Timing of variation in chilling intensity and its effects on winter rapeseed crops

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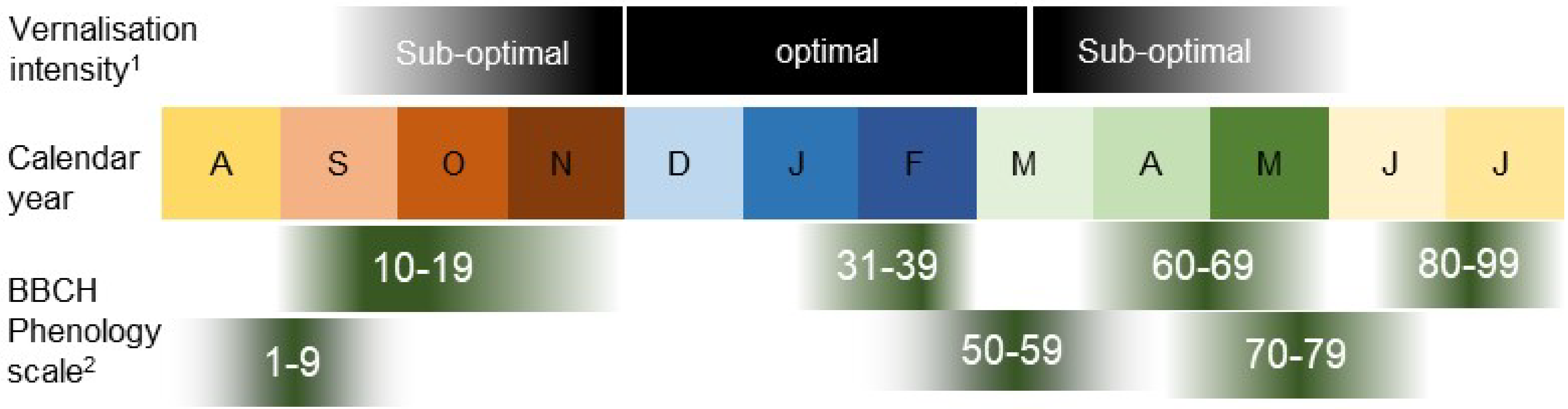
Rethinking chilling in OSR

I’ll show how yield potential in winter rapeseed is shaped by sequential chilling responses in different tissues.

I’ll show how these chilling responses are controlled by three classes of *FLOWERING LOCUS C* genes expressed at different developmental stages.

I’ll show how incomplete chilling leads to yield penalties

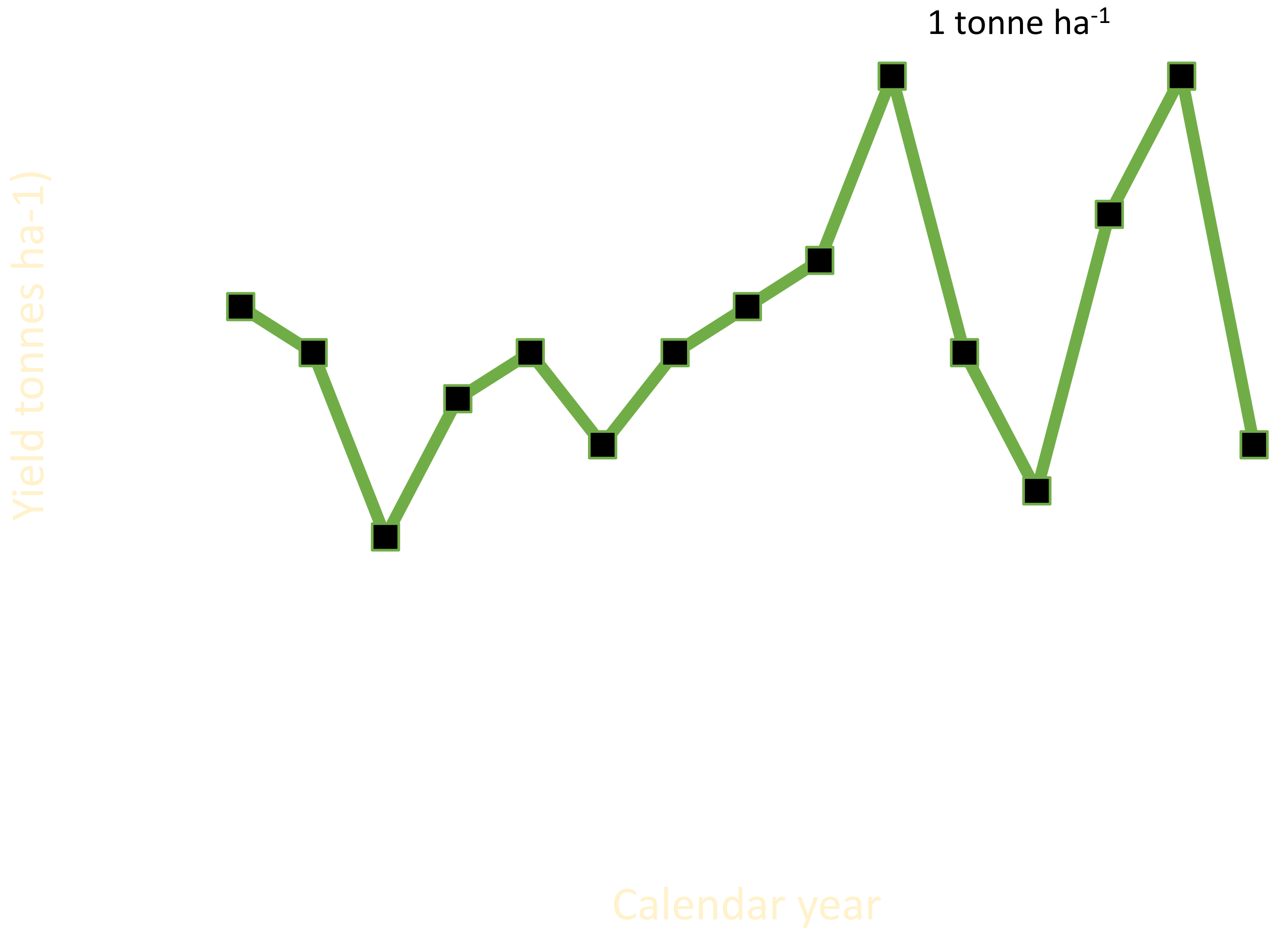
UK winter OSR phenology vs calendar year



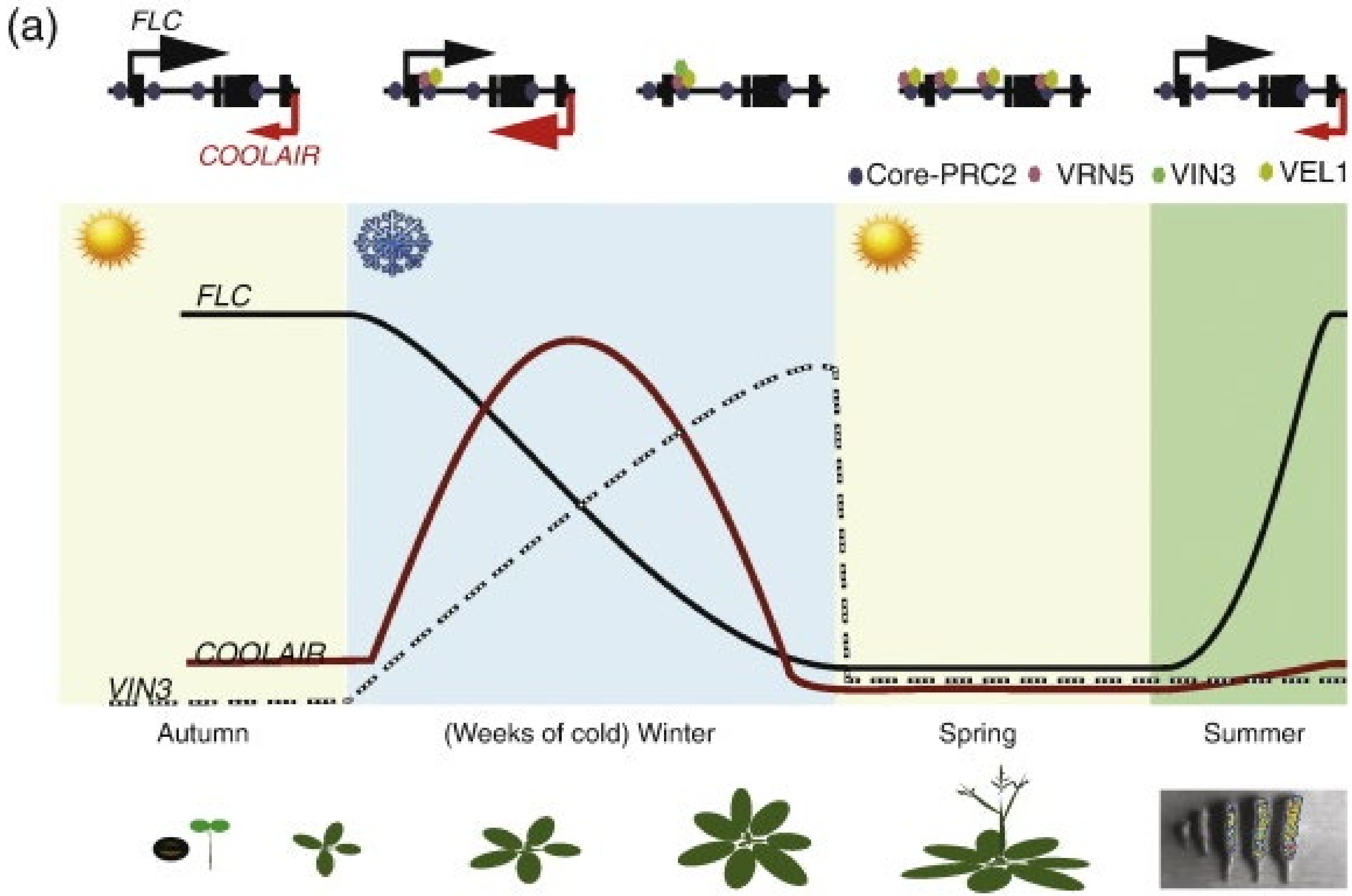
1-9 germination and cotyledon emergence
10-20 vegetative growth
(21-30 branch formation is usually omitted)
31-39 stem elongation

50-59 first flower opening
60-69 flowering
70-79 pod and seed development
80-99 ripening and senescence

