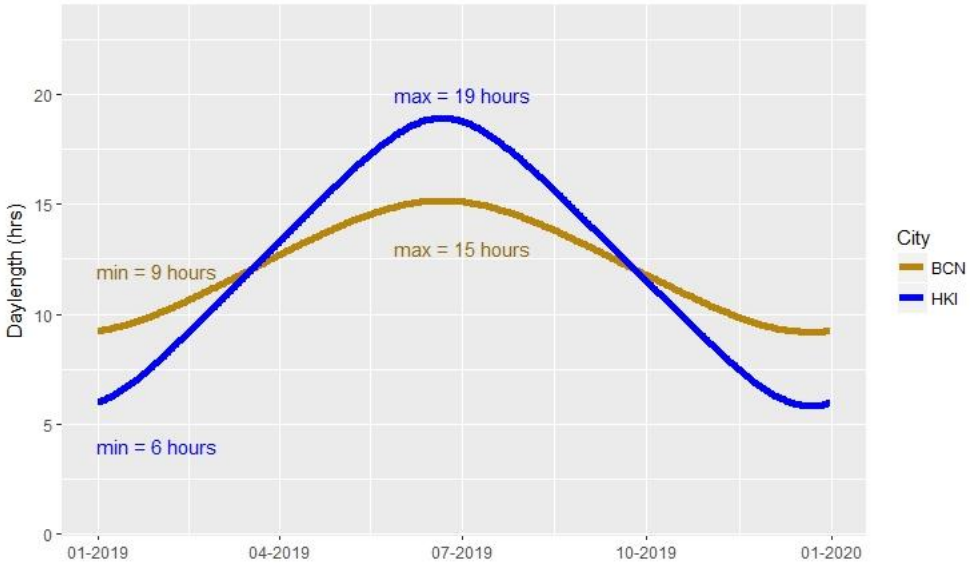
Photoperiodic flowering pathways in *Fragaria*

Elli Koskela

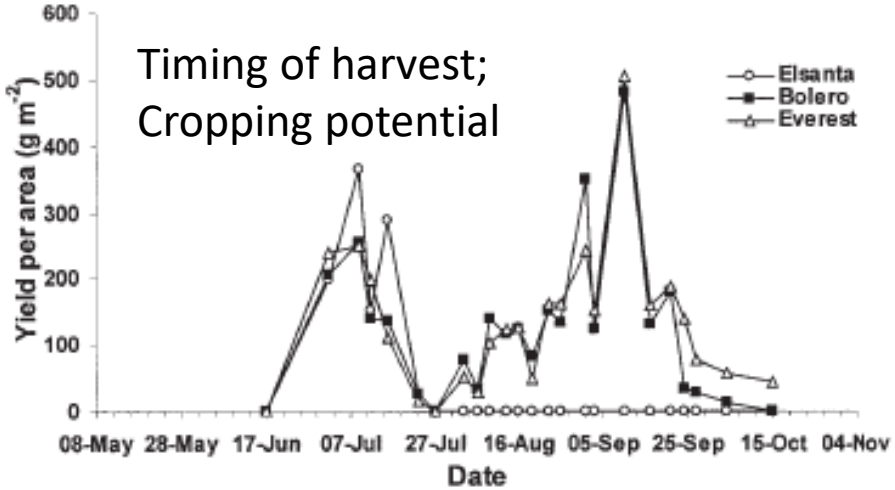
Postdoc
Strawberry group (host: Amparo Monfort)

Why to study photoperiodic responses?



Plant survival in harsh conditions

Frost injury in strawberry flowers

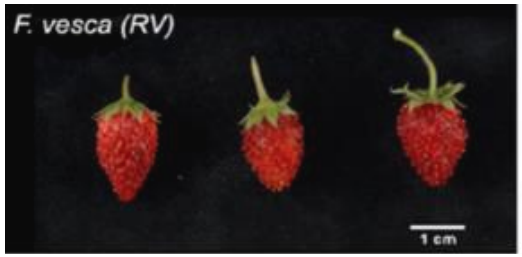


Camacaro et al., 2002

Diploid strawberry Near-Isogenic Lines

Recurrent parent

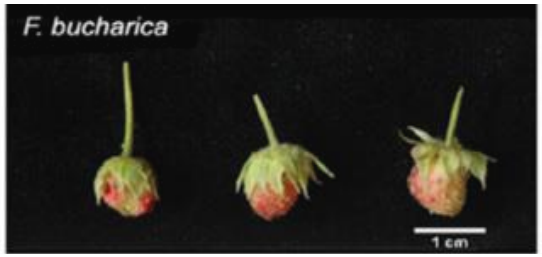
F. vesca 'Reine del Vallées'



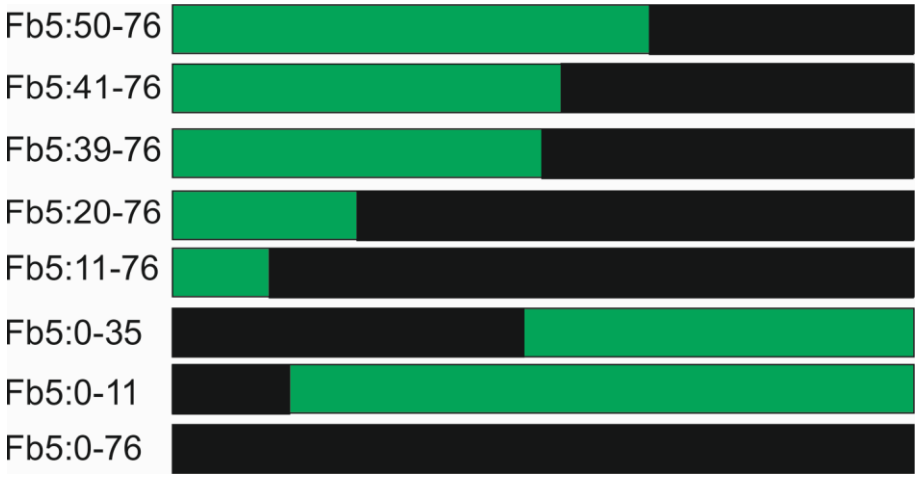
X

Donor parent

F. bucharica



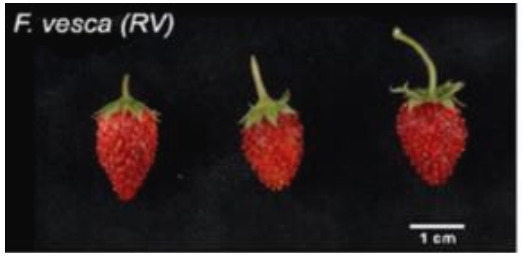
Back-crosses, genotyping, selection, selfing

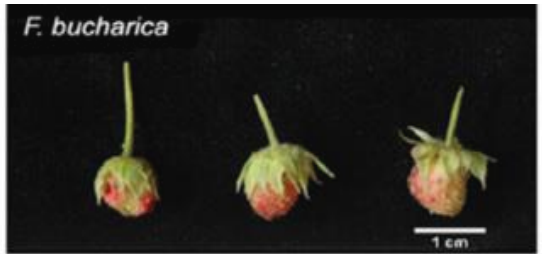


Urrutia et al. 2015. Theor Appl Genet

Diploid strawberry Near-Isogenic Lines

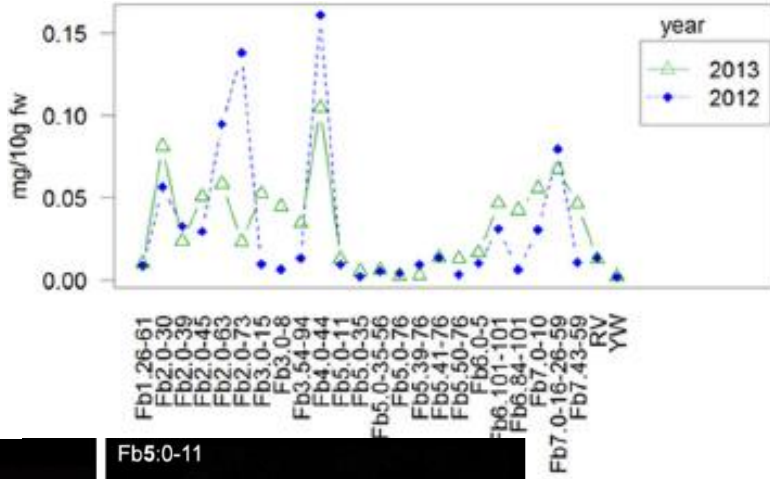
F. vesca 'Reine del Vallées' (RV) X *F. bucharica*





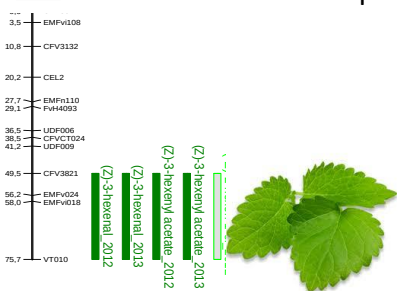
near-isogenic lines segregating for..

Phenolic_compounds

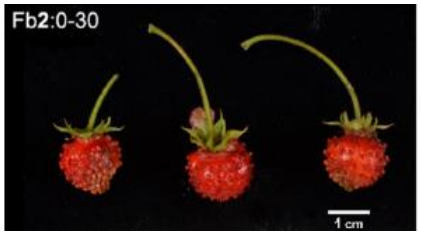


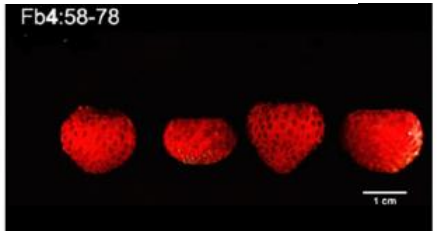
LG5

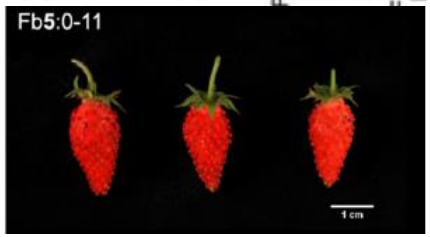
Fruit volatile compounds



Fruit shape, size, fruit sugar content, fruit acid content..







Urrutia et al. 2015. Theor Appl Genet
Urrutia et al. 2016. Plant Science
Urrutia et al. 2017. Plant Physiology and Biochemistry

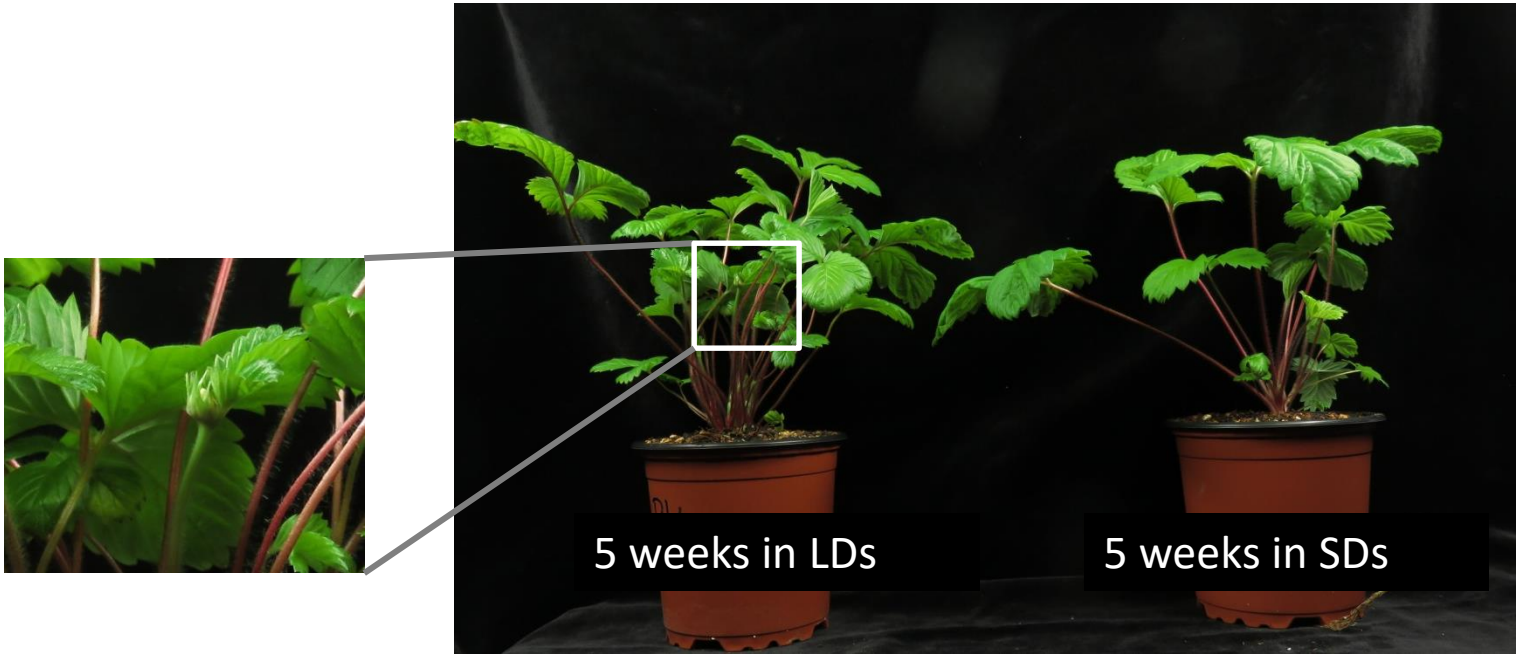
Characteristics of NILs parents

Trait	Reine del Vallees	*F. bucharica*
Photoperiodic flowering	Obligatory long day (LD)	Short day (SD) (?)
Runnering	No	Yes
Fruit aroma	High	Low (?)
Mating	Self-pollinating	Self-incompatible

