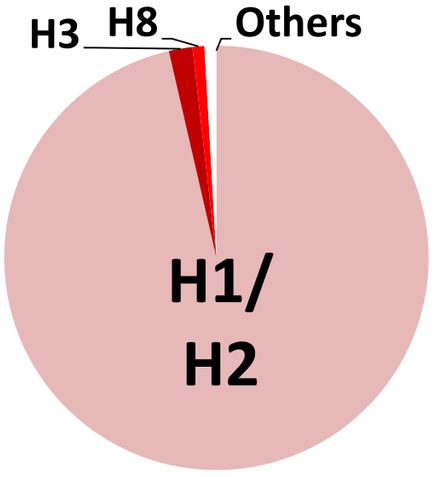


Shorinola *et al.* (2017) *bioRxiv*

Helium:
Shaw *et al.* (2014)
BMC Bioinf 15: 259

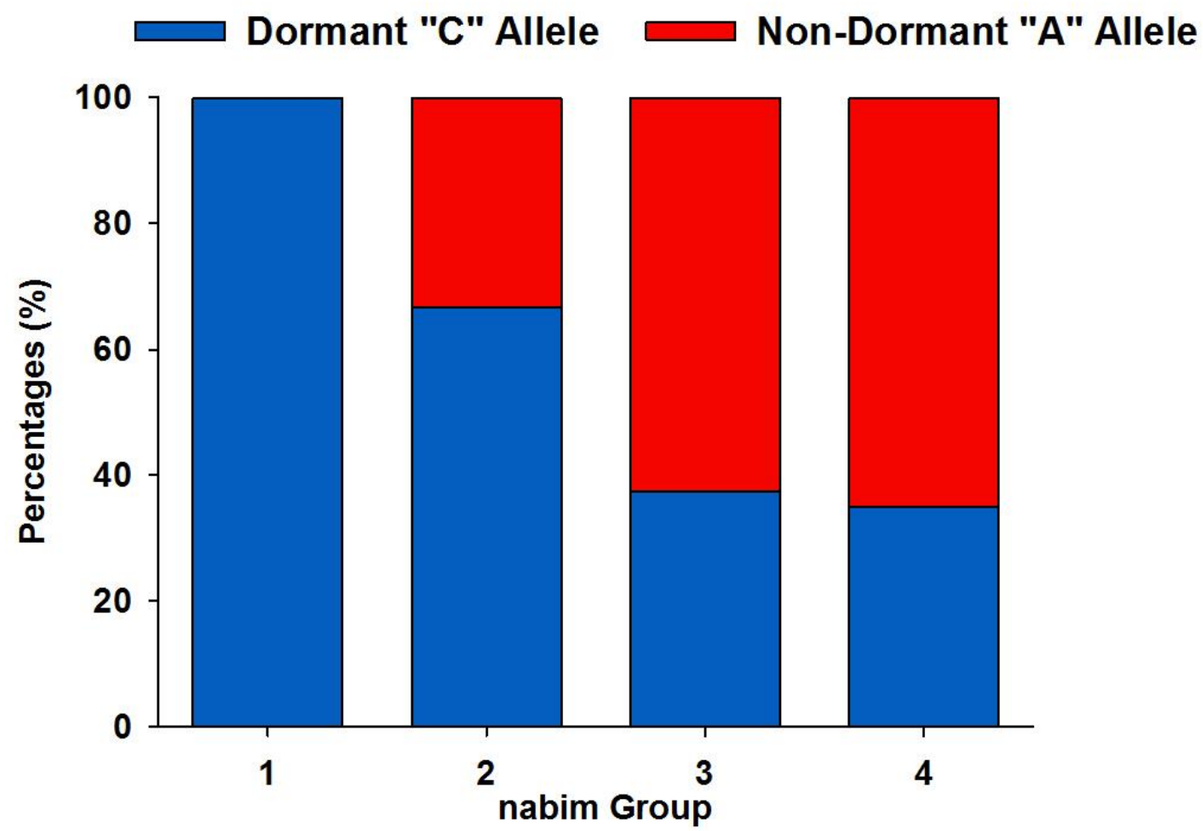






TaMKK3-A and "unprincipled bread"

NABIM Group	End-use
Group 1	Bread-making
Group 2	Bread-making potential
Group 3	Biscuits, cakes etc
Group 4	Animal feed



