Crop Talk
Vernalization and Viruses

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Vernalization

- Defined by Chouard (1960) as the acquisition or acceleration of the ability to flower by a chilling treatment.

Conditions for vernalization

- Vernalization can begin once the seed has imbibed
- Understanding the temperature threshold has been a journey and conflicting information in the literature for a long period of time

Brooking (1996) in Annals of Botany

- Rate of vernalization increases from 1° C to 11°C in a linear fashion
- Rate of vernalization decreases at temperatures above 11°C and does not occur at 18°C and above

https://doi.org/10.1006/anbo.1996.0148

Porter and Gawith (1999)

- Reported minimum, optimum and maximum temperatures for vernalization as -1.3°C, 4.9°C and 15.7°C respectively

https://doi.org/10.1016/S1161-0301(98)00047-1

Vernalization genes

- Four genes control vernalization (*Vrn-A1*, *Vrn-B1*, *Vrn-D1* and *Vrn-B3*)
- Winter wheats have recessive alleles at all four loci
- Spring wheats have at least on dominant *Vrn* allele
- See Loukoianov et al, 2005) for details on the molecular mechanism

Duration of vernalization

- Allelic variation of the recessive Vrn alleles leads to differences in vernalization requirement and heading date
- See Yan et al, 2015
- Range is generally 2-7 weeks of vernalization requirement.
- Flowering date influenced by vernalization requirement and photoperiod (Gonzalez et al. 2002)

Devernalization

- Loss of vernalization at temperatures above 35°C
- First described in rye by Gregory and Purvis (1948)
- Moelcular analysis of devernalization in wheat by Dixon et al, 2019
- Dependent on saturation of vernalization response

Cold hardening

- Roberts (1979) described cold hardening in wheat
- Duration of hardening was more important than stage of resistance
- Maximum hardening persisted several weeks past the completion of vernalization
- Wheat in the field has less cold resistance in late winter than autumn

Question 1

- How much of the wheat in your area would you consider to be excessively growthy?
  1. <10%
  2. 10-25%
  3. 25-50%
  4. >50%

Concerns with current crop

- True winterkill is from cold soil temperatures
- Wheat that has lost its cold hardening only recovers 39% of freezing tolerance after re-acclimation (Trischuk et al, 2014)
- Canola recovers freezing tolerance after re-acclimation
- Vernalization not tightly associated with degree of cold hardiness

Have we lost cold hardening?

- Hard to answer definitively
  - Maintenance of freezing tolerance past satuiration of vernalization is encouraging
- Likely to see variety specific responses
  - Interaction of vernalization, temperature and photoperiod control breaking of dormancy
- Does burn back equal yield loss?
  - Not necessarily
  - Loss of main tillers will negatively affect yield
- Risk of crop development being ahead of schedule

Virus Breeding

- Complex of viruses
  - Wheat streak mosaic virus
  - Triticum mosaic virus
  - High Plains mosaic virus
- Vectored by wheat curl mite

Kansas State University

Question 2

- How well do you think volunteer wheat was controlled in your area this last fall?
  1. Poorly controlled
  2. Fair Control
  3. Good Control
  4. Excellent Control

Kansas State University

Wsm1

- *Wsm1*
  - *Thinopyrum* introgression
  - Around since 1980s but associated with yield drag
  - Shortened segment appears to break linkage drag (Guttieri et al., 2023)
  - Released in 'Bernd'
- Good protection against WSMV and TriMV
- Temperature sensitivity
  - Is it important?

Kansas State University

Wsm2

- Wheat source
  - Colorado experimental line
- Widely deployed
  - Joe, KS Territory, KS Tradition, KS Mako, KS Dallas, Guardian, etc
- Temperature sensitive
- Decent protection from WSMV but not TriMV

Kansas State University

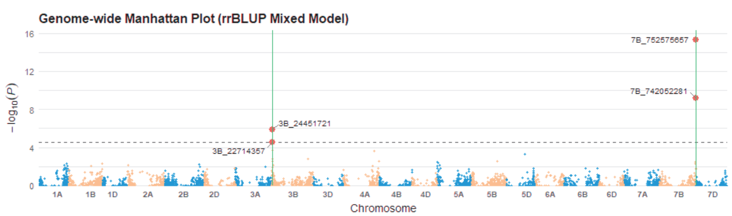
Wsm3

- *Thinopyrum* derived
- Shortened segment in use
- Good protection against WSMV and TriMV
  - Less temperature sensitive
- Release by Colorado State
  - Gabriel
- Advanced line in Guorong's program

WSMV tolerance

- 2024 Belleville
  - Uniform infection
  - Mostly WSMV
  - PYN entries given visual ratings (J. Noller)
  - 320 lines used in GWAS
- Agriseq genotyping platform

Analysis, results and figures by Yemane Belaineh



Marker	Chr	Pos	Major Allele	Minor Allele	MAF	P.value (MLM)	Adj. P (FDR)	Beneficial Allele	Effect (GLM)	Var Explained (GLM)
7B_752575657	7B	752,575,657	G	A	0.4188	5.02×10^{-16}	1.83×10^{-12}	G	−0.452	0.2063
3B_024451721	3B	24,451,721	C	T	0.0759	1.37×10^{-6}	1.66×10^{-3}	T	0.313	0.1003

Tolerance Conclusion…..and questions raised

- The tolerance trait appears to be simply inherited
- Role in variation of temperature tolerance seen with *Wsm2*?
- Does tolerance influence TriMV response?
- Mechanisms?