Urrutia et al. 2015. Theor Appl Genet

Reine del Vallées - flowering

	LD (n = 8)	SD (n = 8)
Percentage flowering	100%	0%
Days to flower (± sd)	41.5 ± 0.9	n/a
Leaves at flowering (± sd)	10.9 ± 0.4	n/a



F. bucharica – flowering

	LD (n = 9)	SD (n = 10)
Percentage flowering	22%	90%
Days to flower	29 ± 0	29.3 ± 3.2

F. bucharica at week 0

Flowering time phenotypes

Table 2 Position of Mendelian traits (A) and QTLs for quantitative agronomic traits (B)

Trait	Name	Effect	% Effect	LG	Initial position (cM)	Final position (cM)	Stability	Shortest NIL
(A)								
Runners	*R*[a]	Presence of runners	–	2	39 (Fvi11)	47 (EMFn134)	All	Fb**2**:39–47
Floral stem length	*LFS*	Longer floral stems	–	2	39 (Fvi11)	47 (EMFn134)	All	Fb**2**:39–47
	SFS	Shorter floral stems	–	5	29 (FvH4093)	39 (CFVCT024)	All	Fb**5**:20–76
Pink petals	*PSP*	Pink spot on petal base	–	1	50 (UFF02F02)	61 (CFV164)	All	Fb**1**:50–61
Petals number	*EPN*	>5 petals/flower	–	3	54 (CFVCT022)	94 (CFVCT012)	All	Fb**3**:54–94
Seasonal flowering	*SDF*	Short-day flowering	–	5	35 (UDF006)	39 (CFVCT024)	All	Fb**5**:20–76
Flowering	*LLF*	Flowering >1 year later	–	6	30 (EMFn117)	38 (EMFn017)	All	Fb**6**:30–39
Plant size	*DWARF*	Dwarf plants	–	3	15 (VT398)	29 (UDF017)	All	Fb**3**:8–94
Germination	*DOG*	Delay of germination	–	5	39 (CFVCT024)	41 (UDF009)	3	Fb**5**:39–76

Trait	QTL name	Effect	% Effect	LG	Initial position (cM)	Final position (cM)	Stability	Shortest NIL
(B)								
Fruit shape	FRS_2	Rounded fruit	−24	2	0 (EMFvi099)	30 (BFACT002)	5/5	Fb**2**:0–30
	FRS_4	Rounded fruit	−35	4	58 (CEL1)	78 (ChFaM23)	5/5	Fb**4**:58–78
	FES_5	Elongated fruit	25	5	0 (CFV3072)	11 (CFV3132)	4/5	Fb**5**:0–11
Weight	FLW_1	Smaller fruit	−70	1	50 (UFF02F02)	61 (CFV164)	3/3	Fb**1**:50–61
	FLW_4	Smaller fruit	−79	4	58 (CEL1)	78 (ChFaM23)	2/3	Fb**4**:58–78
Flowering	EF[b]	Early flowering	−30	6	0 (ARSFL007)	11 (EMFn228)	2/2	Fb**6**:0–5
	LF	Late flowering	36	5	11 (CFV3132)	20 (CEL2)	2/2	Fb**5**:11–76

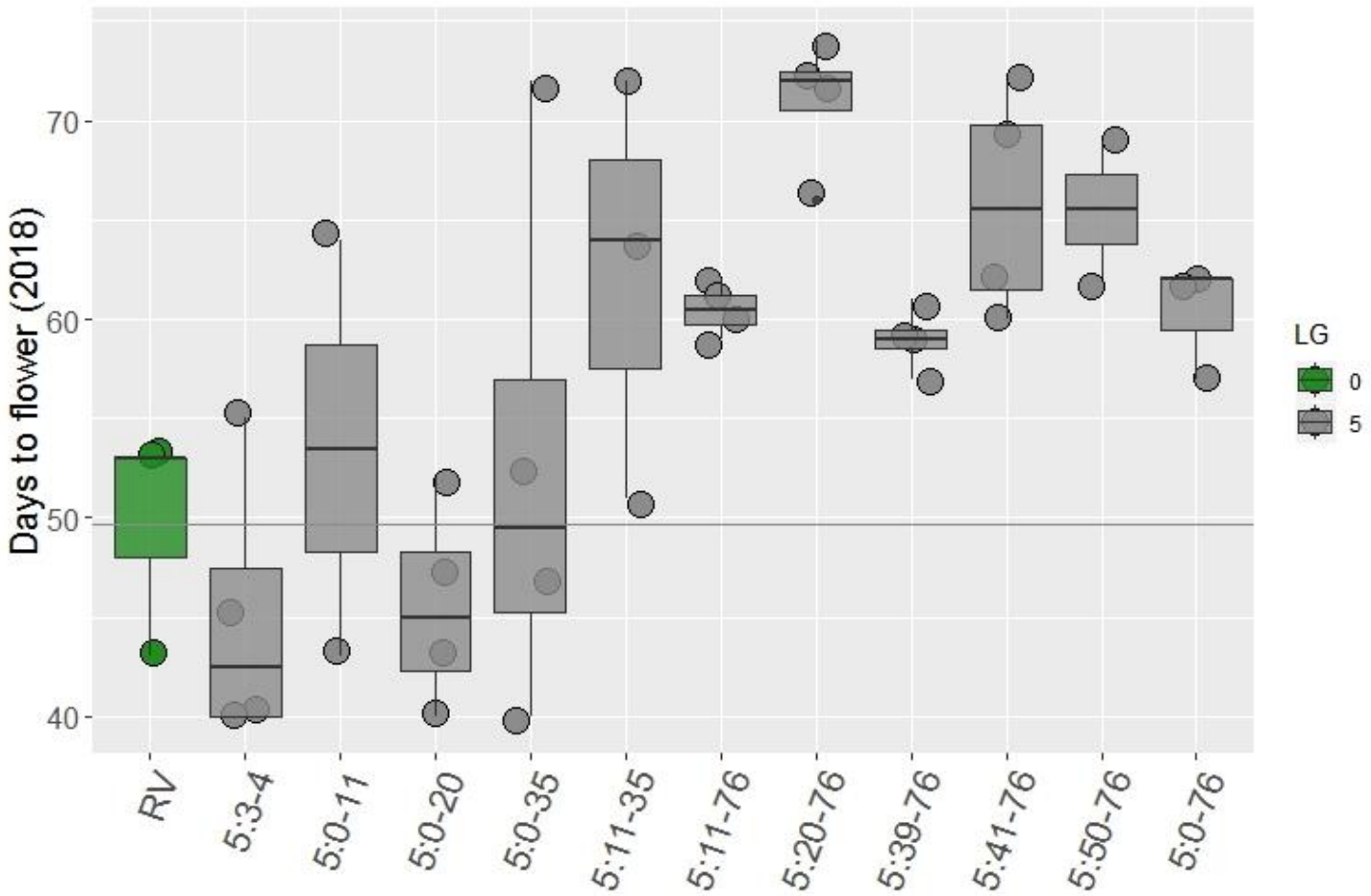
Trait, name of QTL, effect percentage means average of trait value on NIL compared to RV trait value, bin position and markers flanking the bin, stability as number of harvests observed over total measured and the shortest NIL showing trait effect

[a] Locus R (mapped at LG2: 45.2 cM)

[b] Compared to population mean

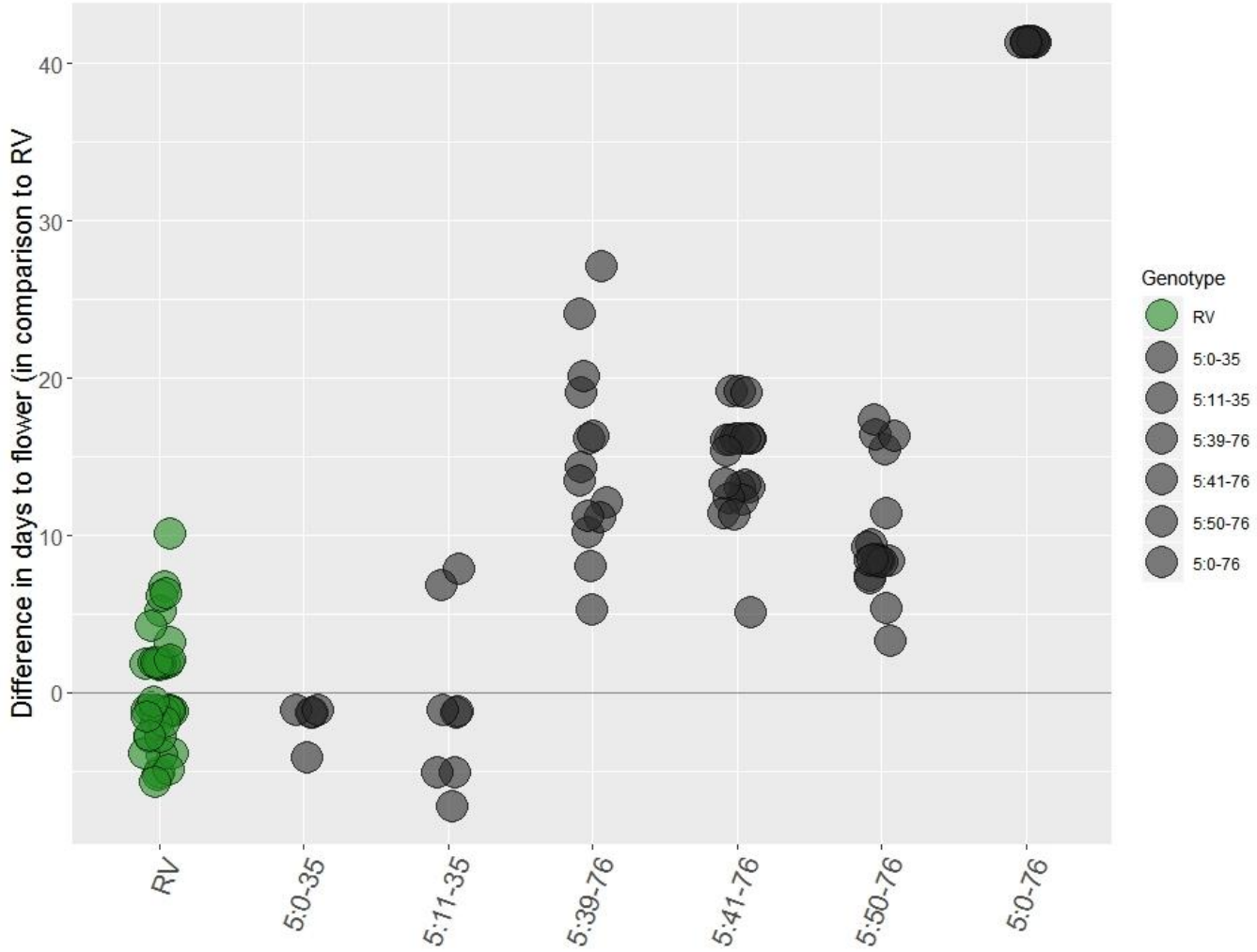
Urrutia et al. (2015)

Late flowering in LG5 NILs



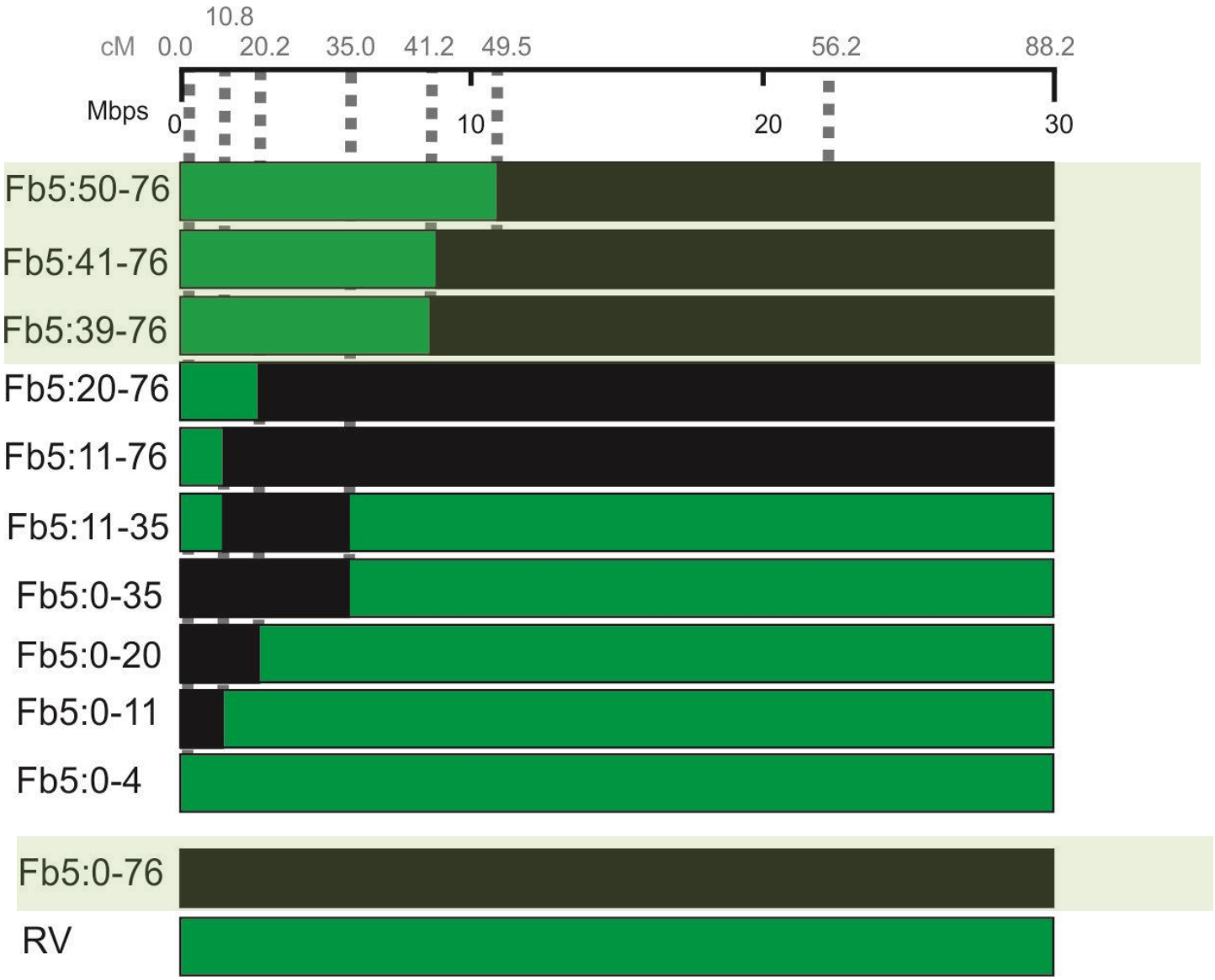
Days to flower (from March 15th 2018) in outdoor conditions (Torre Marimon)