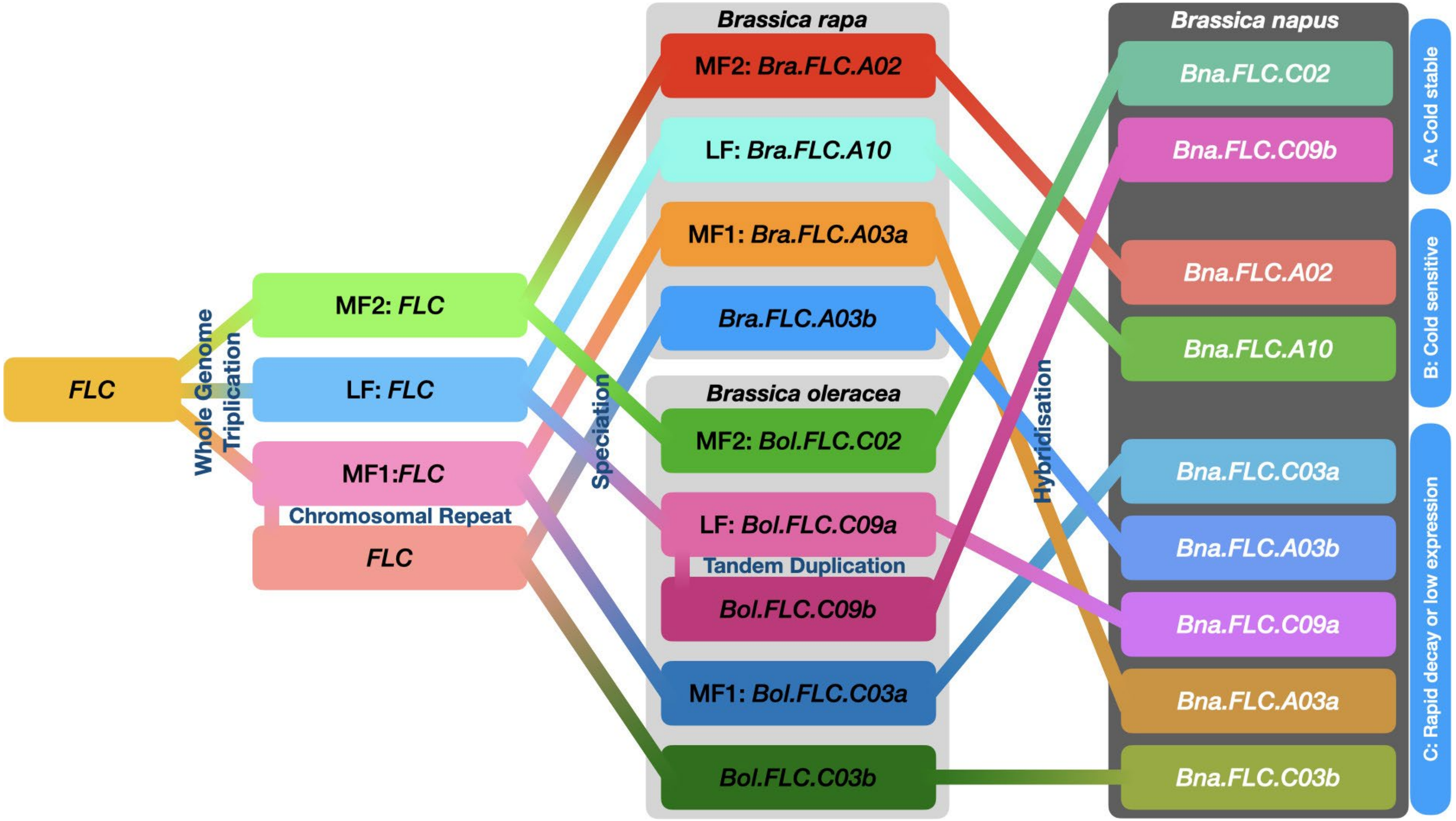
Yield instability in winter oilseed rape due to weather variation between years



Winter annual behaviour in Brassicas is conferred by *FLOWERING LOCUS C* (*FLC*) activity

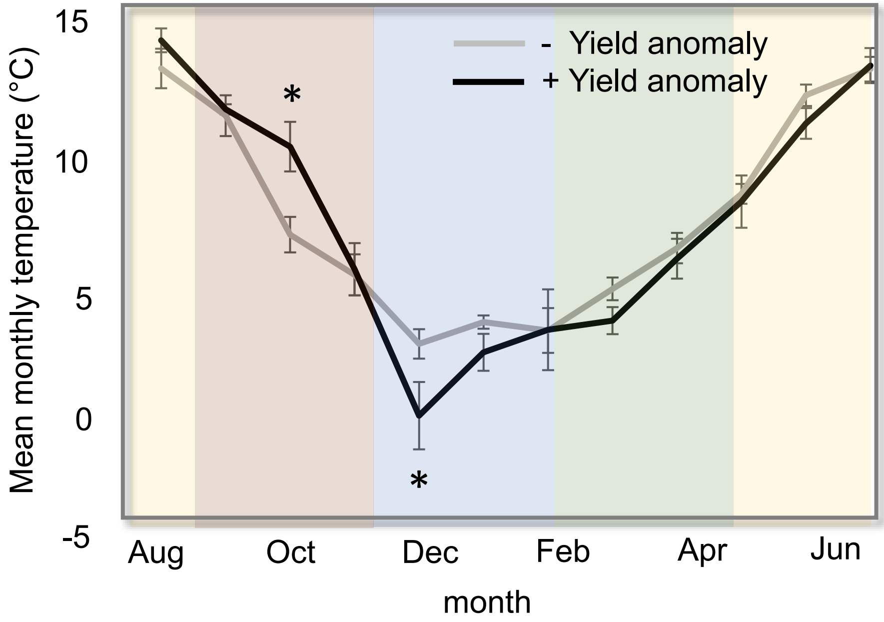


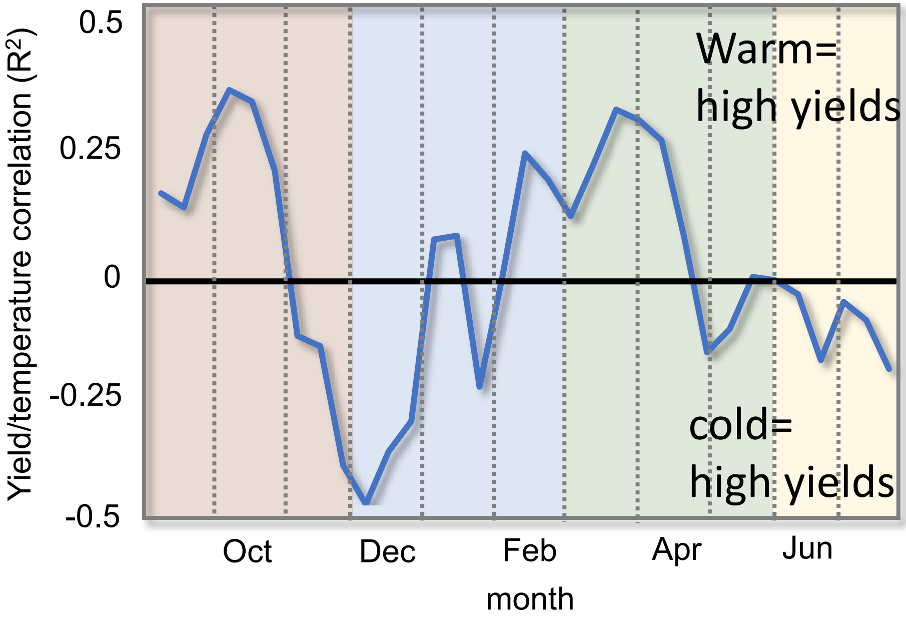
B. Napus has up to 9 *FLC* genes

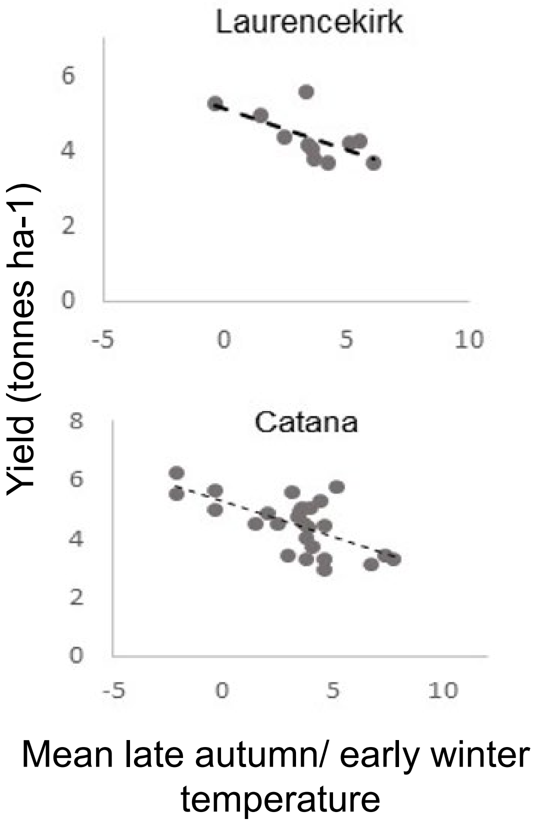


Calderwood et al., 2020

Using whole UK yield data 1990-2016, temperature relationships with yield

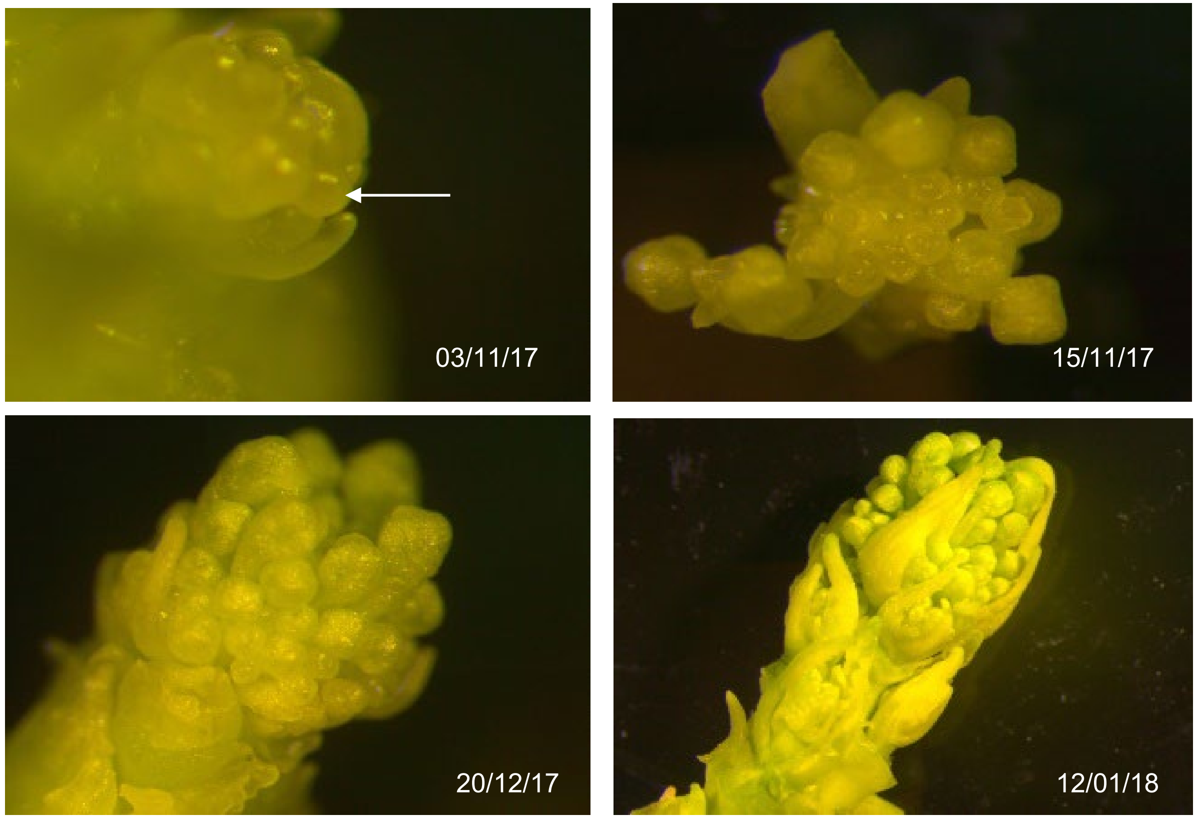






Brown et al. 2019 Sci. Rep.

