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Temperature-sensitivity of resistance against phoma stem canker in oilseed rape

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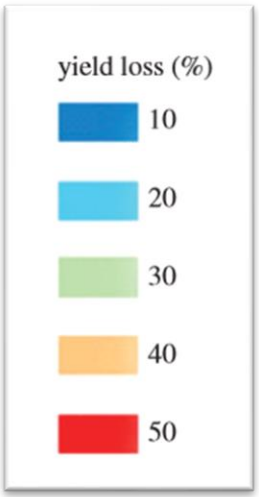
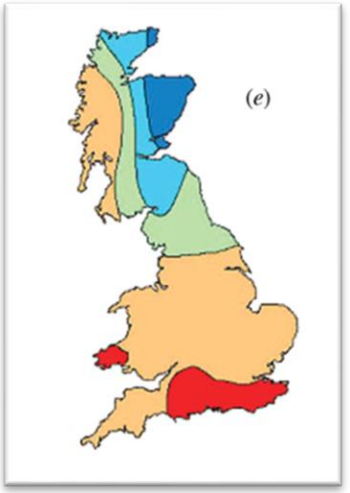
1. Effect of climate change on phoma stem canker epidemics

2050HI CO_2 climate model projects yield losses.



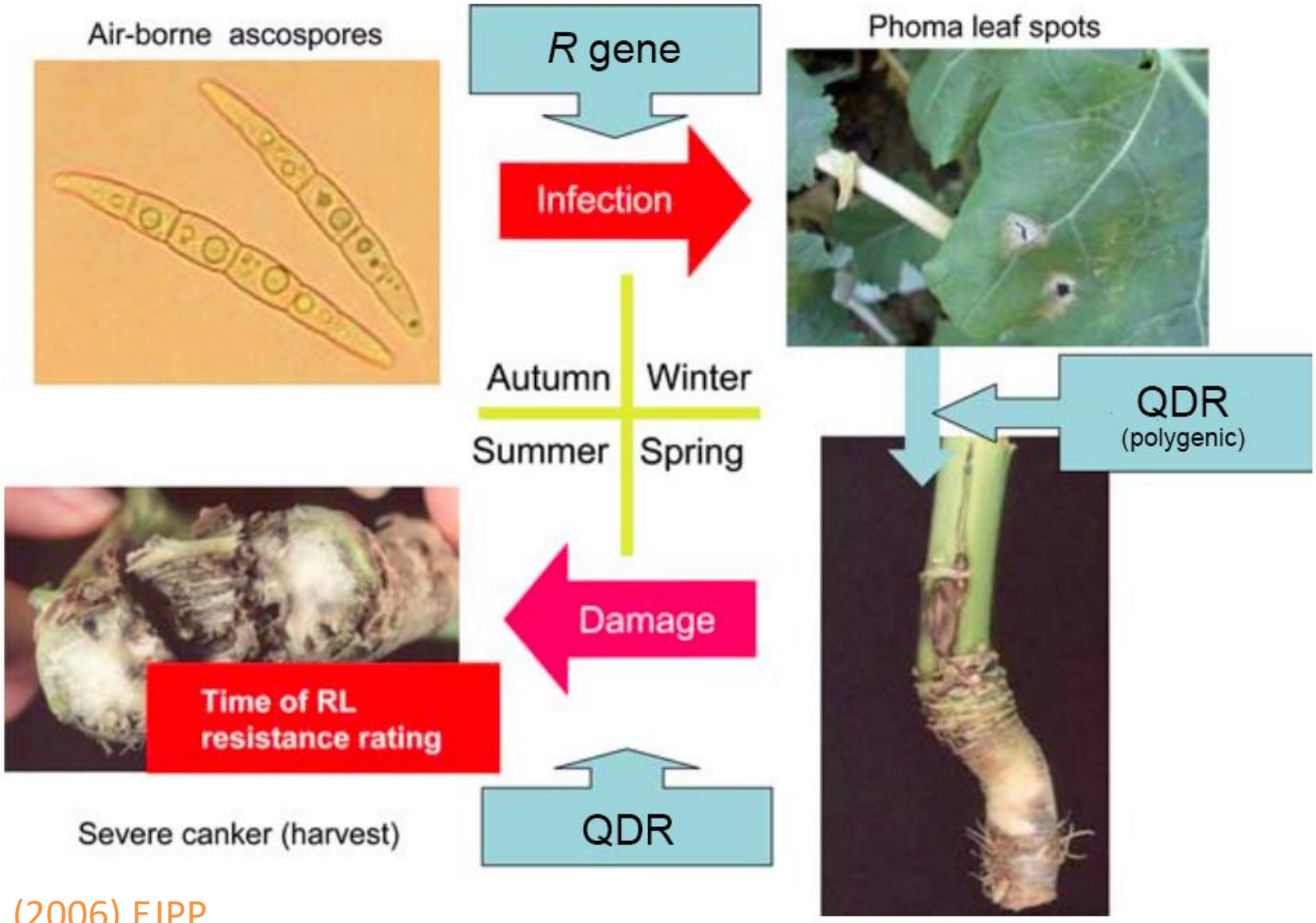
Susceptible cultivars



Resistant cultivars