Late flowering in LG5 NILs

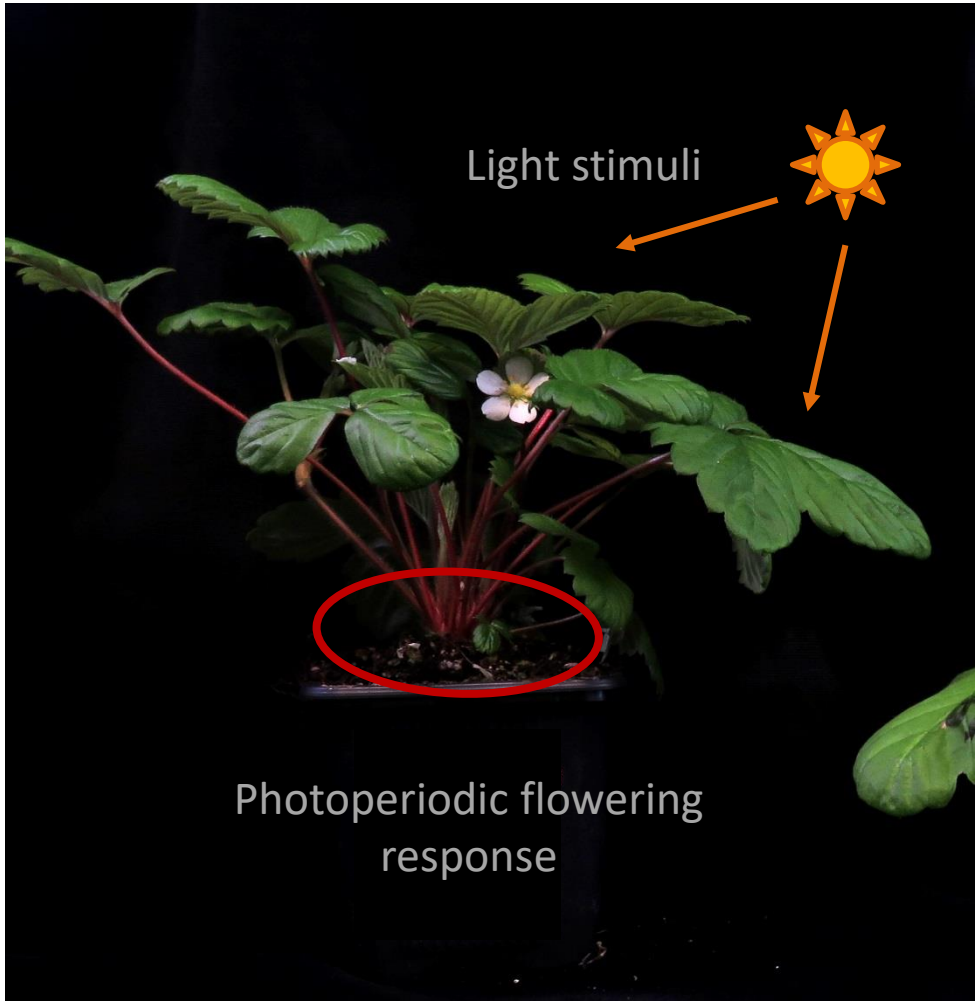


Flowering time in controlled climate (16-hour long days, 22°C)

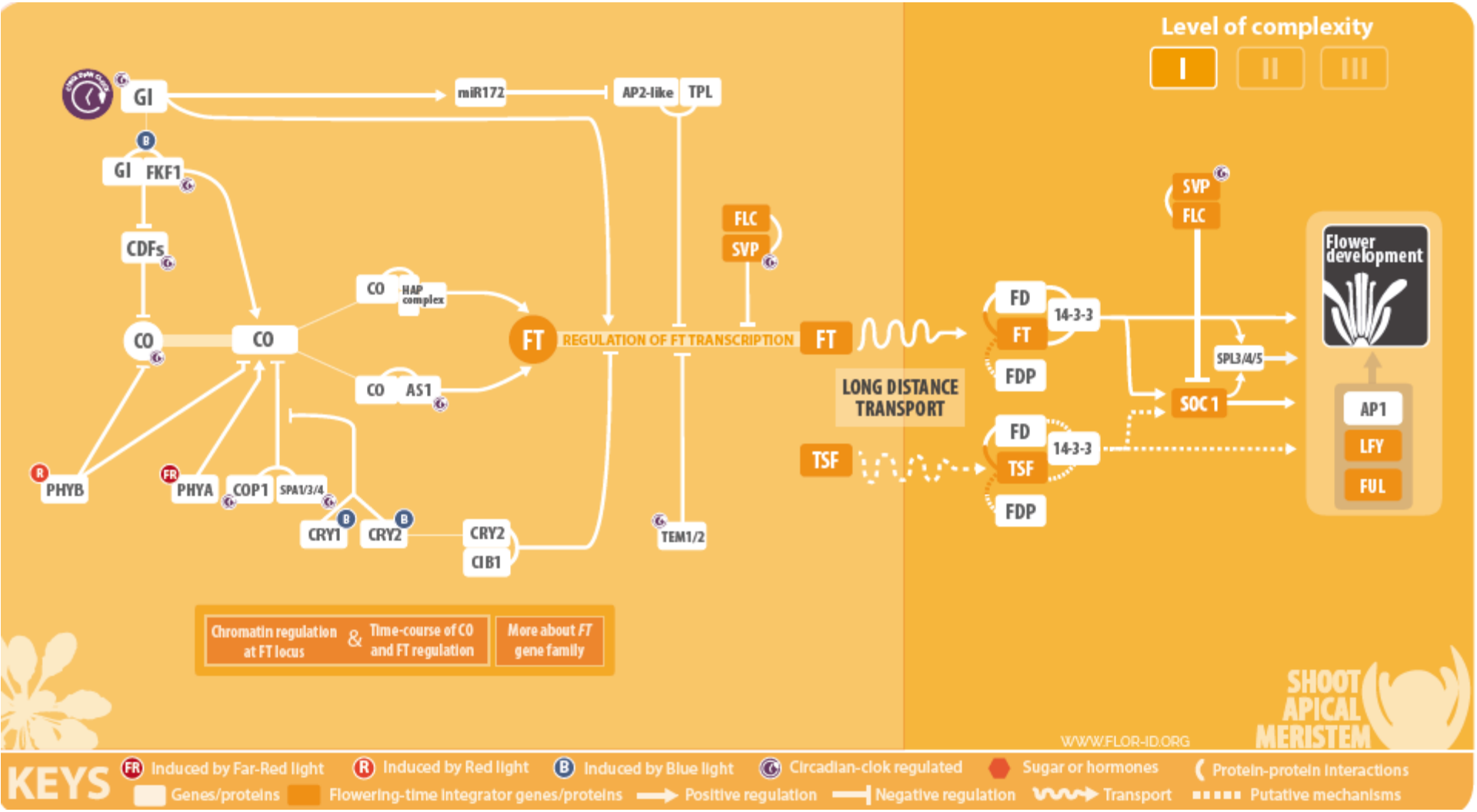
Late flowering phenotype in LG5



Photoperiodic pathway

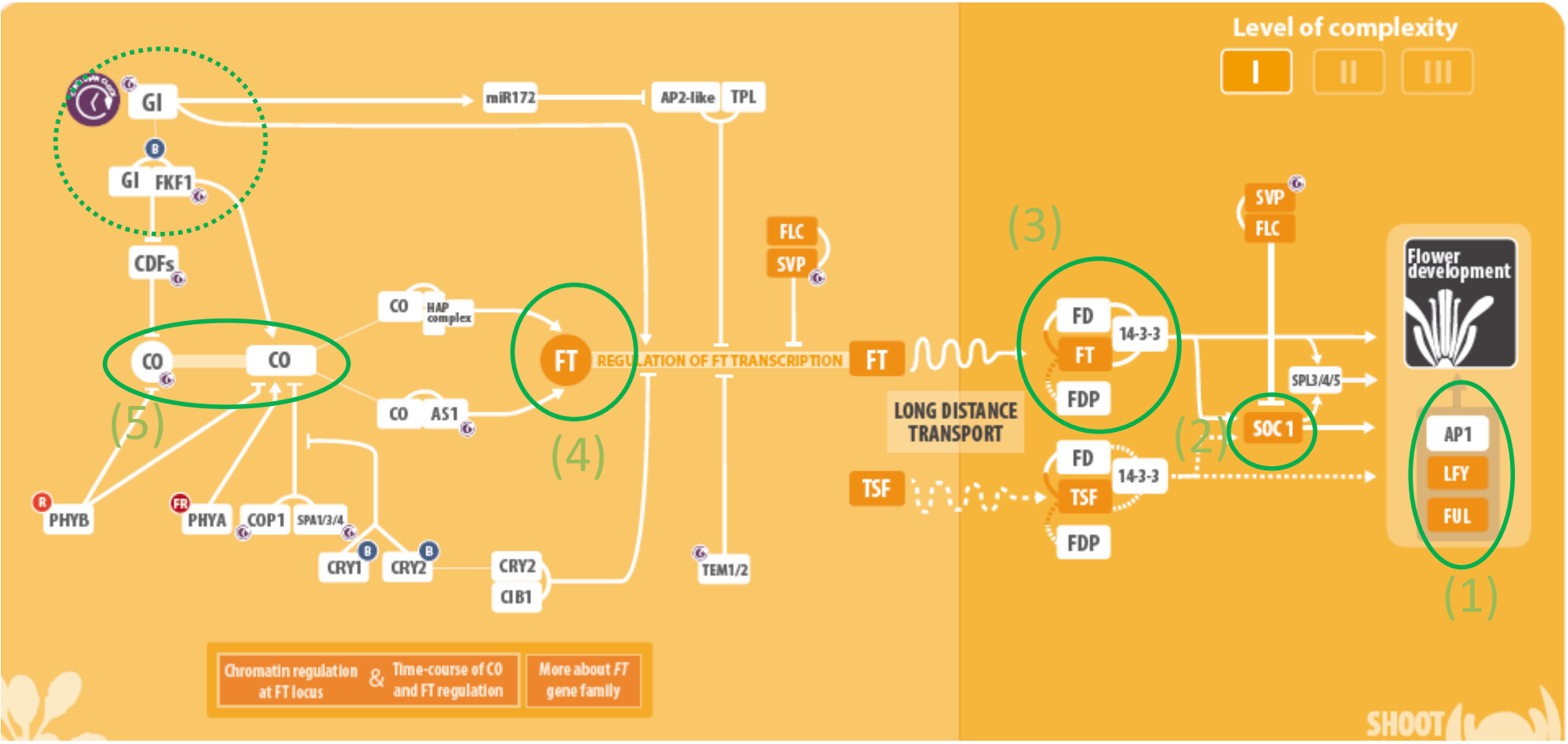


Photoperiodic pathway in Arabidopsis



Flowering Interactive Datebase (Flor-ID): Bouché, Lobet et al. (2016) Nucleic Acid Research

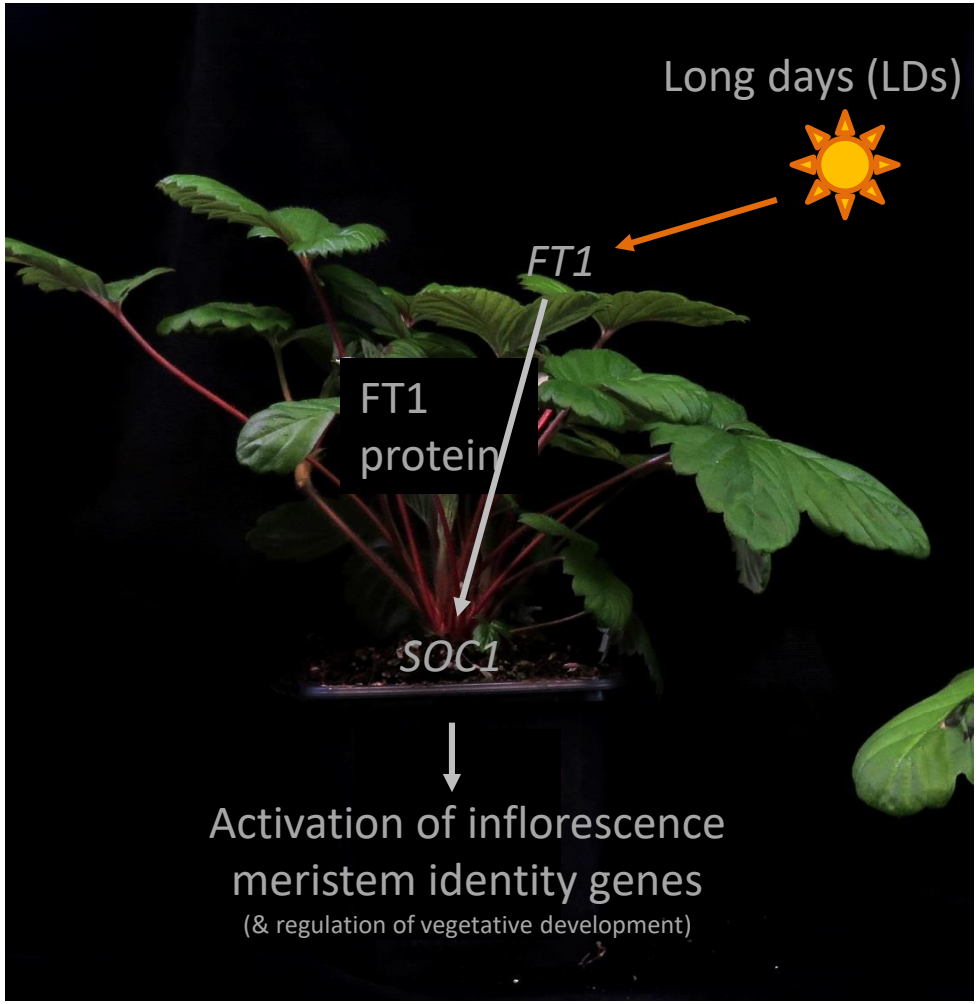
Photoperiodic pathway in Arabidopsis.. And in strawberry?