WOSR yield versus temperature relationships invert at floral initiation



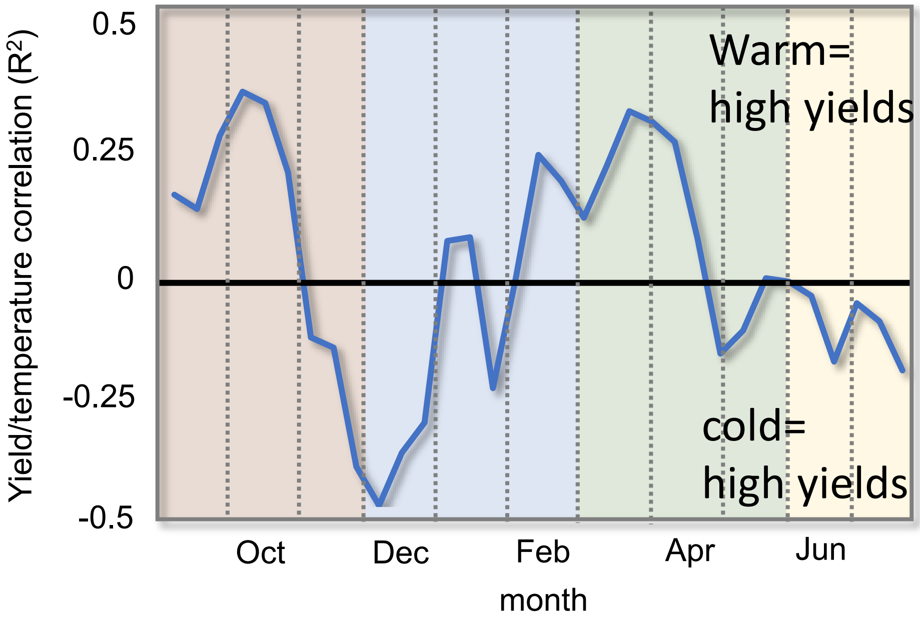


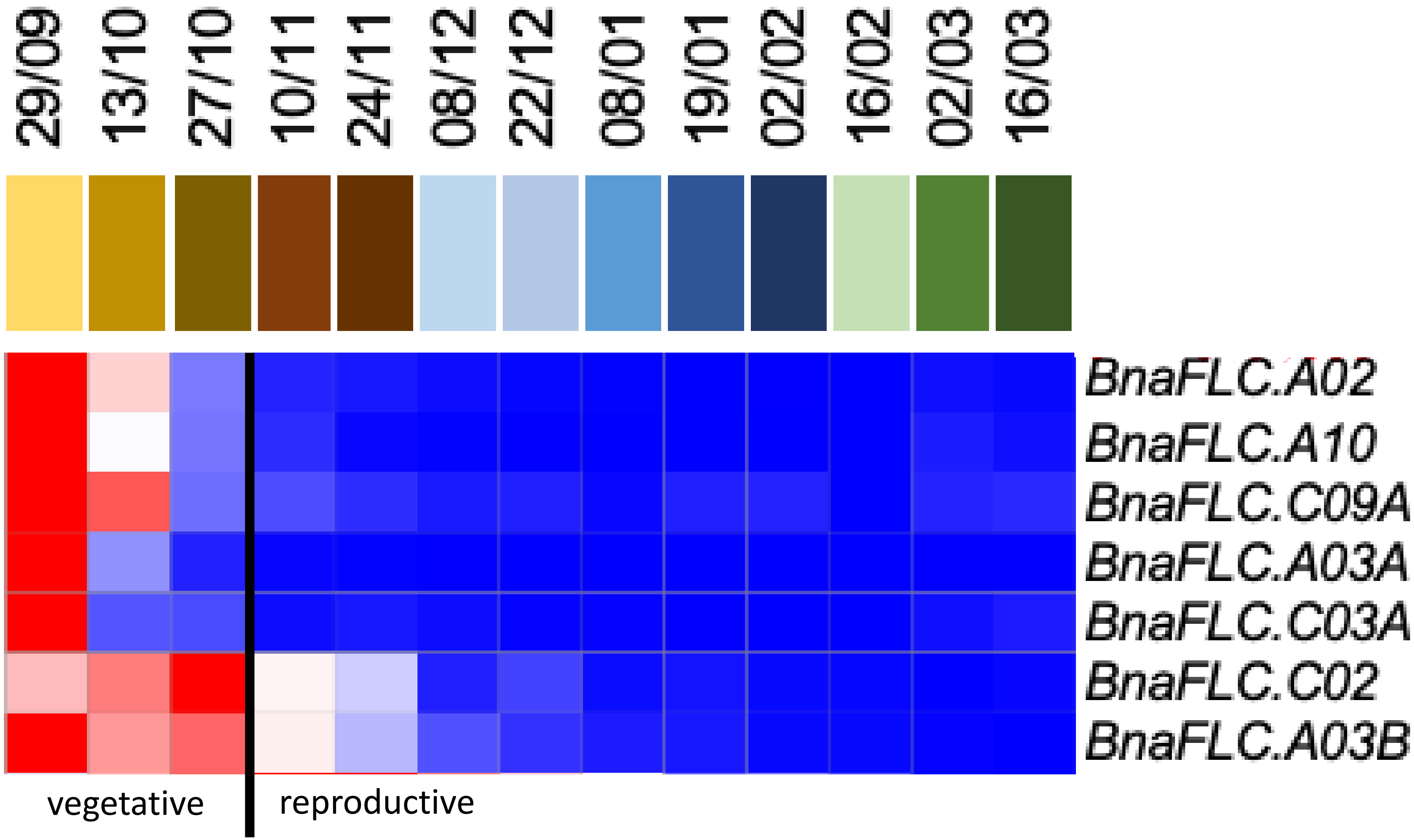
Table 1
A summary of the different aspects of perennial fruit crop growth, development, and production impacted by low winter chill.

Commodity	Aspects which are affected by low winter chilling									
	Vegetative bud break[a]	Floral bud break[a]	Bud abscission[b]	Flower abscission[c]	Flower quality[d]	Reproductive morphology[e]	Fruit set[f]	Vegetative growth[g]	Crop yield[h]	Product quality[i]
Apple	+	+		+	+			+	+	+
Pear				+		+			+	
Cherry			+		+	+	+			
Plum			+							
Peach		+	+		+	+		+		
Nectarine			+		+					
Apricots			+		+					
Almond			+				+			
Raspberry	+	+								
Blackberry	+									
Blackcurrant	+	+					+		+	+
Strawberry	+						+	+	+	+

[a] Delayed, erratic or uneven bud break (column 1 vegetative and column 2 floral).
[b] Abscission of entire flower buds.
[c] Abscission of single flowers within a cluster.
[d] Reduction in flower quality.
[e] Changes in reproductive morphology.
[f] Reduction in fruit set or increased run-off.
[g] Changes in vegetative growth, apical dominance, etc.
[h] Reduction in crop yield.
[i] Changes in crop/product quality.

Class 1 FLCs

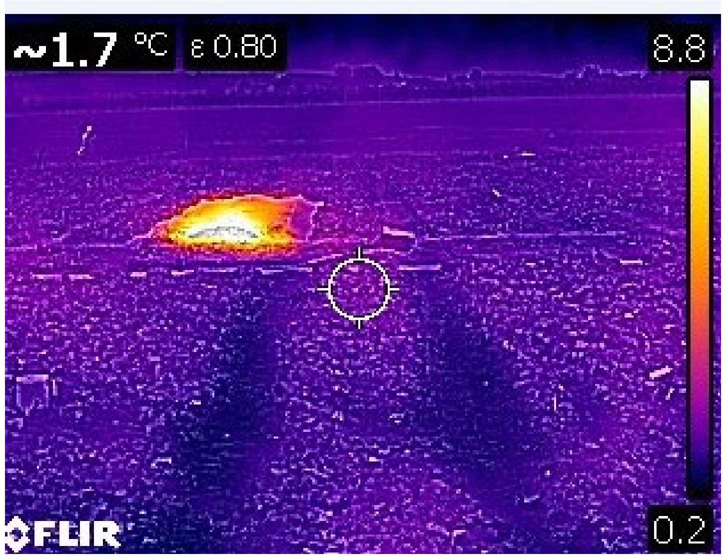
FLC genes exist that have nothing to do with the vegetative to floral transition

