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Genetic diversity and plant-plant interactions as drivers of disease resistance in cereals

Jean-Benoit Morel

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Genetic diversity and plant-plant interactions as drivers of disease resistance in cereals

PHIM

Plant
Health
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Montpellier

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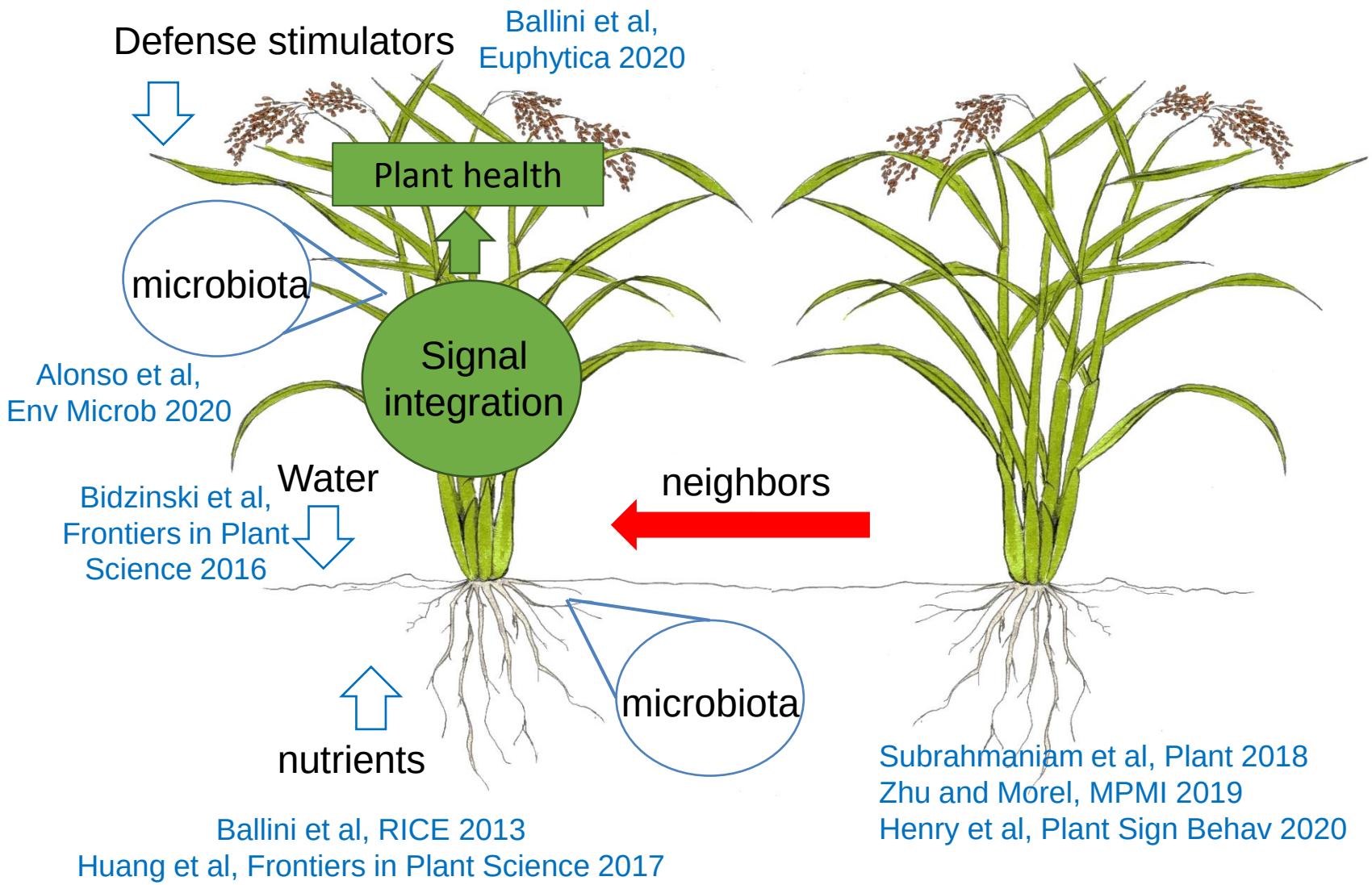
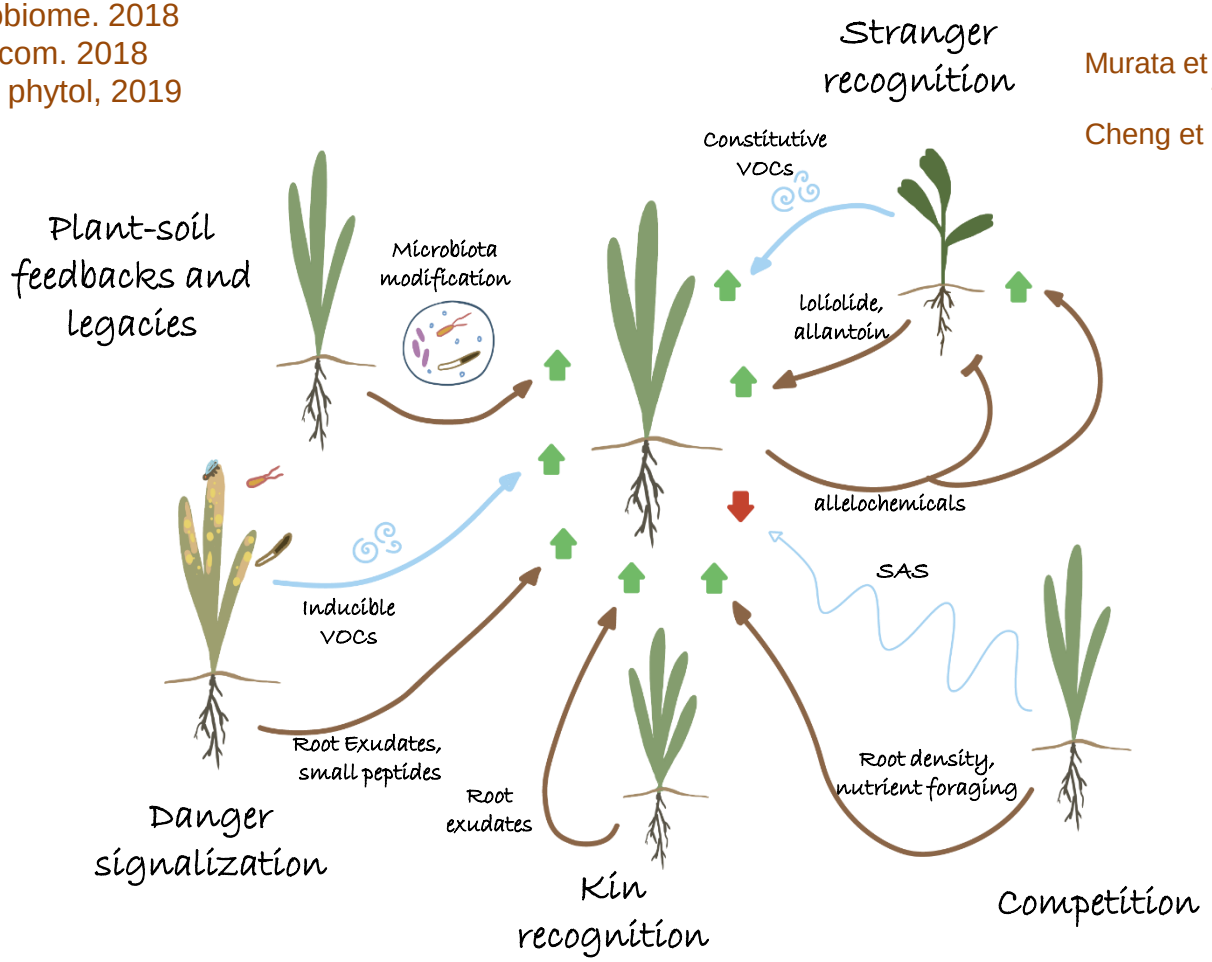
Plant immunity is modulated by the environment