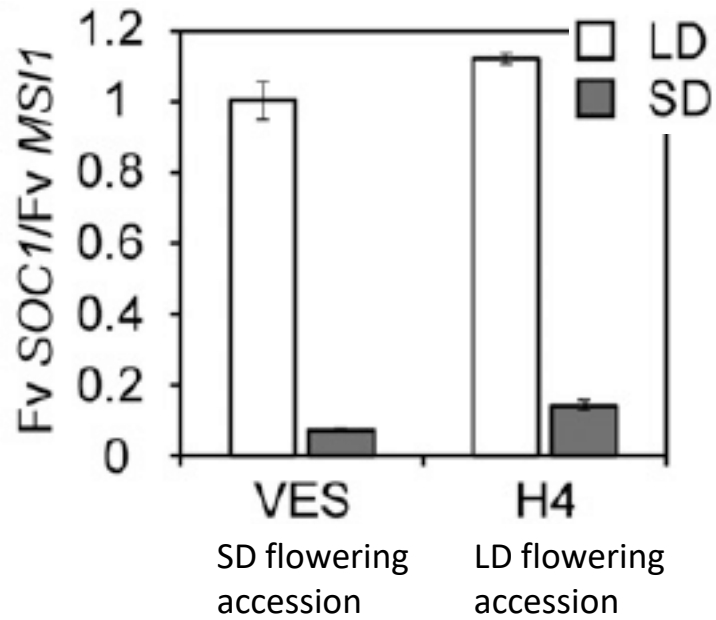
Flowering Interactive Datebase (Flor-ID): Bouché, Lobet et al. (2016) Nucleic Acid Research

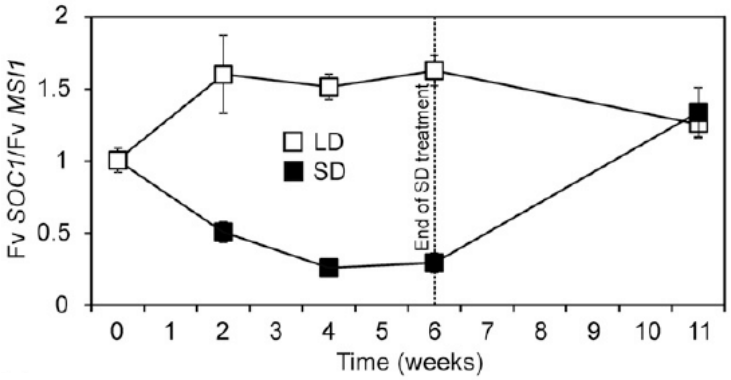
(1) Mouhu et al (2009) BMC Plant Biology
(2) Mouhu et al (2013) Plant Cell
(3) Randoux et al (2014) New Phytologist
(4) Koskela et al (2012) Plant Physiology
(5) Kurokura et al (2017) J Exp Bot