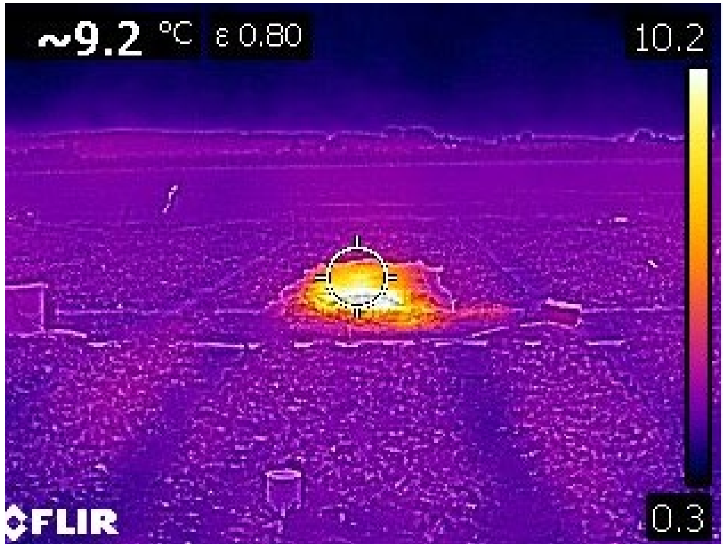


Deployment of warming cables either side of the plants

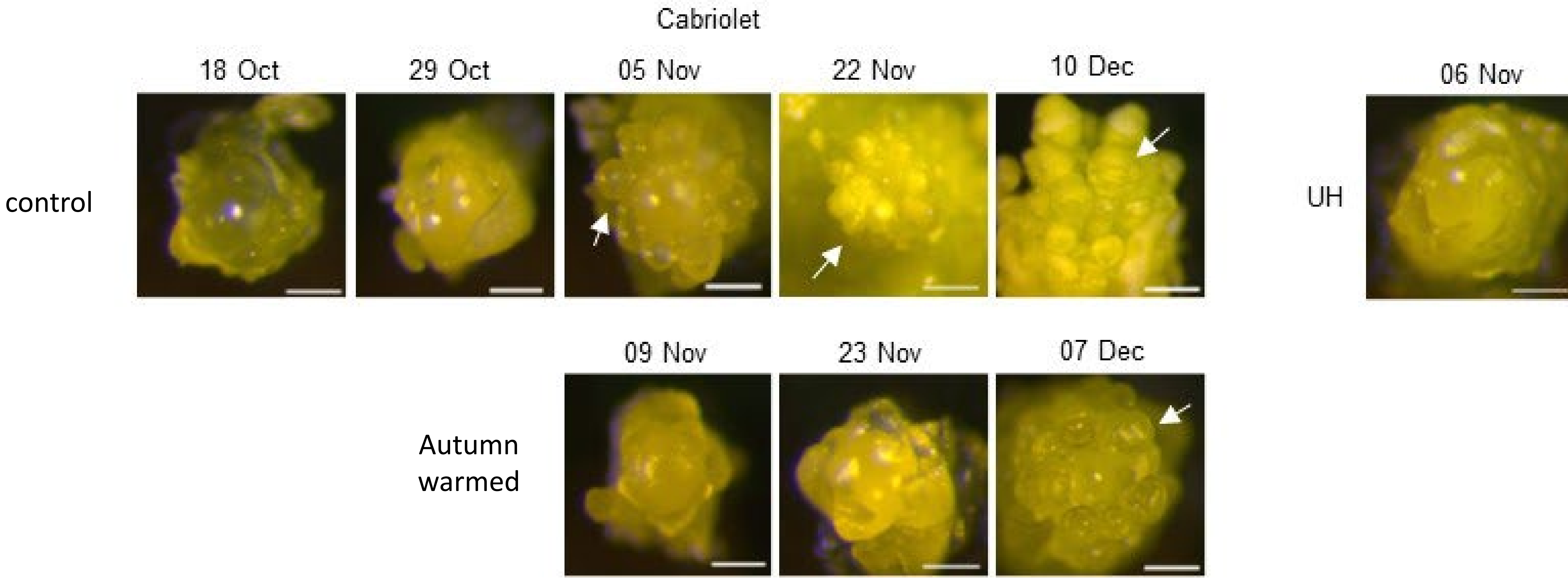
Carmel O’Neill

Thermal Imaging of field trials at the JIC experimental Farm

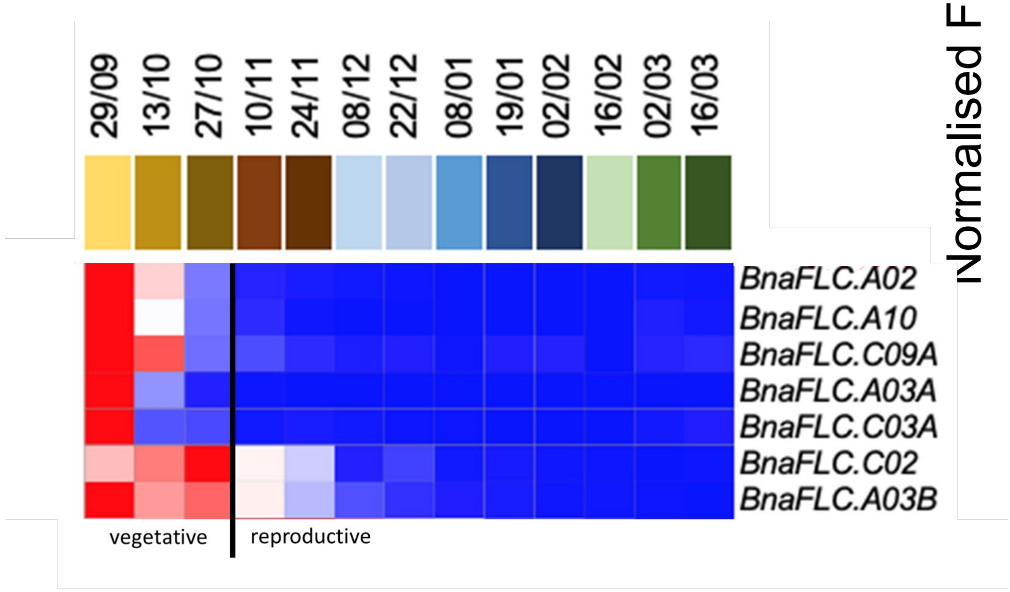


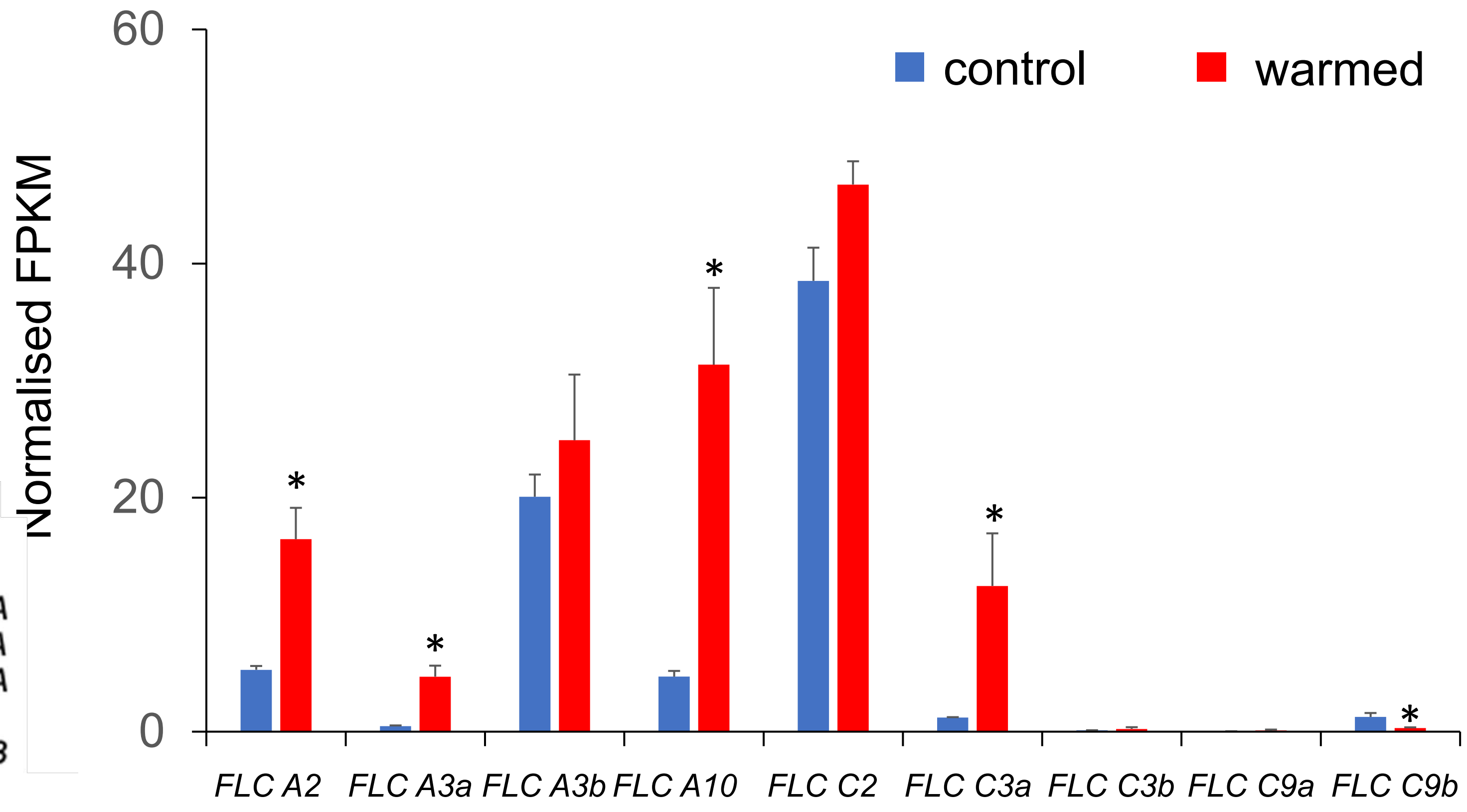


Warming WOSR in October delays flower development by up to 1 month



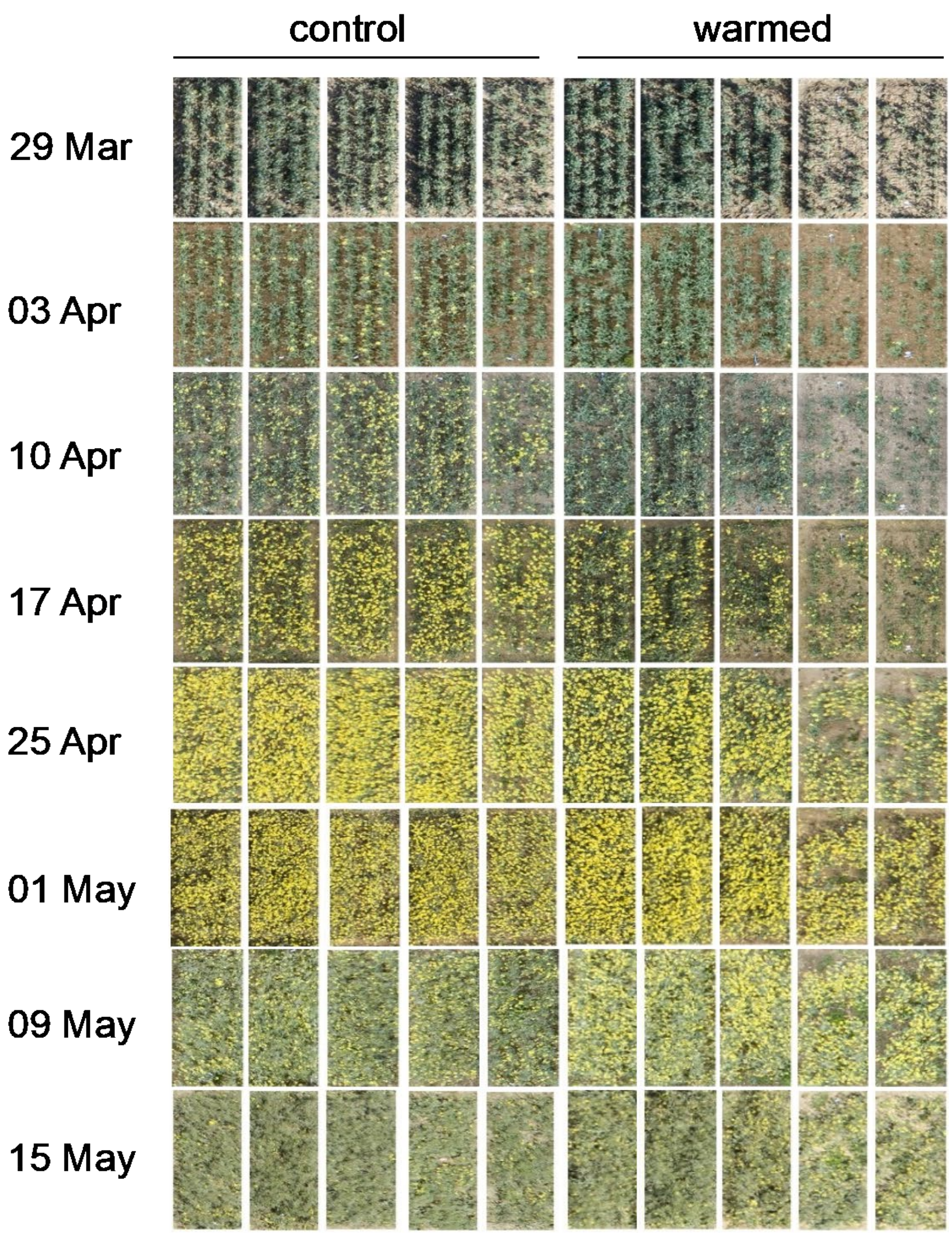
Class 1 *FLC* genes mediates the effects of autumn chilling on the timing of floral initiation.





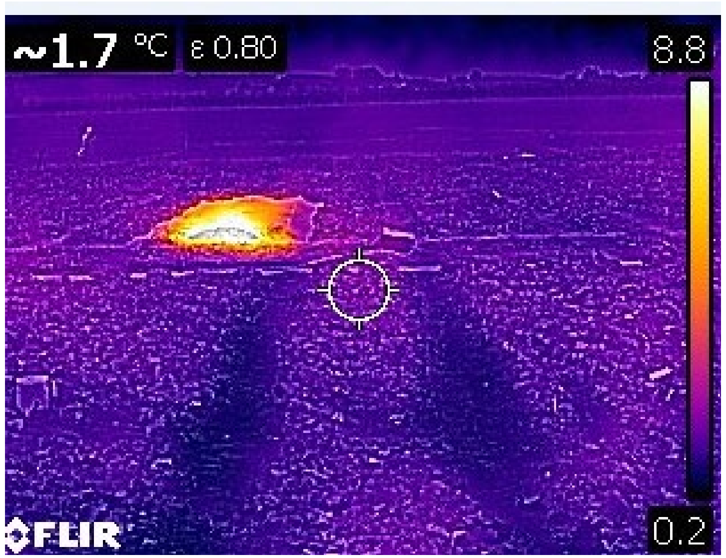
October warming delays floral initiation by 4 weeks, but delays flowering in spring by only 1 week

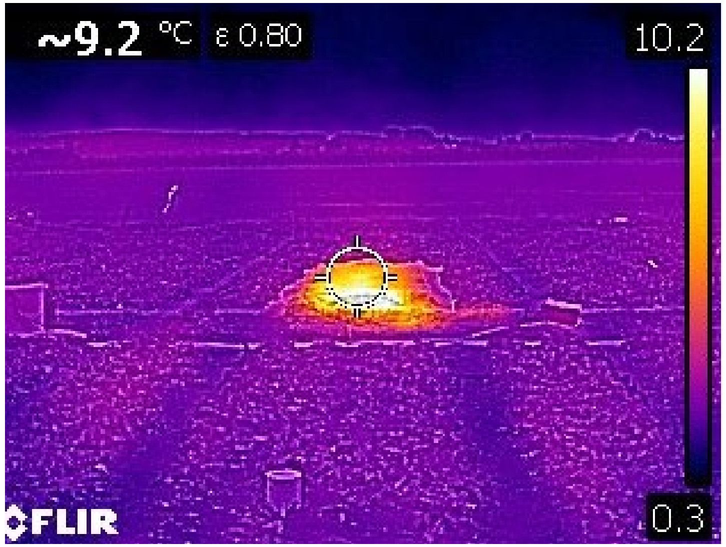
So somehow the warmed plants catch up....