Plants modulate immunity and susceptiblity in their neighborhood

Ma et al, Frontier in plant science. 2017
Beredsen et al, ISME journal. 2018
Yuan et al, Microbiome. 2018
Hu et al, Nature com. 2018
Wang et al. New phytol, 2019

Sukegawa et al. Plant journal, 2018
Venturelli et al. Plant cell, 2015
Kong et al. 2018
Li et al. JEBX, 2020
Murata et al, Plant phisiology 2019
Takagi et al. JEBX, 2016
Cheng et al. Scientific report, 2016



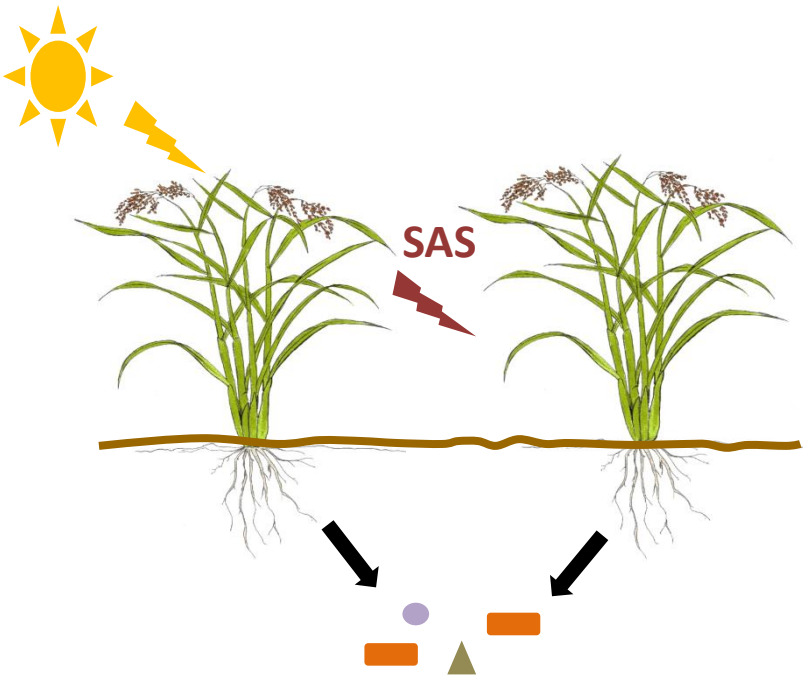
Markovic et al, JEBX. 2019
Wenig et al, Nature com. 2019
Orlovskis et al, New phytol. 2020
Coppola et al, Scientific reports. 2017

Biedrzycki et al, Plant Signaling & Behavior 2011

Wit et al, Plant Journal 2013
Cerrudo et al, Plant Physiology 2012
Ballaré, An. rev. of Plant biology 2014
Chen et al. Frontiers in P. Science, 2019

Intraspecific competition for nutrients between conspecifics

Intraspecific competition ↗ → **Intraspecific plant density** ↗



Competition for nutrient

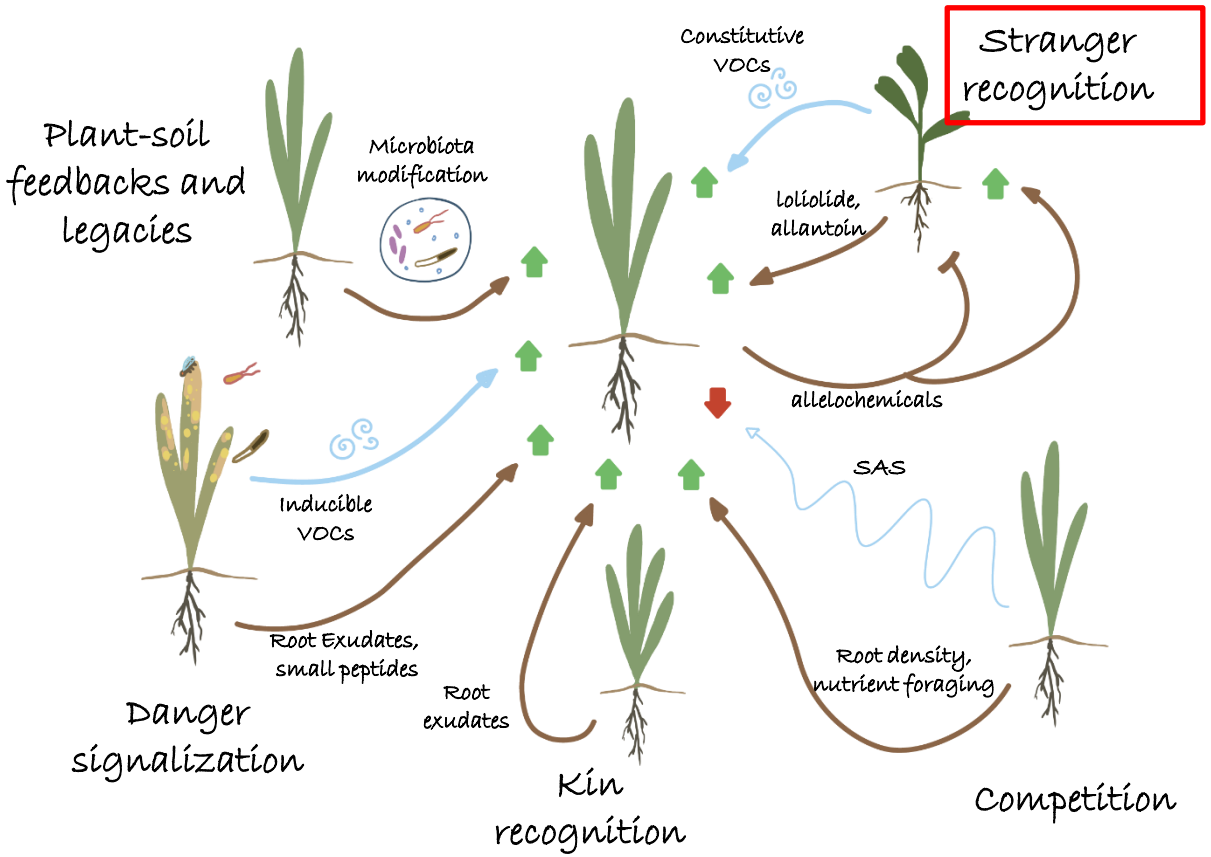
↗ **Shade Avoidance Syndrom** increases *A.thaliana* susceptibility to pathogens

Wit et al, Plant Journal 2013
Cerrudo et al, Plant Physiology 2012
Review in Ballaré, An. rev. of Plant biology 2014

↘ **Root interaction with conspecifics** increases accumulation of chemical defense in tobacco

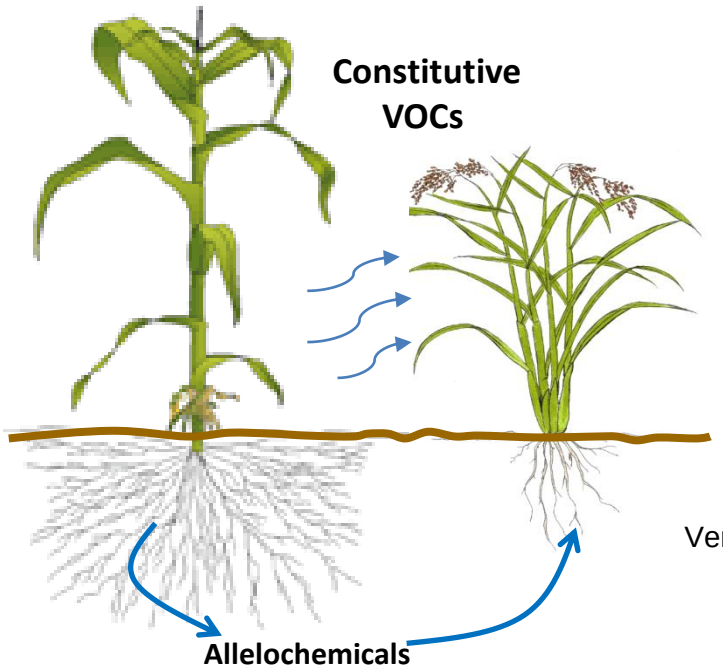
Chen et al. Frontiers in Plants Science, 2019

