Plant-plant interactions modulate wheat severity to Septoria Tritici Blotch in some specific mixtures through intergenomic epistatic interactions and transcriptomic-metabolomic changes

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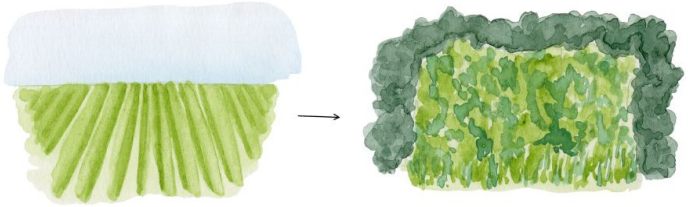
[2] AGAP Genetic Improvement and Adaptation of Mediterranean and Tropical Plants, Institut Agro, INRAE, Univ Montpellier, CIRAD, Montpellier, France

PHIM Plant Health Institute Montpellier

INRAE SFP MoBiDiv L'INSTITUT agro

Ecole Doctorale GAIA Biodiversité Agriculture Alimentation Environnement Terre Eau

Promoting crop diversification for a sustainable agriculture



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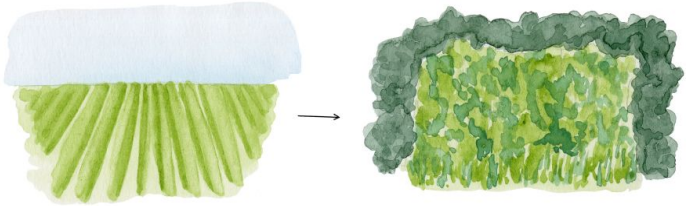

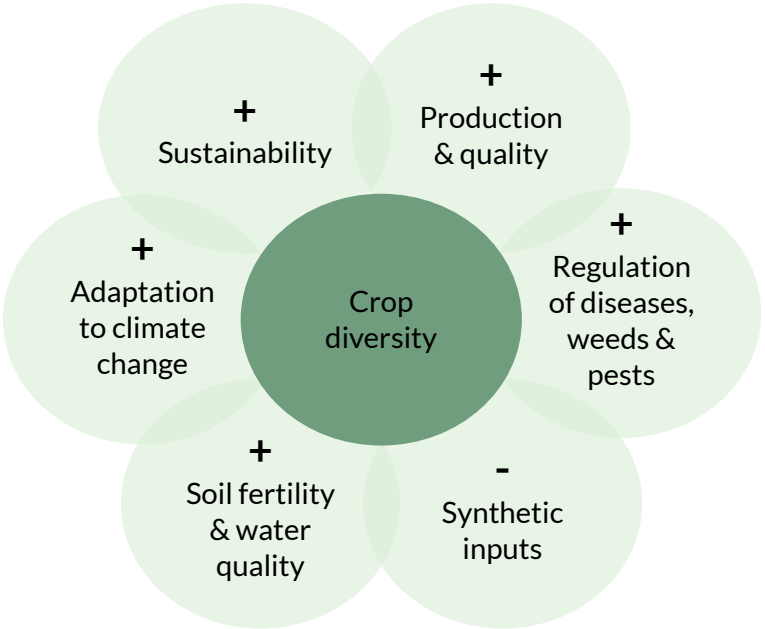

Tamburini *et al.*, Sci Adv, 2020
Beillouin *et al.*, Global Change Biology, 2021

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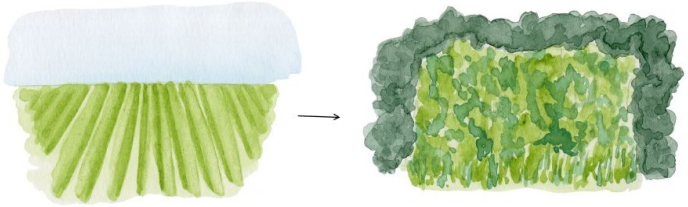

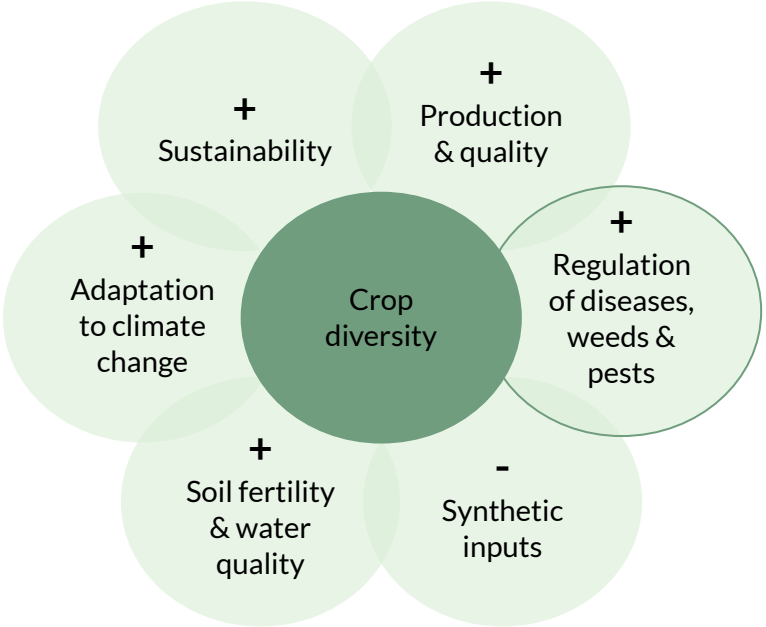

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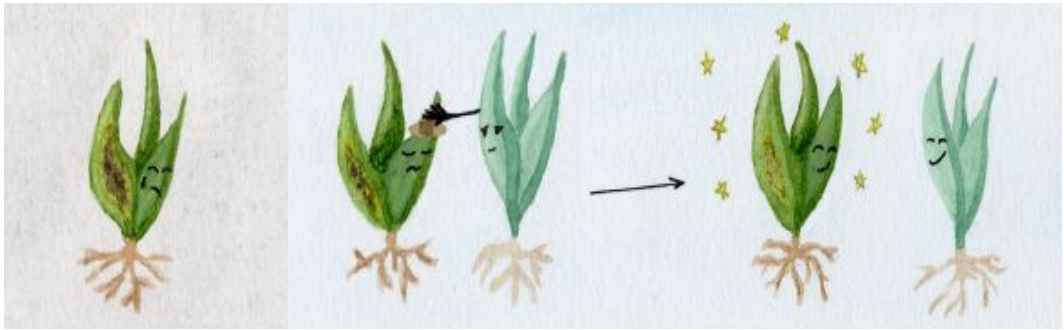
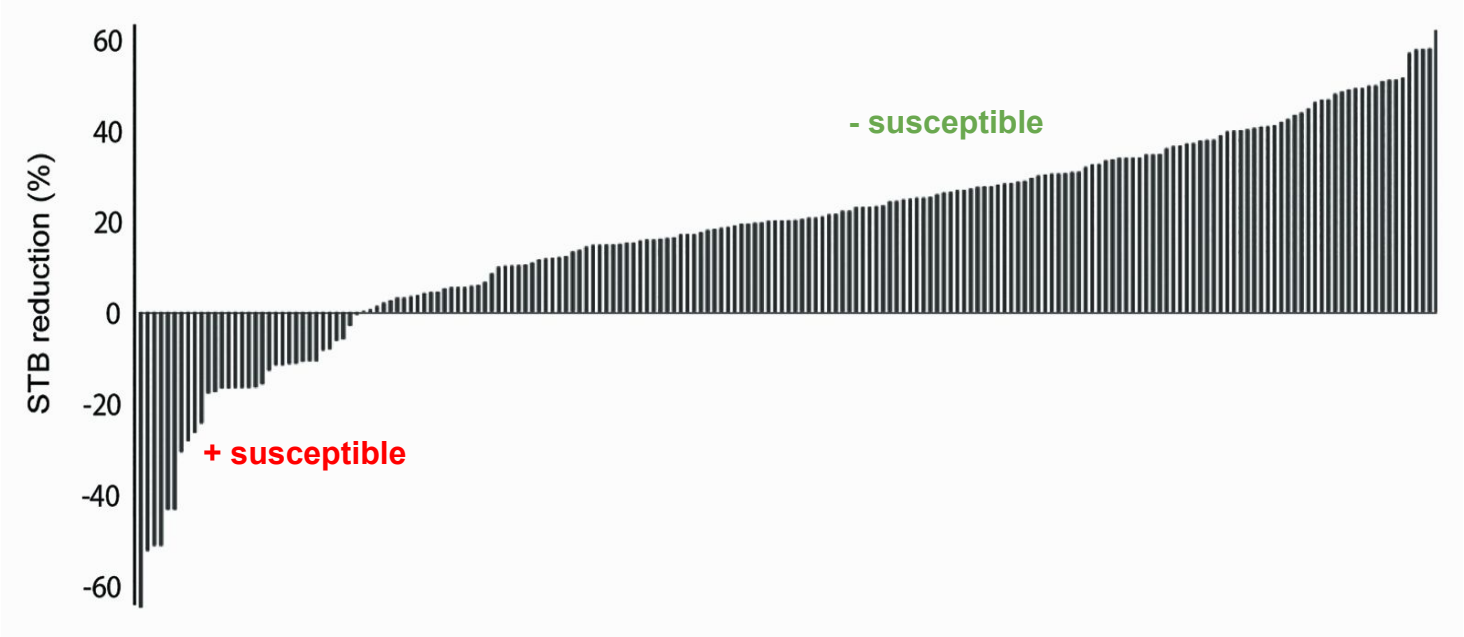