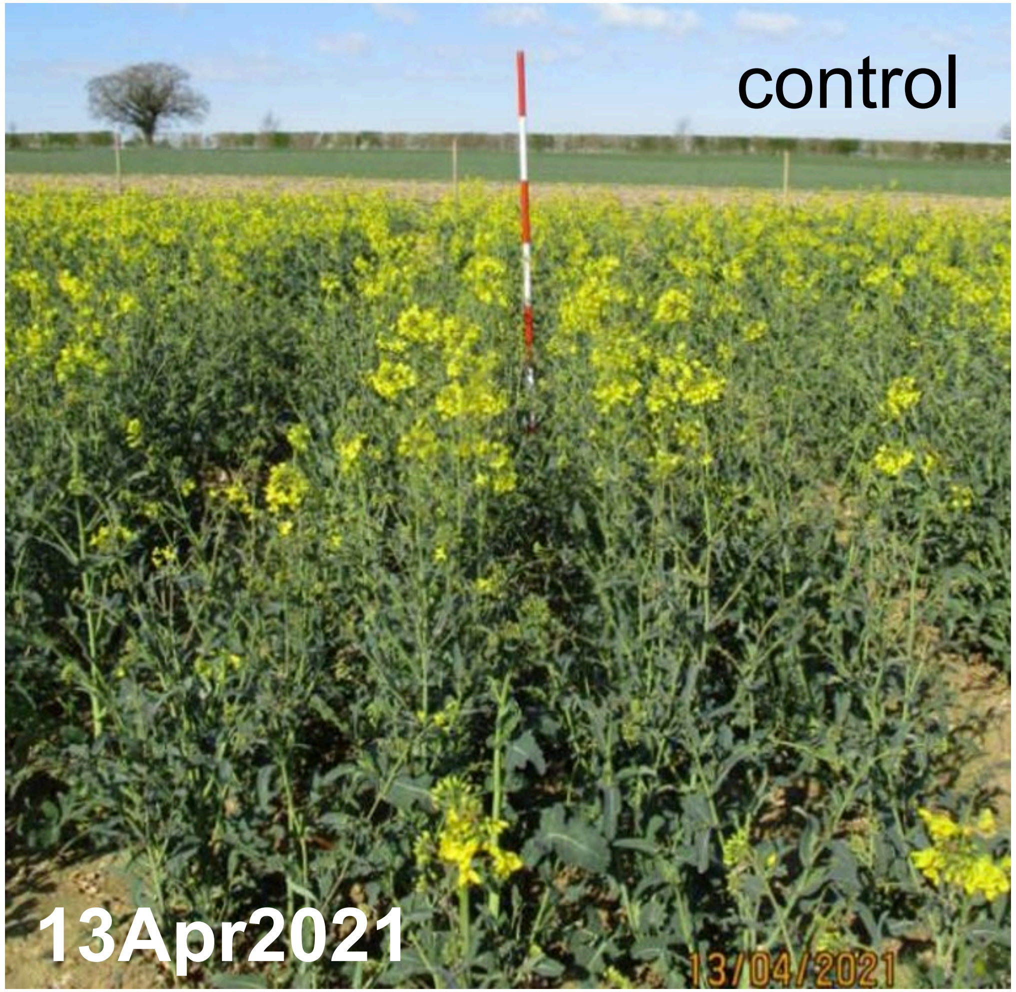
Class 2 FLCs

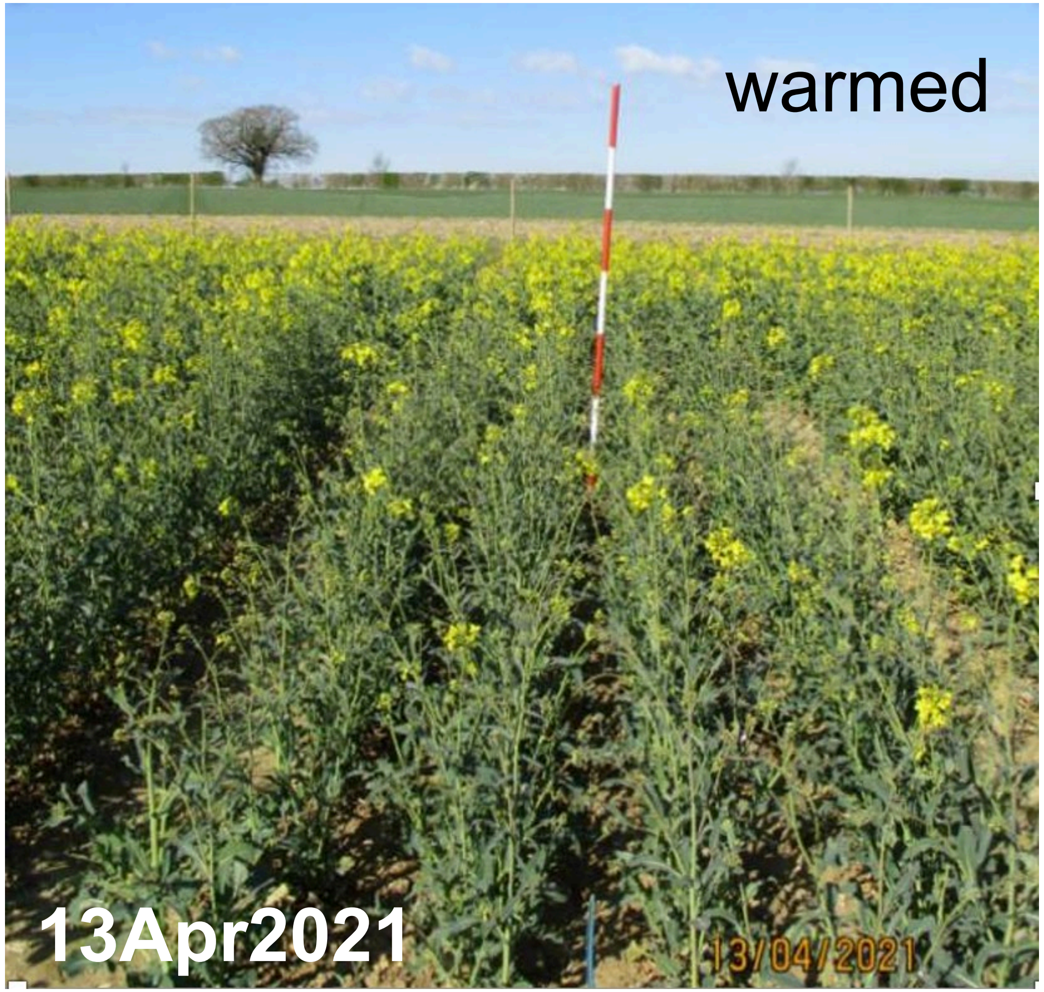
Thermal Imaging of field trials at the JIC experimental Farm



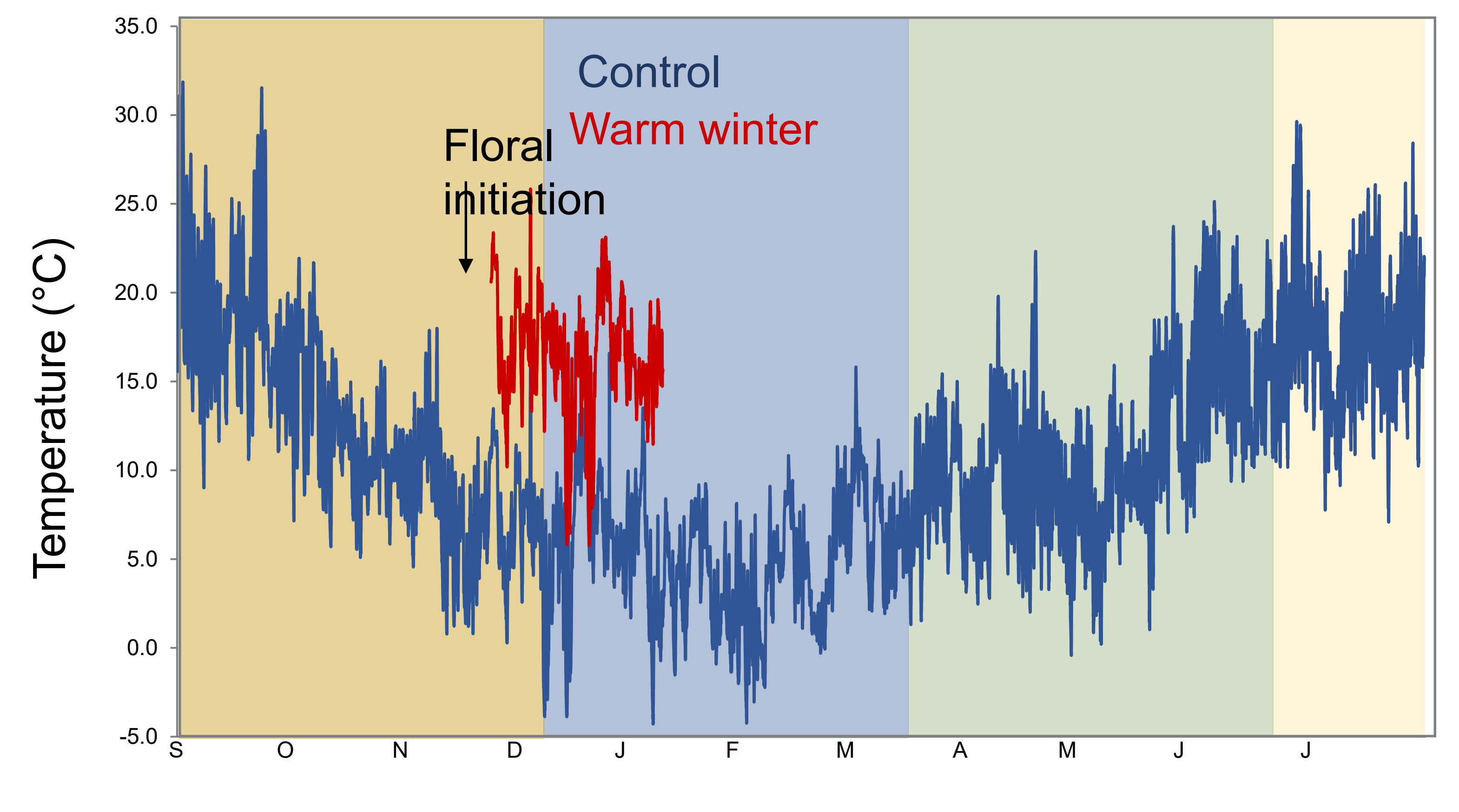


Warming in winter after floral initiation also delays flowering in the field

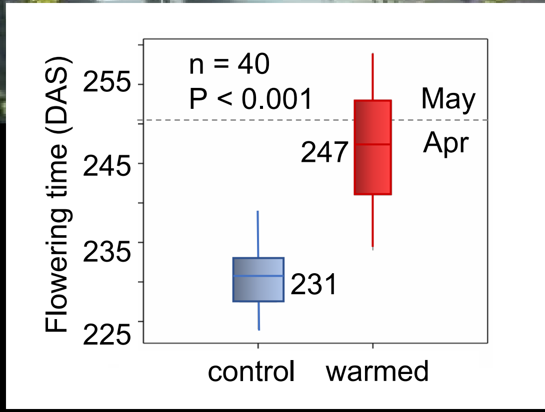




Simulation of complete winter annual growing seasons in real time, with warming interruption