Plants modulate immunity and susceptiblity in their neighborhood



Stranger's things from healthy neighbors

Sukegawa et al. Plant journal, 2018



Menthol (cVOCs)

Modifiying histone acetylation of promoters of defense genes

DIMBOA and derivatives

Venturelli et al. Plant cell, 2015
Kong et al. 2018

(-)-Loliolide

Li et al. JEBX, 2020
Murata et al, Plant phisiology 2019

Allantoine

Takagi et al. JEBX, 2016

Diallyl disulfide

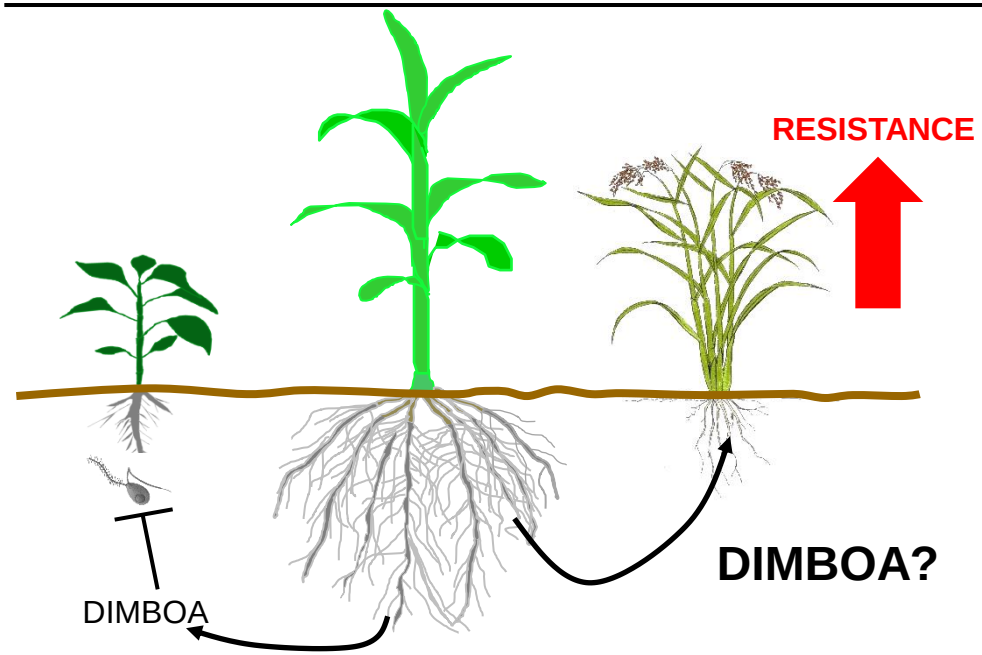
Cheng et al. Scientific report, 2016

- Defense gene upregulated

- Herbivory & pathogen resistance increased

- Production of allelopathic molecules against parasites

DIMBOA hypothesis



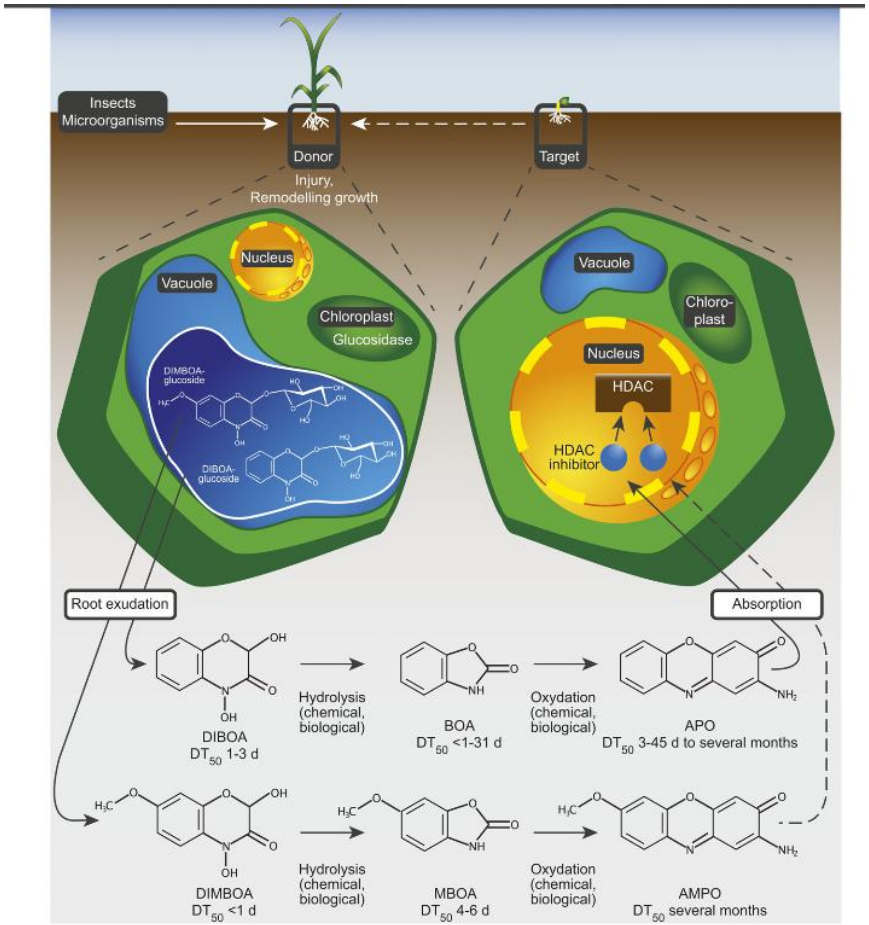


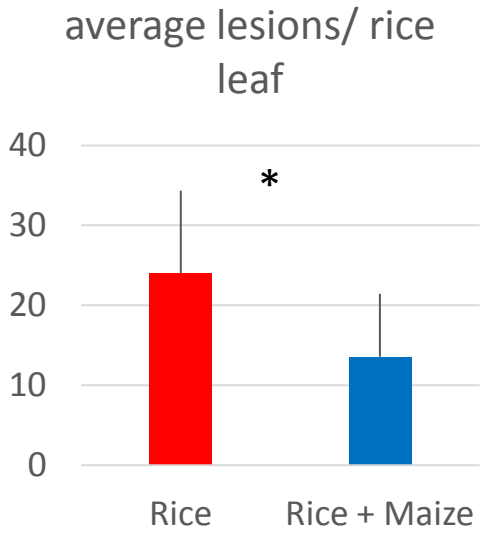
Figure 5. Model of a Chromatin-Based Mode of Action of the Allelochemicals APO and AMPO.