van der Werf & Bianchi, Outlook Agric, 2022

A general beneficial effect of mixtures on pathogen susceptibility, but great variability depending on their composition



82% of bread wheat cultivar mixtures reduce susceptibility to Septoria tritici blotch, with an average 14% reduction

Kristoffersen et *al.*, Plant Dis., 2022

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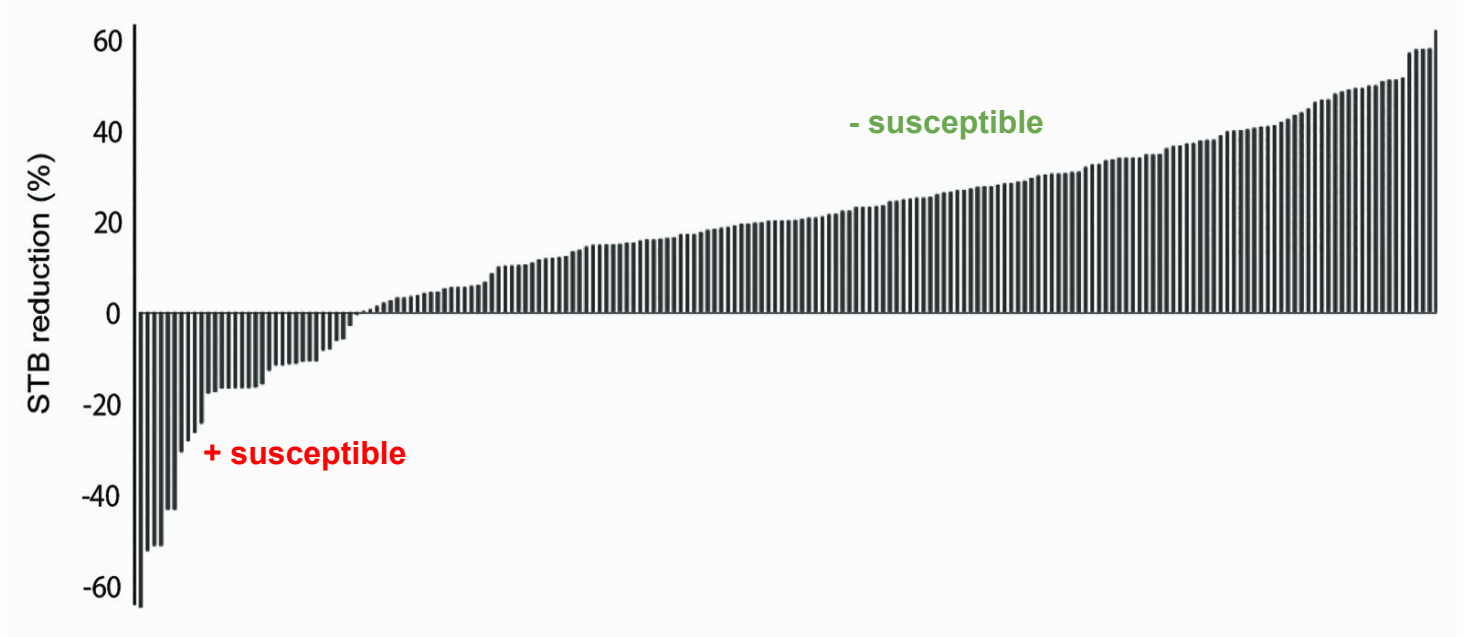

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Mechanisms at play: Epidemic & plant-plant interactions

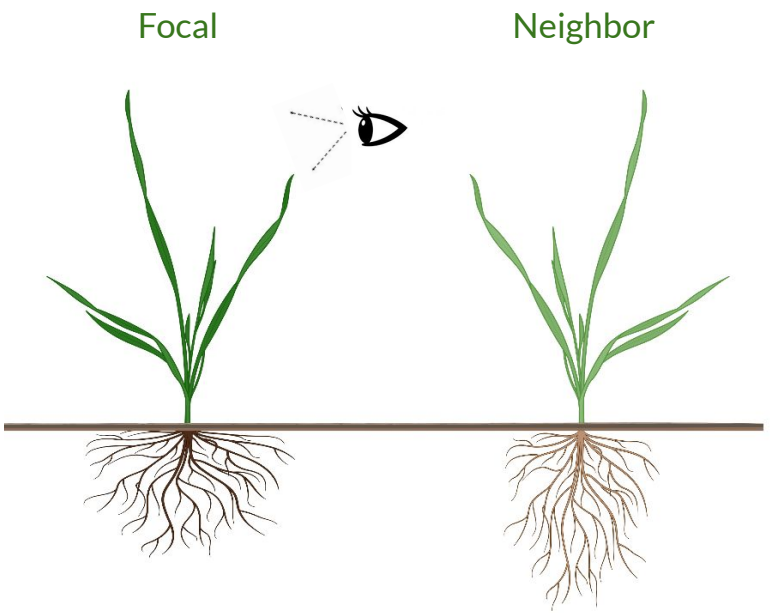
Kristoffersen et *al.*, Plant Dis., 2022
Mathieu *et al.*, Plant Cell & Environment., under review
on root exudates: Mathieu *et al.*, Curr. Opin. Plant Biol., 2024

How is wheat susceptibility to septoria modified by plant-plant interactions?

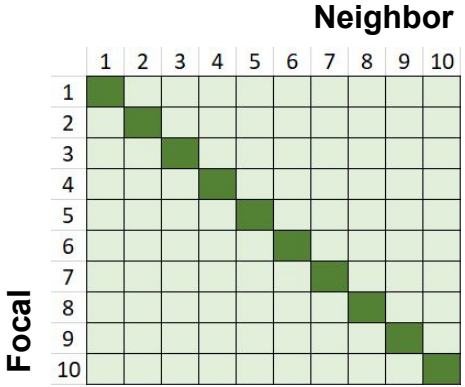
PLANT-PLANT INTERACTIONS IN THE ABSENCE OF EPIDEMIC

Focal plant: the one on which the effects of neighboring plants are observed

Neighboring plant: the one which causes effects on the focal plant



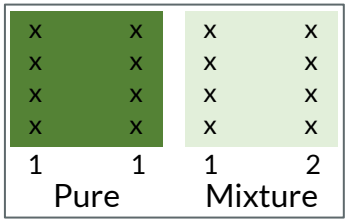
Experimental design

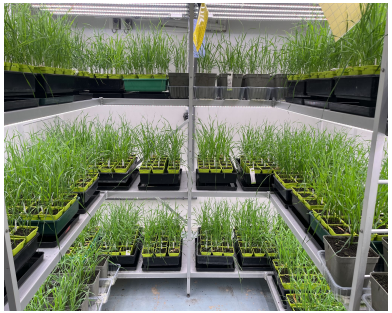


D21 after sowing
Inoculation with one strain of *Zymoseptoria tritici*
(IPO9415 for bread wheat or P1A for durum wheat)