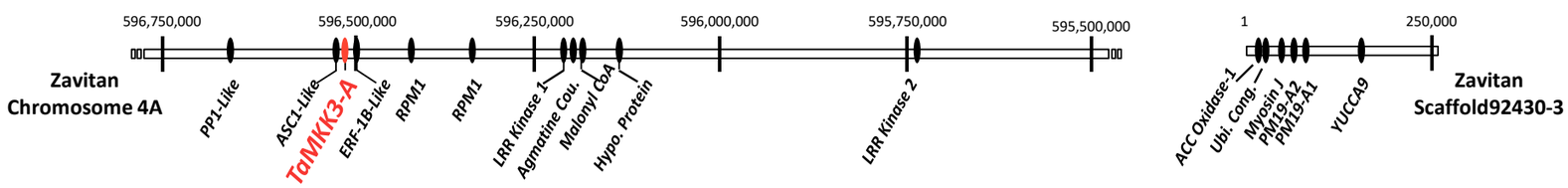
Shorinola *et al.* (2017) *bioRxiv*

Summary

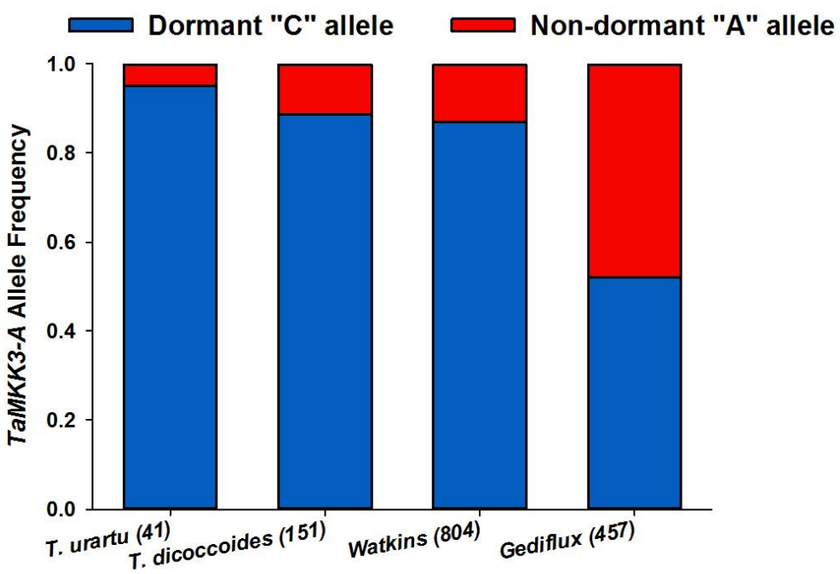
Phs-A1 confers major resistance to sprouting in diverse population.

- Phs-A1 *+ Phs-A1*

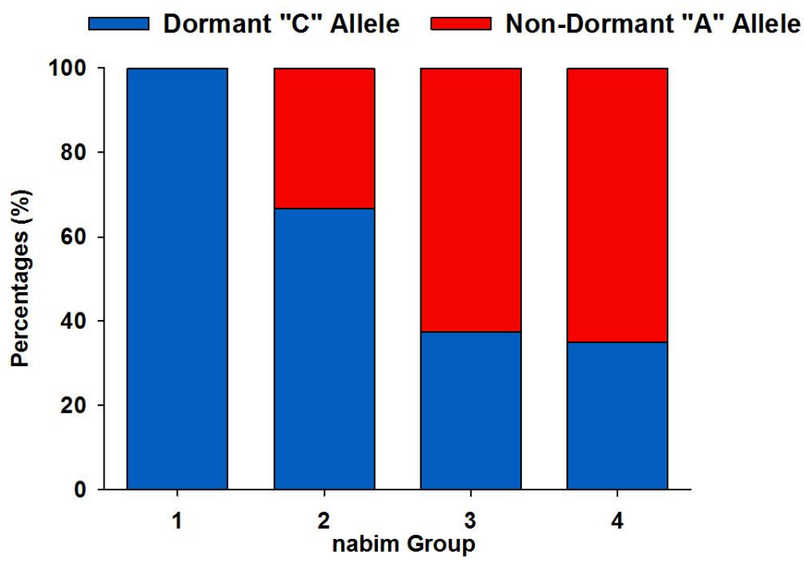
TaMKK3-A is the major causal gene underlying *Phs-A1* in UK germplasm.



TaMKK3-A mutation present in progenitors and increased in elite modern germplasm



TaMKK3-A marker is associated to grain end-use in the UK



Acknowledgements

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Peter Jack (RAGT, UK)

Simon Berry (Limagrain, UK)
Tina Henriksson (Lantmannen)
Peter Werner (KWS, UK)
Tanja Gergets
Duncan Scholefield (UoN, UK)
Michael Holdsworth (UoNt, UK)

Limagrain United Kingdom
RAGT SEEDS
Lantmännen
KWS
AHDB AGRICULTURE & HORTICULTURE DEVELOPMENT BOARD
defra Department for Environment Food and Rural Affairs
BBSRC bioscience for the future
UEA University of East Anglia
John Innes Foundation

www.wheat-expression.com

Wheat Expression Browser powered by expVIP

Traes_1AL_A1B2A8EB0.1 Search
Compare
Gene set IWGSC2.26

Home Studies Download Add your data Tutorials Videos Cite

One or two genes

Gene set IWGSC2.26 Gene: Search Compare
Examples: Traes_5BS_0AFC3F795.1, Traes_4DS_1CF5D9107.1

Multiple genes

If you want to compare more than two genes, you can add a list of genes separated by commas or one gene in each line.