(Venturelli et al, 2015)

DIMBOA derivatives ⊣ HDAC ⊣ defense

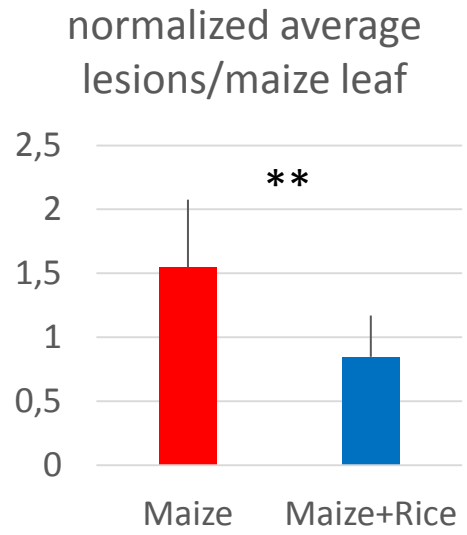
Intercropping rice and maize

Rice blast disease (GY11)



(Nipponbare and B73)

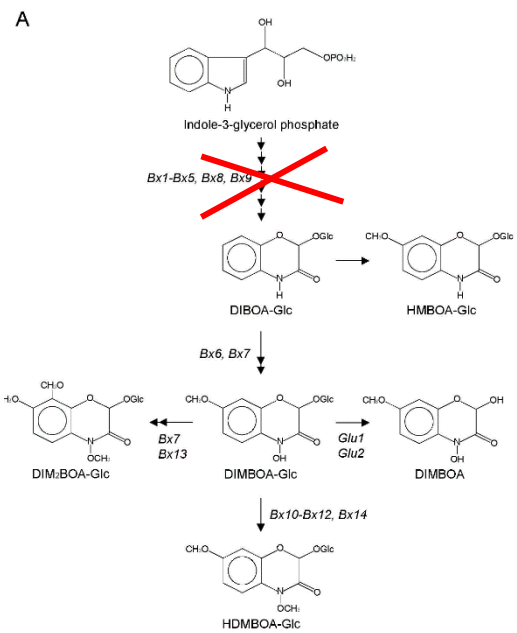
Maize blast disease (2 isolates)

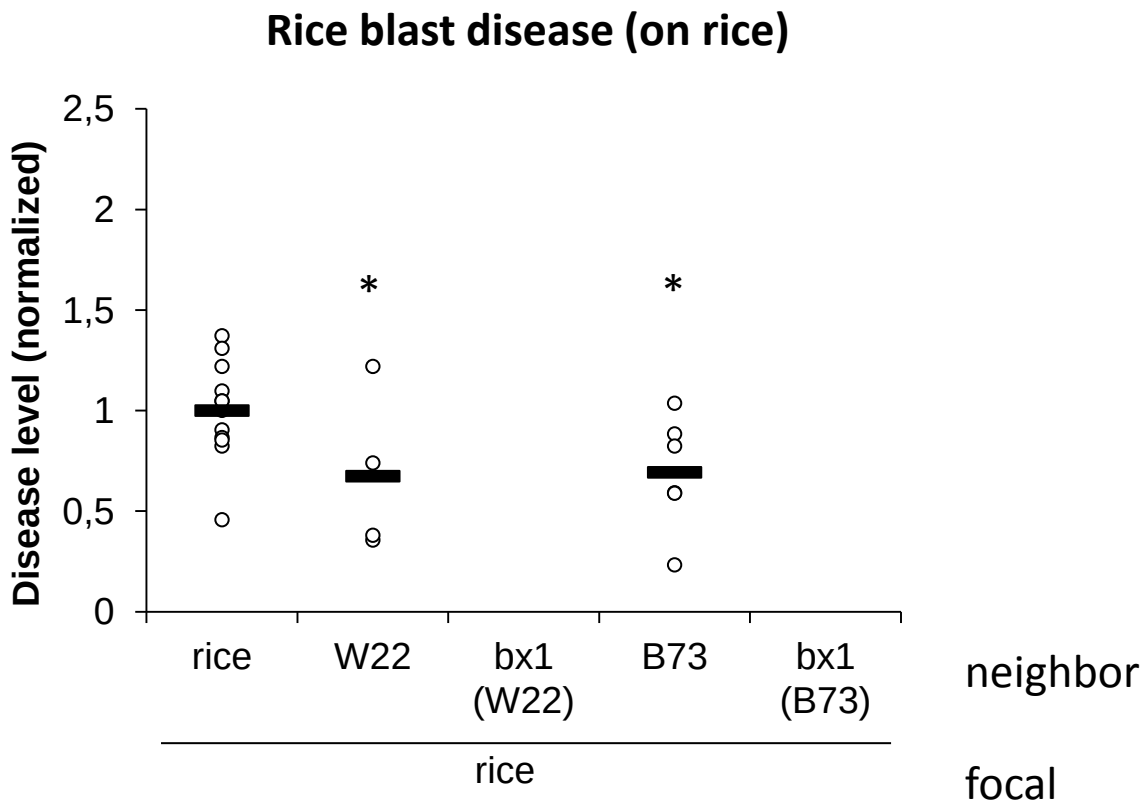


(B73 and Maratelli)

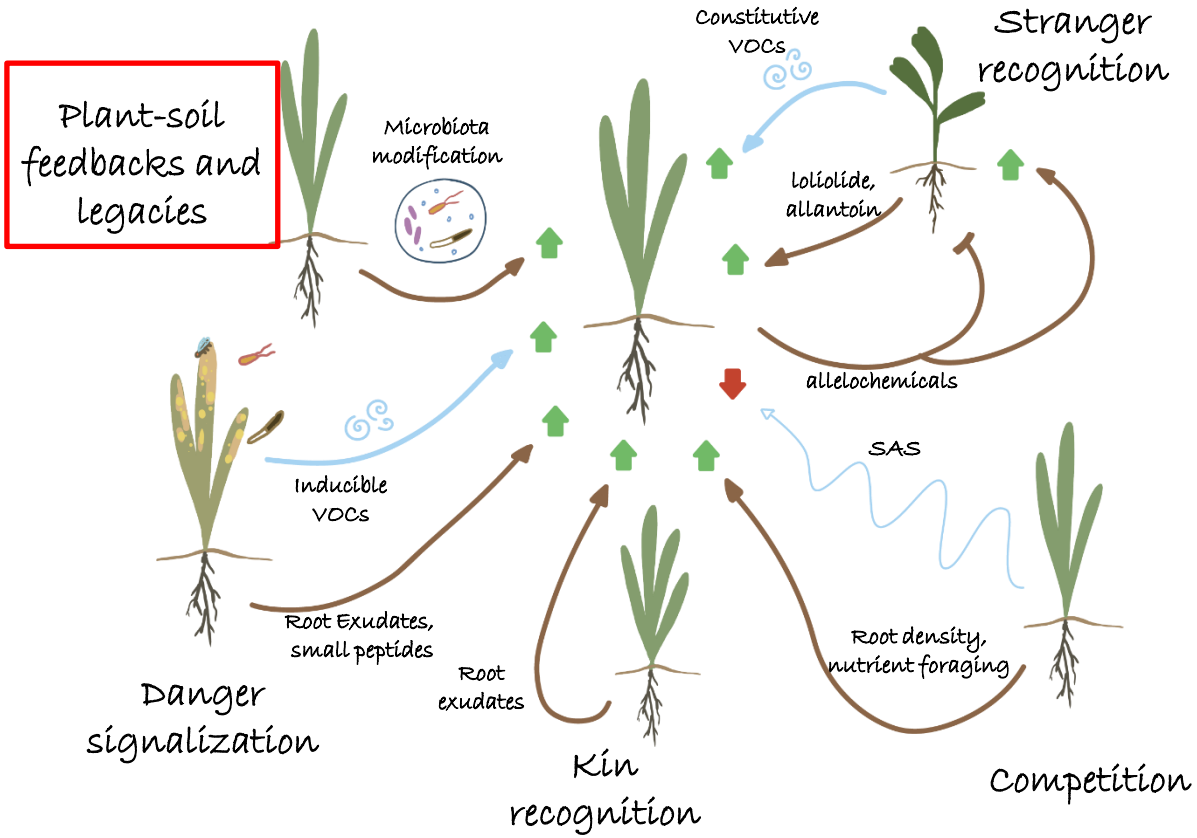
~40% reduction of symptoms

DIMBOA biosynthesis is required for protection in intercropping





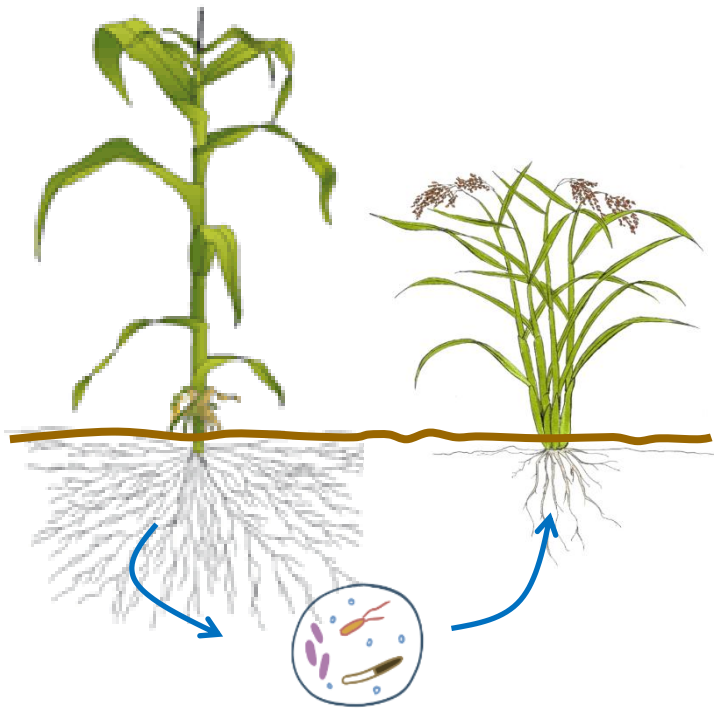
Plants modulate immunity and susceptiblity in their neighborhood