Photoperiodic flowering pathway in *F. vesca*



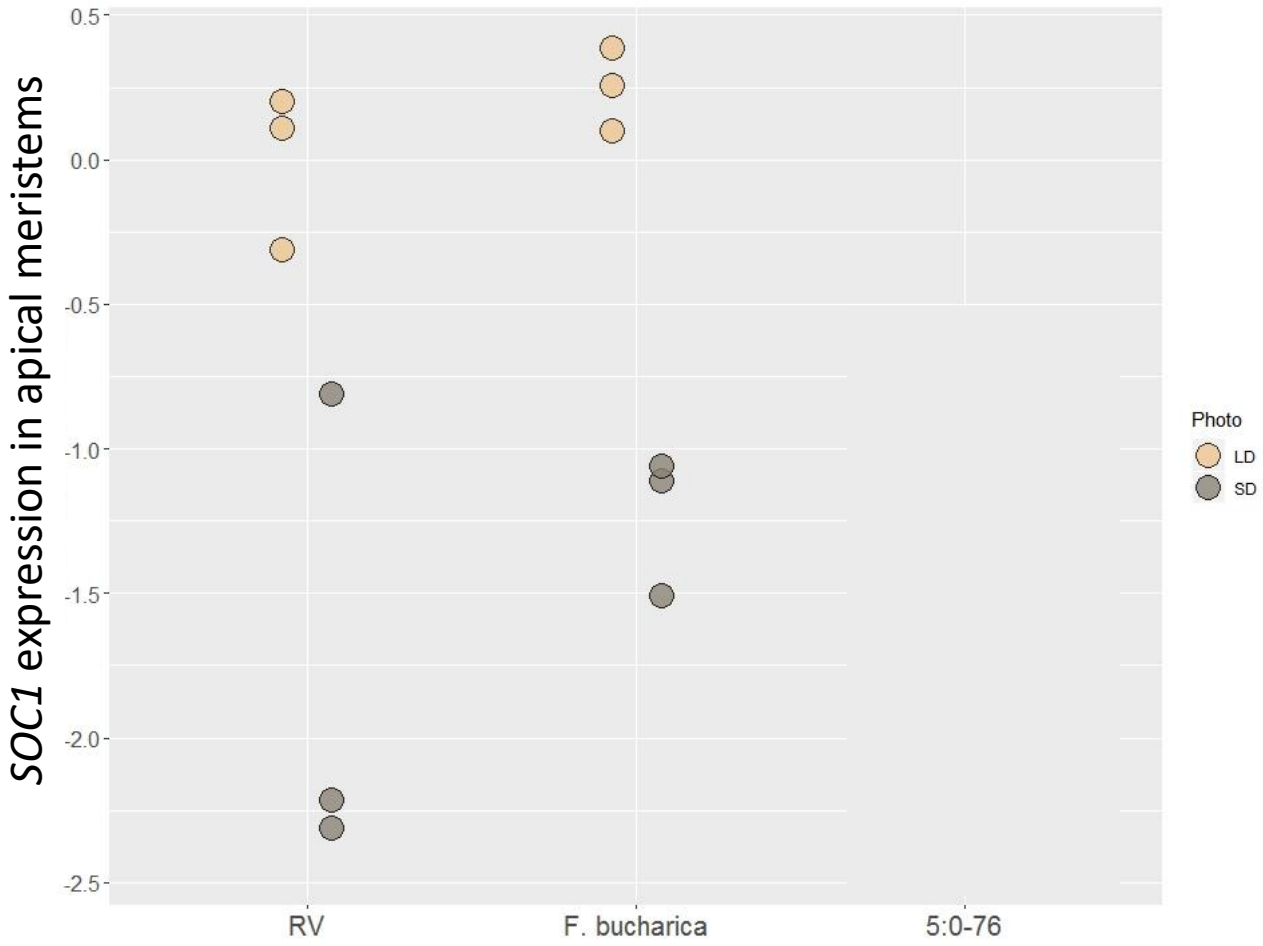
SOC1 expression in apical meristems





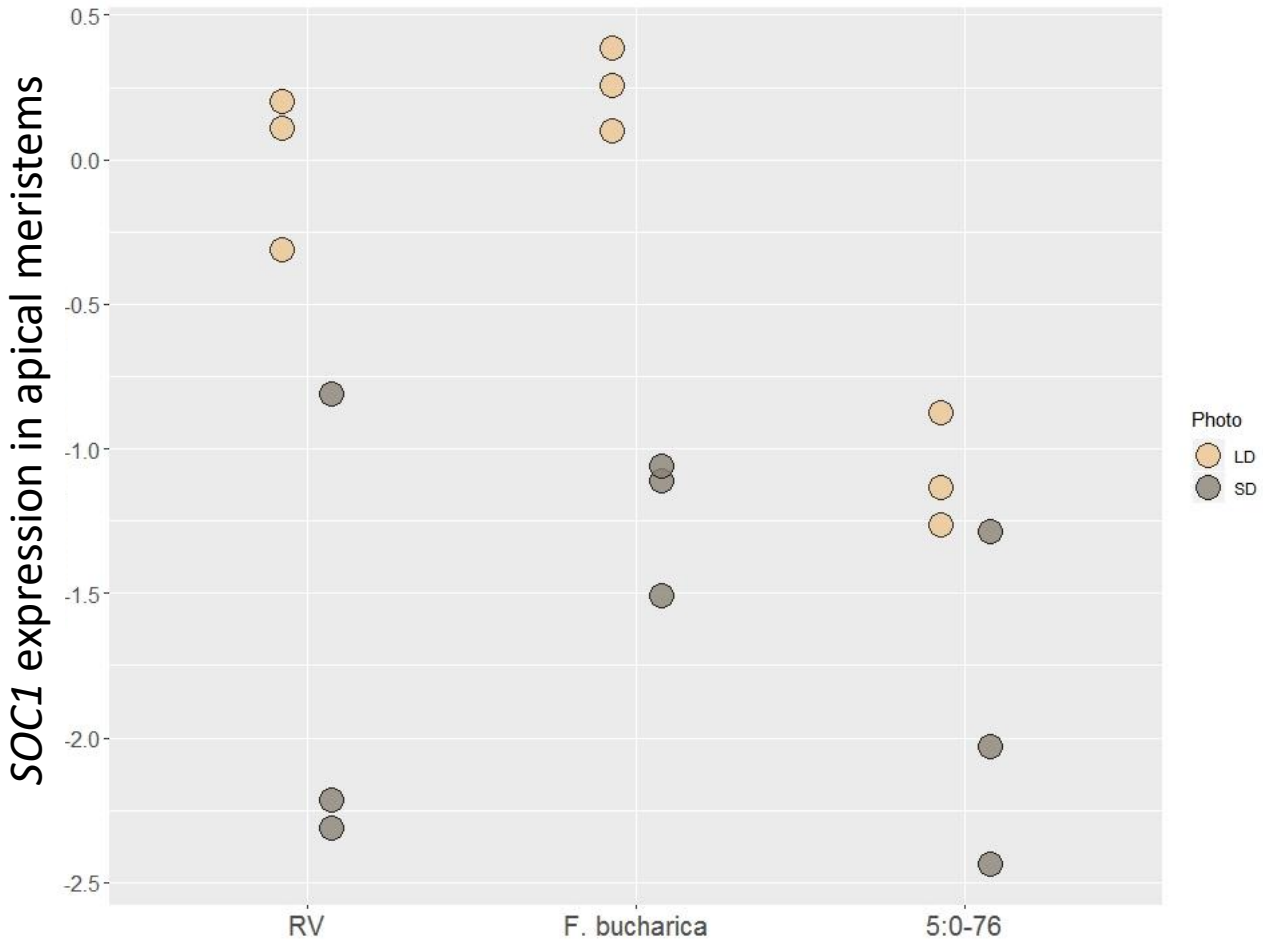
Mouhu et al. 2013. The Plant Cell

Photoperiodic pathway in LG5 NILs



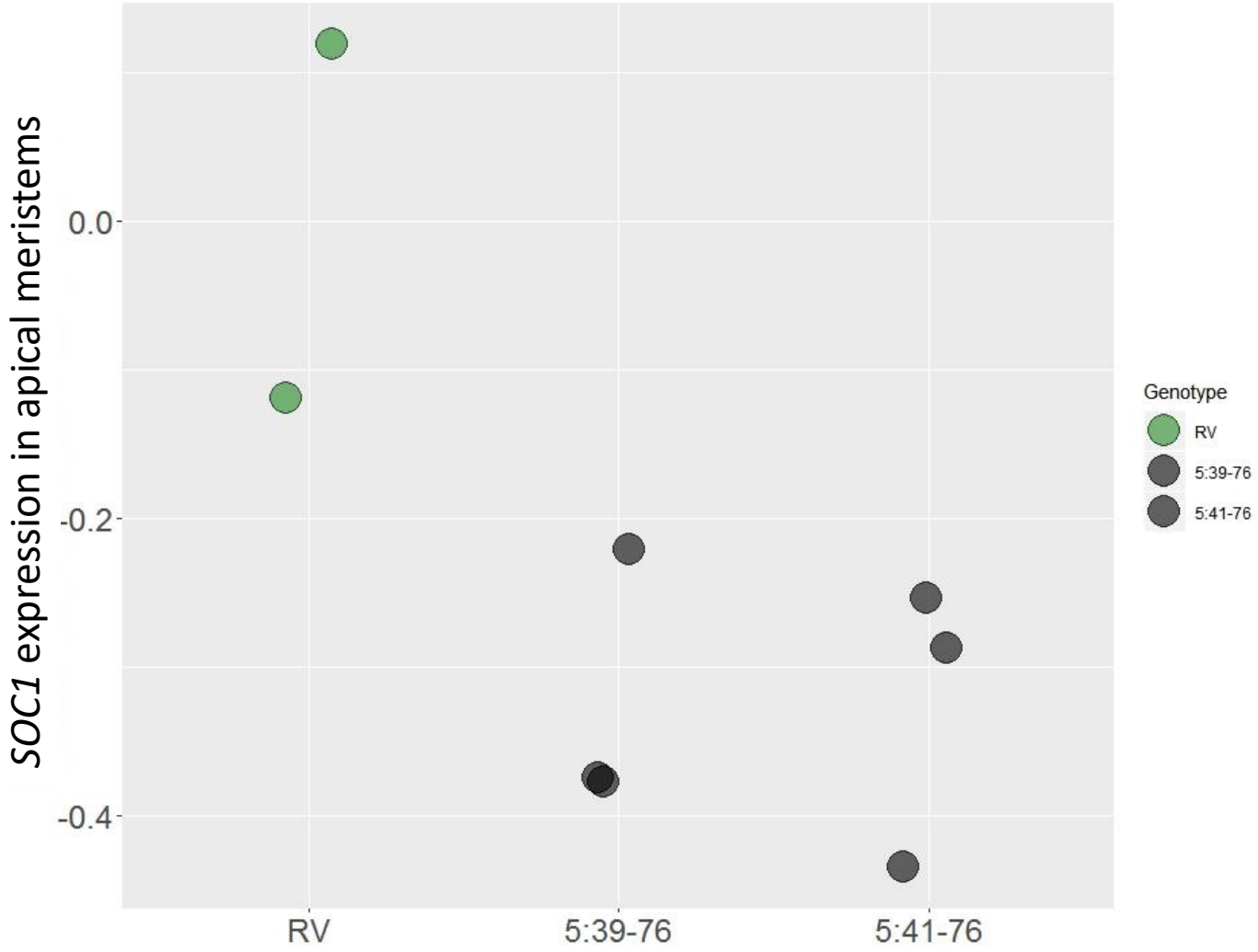
Samples collected after four weeks under LDs or SDs (22°C)

Photoperiodic pathway in LG5 NILs



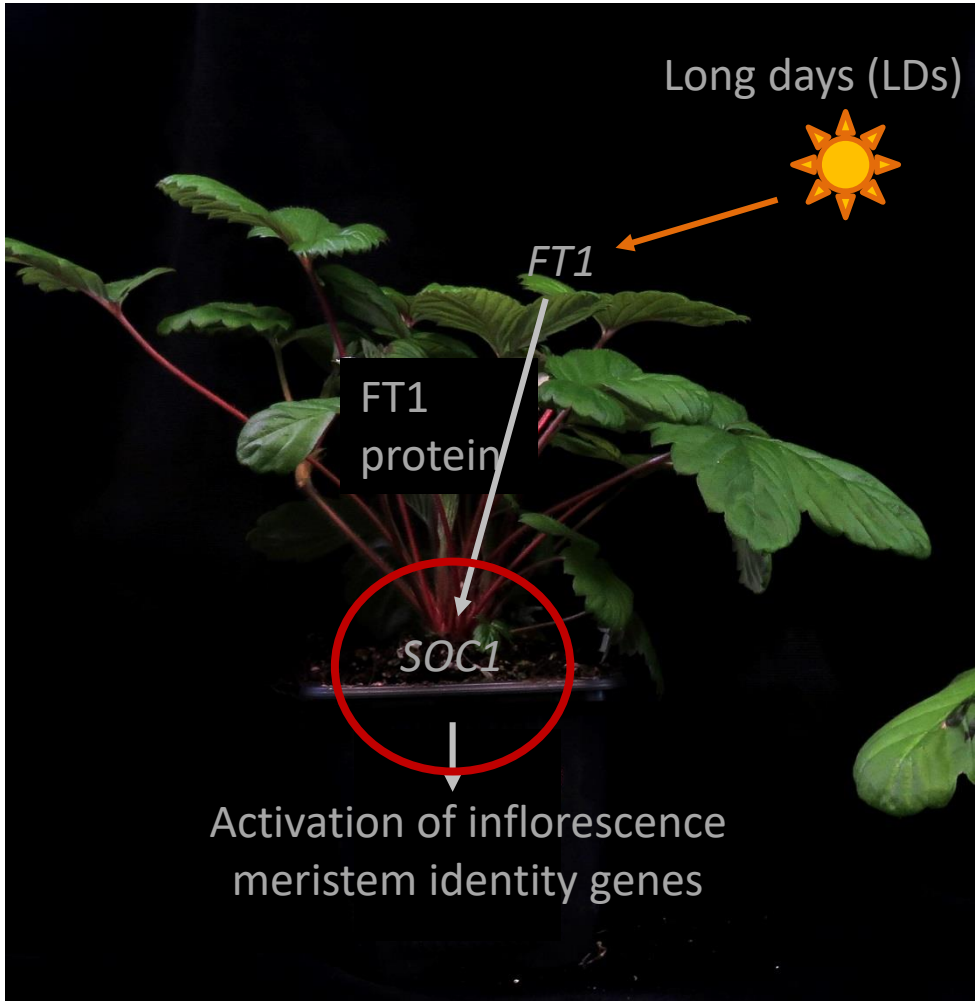
Samples collected after four weeks under LDs or SDs (22°C)

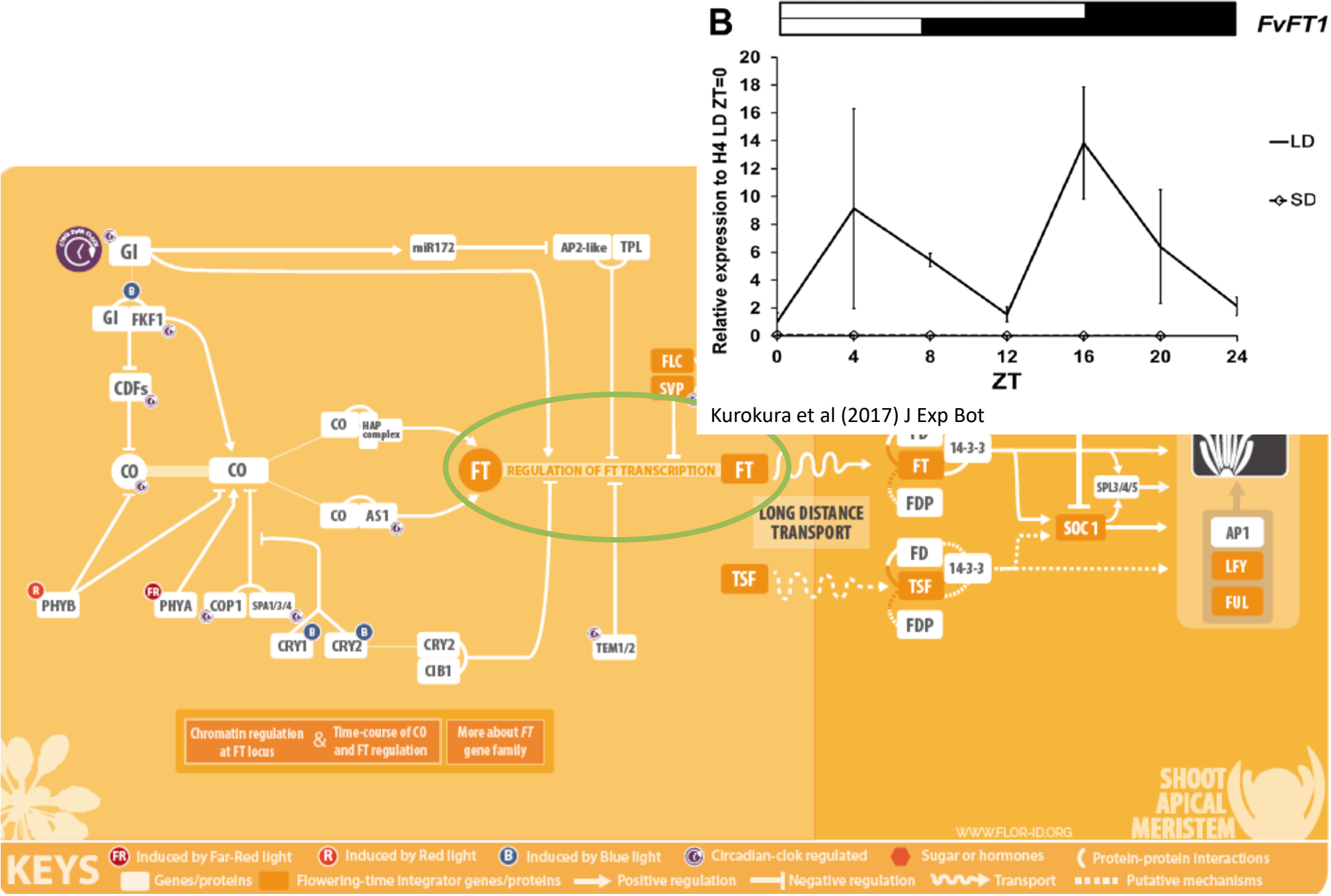
Photoperiodic pathway in LG5 NILs



Samples collected after ten weeks under LDs (22°C)

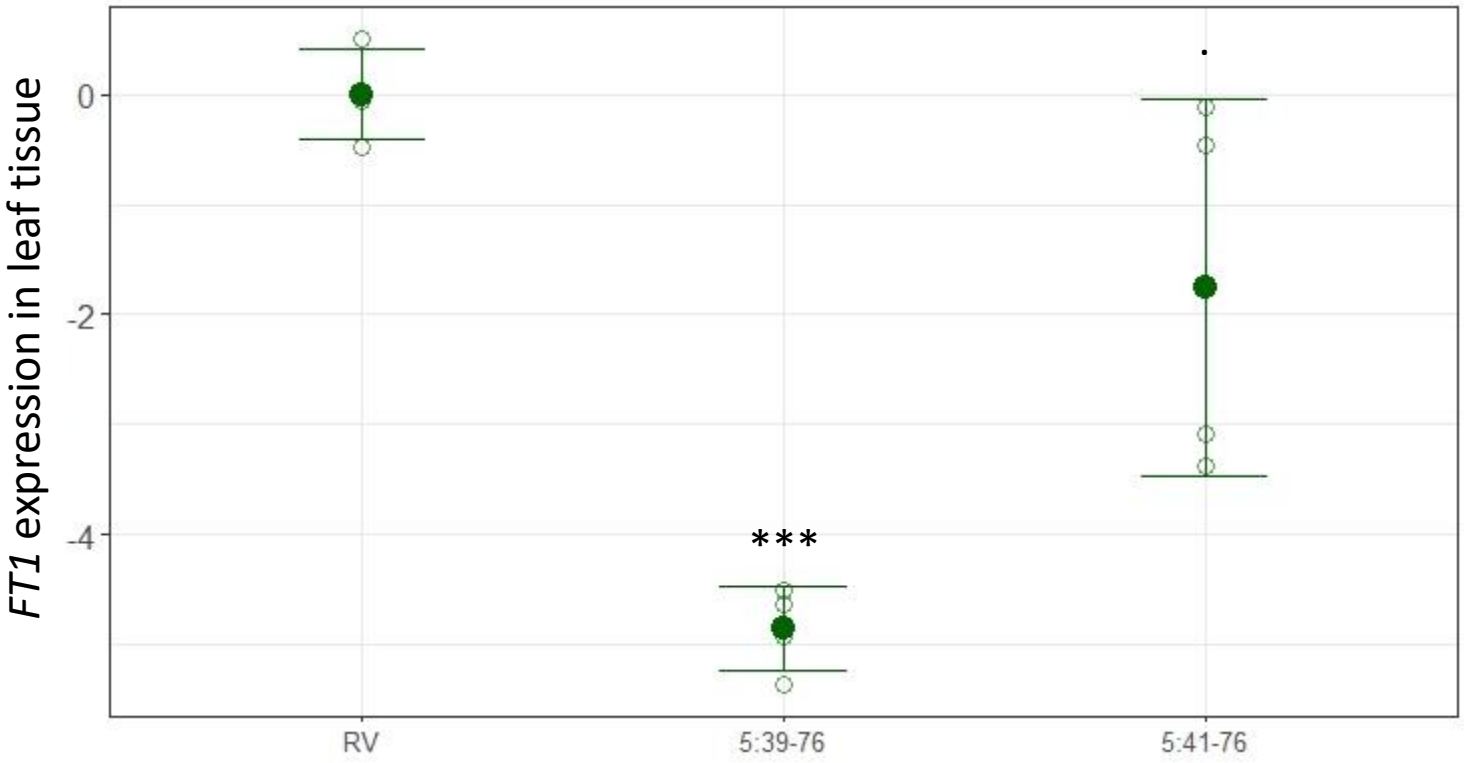
Photoperiodic pathway in LG5 NILs





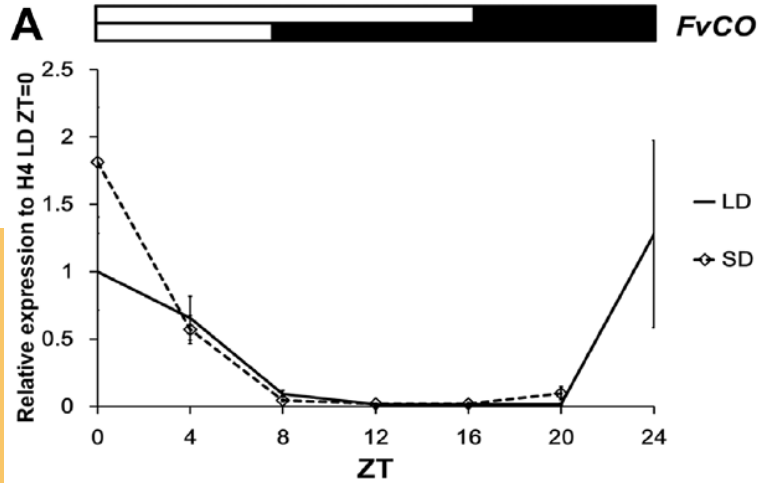
Flowering Interactive Datebase (Flor-ID): Bouché, Lobet et al. (2016) Nucleic Acid Research