D0
Sowing

D42 after sowing
Phenotyping of symptoms after one infection cycle:
Necroses & pycnidia using SeptoSympto (Mathieu *et al*., 2024)
Aerial biomass





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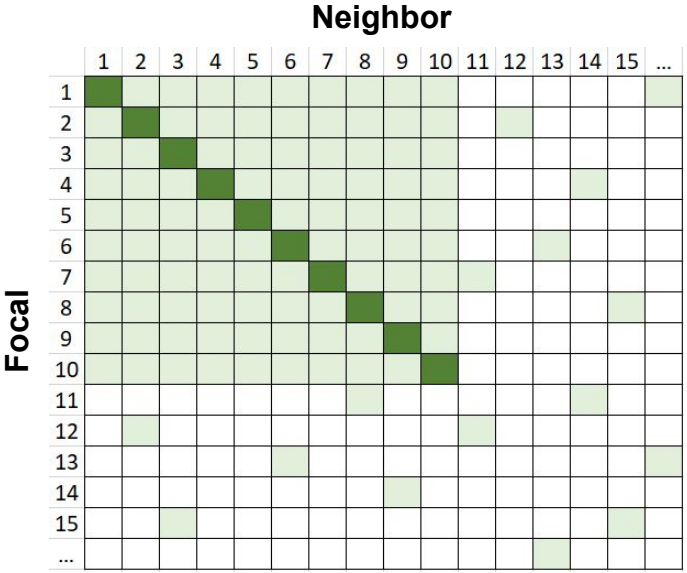

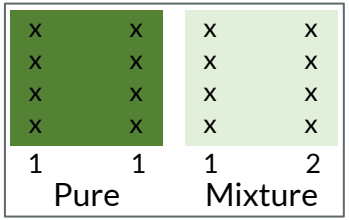

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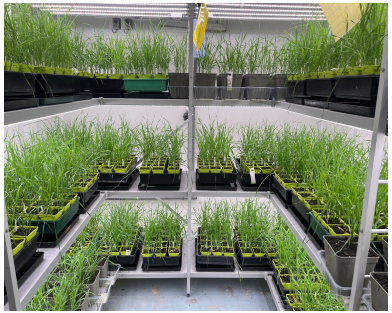
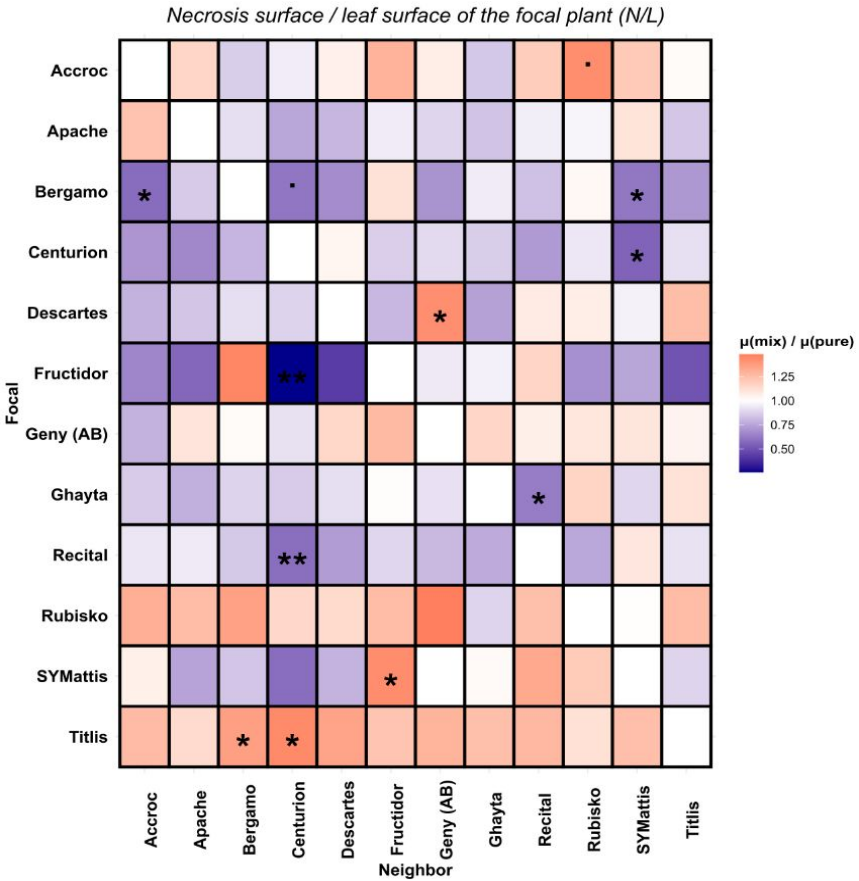


Specific plant-plant interactions modulate susceptibility to Septoria

Focal necrosis surface in the bread wheat - *Z. tritici* matrix



Mathieu *et al*. Plant Methods, 2024

Mathieu *et al*. J. Exp. Bot., under review

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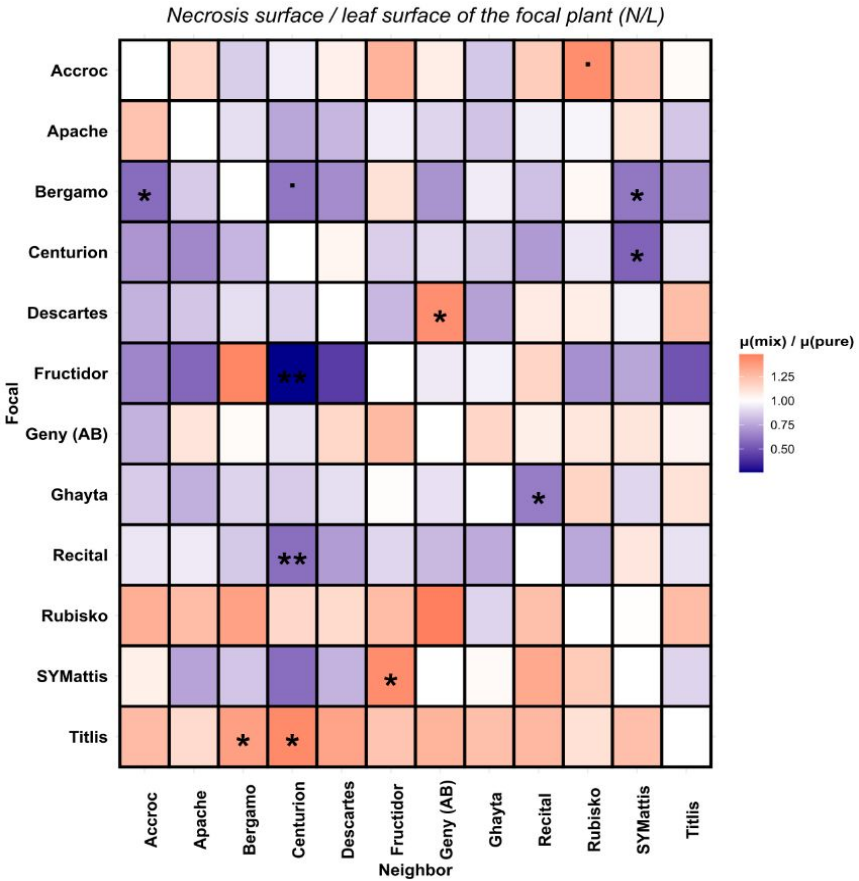


Percent of symptom variation explained by each factor

	Focal identity	Neighbor identity	Focal : neighbor interaction
Bread wheat - *Z. tritici* Necrosis	14,6% ***	4,3% ***	17,4% ***

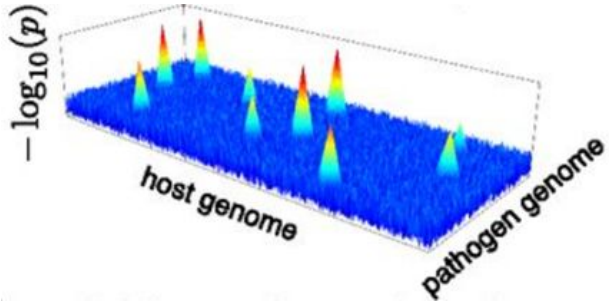
General Specific

Neighbor effects

Mathieu *et al*. Plant Methods, 2024
Mathieu *et al*. J. Exp. Bot., under review

Which genes are involved in wheat-wheat interactions that modulate susceptibility to septoria in focal plants?