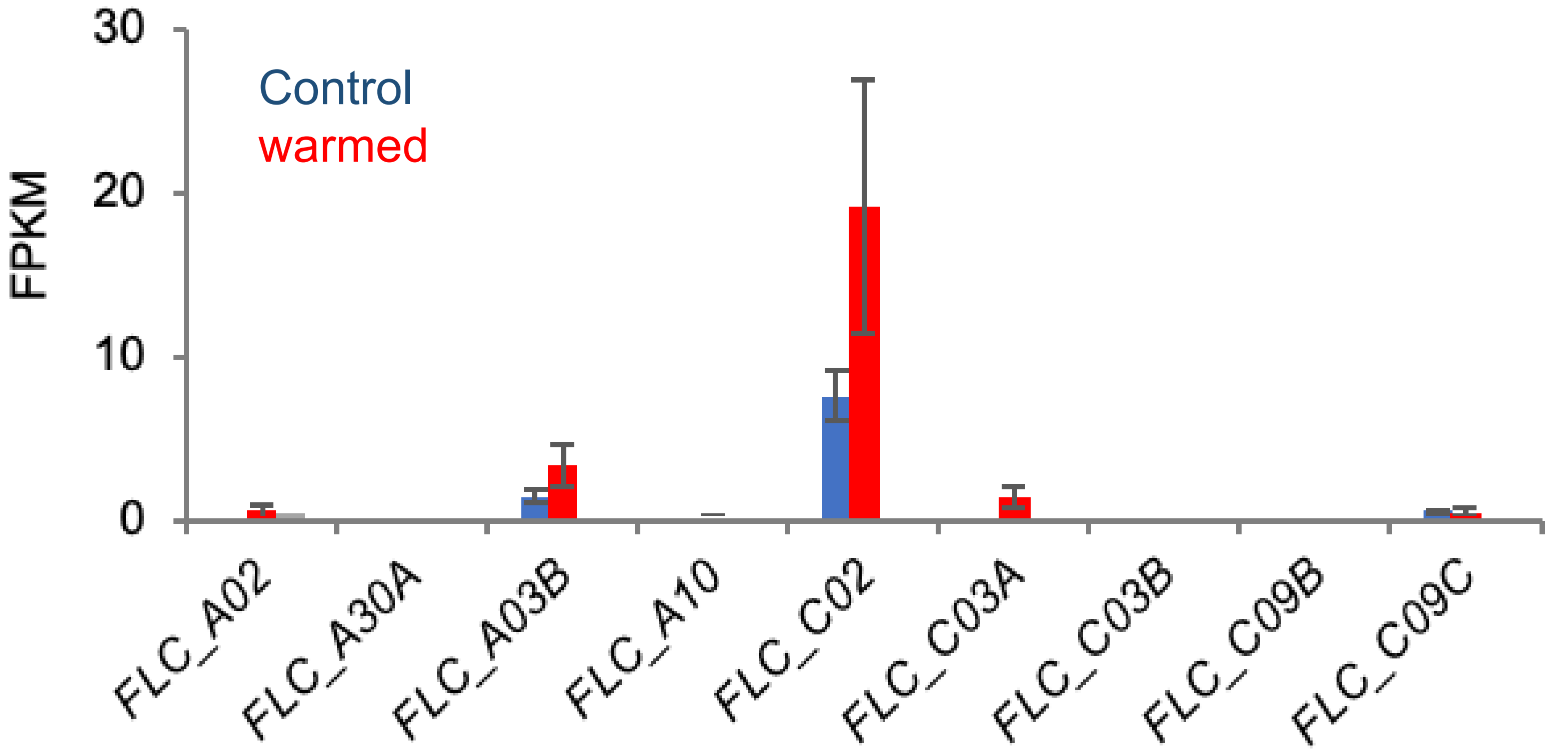


Warming WOSR during winter flower development delays bolting and flowering

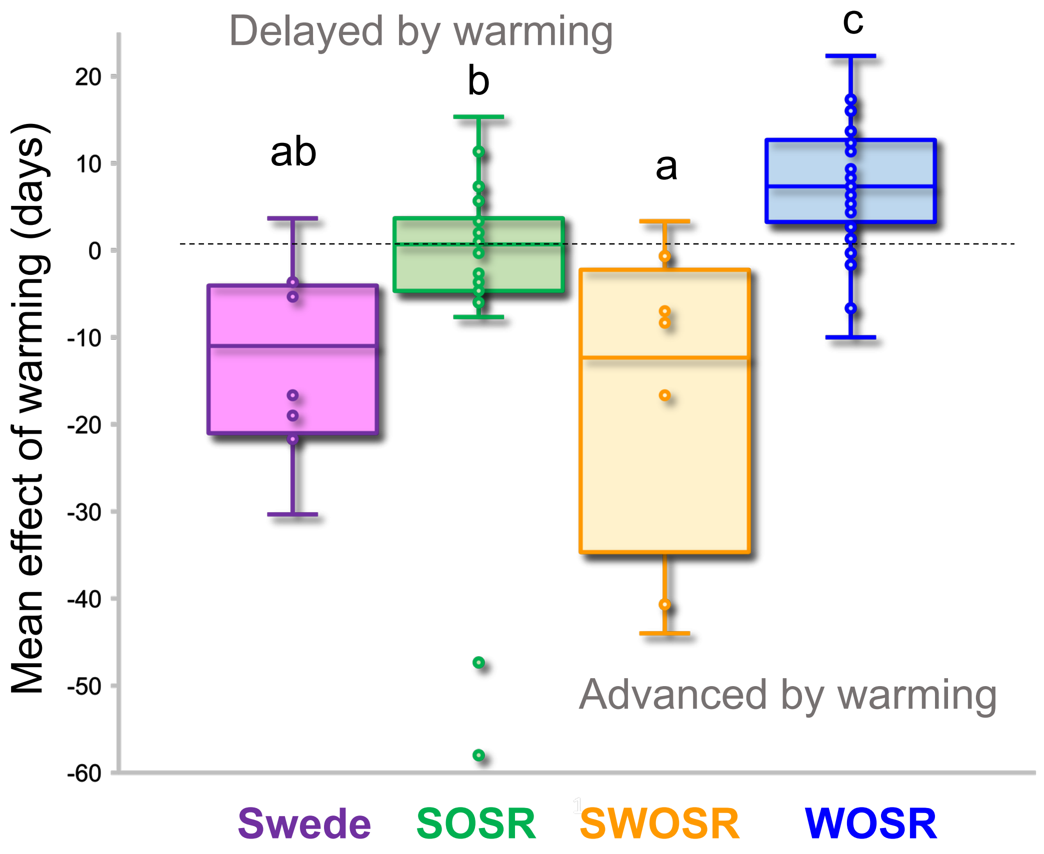



inflorescence dormancy

Warming in winter specifically prevents silencing of Class 2 *FLC* genes

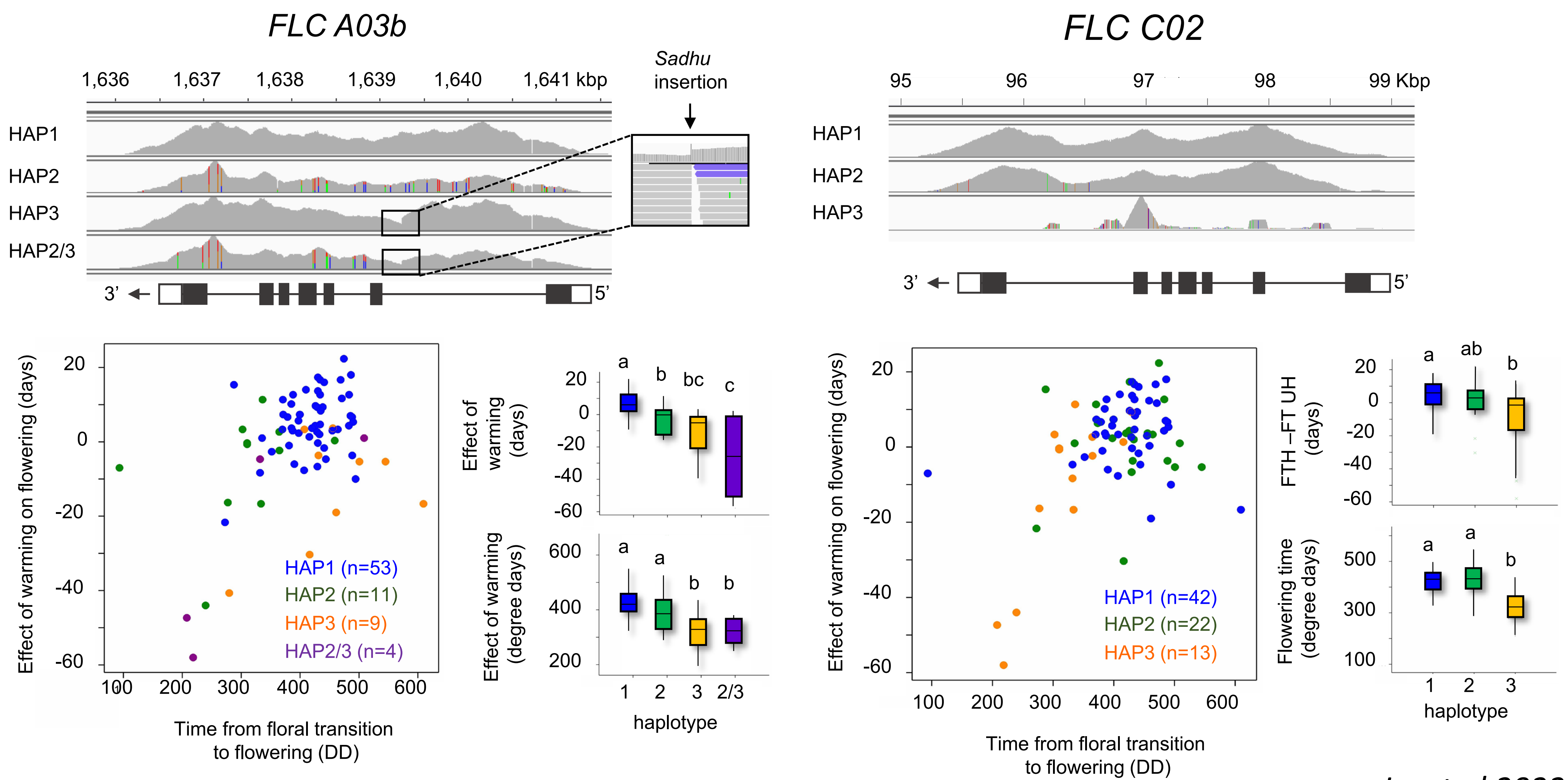


Flower bud responses to warming are not a generalised stress, but related to life history