Photoperiodic pathway in LG5 NILs

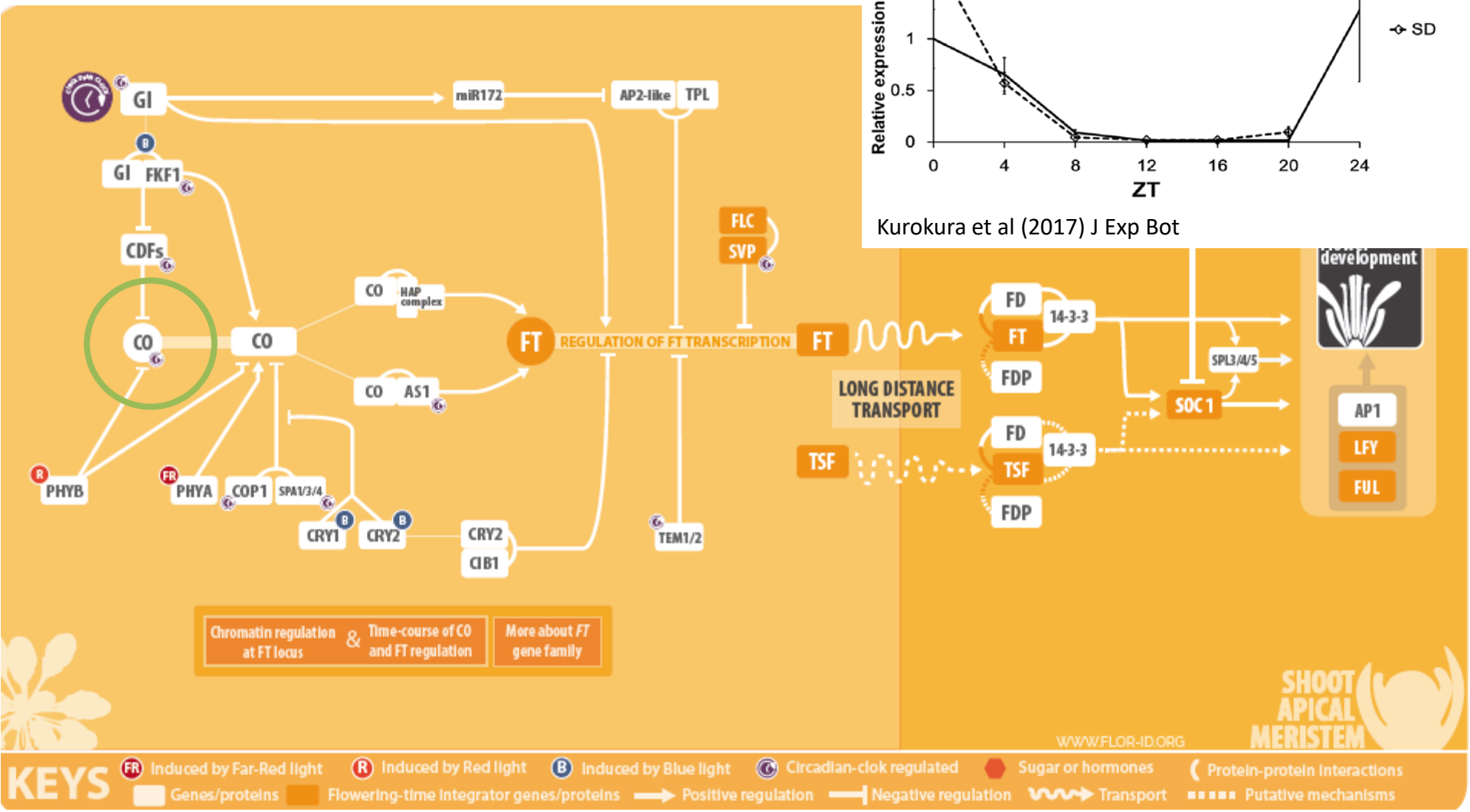


. p < 0.1
*** p < 0.001
(Dunnet´s test)

Plants grown in LDs 22°C, sampling at ZT04

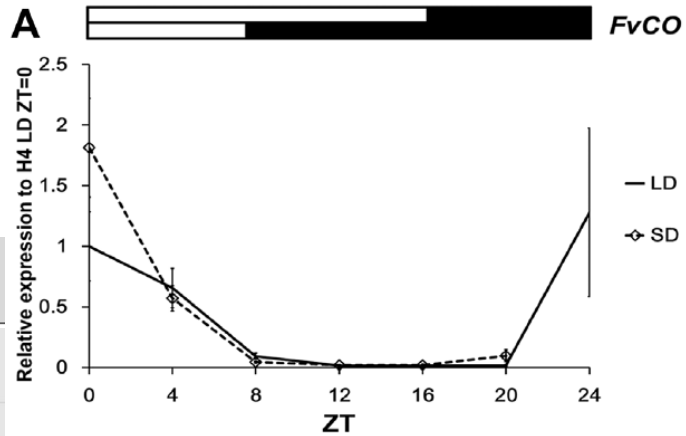


Kurokura et al (2017) J Exp Bot

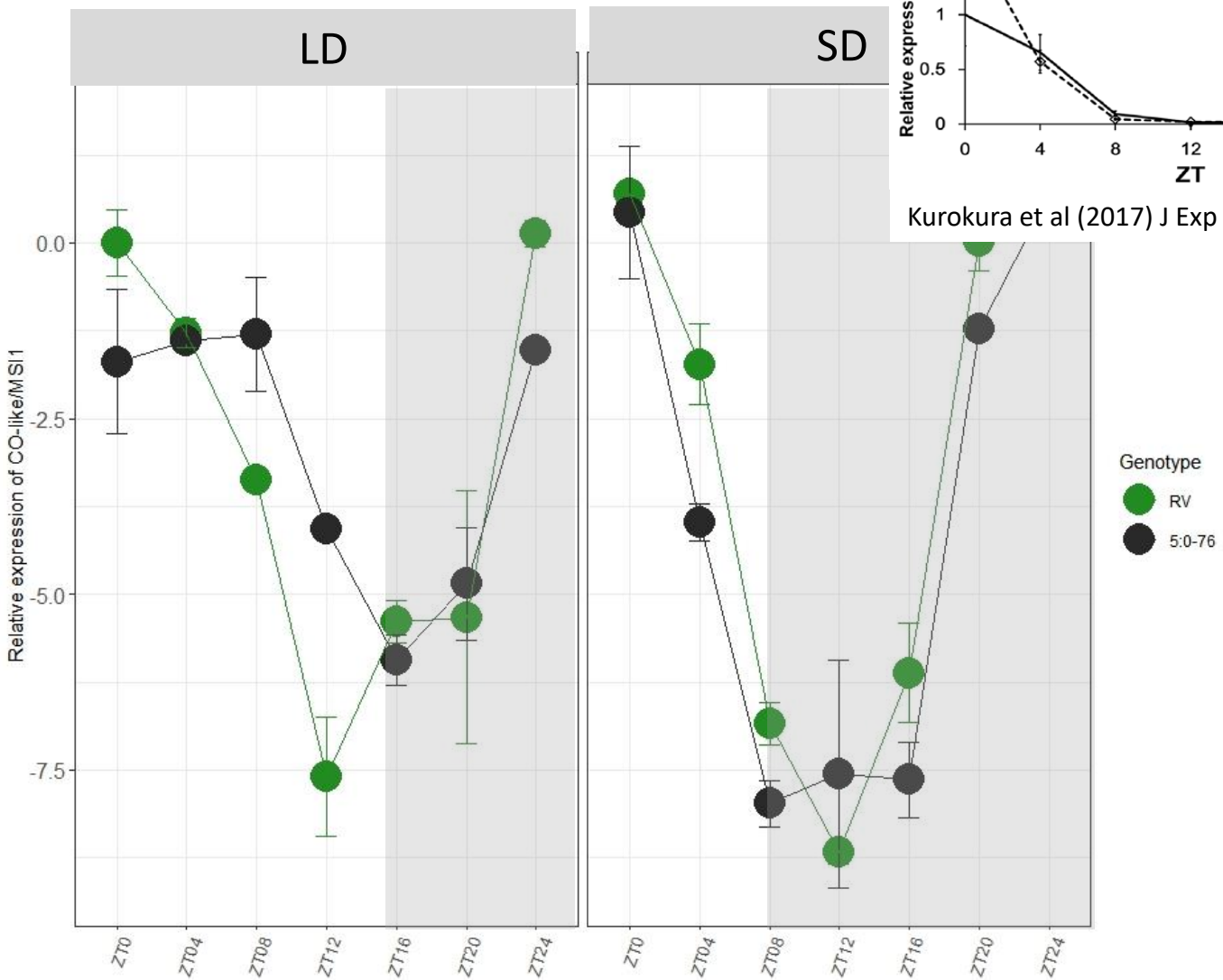


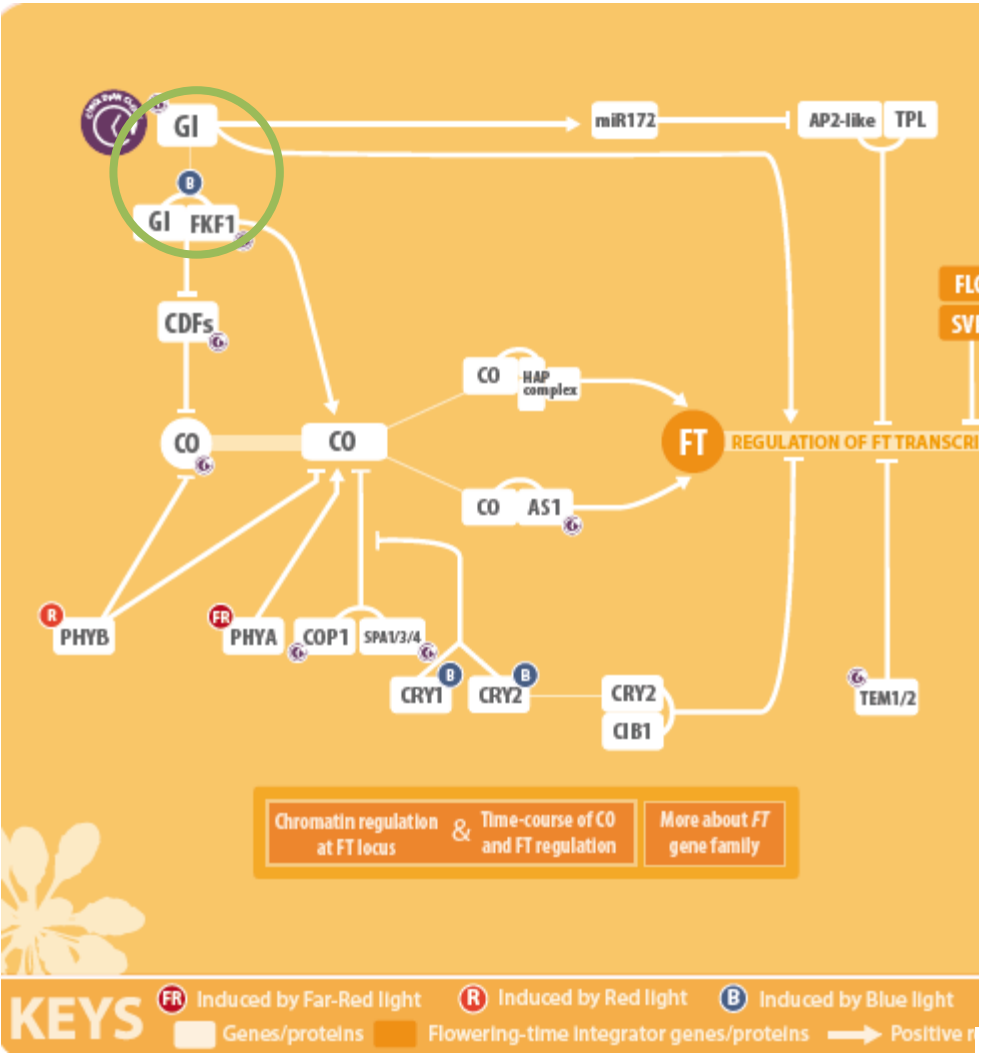
Flowering Interactive Datebase (Flor-ID): Bouché, Lobet et al. (2016) Nucleic Acid Research