Plant-pathogen interactions



176 different inbred lines of *A. thaliana* (host - 1,220,413 SNPs)
24 different strains of *X. arboricola* (pathogen – 33,610 SNPs)

Wang *et al.*, PNAS, 2018

Hypothesis:
Interactions between avirulence and resistance genes

Plant-plant interactions

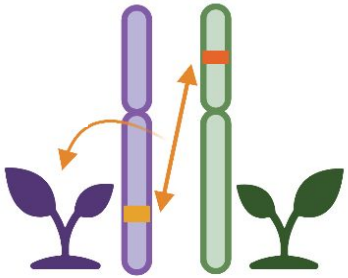
Focal Neighbor

180 different lines of *T. turgidum ssp. durum* (focal – 43,509 SNPs)

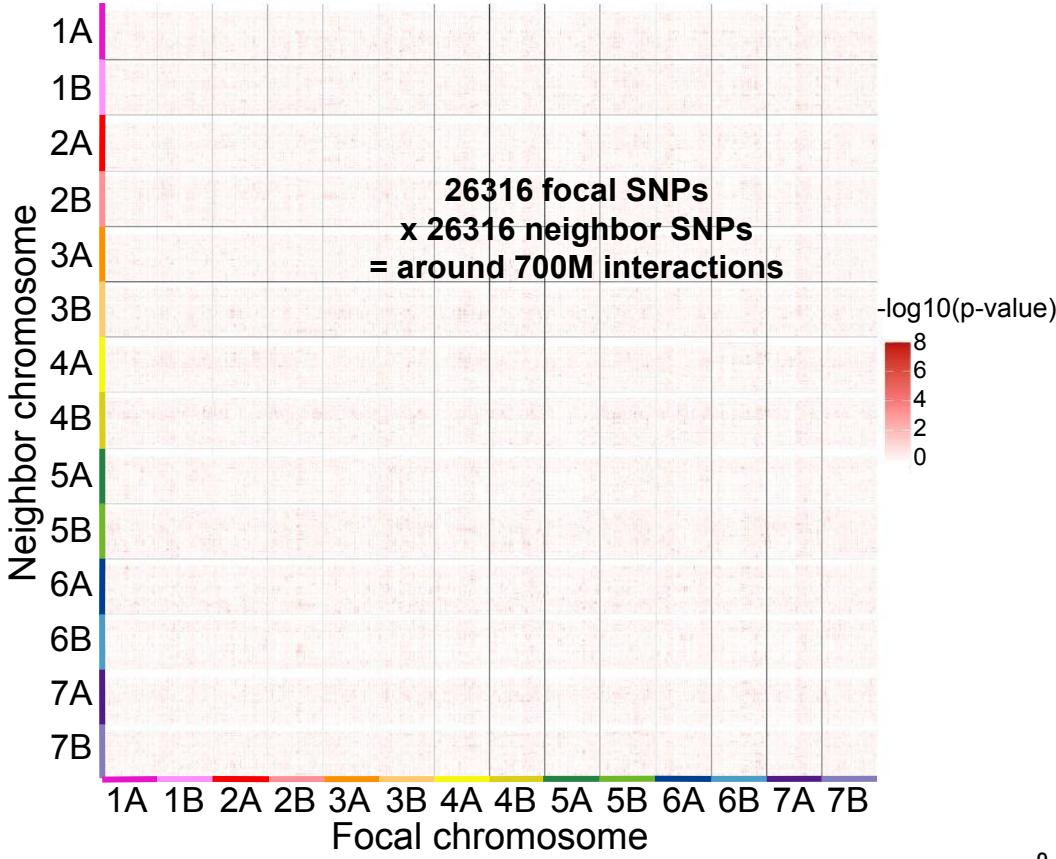
180 different lines of *T. turgidum ssp. durum* (neighbor – 43,509 SNPs)

Hypothesis:
Interactions between a signal sent by neighbor perceived by a receptor in focal

co-GWAS to test all possible allelic interactions between focal and neighboring plants



Focal phenotype ~ Focal SNP : Neighbor SNP



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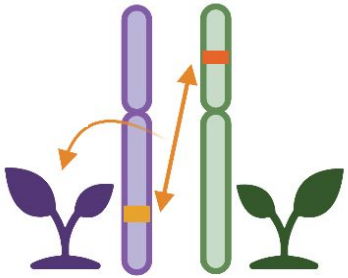