Butterworth et al. (2011) J. R. Soc. Interface

Seasonal cycle of phoma stem canker epidemics in Europe



Fitt et al. (2006) EJPP

2. Canker assessments in fields of France and England


Katherine Noel

2016/17, 2017/18 and 2018/19 cropping years

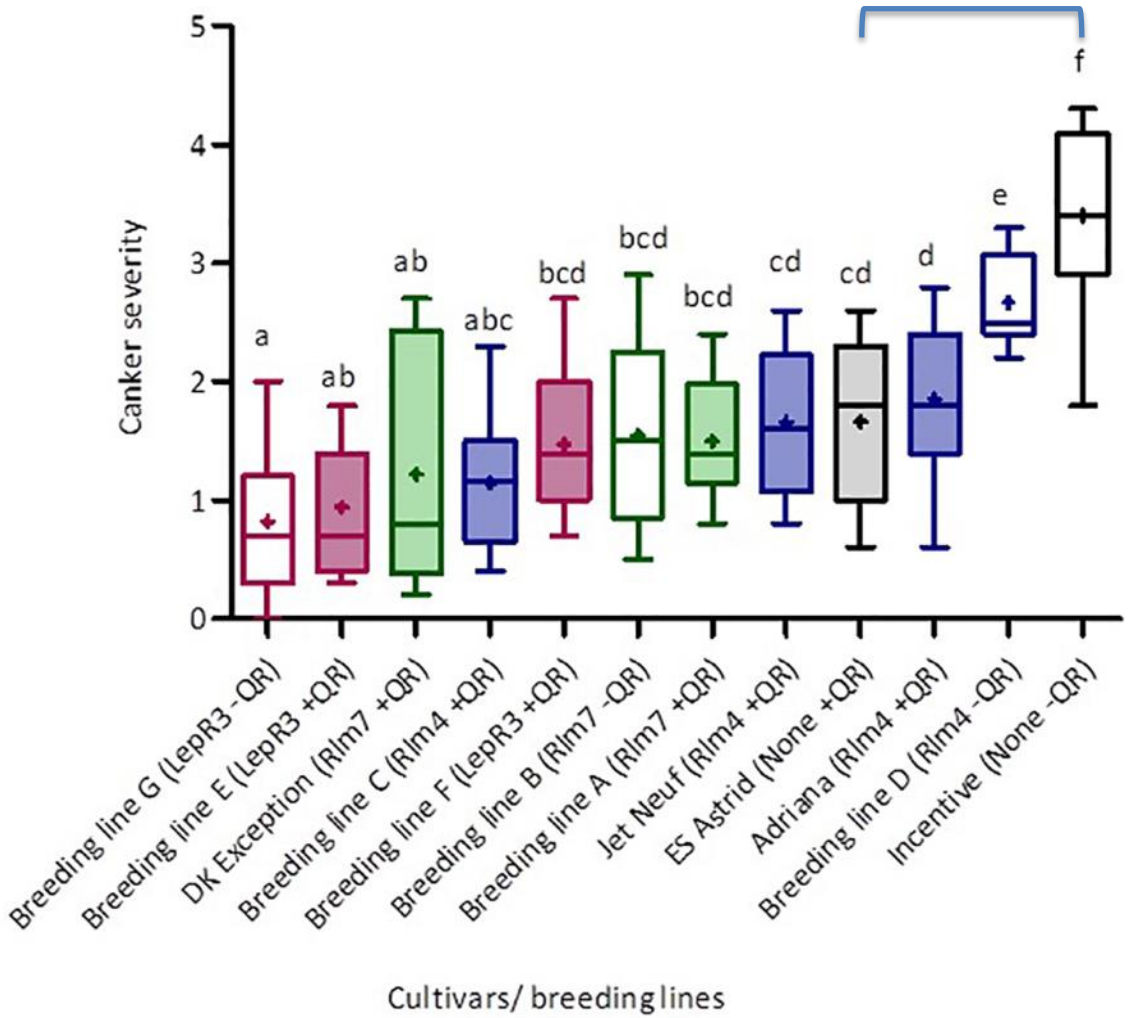


TABLE 2 | Fisher's least significance comparison of average canker severity scores for 12 winter oilseed rape cultivars/breeding lines grouped by single *R* gene and quantitative resistance.