Cmc4

- Provides resistance to wheat curl mite
  - TAM 112, Byrd, Avery, Langin, Guardian
- Helpful but not a silver bullet
- Rearing mites on plants with the gene for multiple generations results in less efficacy
- Complementary approach to resistance

Breeding approaches

- Hays program
  - *Wsm2* is present at high frequency
  - Some lines with *Wsm2* also appear to have better TriMV tolerance
  - *Wsm1* and *Wsm3* are being used in the program
  - *Wsm3* line in elite trials
    - Segment that was associated with yield drag in Guttieri trials

Breeding approaches

- Manhattan program
  - *Wsm2* is present at low frequency
    - KS Mako and KS150167-17 have *Wsm2*
  - Focus on increasing frequency of *Wsm1* through backcrossing
  - The shortest translocation with *Wsm3* also being used
    - No guarantee yield drag issue is solved

	A genome		B genome		D genome	
Group 1		*Glu-A1y*	*Yr15*	*Lr46 , Bx7oe*	*Lr42*	
Group 2		*Yr5*	*2NS*	*H21*		
Group 3		*Sr35*	*Wsm2*			
Group 4						*ALMT1, Wsm1*
Group 5			*Lr52/Yr47*	*tsn1*		*Sbm1*
Group 6		*Sr26*	*Yr36*		*Cmc4*	
Group 7		*Sr22*		*Wsm3, Lr68*	*Lr34*	*Fhb7*

Building a Universal Donor

Leaf rust	*Lr34, Lr68, Lr42, Lr52*
Stripe rust	*Yr5, Yr15, Yr36, Yr47*
Soil-borne mosaic	*Sbm1*
Acid Soil tolerance	*ALMT1*
Stem rust	*Wsm1, Sr22, Sr26, Sr35, Sr38*
FHB	*Fhb7*
Hessian fly	*H21, H26*
Wheat Curl Mite	*Cmc4*
WSMV	*Wsm1, Wsm2, Wsm3*
Quality	*Bx7oe, Glu-A1y*

Conversion program

- Use of Bernd (*Wsm1+Cmc4*)
  - Now using KS Providence+*Wsm1+Cmc4*
- Conversion approach provides potential commercial varieties and high performing parents to rapidly increase frequency of resistance in the breeding program
- Materials useful for virus research

KS Providence series

- KS Providence+*Wsm1+Cmc4*
  - 196 rows of increase in Arizona
  - Should provide 5-6 bushels of seed for increase for potential release in 2028
- KS Providence+*Wsm1*
- KS Providence+*Cmc4*
- Also creating KS Providence+*Wsm2* and all combinations with *Wsm1* and *Cmc4*

Status of backcross program

Line	Status*	Completion date	Gene(s)
KS Mako+*Yr5+Yr15 (Wsm2)*	BC5	Summer 2026	Wsm1+Cmc4
KS Bill Snyder (Wsm2)	BC5	Summer 2026	Wsm1+Cmc4+Sbm1
KS150167-17 (Wsm2)	BC4	Fall 2026	Wsm1
KS Chikaskia	BC4	Fall 2027	Wsm1
KS Flintlock	BC3	Spring 2027	Wsm1+Cmc4
KS200463S4-6	BC3	Spring 2027	Wsm1+Cmc4
KS Tradition (Wsm2)	BC1	Spring 2028	Wsm1+Cmc4
KS190344S-3	BC1	Spring 2028	Wsm1+Cmc4
KS190417S-7	BC1	Spring 2028	Wsm1+Cmc4
KS190488S-1	BC1	Spring 2028	Wsm1+Cmc4
KS170908-10	BC1	Spring 2028	Wsm1+Cmc4
KS200303S4-7	BC1	Spring 2028	Wsm1+Cmc4
KS200408S4-1	BC1	Spring 2028	Wsm1+Cmc4
KS170908-7	BC1	Spring 2028	Wsm1+Cmc4
KS170922L-1	BC1	Spring 2028	Wsm1+Cmc4
KS170477-6	BC1	Spring 2028	Wsm1+Cmc4
KS22H88 (*Wsm2*)	BC1	Spring 2028	Wsm1+Cmc4
KS23H5245 (*Wsm2*)	BC1	Spring 2028	Wsm1+Cmc4
KS23H5419 (*Wsm2*)	BC1	Spring 2028	Wsm1+Cmc4
KS23H5484 (*Wsm2*)	BC1	Spring 2028	Wsm1+Cmc4
KS21H36 (*Wsm2*)	BC1	Spring 2028	Wsm1+Cmc4
KS23H5403 (*Wsm2*)	BC1	Spring 2028	Wsm1+Cmc4

* Expected at completion of Spring 2026 greenhouse cycle

Shortest *Wsm3* crosses

TA 6715/KS Mako
TA 6715/KS Mako+Yr5+Yr15
TA 6715/KS Providence
TA 6715/KS Tradition
TA 6715/KS150167-17
TA 6715/KS190344S-3
TA 6715/KS200463S4-6
TA 6715/KS190417S-7
TA 6715/KS170922L-1