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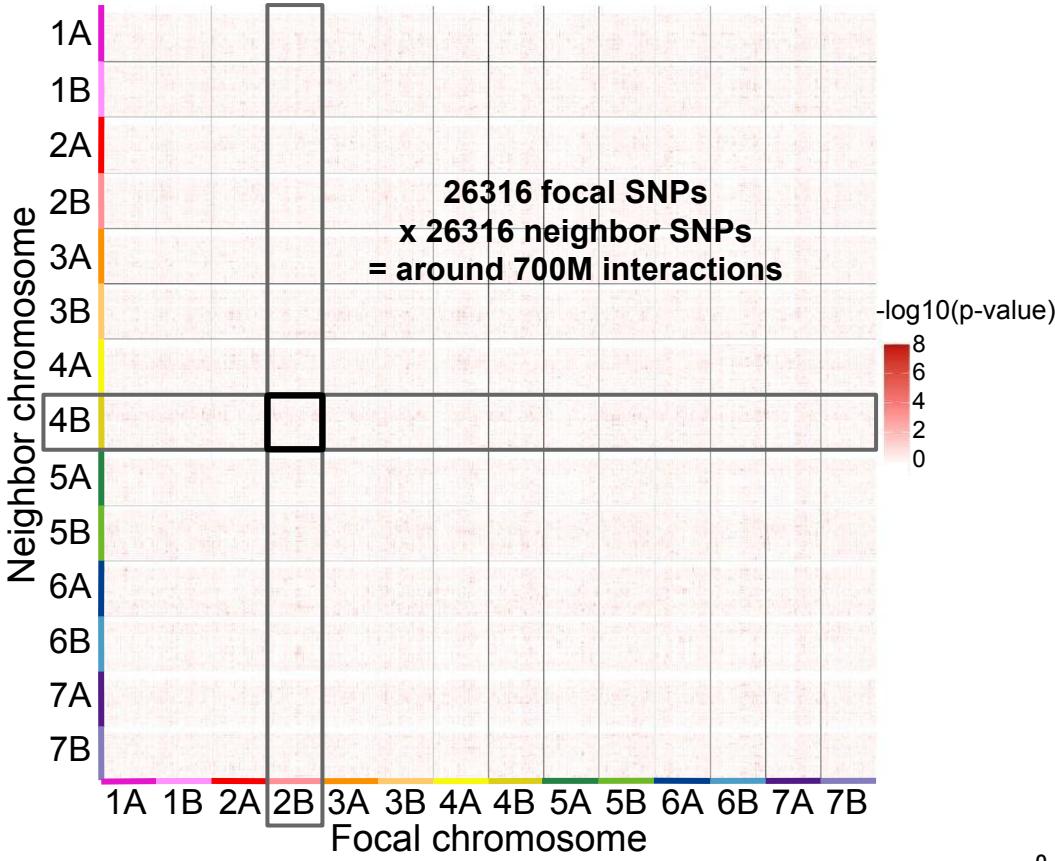
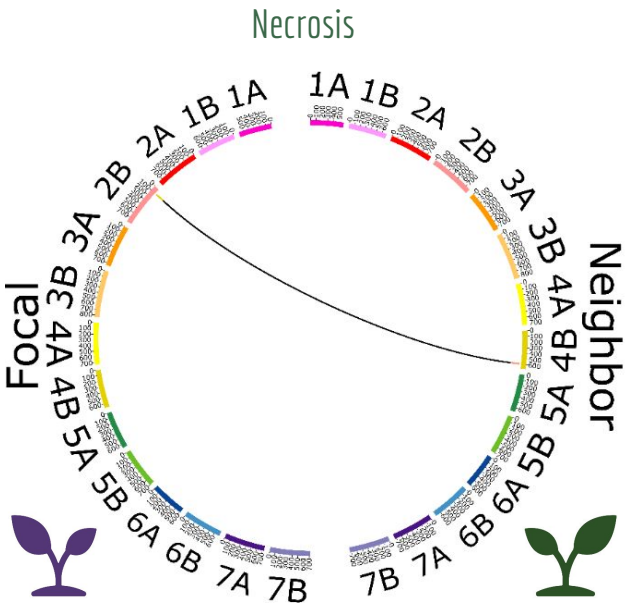
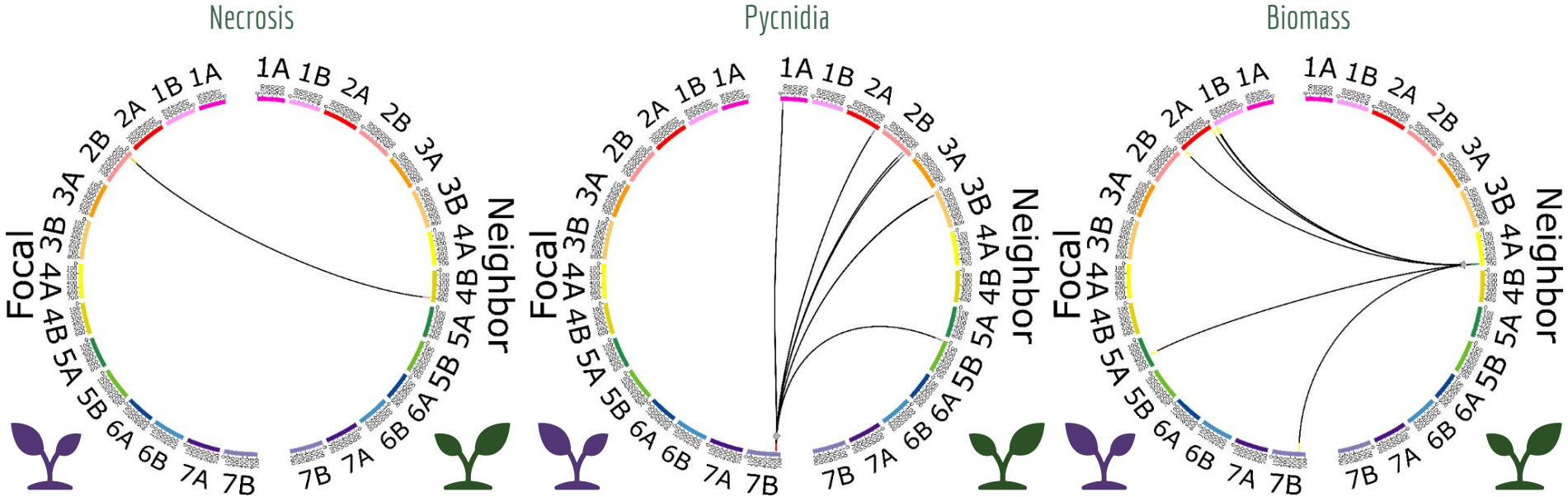


Inter-individual epistases involve different regions between focal and neighbor QTLs



Inter-individual epistases involve different regions between focal and neighbor QTLs and hub loci



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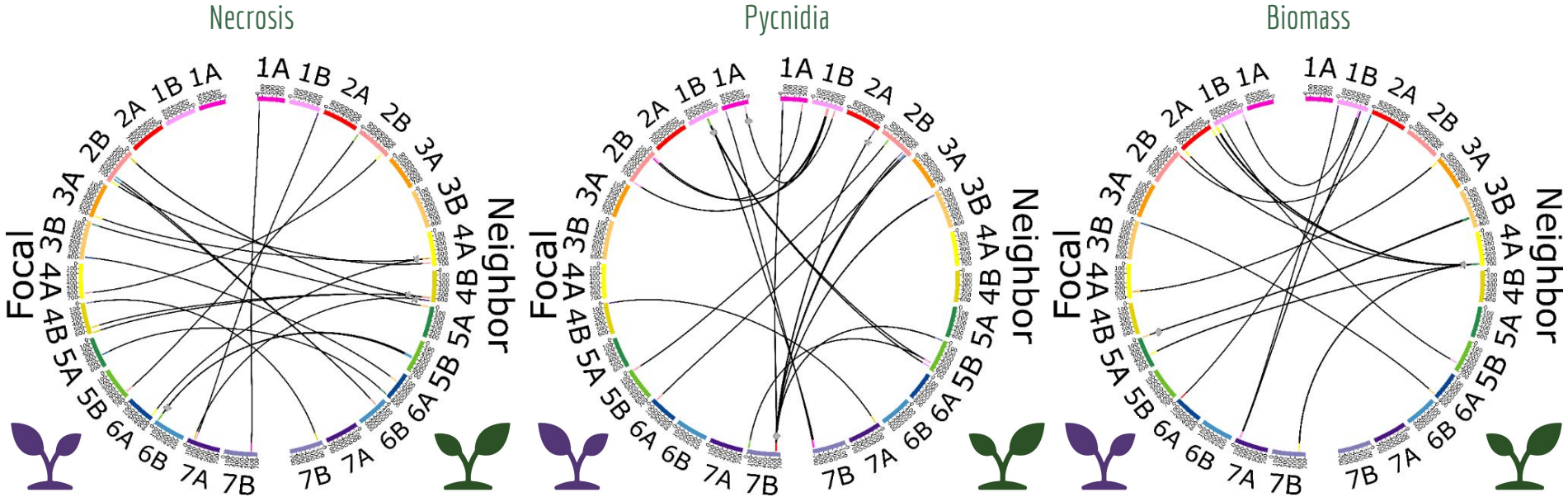
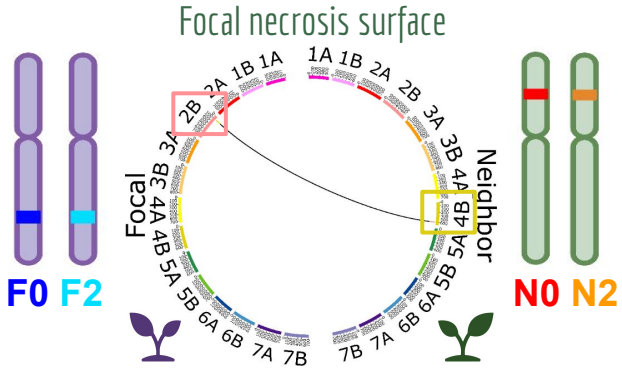
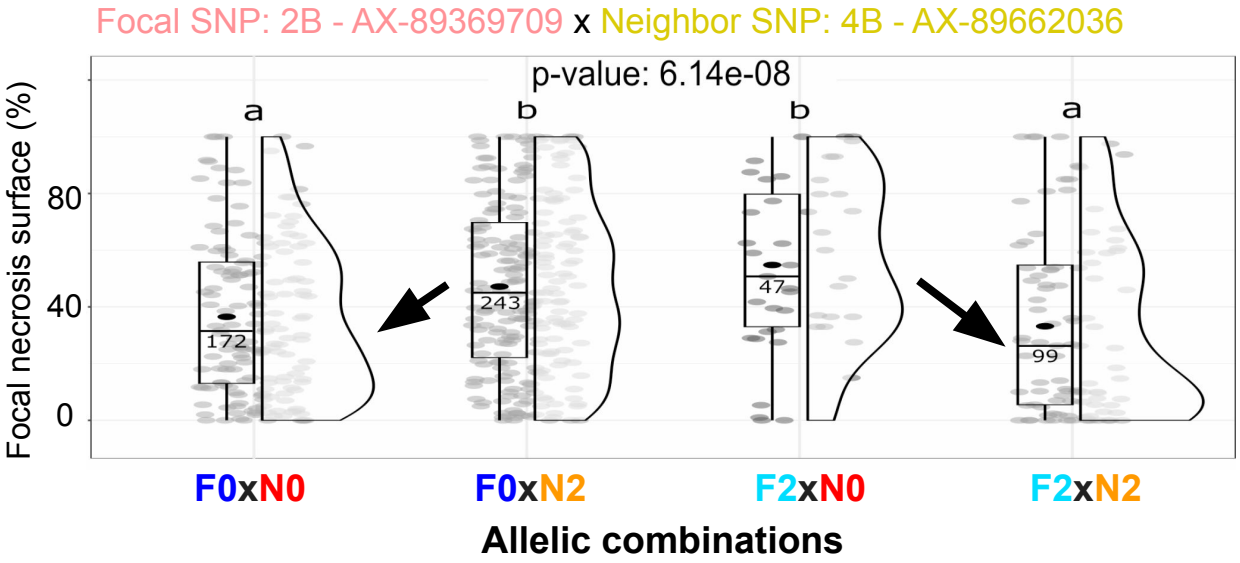