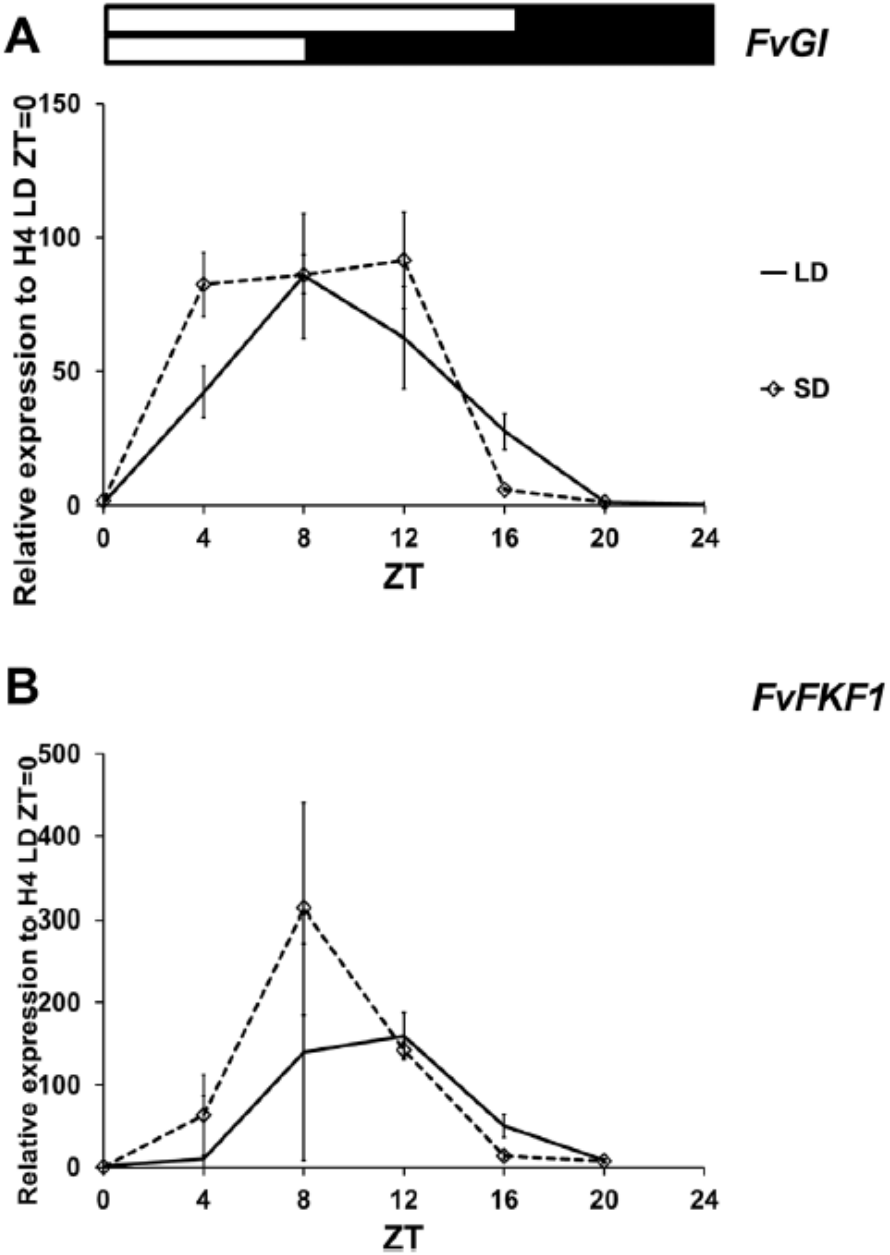
FvCO diurnal rhythm



Kurokura et al (2017) J Exp Bot



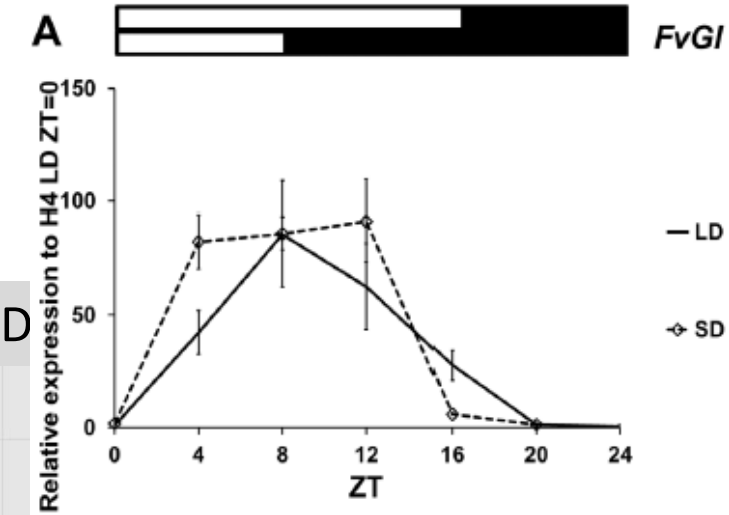




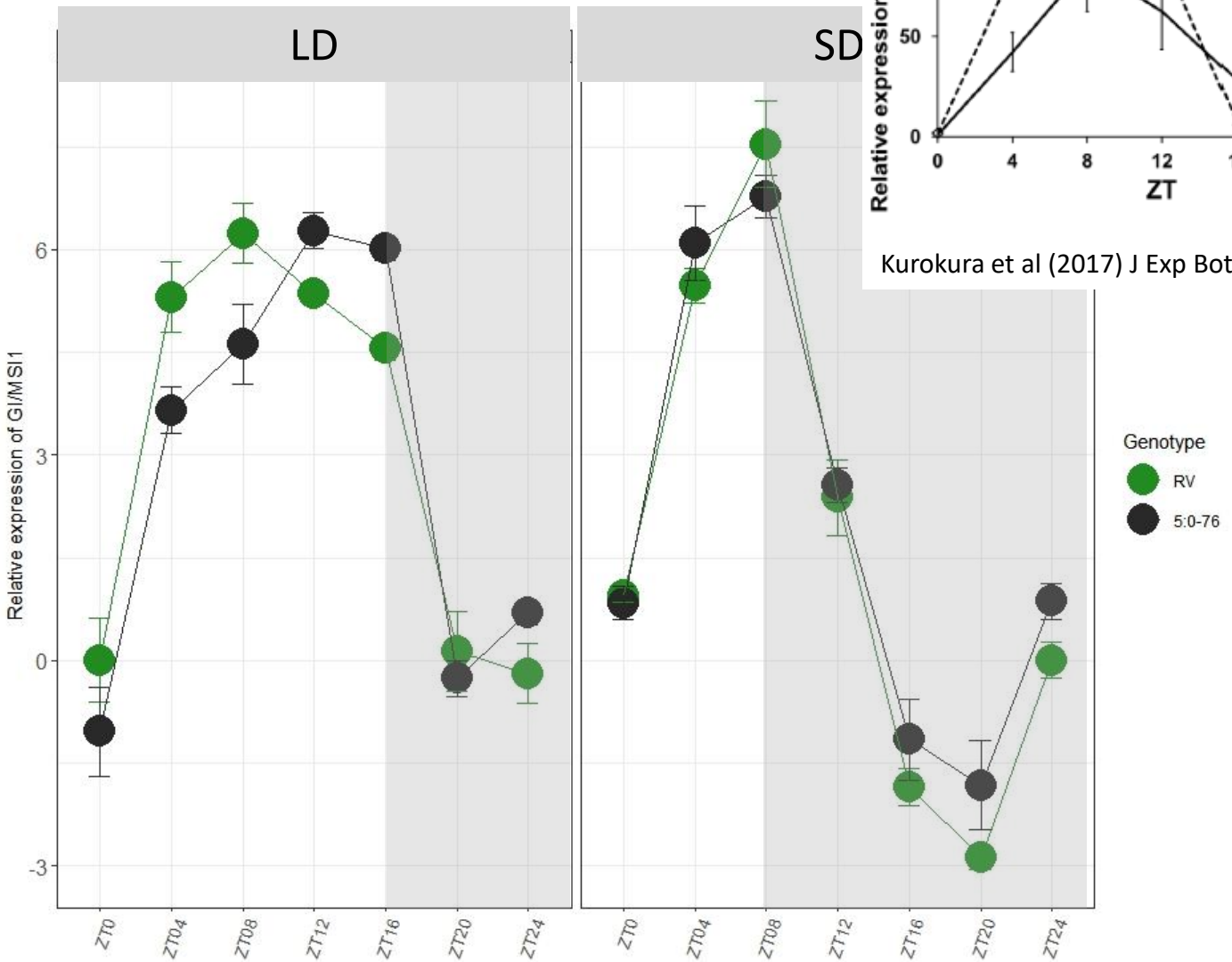
Kurokura et al (2017) J Exp Bot

Flowering Interactive Datebase (Flor-ID): Bouché, Lobet et al. (2016) Nucleic Acid Research