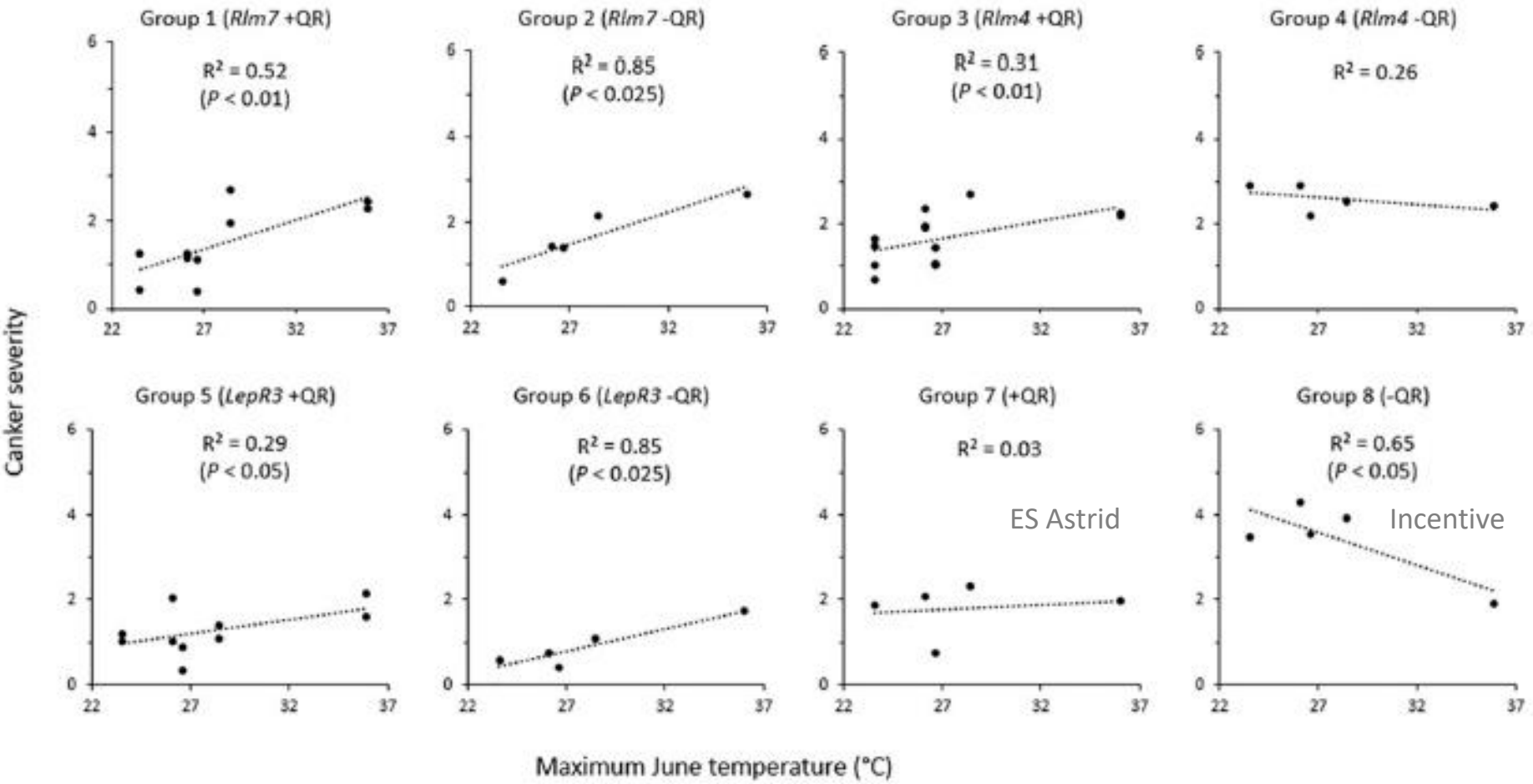
***R* gene**	**Quantitative resistance***		***R* gene mean**
	"Little"	**"Good"**	
Rlm7	1.53b	1.36b	**1.421**
Rlm4	2.66c	1.57b	**1.830**
LepR3	0.82a	1.20ab	**1.072**
None	3.39d	1.66b	**2.520**
Quantitative resistance mean	**2.074**	**1.433**	

**Average scores sharing the same letter were not statistically different at $P < 0.05$ in multiple comparisons with Fisher's least significant difference (LSD) test. Values in bold are overall means for genotypes with R gene-mediated or quantitative resistance.*

- Note effect of quantitative resistance (QDR, Incentive vs ES Astrid)
- All *R* genes had an effect, even in absence of QDR.
- QDR contributes significantly to resistance in lines with *Rlm4*.