Detection of 54 epistatic interactions, all between different loci in the focal genome and neighbor genome, and 29 involving hub loci.

The most significant interaction modulating focal necrosis surface

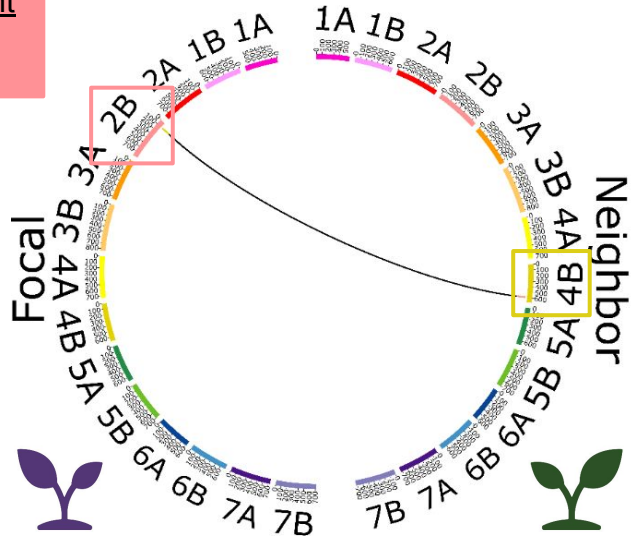


		Alleles at focal locus	
		F0	F2
Alleles at neighbor locus	N0	-	+
	N2	+	-



The most significant interaction modulating focal necrosis surface involves genes related to shade avoidance syndrome

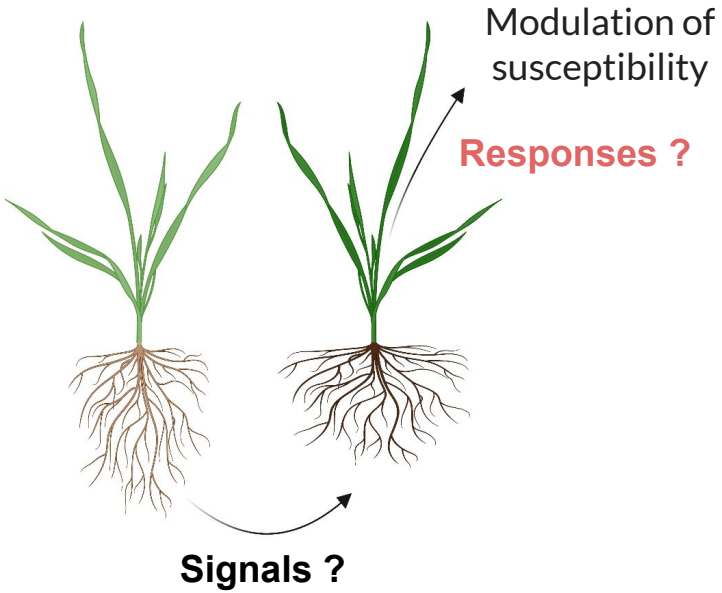
67 genes
1 gene encoding a <u>WEAK movement UNDER BLUE LIGHT-like protein</u>

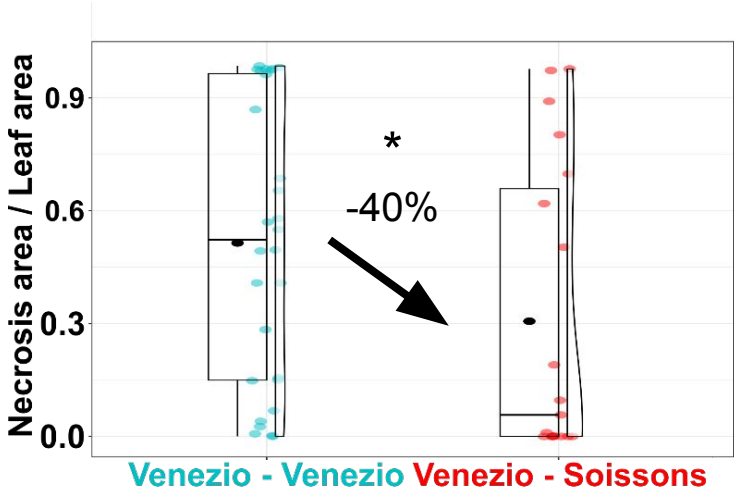


1 gene encoding
a <u>protein FAR1-related sequence</u> &
an ortholog of the rice FHY3/FAR1 gene

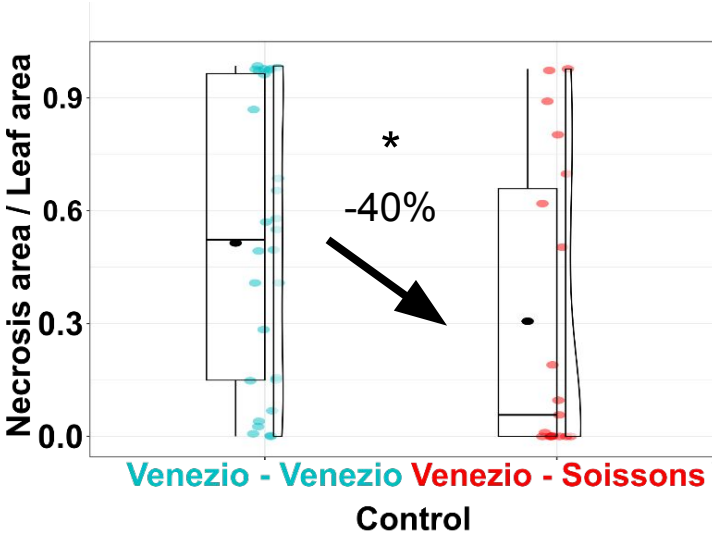
Xu *et al.*, Front. Plant Sci., 2021
Fernández-Milmanda and Ballaré, Trends in Plant Science, 2021
Mathieu *et al.*, Genome Biology, under review

What are the molecular responses of focal wheat plants to their neighbors that modulate their susceptibility to Septoria ?





Phenolic root exudates could drive reduced susceptibility to Septoria in the Venezio-Soissons mixture



PVPP = polyvinylpolypyrrolidone

Mathieu *et al.*, in prep.