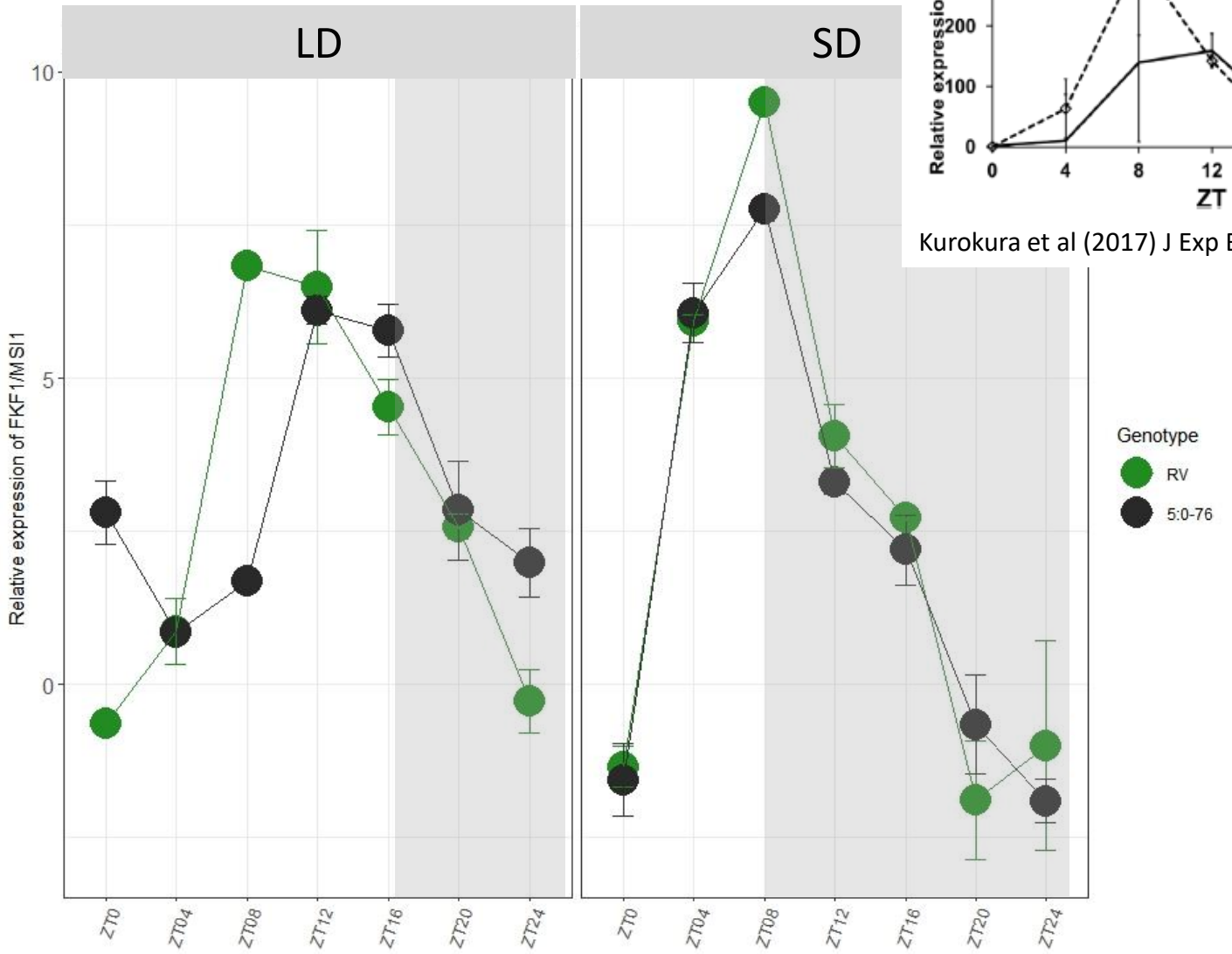
GI diurnal rhythm

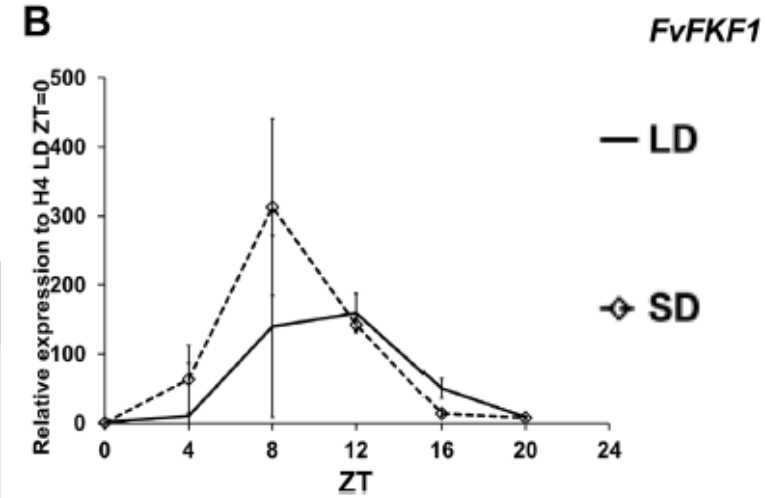


Kurokura et al (2017) J Exp Bot



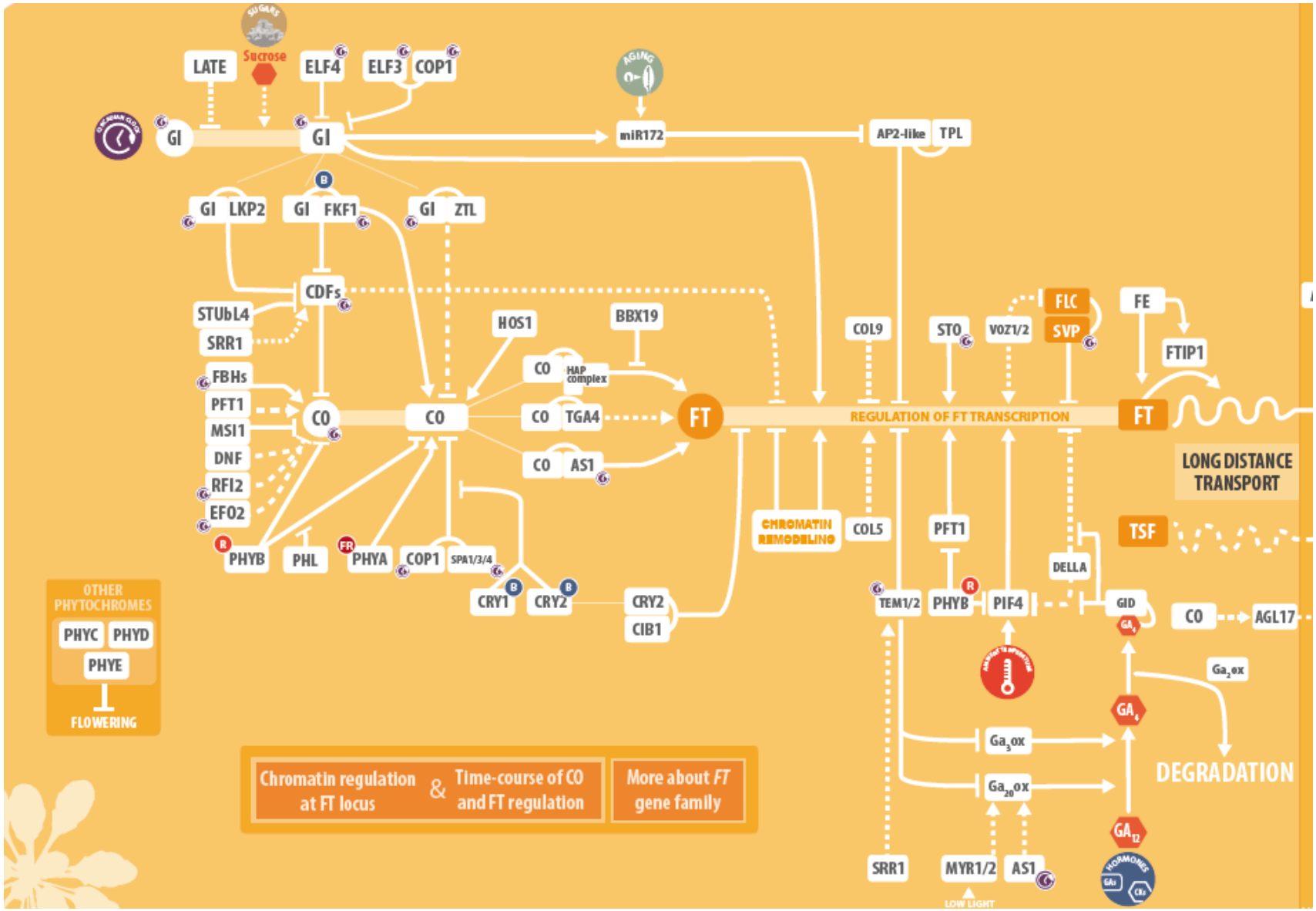
FKF1 diurnal rhythm





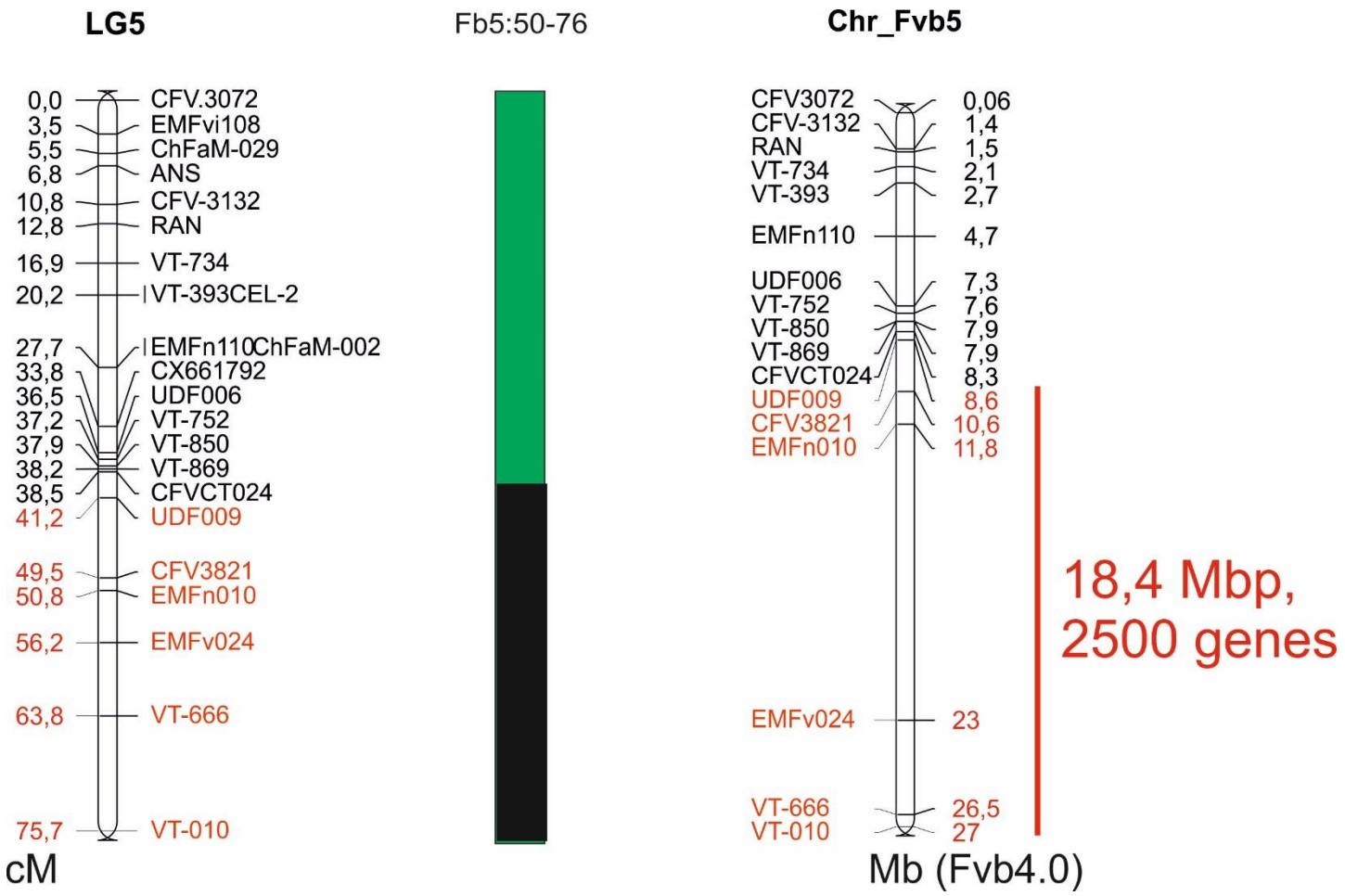
Kurokura et al (2017) J Exp Bot

Looking for a leaf-expressed gene with functions in LD-photoperiodism and/or circadian rhythms

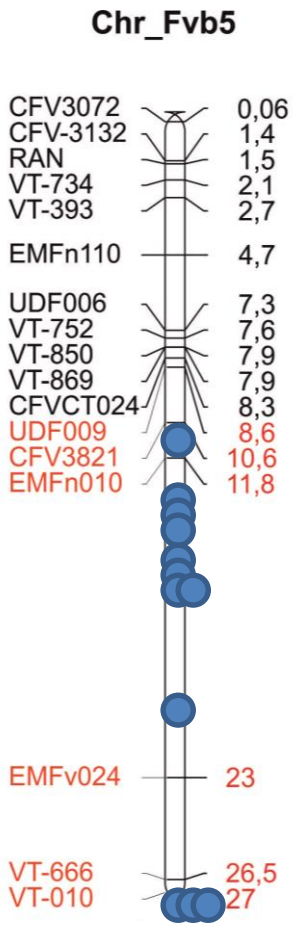


Flowering Interactive Datebase (Flor-ID): Bouché, Lobet et al. (2016) Nucleic Acid Research

Shortest introgression 18.4 Mbp

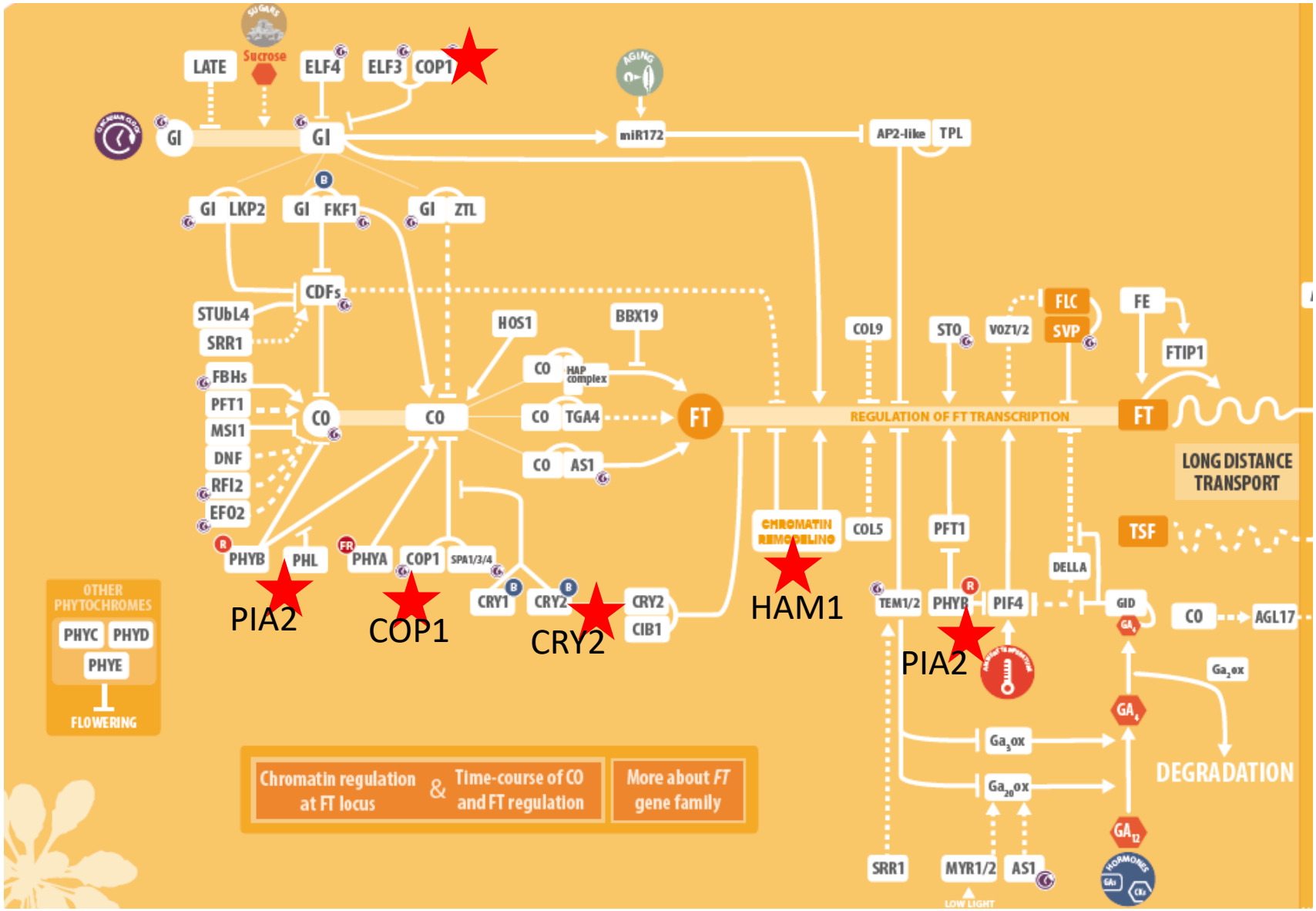


GO-annotations



GeneID	GO classification	Location (Mb)	Arabidopsis homolog
FvH4_5g19660	Regulation of circadian rhythm	11.5	Cullin-1 (CUL1)
FvH4_5g20290	Long-day photoperiodism	12.5	ATP-dependent helicase (UPF1)
FvH4_5g21940	Vegetative to reproductive phase change of meristem	13.3	ATP-dependent RNA helicase (BRR2A)
FvH4_5g22570	Entrainment of circadian clock	13.9	CONSTITUTIVE PHOTOMORPHOGENIC 1 (COP1)
FvH4_5g24200	Phytochrome binding	15.5	Phytochrome-interacting ankyrin-repeat protein (PIA2)
FvH4_5g25150	Response to red or far-red light	16.6	CYP707A3
FvH4_5g26450	Photoperiodism	17.9	U2 auxiliary factor small subunit (U2AF35B)
FvH4_5g26480	Response to blue/far-red light	17.9	Light-harvesting complex B7 (LHCB7)
FvH4_5g30610	Circadian rhythm	21.5	Accumulation and replication of chloroplast 5 (ARC5)
FvH4_5g37290	Light responses	27.4	Cryptochrome 1 (CRY1)
FvH4_5g37300	Regulation of photoperiodism	27.4	Mediator 18 (MED18)
FvH4_5g38850	Regulation of photoperiodism	28.7	Histone acetyltransferase of the myst family 1 (HAM1)

Looking for a leaf-expressed gene with functions in LD-photoperiodism and/or circadian rhythms..



Flowering Interactive Datebase (Flor-ID): Bouché, Lobet et al. (2016) Nucleic Acid Research

Thank you!

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