Plants leave a message : plant soil feedback and legacies

Plant–soil feedback is a process where plants alter the biotic and abiotic qualities of soil they grow in, which then alters the ability of plants to grow in that soil in the future

Wikipedia



Microbiota modification

→ **Intraspecific & Interspecific**

Ma et al, Frontier in plant science. 2017

→ **Inductible or constitutive**

Beredsen et al, ISME journal. 2018
Yuan et al, Microbiome. 2018

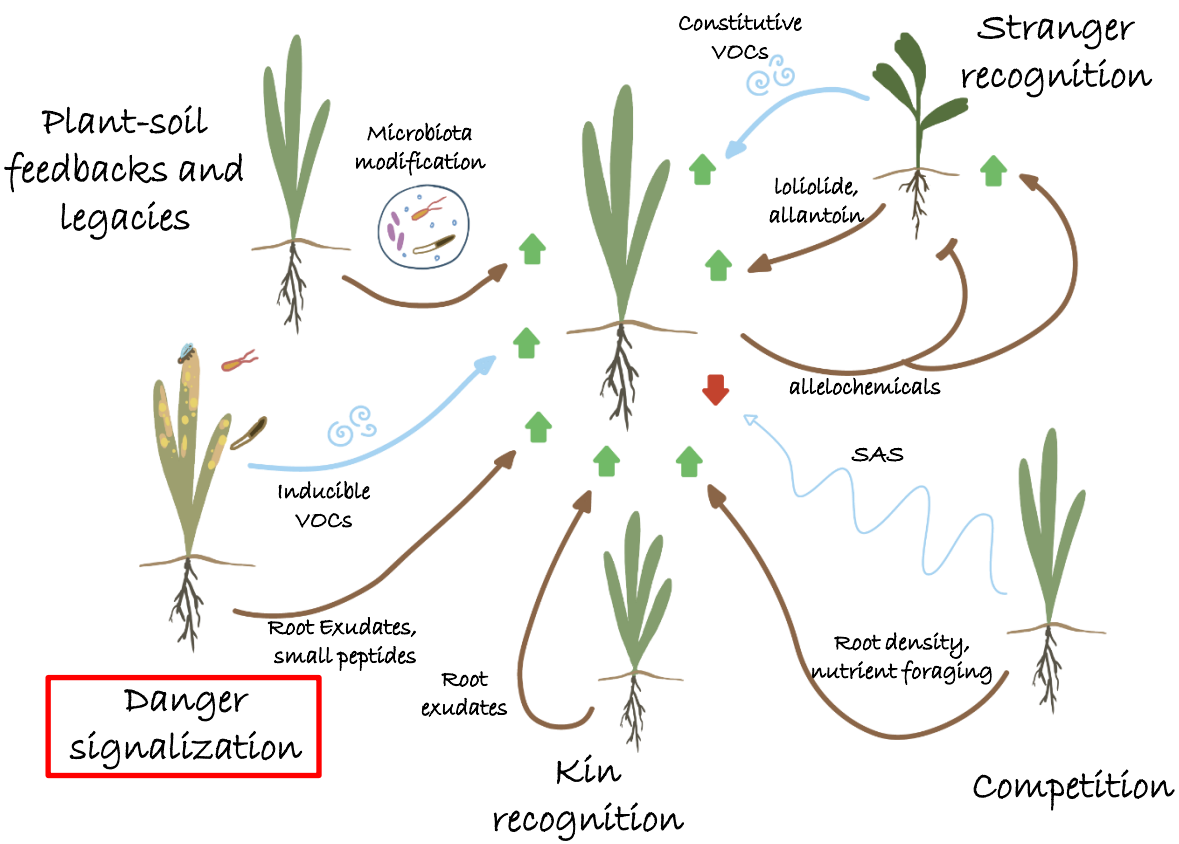
→ **Induces defense genes, pathogen and herbivory resistance**

Hu et al, Nature com. 2018

→ **Depend on specific species of fungi, bacteria or combinaison**

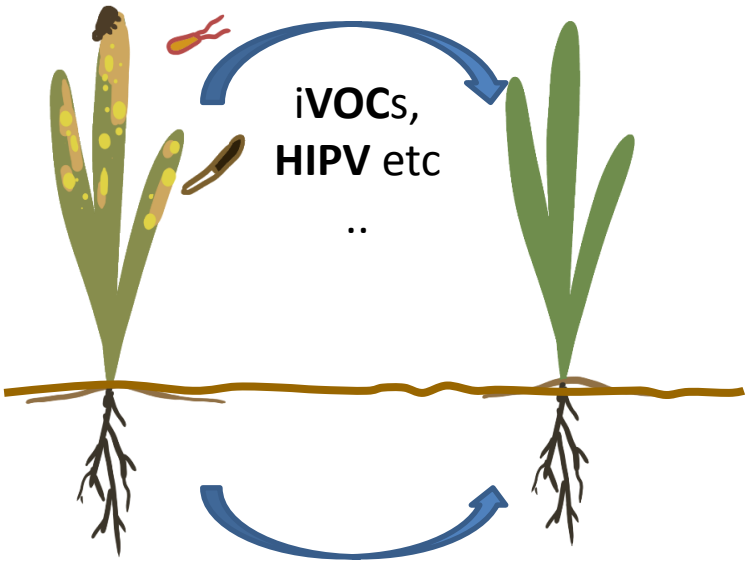
Wang et al. New phytol, 2019

Plants modulate immunity and susceptiblity in their neighborhood



The neighbor watch, Signalisation of danger between plant

Disease / attack plant



Inductible **Root exudates**, small **peptides** ...