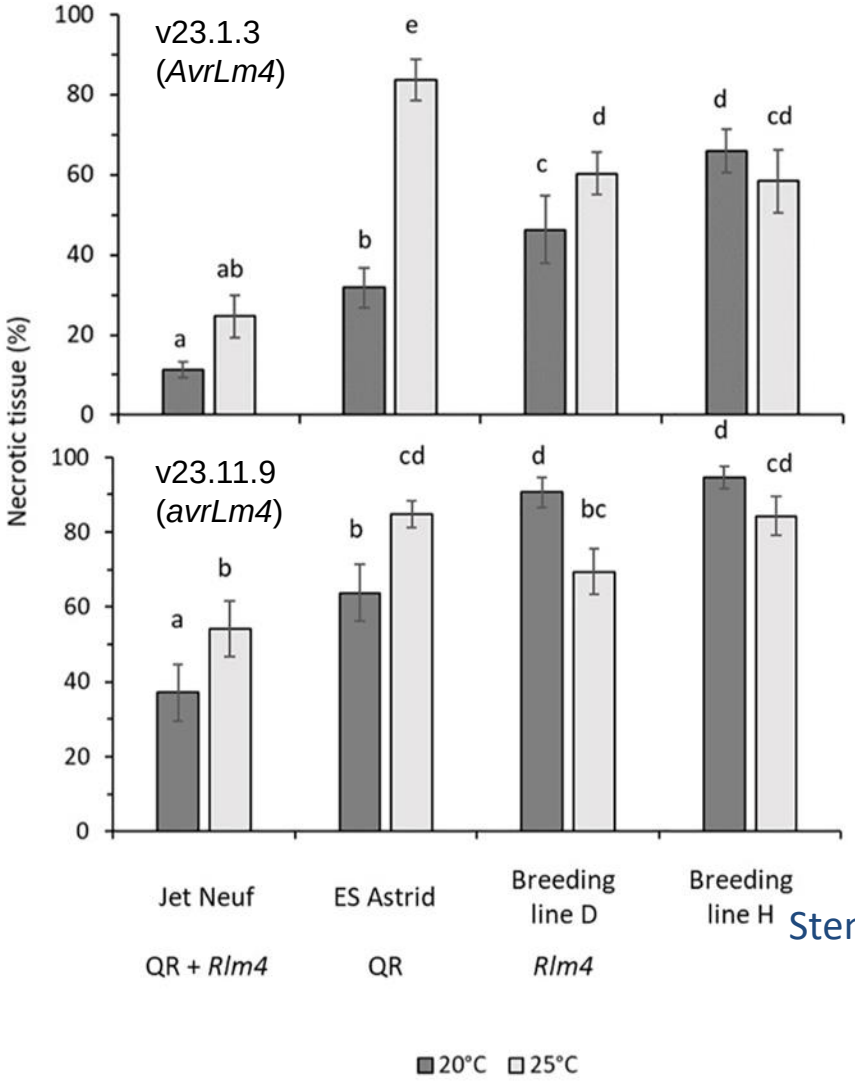
Noel et al. (2022) Front Plant Sci

Effect of June temperature on canker severity in the field



- Maximum temperature in June had largest effect on stem canker severity.
- Temperature effect on *Rlm7* +/- QDR > *LepR3* +/- QDR > *Rlm4* + QDR (*L. maculans* races)
- No effect of temperature on stem canker severity in ES Astrid with QDR
- Negative correlation between temperature and canker severity in cv. Incentive (high temperature optimum of PTI)

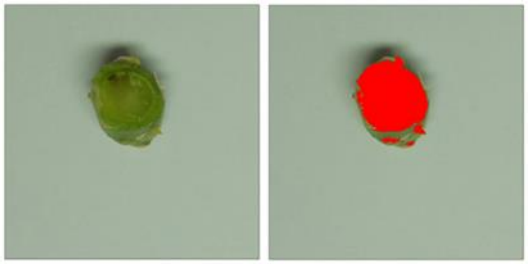
Effect of temperature on canker severity under CE conditions



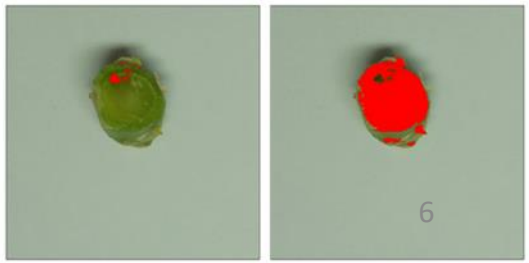
- Stems of 6-weeks old plants inoculated; canker assessed 6 weeks later.
- *Rlm4* operates in stems of young plants.
- QDR of cv. ES Astrid temperature-sensitive, in contrast to field conditions.

- *L. maculans* grew similarly at 20°C and 25°C.
- Plant growth did not vary between 20°C and 25°C.