Heatmap

Select studies to display:

- phosphate starvation in roots and shoots
- fusarium head blight infected spikelets
- grain tissue-specific developmental timecourse
- flag leaf downregulation of GPC
- grain tissue-specific developmental timecourse
- stripe rust infected seedlings
- Septoria tritici infected seedlings
- shoots and leaves of nulli tetra group 1 and group 5
- grain tissue-specific developmental timecourse
- comparison of stamen, pistil and pistilloidy expression
- stripe rust and powdery mildew timecourse of infection in seedlings
- developmental time-course of synthetic hexaploid
- grain tissue-specific expression at 12 days post anthesis
- drought and heat stress time-course in seedlings
- developmental time-course of Chinese Spring
- grain developmental timecourse with 4A dormancy QTL
- TGAC wheat genome tissues

17 studies, 424 RNA-seq samples:

- different tissues over development
- grain development,
- grain layers
- senescence
- abiotic stresses (phosphate starvation
- drought and heat stress)
- disease infection (yellow rust, powdery mildew, septoria, fusarium)

Borrill *et al.*, 2016, Plant Physiol.

www.wheat-expression.com

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Traes_2AL_173FE664B.2 Search
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Gene set IWGSC2.26

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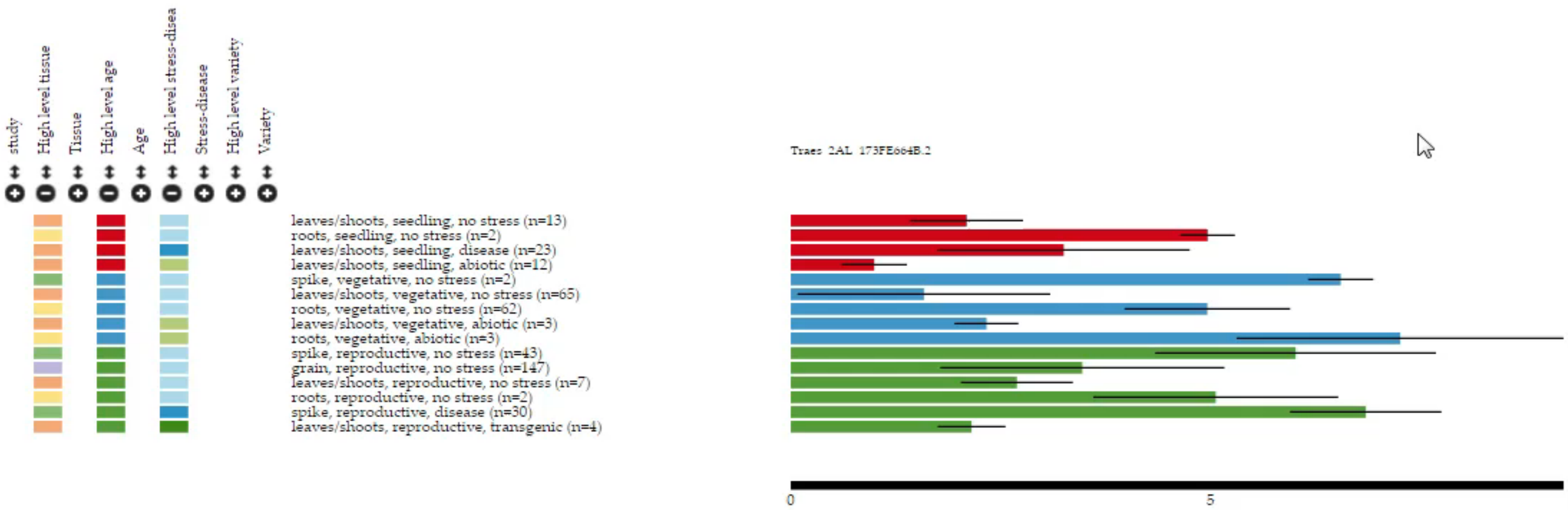
Gene: Traes_2AL_173FE664B.2 Ensembl

Expression unit: tpm log2 Save as SVG Save as PNG Save data Restore Defaults Homoeologues



Borrill *et al.*, 2016, Plant Physiol.

www.wheat-training.com

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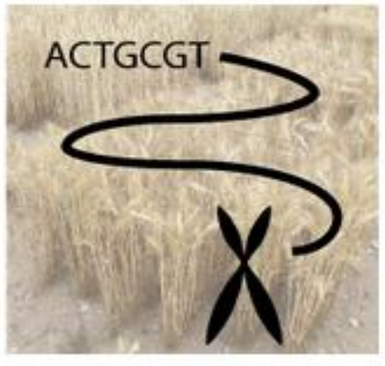
Home page

This website provides b … **heat scientists as well as researchers l** …

As we move into the futur … and to cope with climate change. One pote … research (e.g. from *Arabidopsis thaliana* … ng and crossing wheat plants requires time … short and cannot substitute teaching … spect of wheat.

Here we provide inform …

Growing wheat



Wheat genomic resources

TILLING mutant resources

Useful wheat links

Poster No: 225