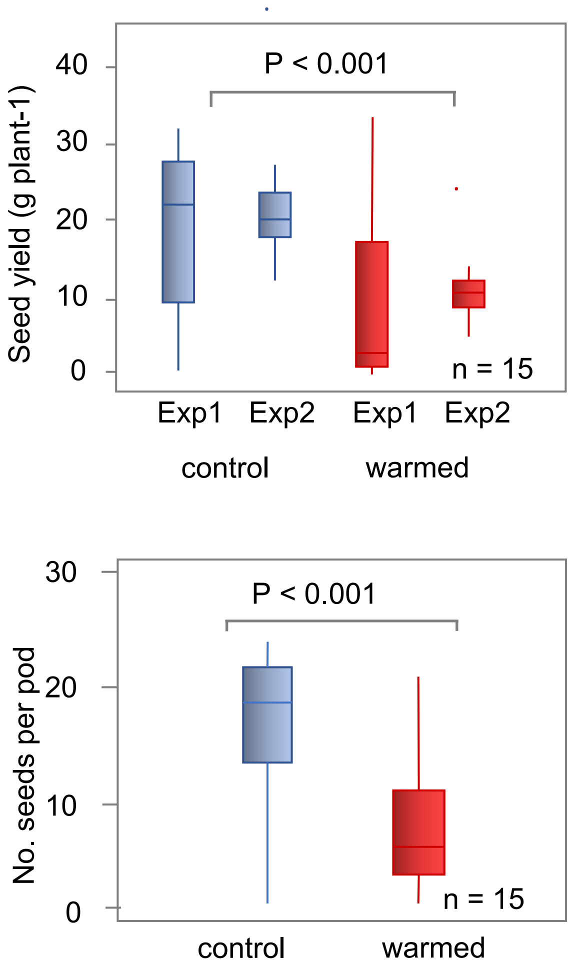
Sam Warner

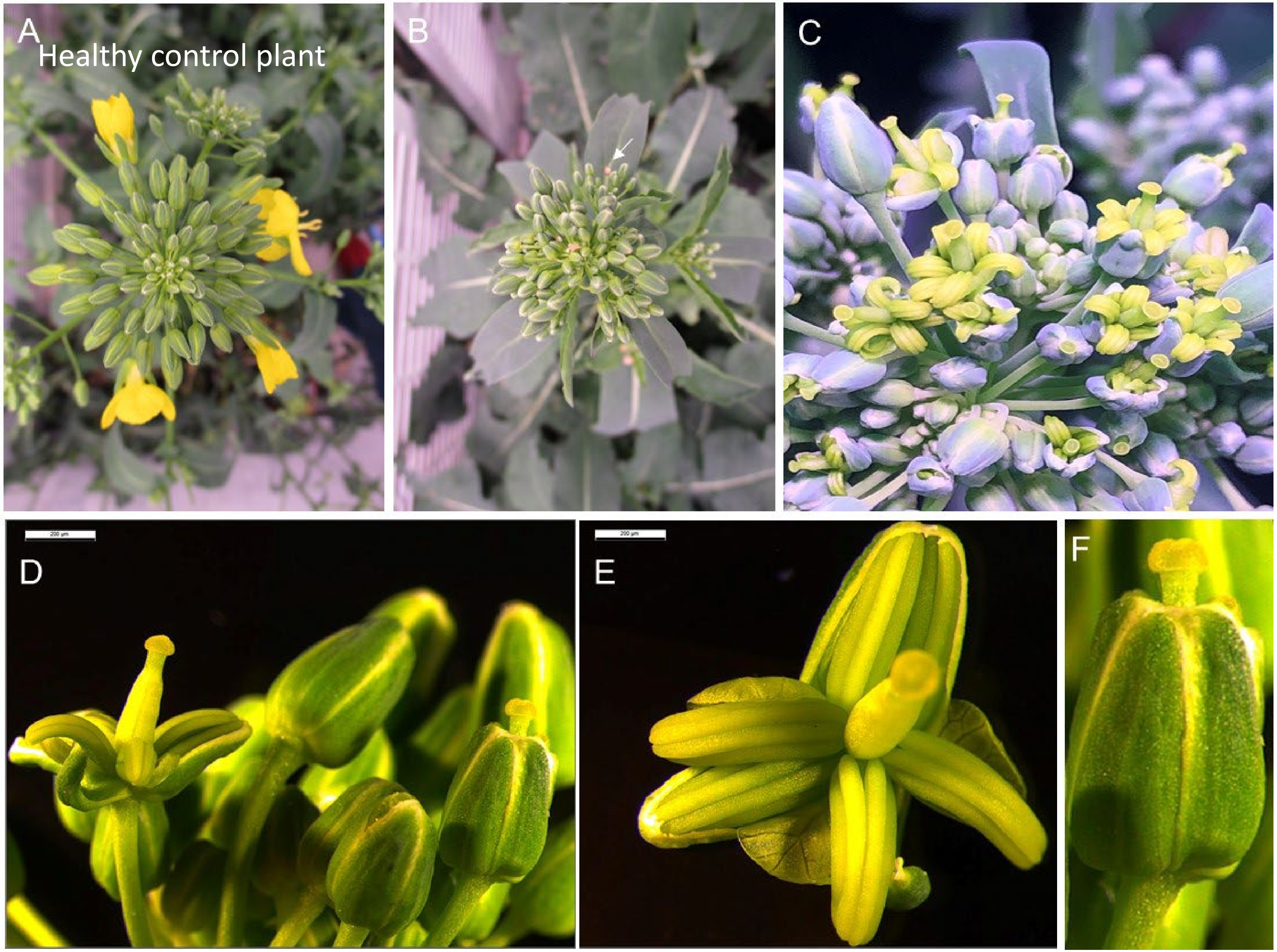
Class 2 *FLC* genes control flowering time via flower bud development in response to deep winter chilling



Lu et al 2022 PNAS

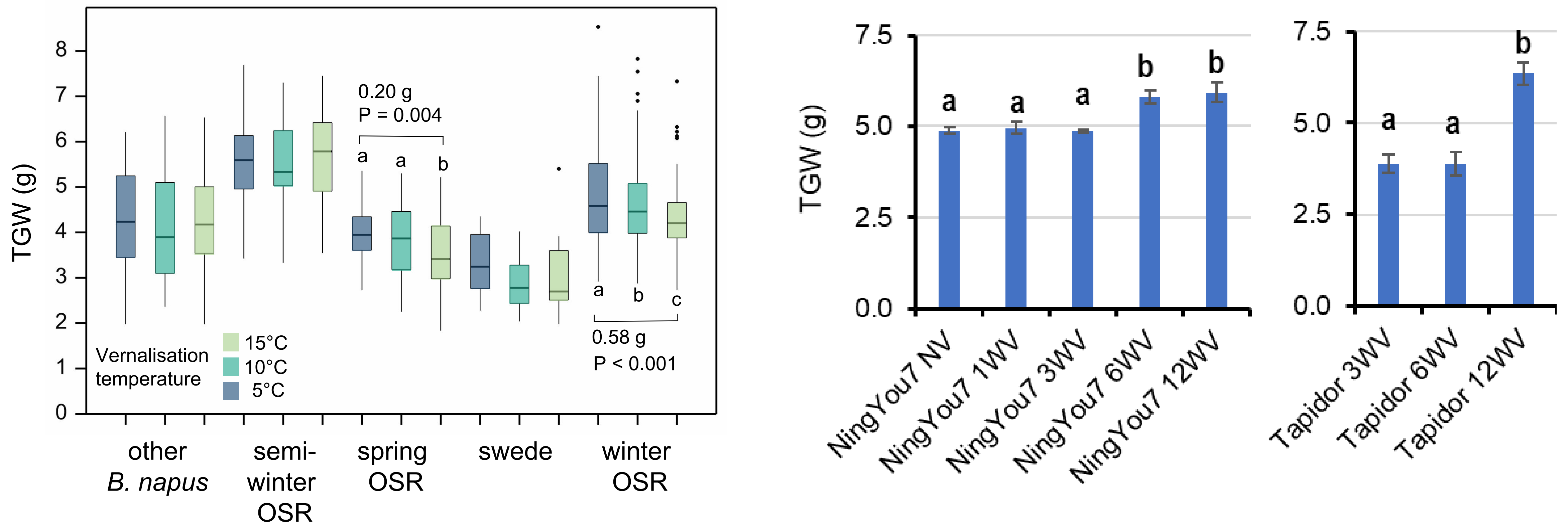
Effect of winter warming on seed set in full growing season simulations