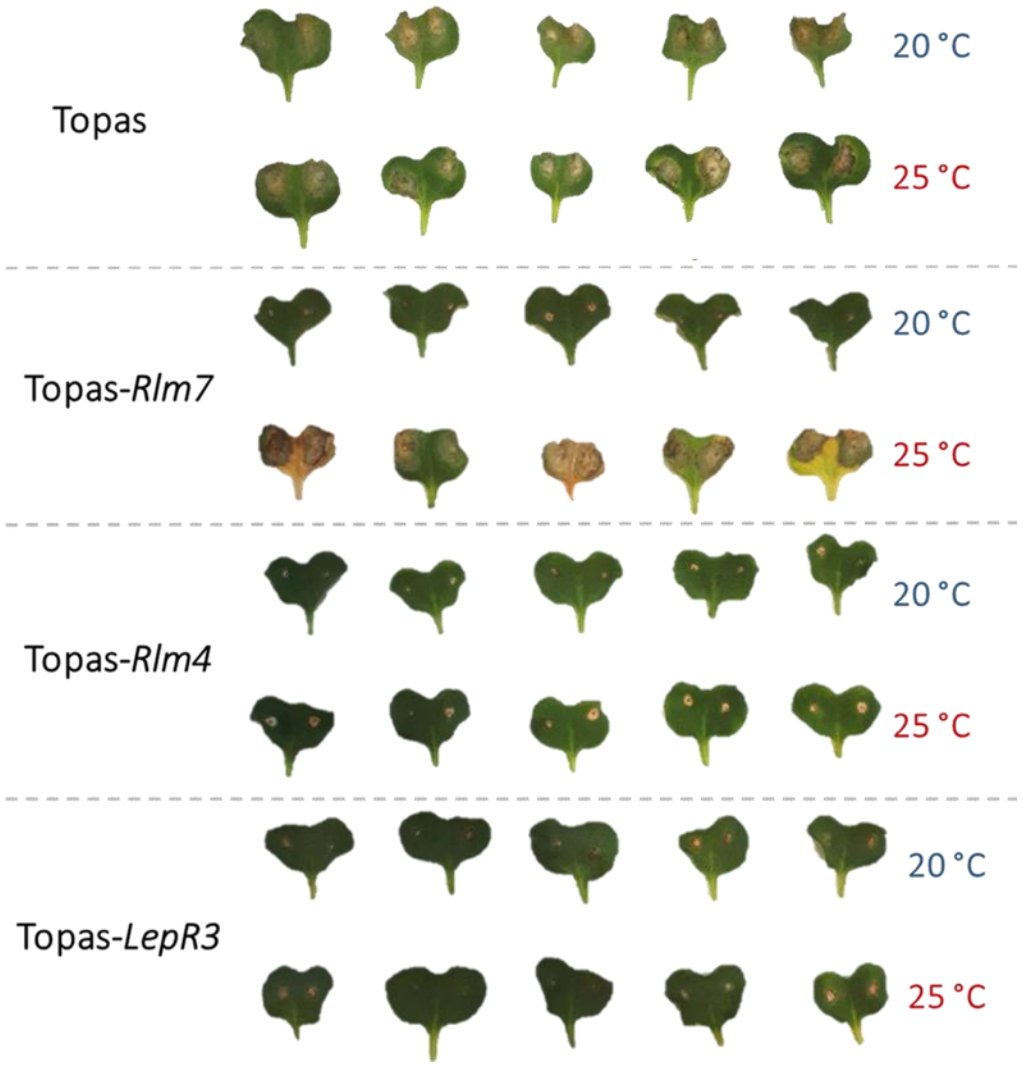
Cross sectional area



Stem canker quantification



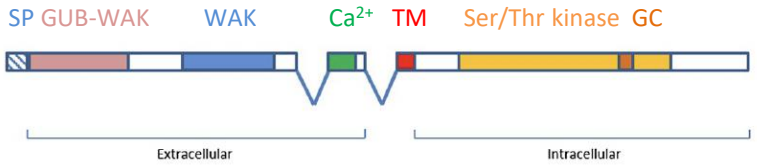
3. Temperature-sensitivity of *R* gene-mediated resistance in introgression lines



Seedling inoculations

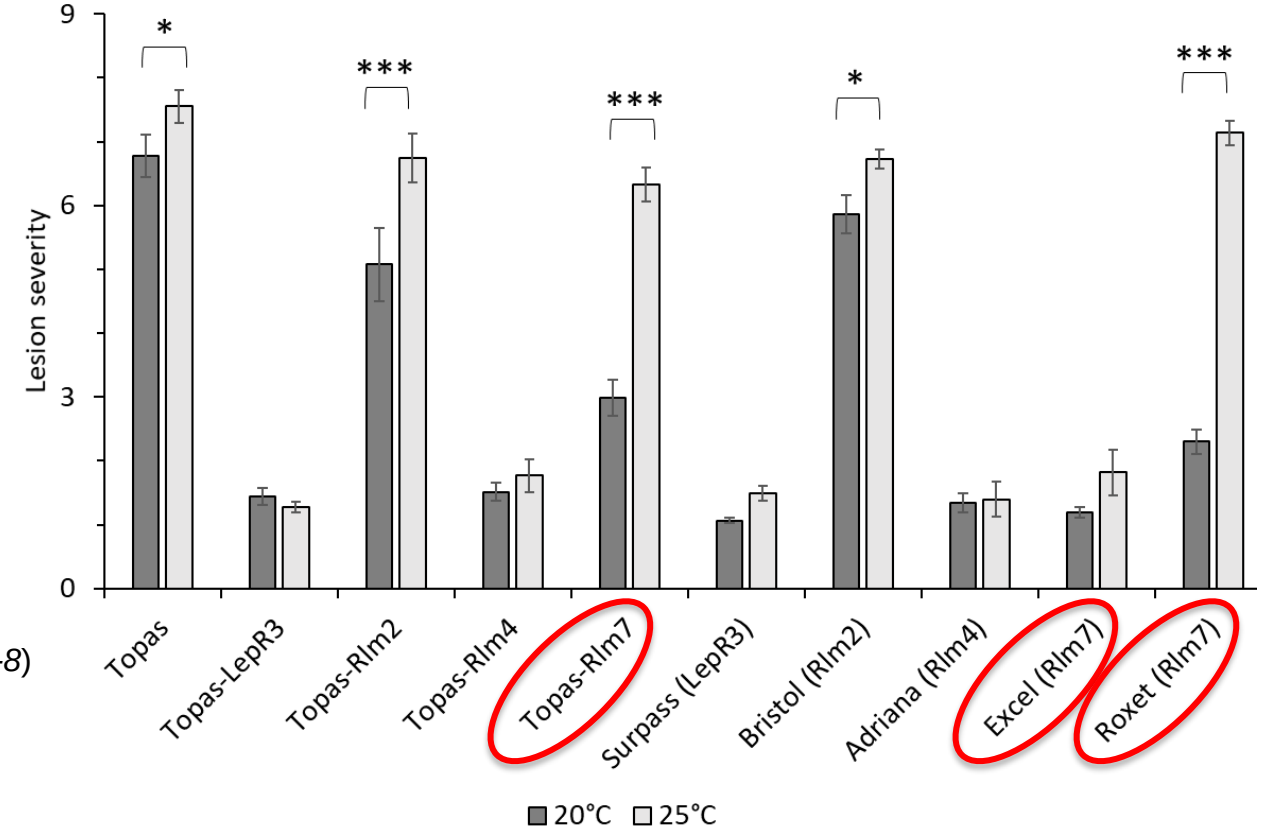
- Topas DH16516 background (compatible interaction)
- *L. maculans* isolate JN3 (*AvrLm1-4-5-6-7-8*)
- Two weeks after seedling inoculation, cotyledons excised and photographed