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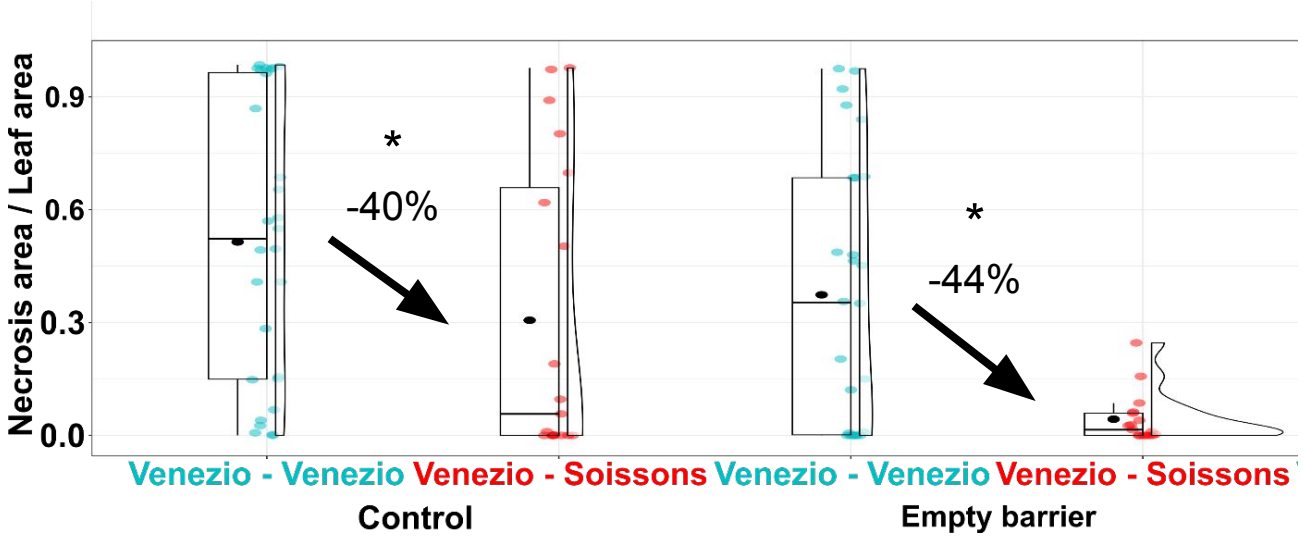

Blockage of root physical contact between genotypes

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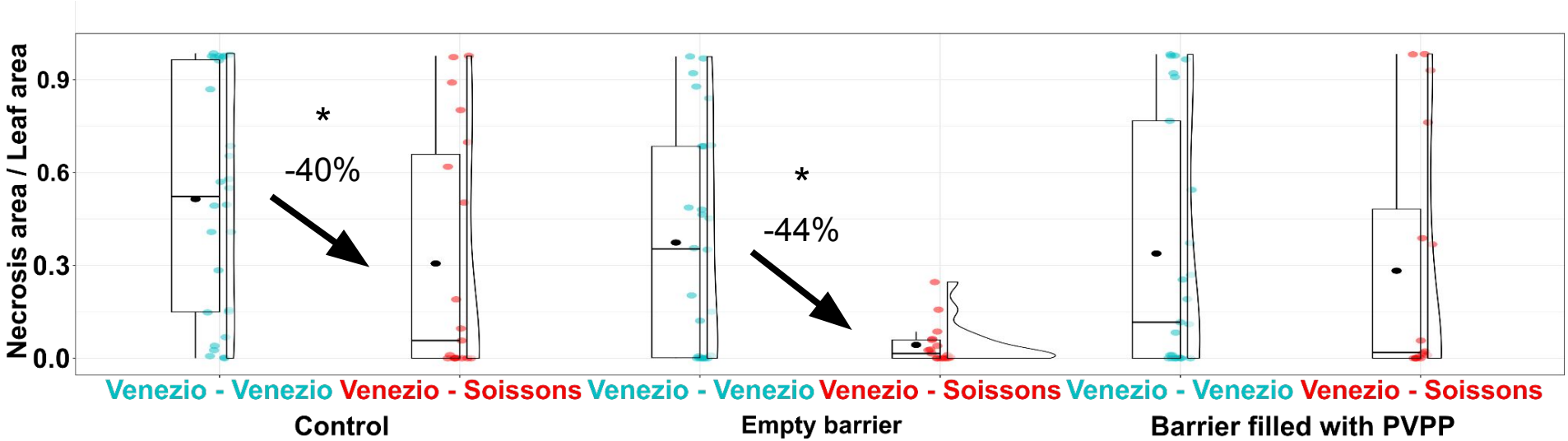

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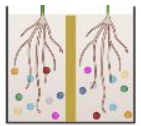


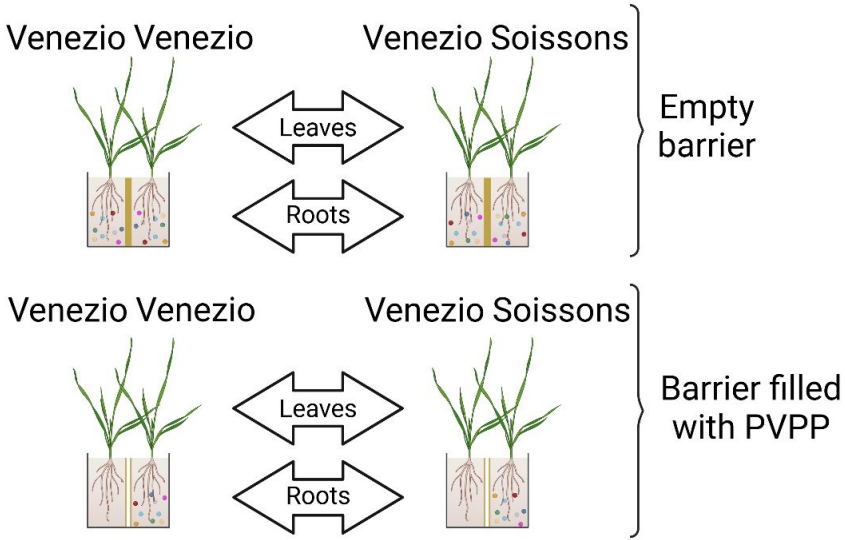
Blockage of exchanges of phenolic molecules between genotypes

PVPP = polyvinylpolypyrrolidone

Mathieu *et al.*, in prep.