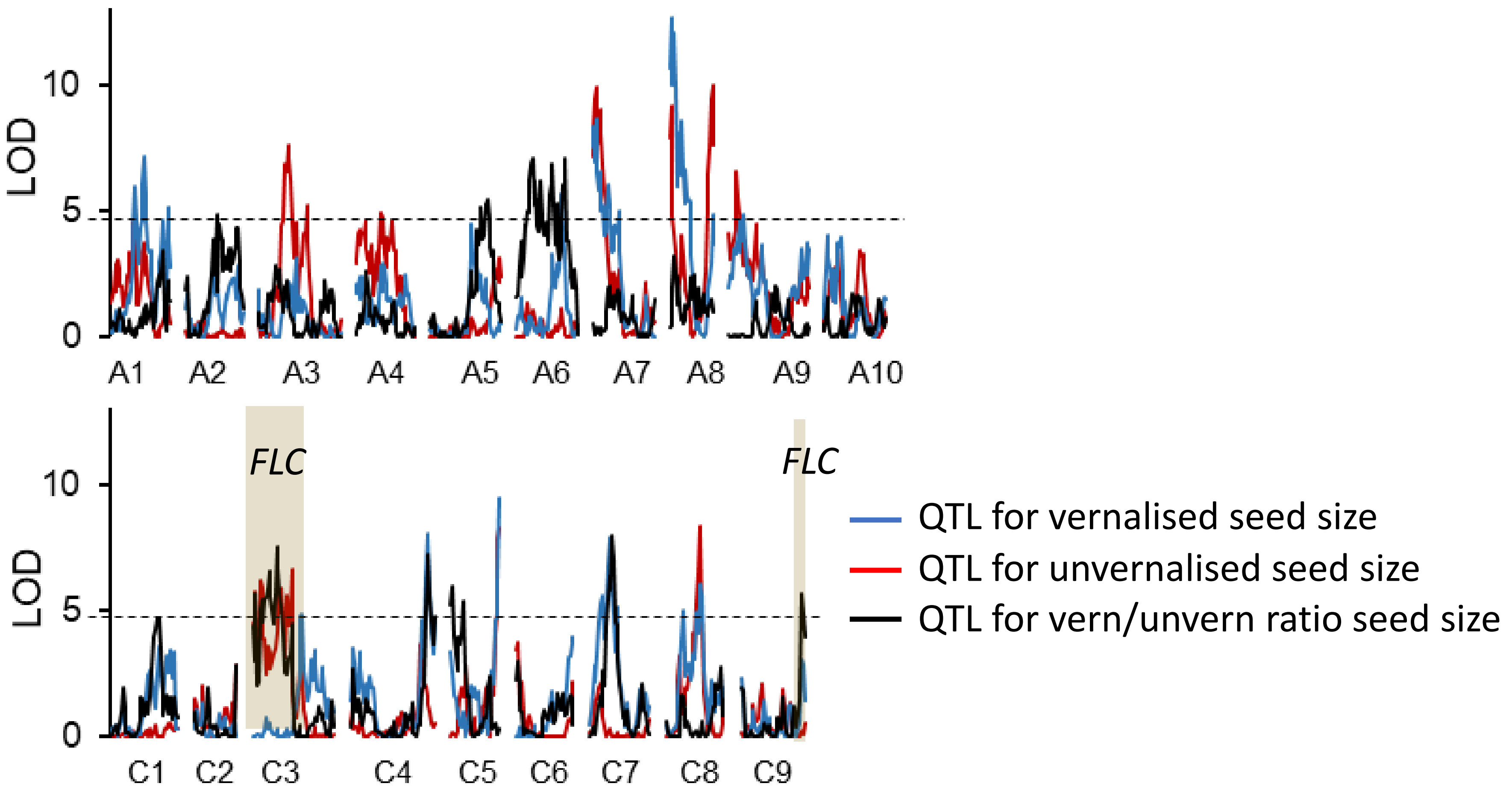

A
Healthy control plant
B
C
D
E
F

Class 3 FLCs

Variation in chilling intensity in winter oilseed rape affects seed size

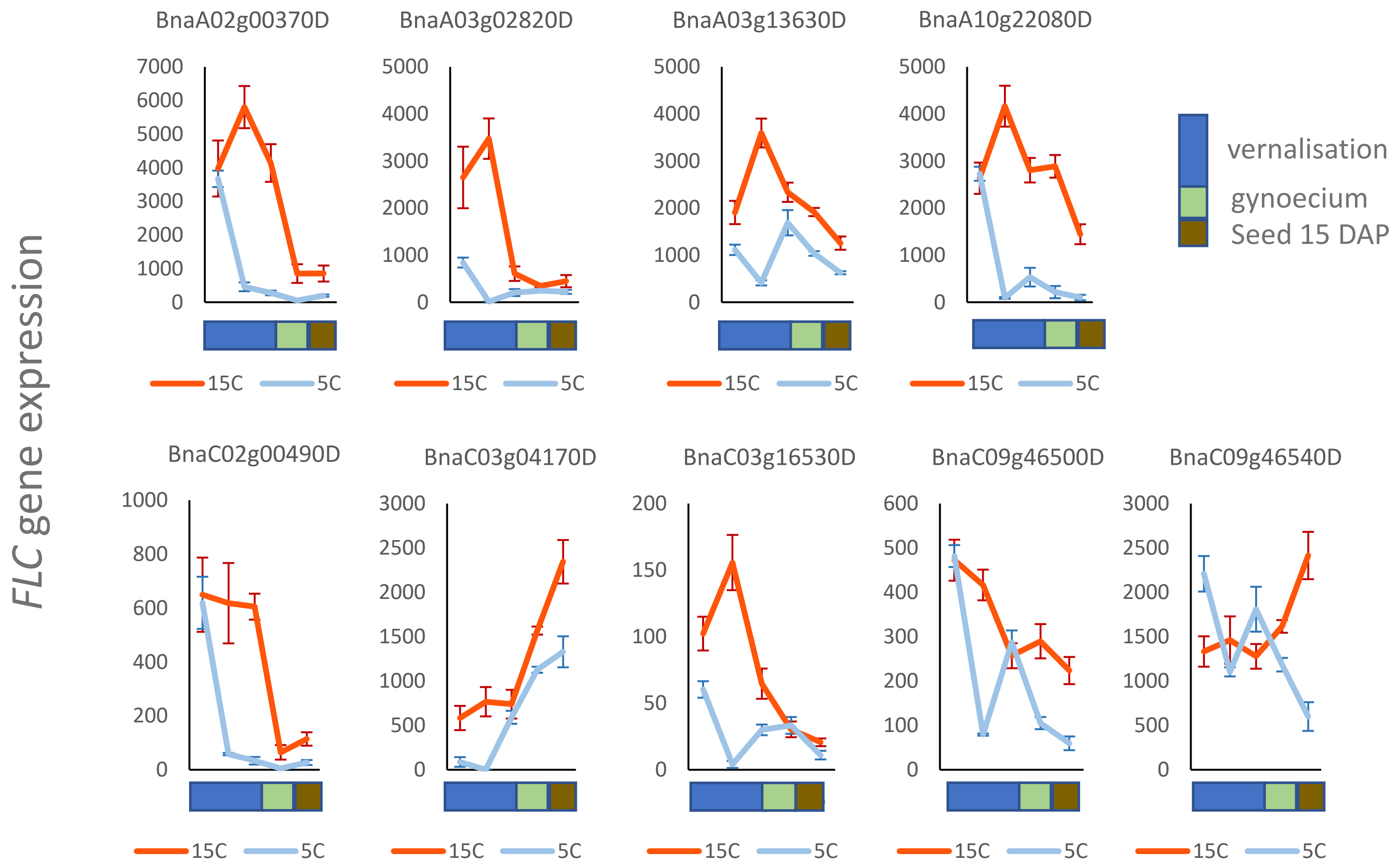


QTL mapping identifies *FLC* loci involved in the regulation of seed size by maternal vernalisation



Rachel Wells

Class 3 *FLC* genes are expressed mainly during seed development and control Thousand Grain Weight



Lack of flower bud chilling leads to yield effects in WOSR that resemble those in perennial crops

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Peach		+	+		+	+		+		
Nectarine			+		+					
Apricots			+		+					
Almond			+				+			
Raspberry	+	+								
Blackberry	+									
WOSR		+	+		+	+	+		+	

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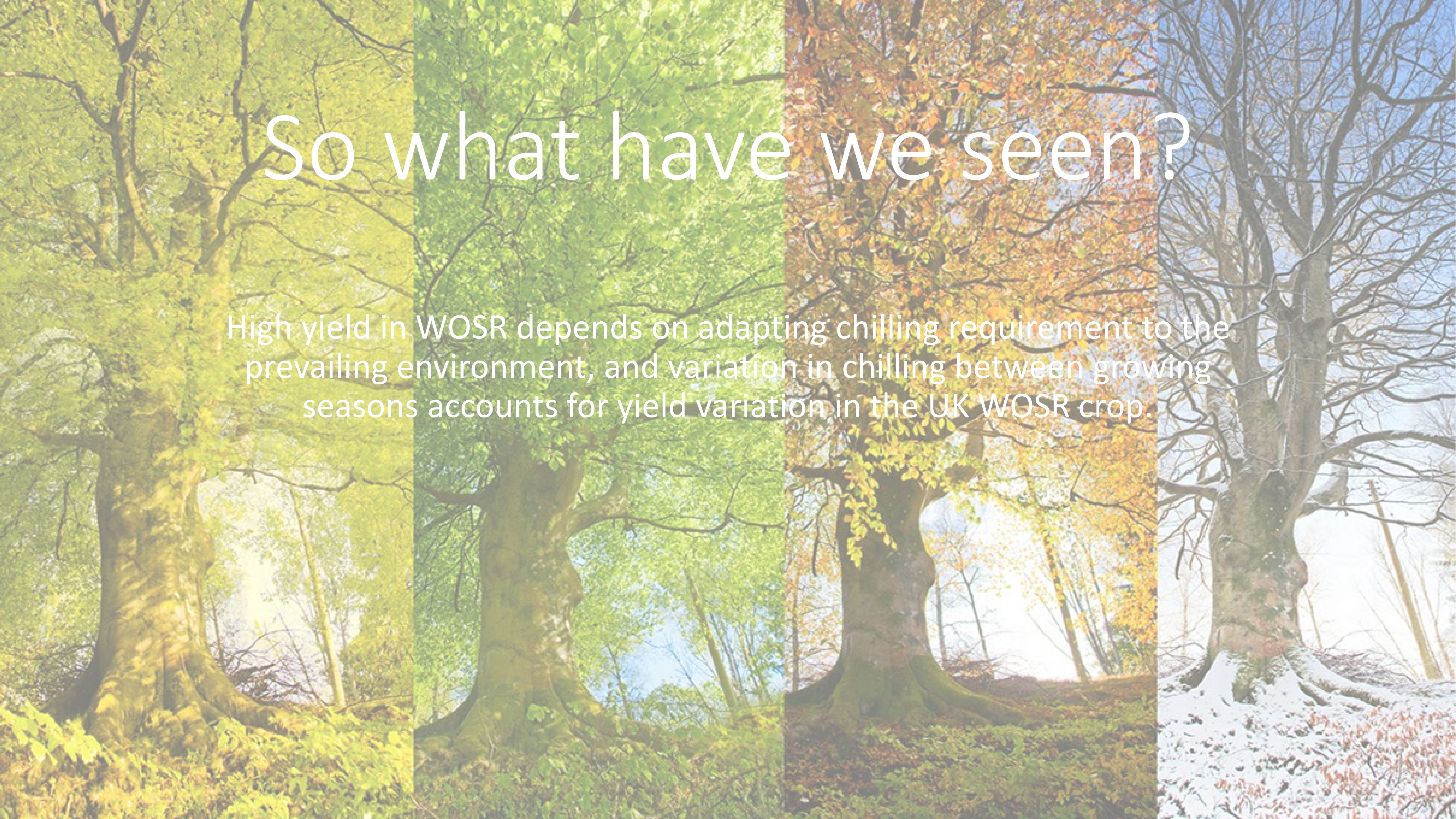


So what have we seen?

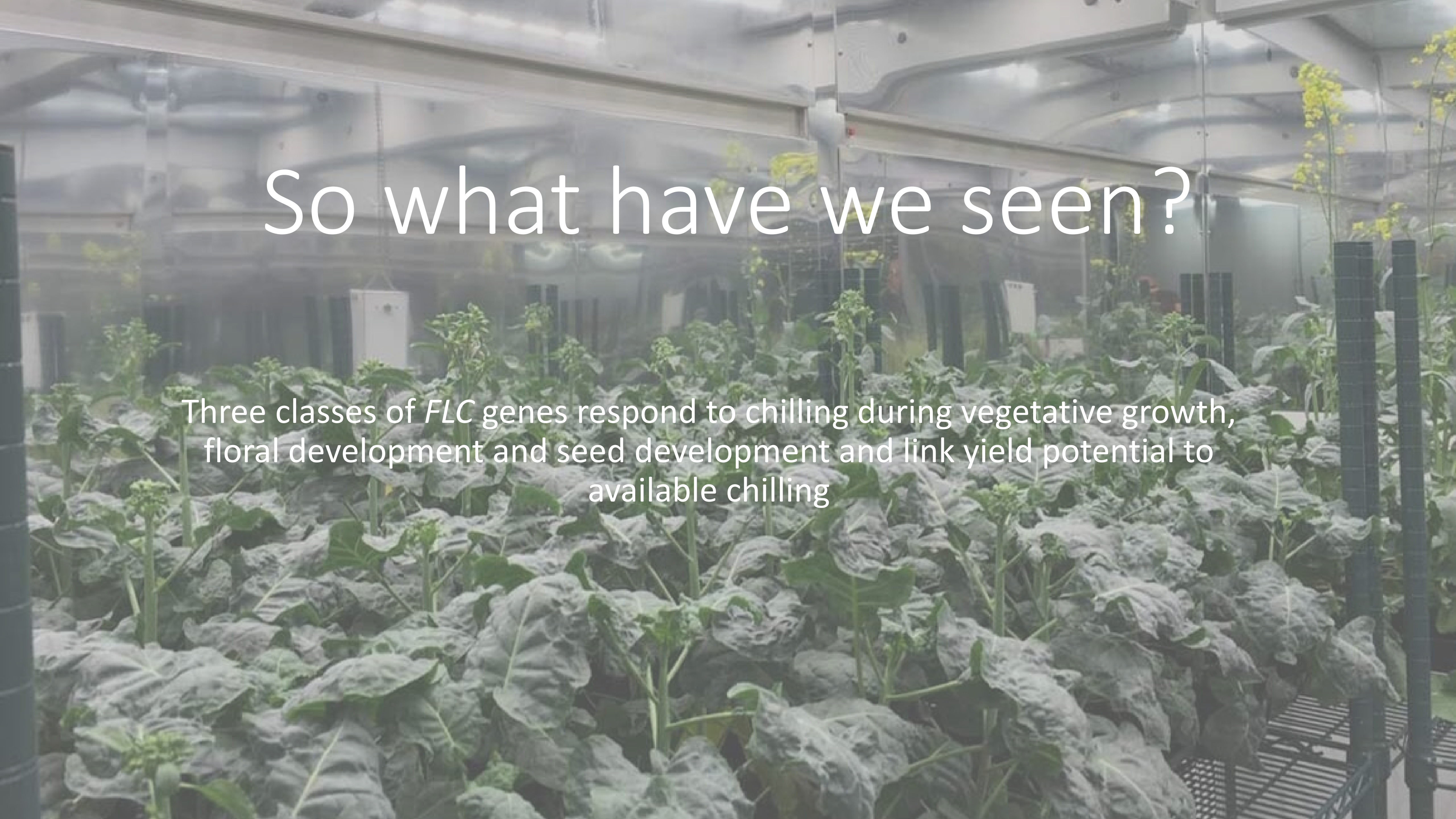
High yield in WOSR depends on adapting chilling requirement to the prevailing environment, and variation in chilling between growing seasons accounts for yield variation in the UK WOSR crop.

So what have we seen?

WOSR has a winter flower bud requirement for chilling in a manner that parallels perennial species.

So what have we seen?

FLC can also directly affect seed traits such as thousand grain weight and contribute to variation in TGW between growing seasons



So what have we seen?

Three classes of *FLC* genes respond to chilling during vegetative growth, floral development and seed development and link yield potential to available chilling

Penfield lab

- Carmel O'Neill
- Xiang Lu (Sichuan Agricultural University)
- Sam Warner
- Becca Doherty
- Catherine Chinoy
- Tom Lock
- Xiaochao Chen
- Thiago Barros-Galvao
- William Bezodis
- Susannah Gill

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Liu Shengyi (OCRI-CAAS, Wuhan)