Inducible VOCs → Can be triggered by touch in maize

Markovic et al, JEBX. 2019

Monoterpene

Wenig et al, Nature com. 2019

Unknown root signal

Orlovskis et al, New phytol. 2020

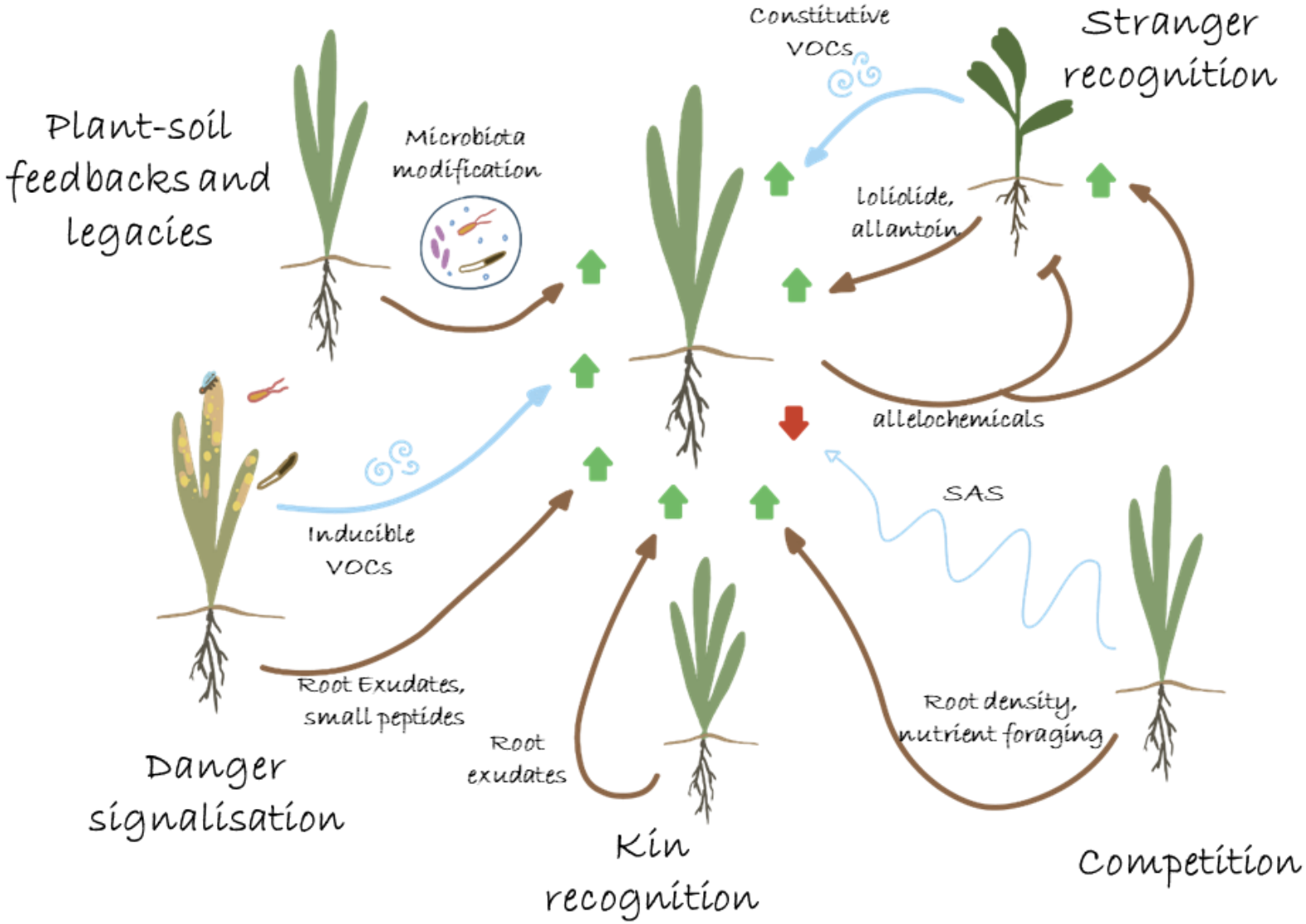
Propagation of SAR (Systemic acquired Resistance) between neighbor plants

Systemin → Excreted soil peptide (18 AA) by tomato roots

Coppola et al, Scientific reports. 2017

Plants modulate immunity and susceptiblity in their neighborhood

Pelissier, Violle and Morel, review submitted

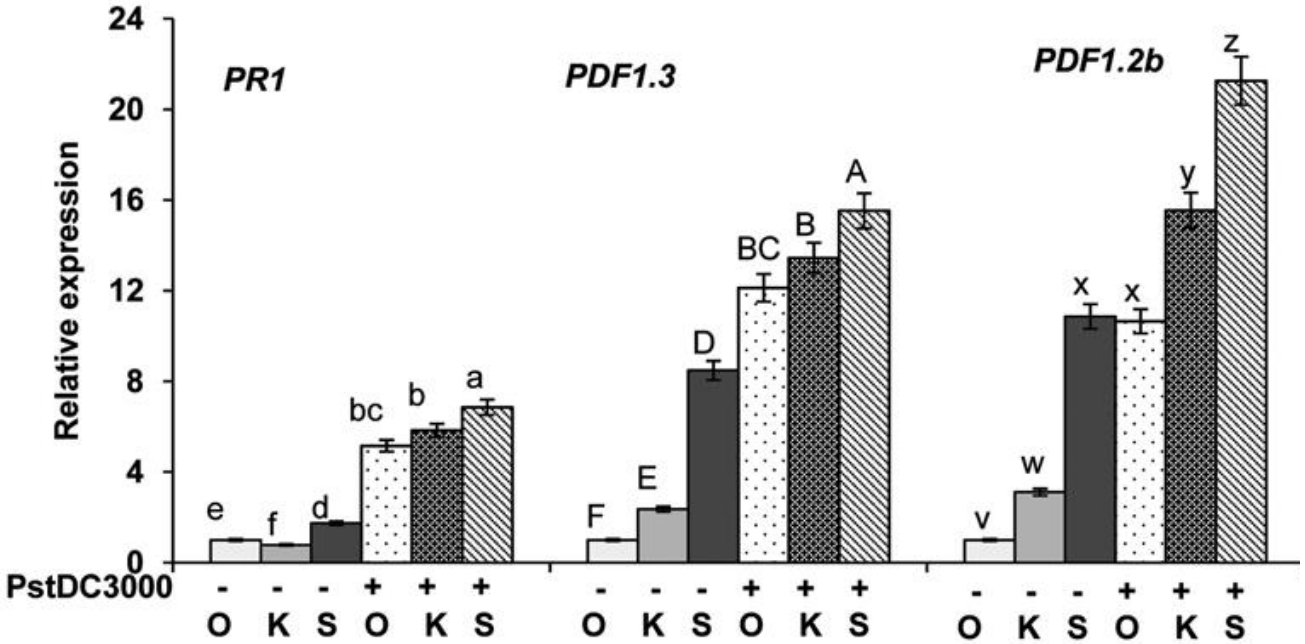


Can kins/conspecifics modulate susceptiblity in their neighborhood?

Kin recognition: when plants recognize conspecifics

Kin recognition is an organism's ability to distinguish between close genetic kin and non-kin