Experimental design

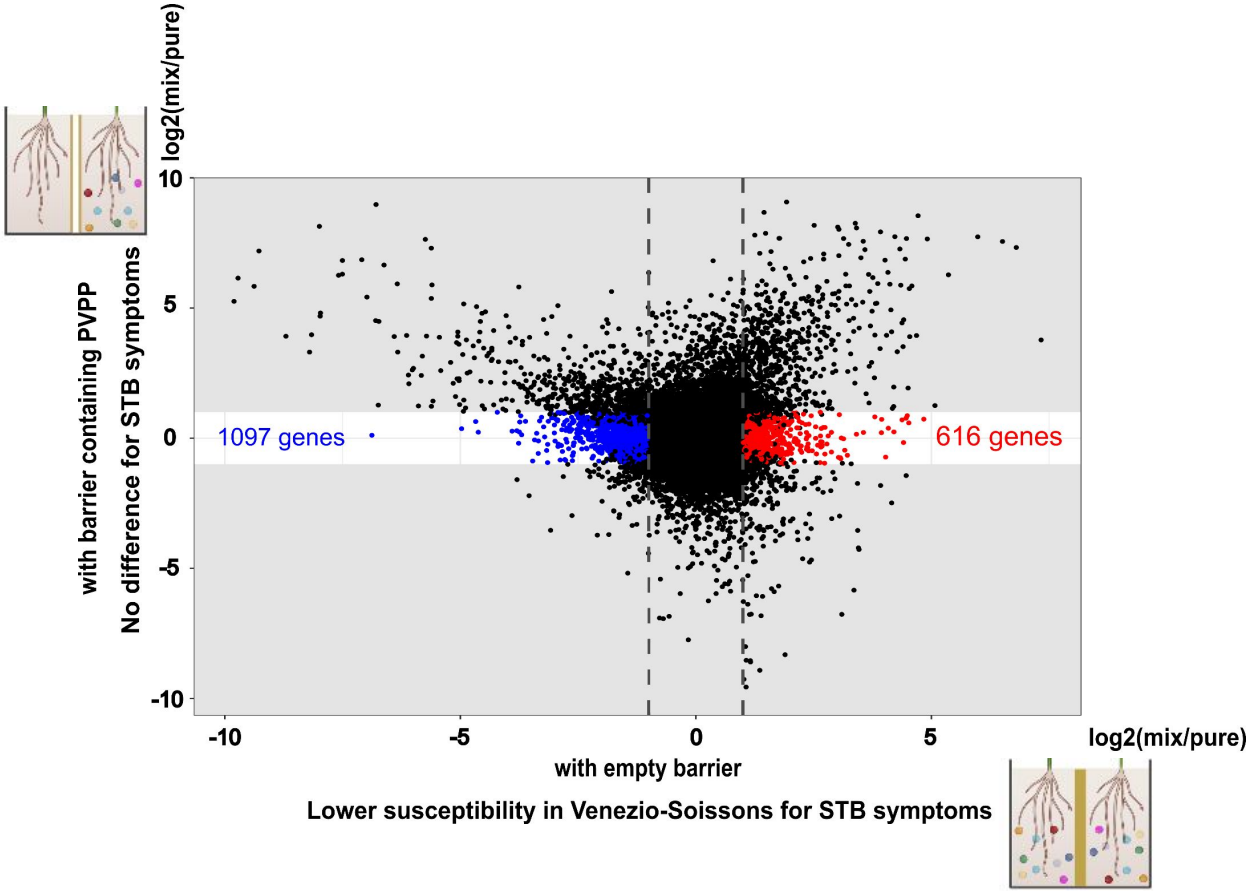
Metabolomic & transcriptomic analyses



PVPP = polyvinylpolypyrrolidone

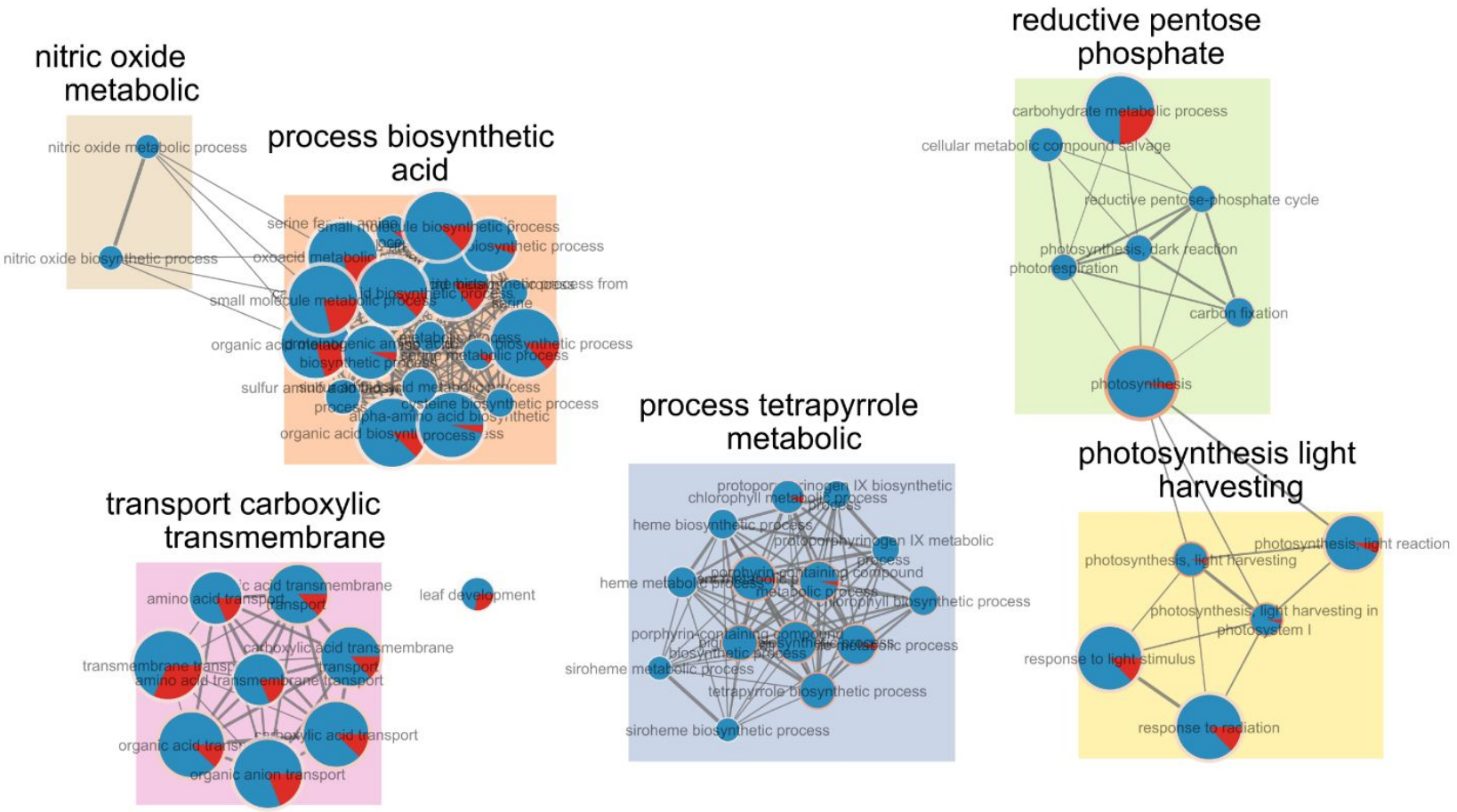
Mathieu *et al.*, in prep.

Transcriptomic changes associated with a modulation of Septoria symptoms in Venezio leaves at the day of inoculation



Mathieu *et al.*, in prep.

Molecular pathways potentially related to a modulation of Septoria symptoms in Venezio



● Down-regulated & ● up-regulated genes

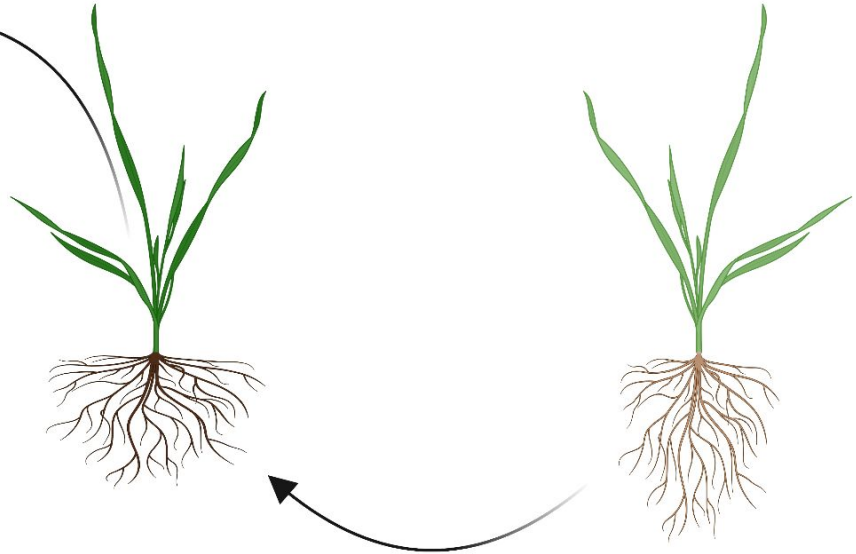
Mathieu *et al.*, in prep.

What are the mechanisms underlying plant-plant interactions that condition the reduction of septoria susceptibility in wheat intraspecific mixtures ?

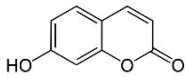
Modulation of susceptibility to Septoria

⚠ Mechanisms dependent on the combination

✔ Responses to resources
✔ Primary metabolism
✔ Specialized metabolism



✔ Belowground signals



Phenolics

Take home messages

Thank you for your attention !

Thanks to the MOMIE (UMR PHIM) & Ge2pop (UMR AGAP) teams

Laura MATHIEU
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Actively seeking new job opportunities