- Temperature-sensitive *Rlm7* gene
- Temperature-resilient *Rlm4* and *LepR3* genes



Noel et al. (2024) Sci. Rep.

Temperature-sensitivity of *R* gene-mediated resistance in ILs and cultivars

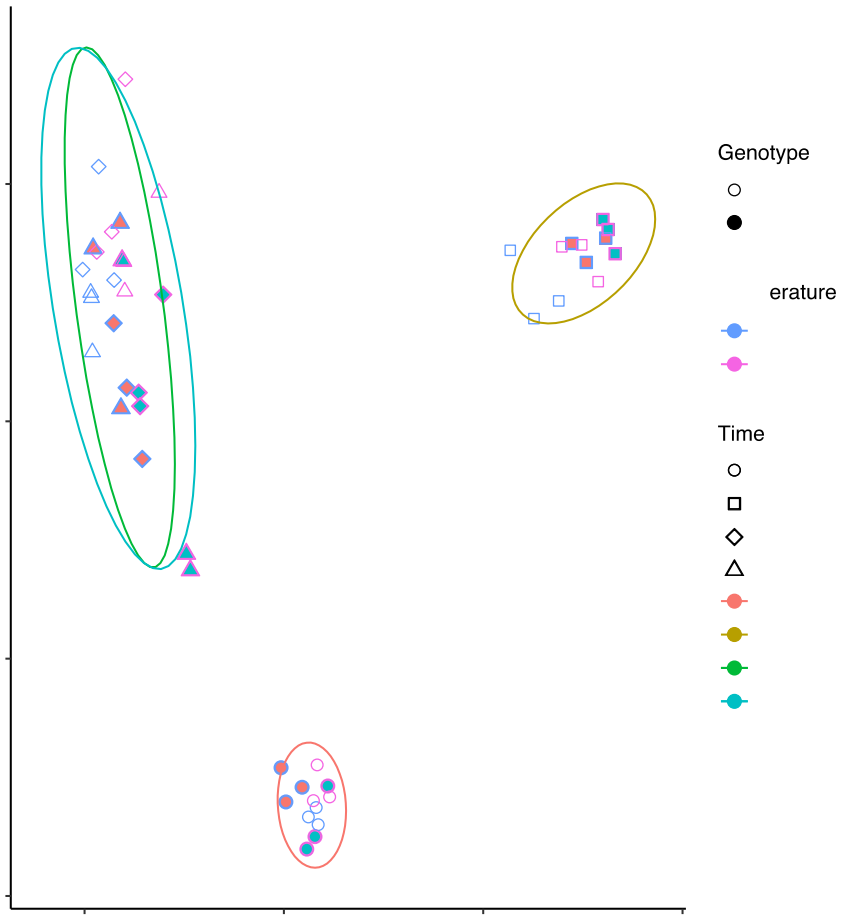


JN3 (*AvrLm1-4-5-6-7-8*)