Wikipedia

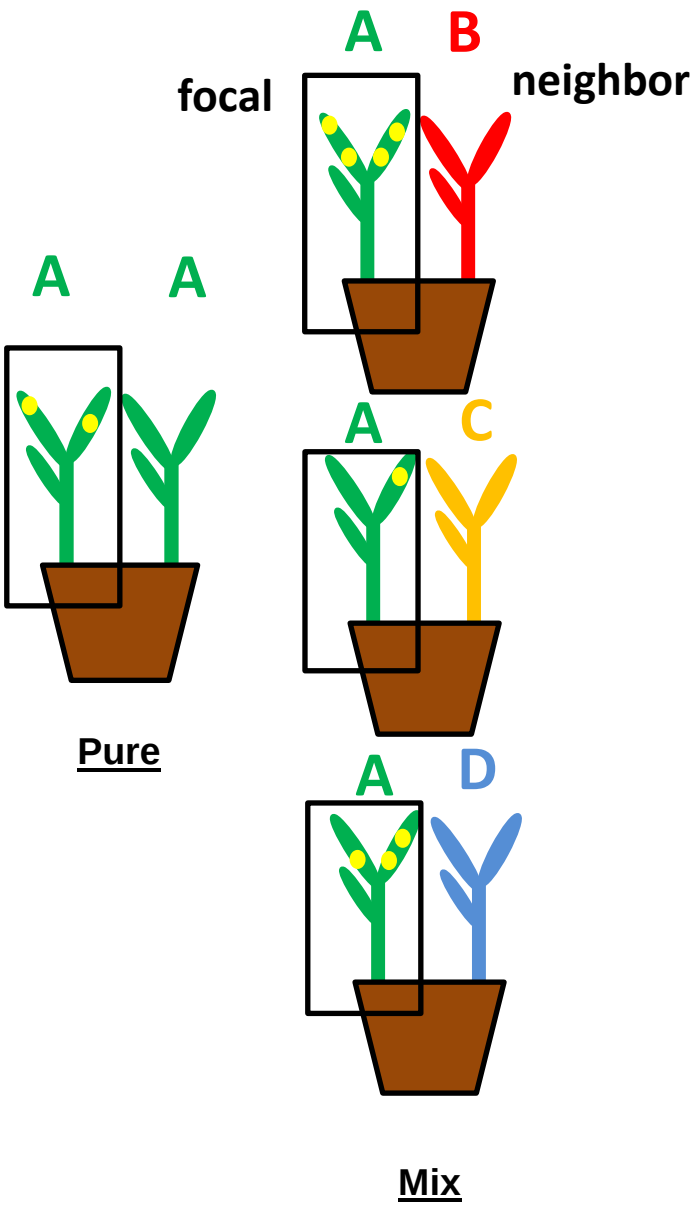


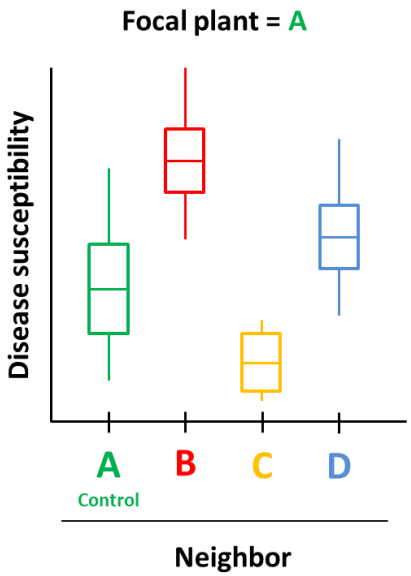
O= Own= plant alone
K= Kin= 2 plants together
S= Stranger= different ecotype

Biedrzycki et al, Plant Signaling & Behavior 2011

→ Only one example to our knowledge shows that **Kin recognition** can trigger the expression of immunity (kin relations known to affect response to insects)

Screening for Neighbor-modulated susceptiblity





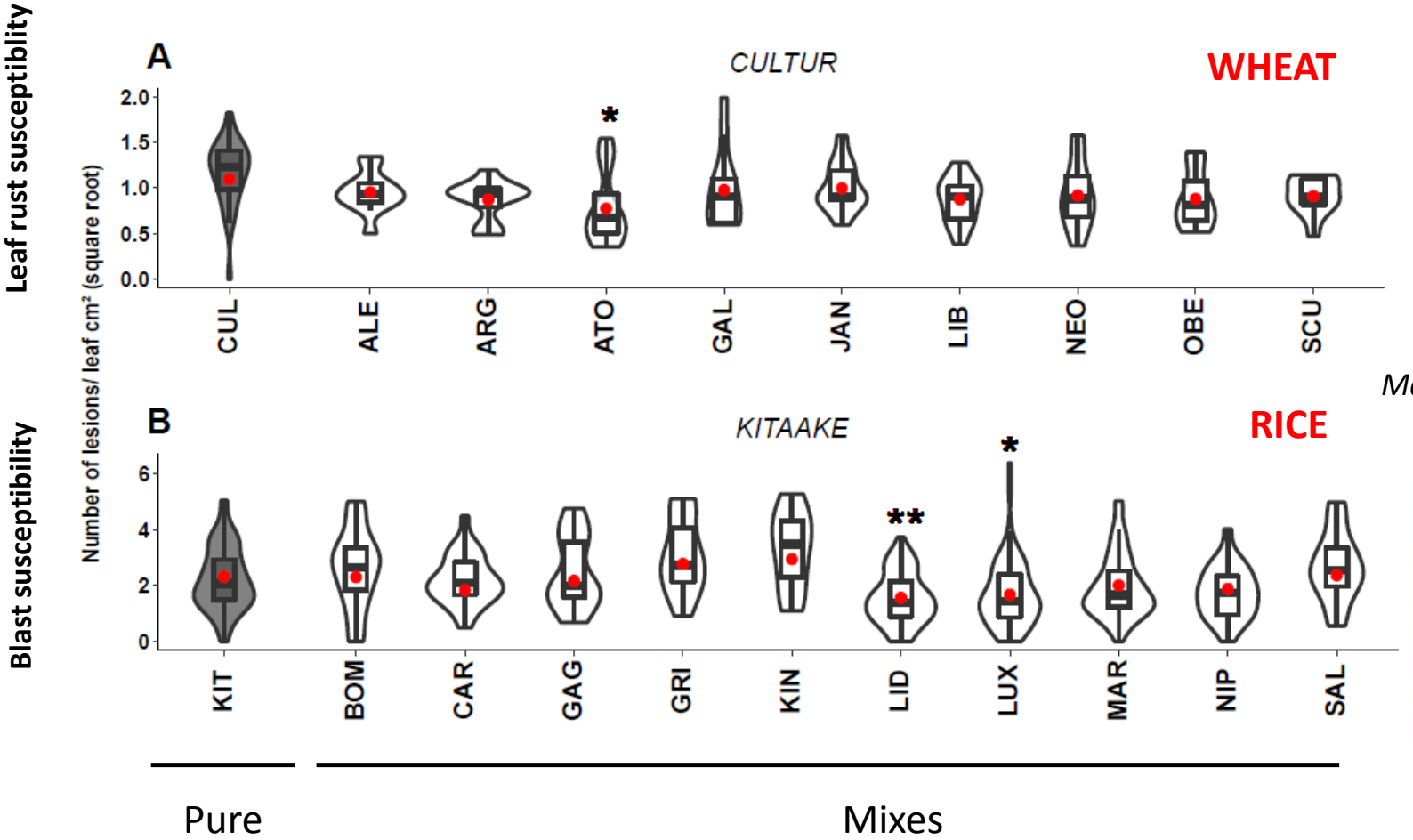
Specific ability
of a given neighbor
to modulate
susceptibility of focal A
(« good » or « bad » neighbor)