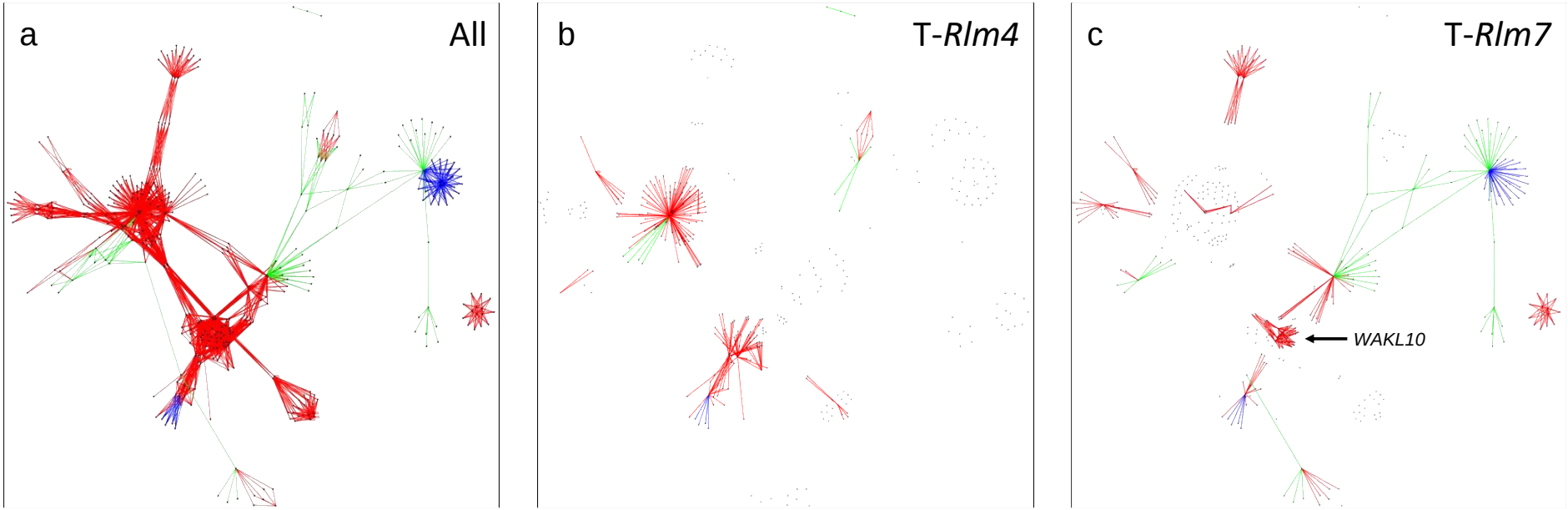
- *LepR3* and *Rlm4* are consistently temperature-resilient.
- Differences in temperature-sensitivity between *Rlm7* cultivars/lines.

Transcriptomic analysis

- Principal component analysis
  - Early infection stage (1 dpi) separated from defence response phases (4 and 7 dpi)
  - Some genotype differences were detected at 4 dpi.
  - *PR1* expression was induced at 4 and 7 dpi.



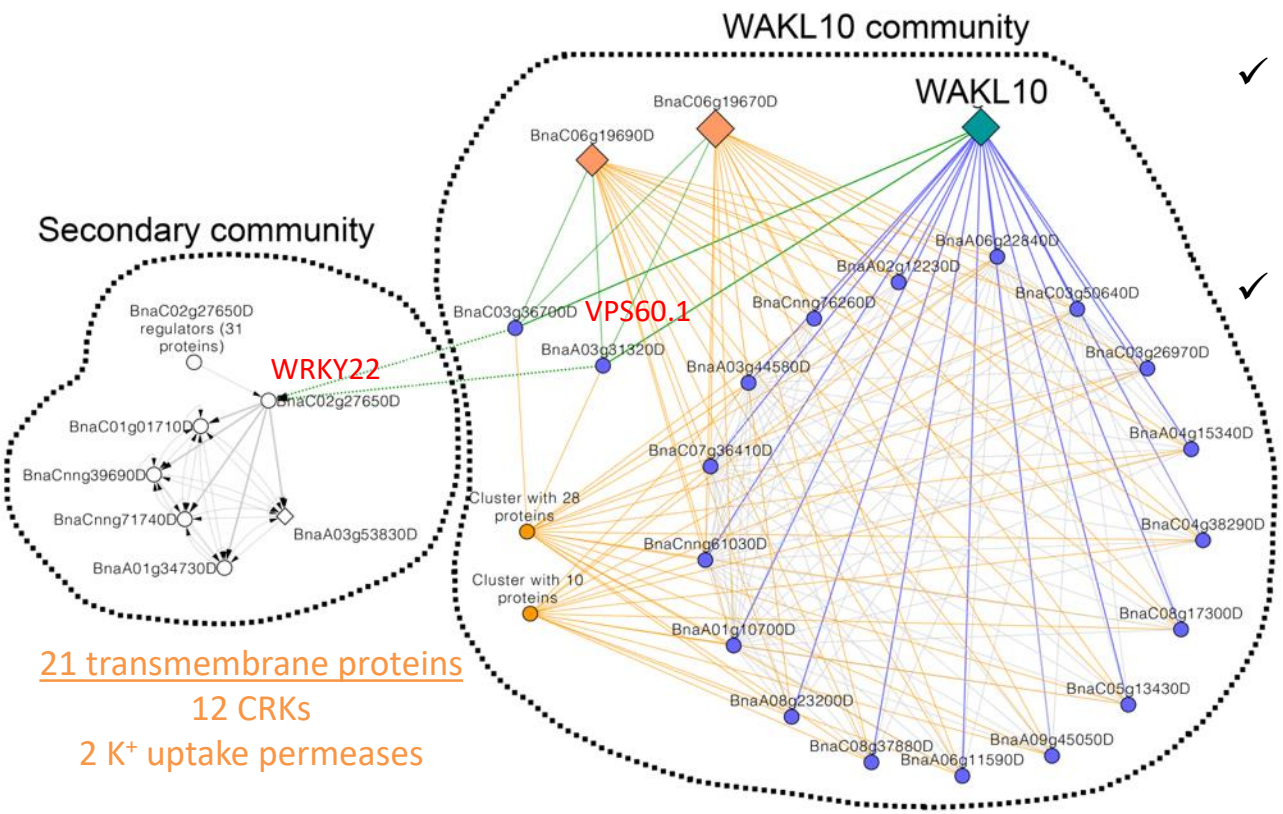
Sub-network analysis



1,646 DEGs combined with available network data to generate sub-networks

- Protein interaction (red), metabolic (green) and regulatory (blue) networks
- *WAKL10*-specific protein interaction network in Topas-*RLM7* as a function of temperature

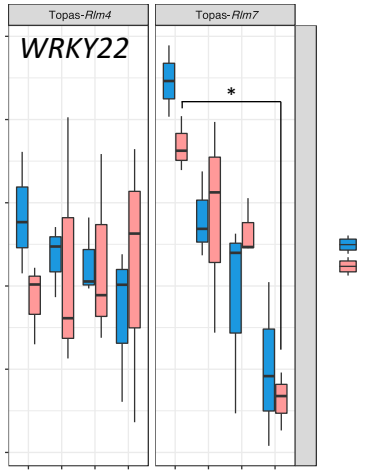
Network diffusion analysis



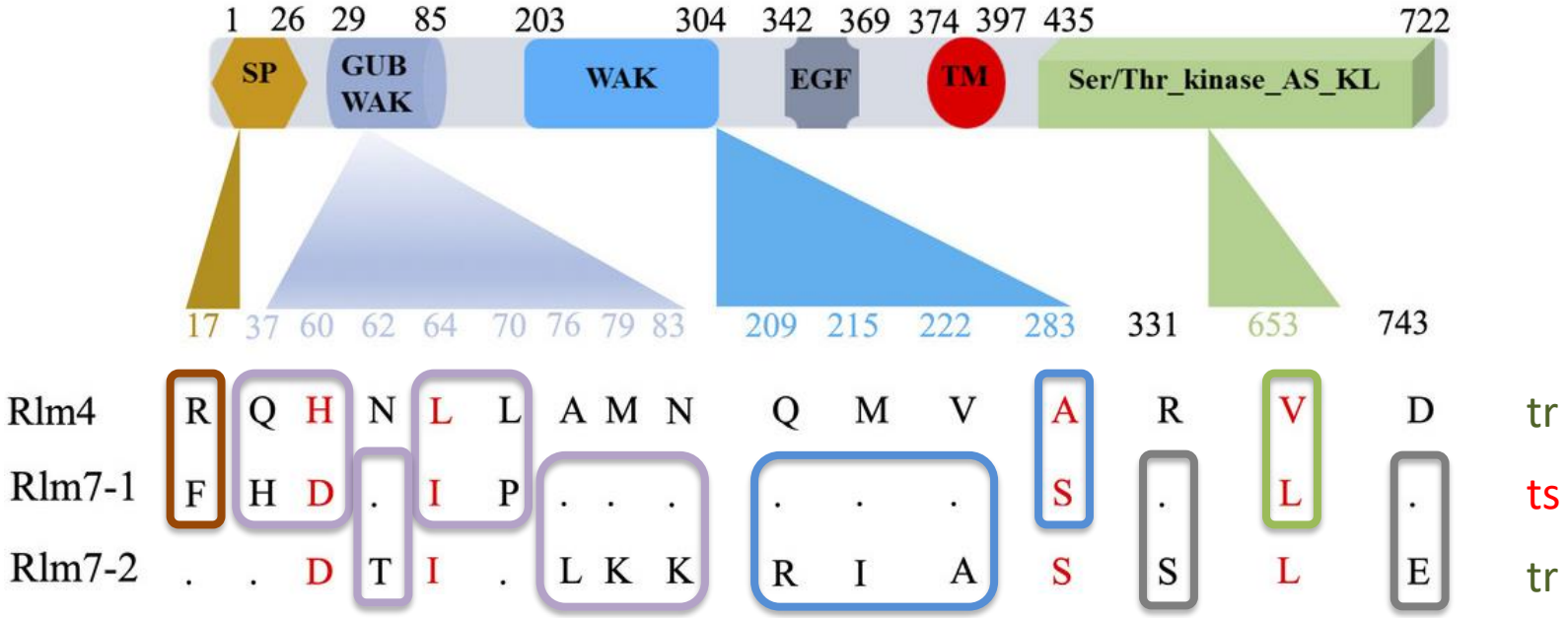
21 transmembrane proteins
12 CRKs
2 K^+ uptake permeases

6 *LRR-PK* genes
6 ubiquitin-conjugating enzyme genes
3 IQ domain protein genes
2 *NDR1*/*HIN1*-like genes

- ✓ Regulatory network connections to 2º community in Topas-*Rlm4*
- ✓ ***VPS60.1,*** involved in intraluminal vesicle release into endosome, propagates to ***WRKY22*** in 2º community.
- ✓ *WRKY22* connected to five *AP2/ERF* genes and a group of submergence-induced immunity genes.



Conclusions



- Basis of temperature-resilience may differ between *Rlm4* and *Rlm7-2*.
- There are only seven and nine amino acid differences between *Rlm4* and *Rlm7-1* and *Rlm7-1* and *Rlm7-2* that may be responsible for temperature-sensitivity, respectively. Other proteins, e.g. *VPS60.1*, may be involved.

Haddadi et al. (2022) Plant Biotechnol. J.

Acknowledgements

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