Neighbor-modulated susceptibility (NMS) in rice and wheat

Pelissier et al, submitted

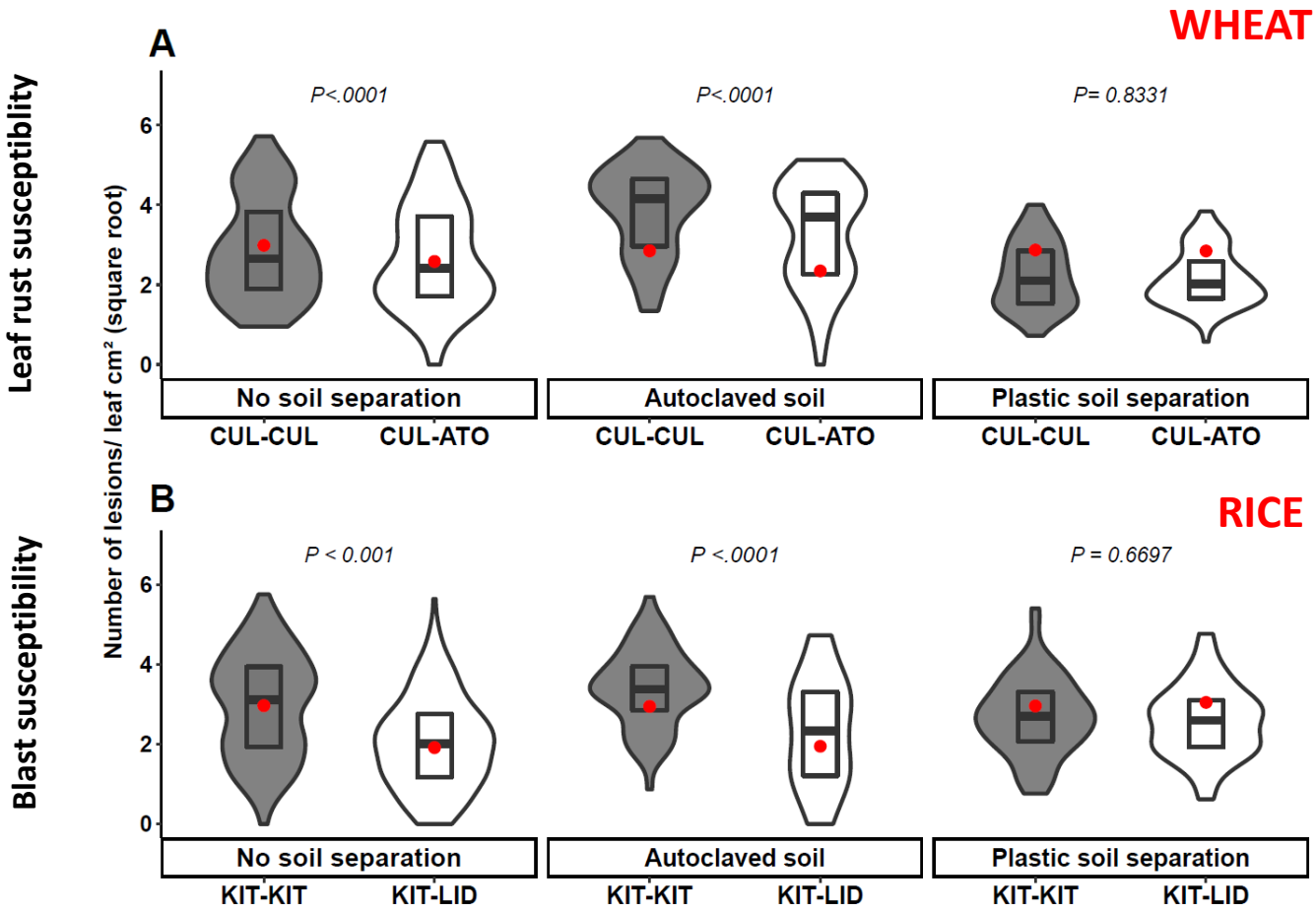
Puccinia triticina

Magnaporthe oryzae



Some kins can modulate susceptiblity in their neighborhood (NMS)

Localization of intra-specific plant-plant interactions leading to NMS

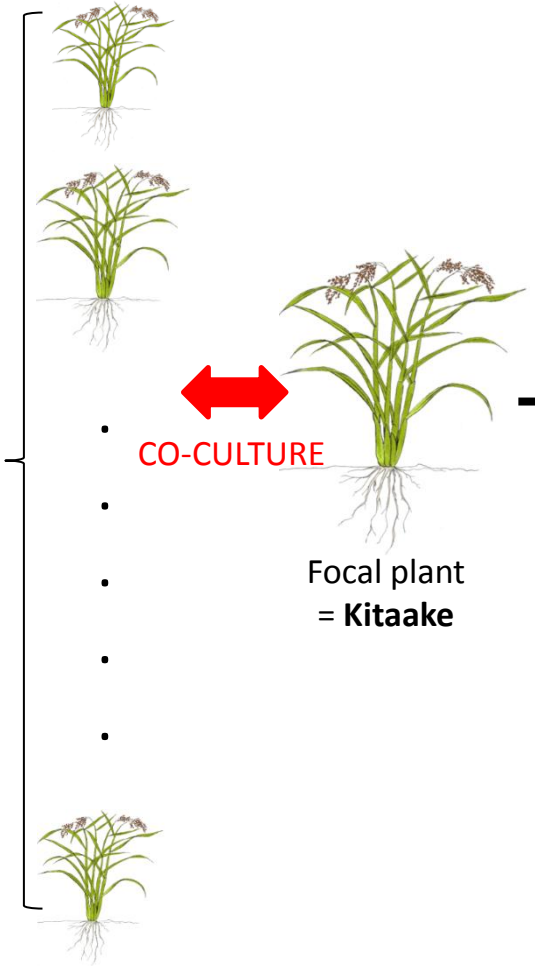


NMS takes place in the soil and does not require microbiome (nor an infected neighbor)

Pelissier et al, submitted

Mapping rice ability to modulate susceptibility in its neighborhood

Neighbor plant
=
280 genotypes of
temperate japonica



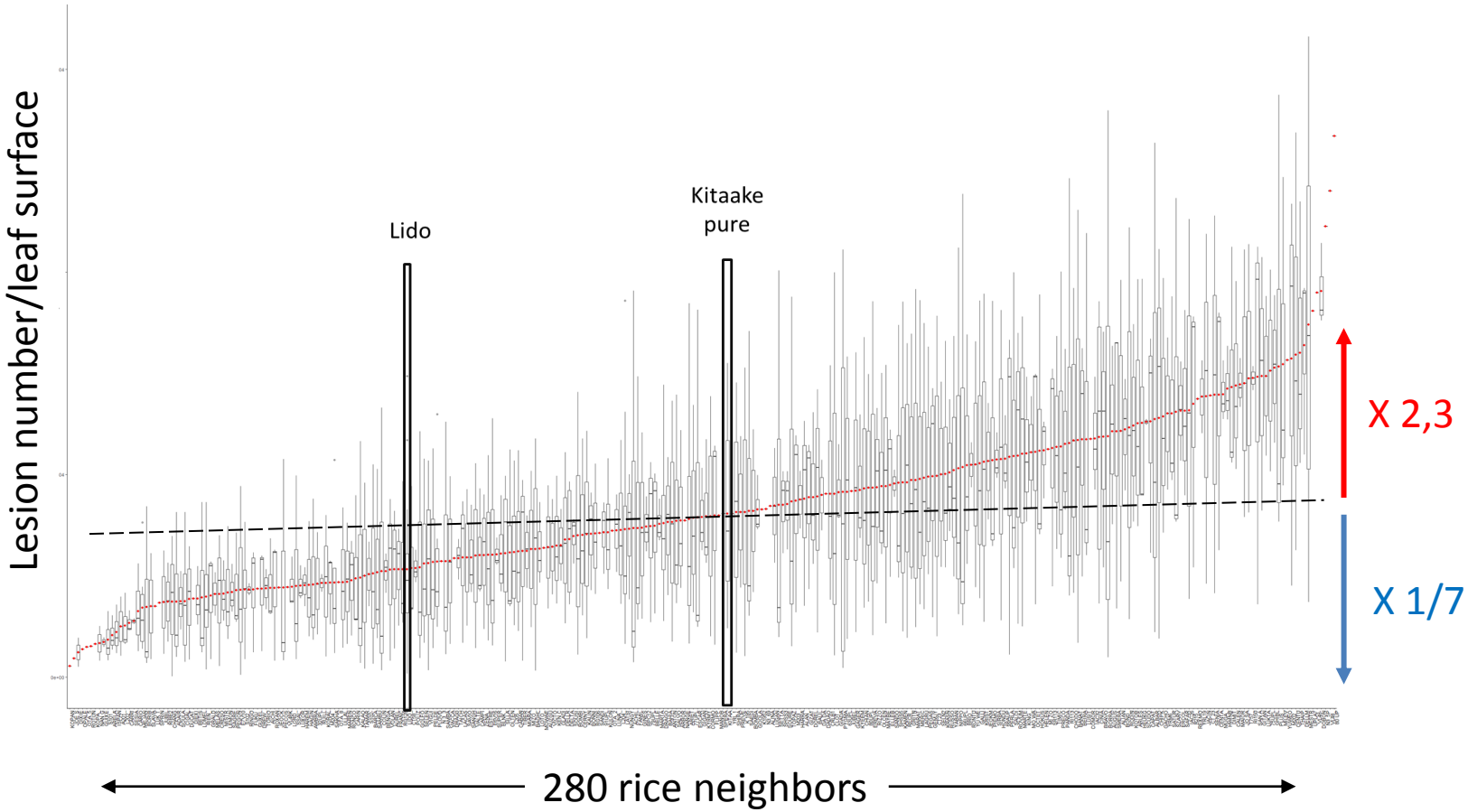
Blast susceptibility on Kitaake → X 3 replicates → **GWAS (Genome Wide Association Study) of NMS emission**

Diversity of NMS?
Rice loci involved in NMS emission?

Rémi

Pelissier et al, unpublished

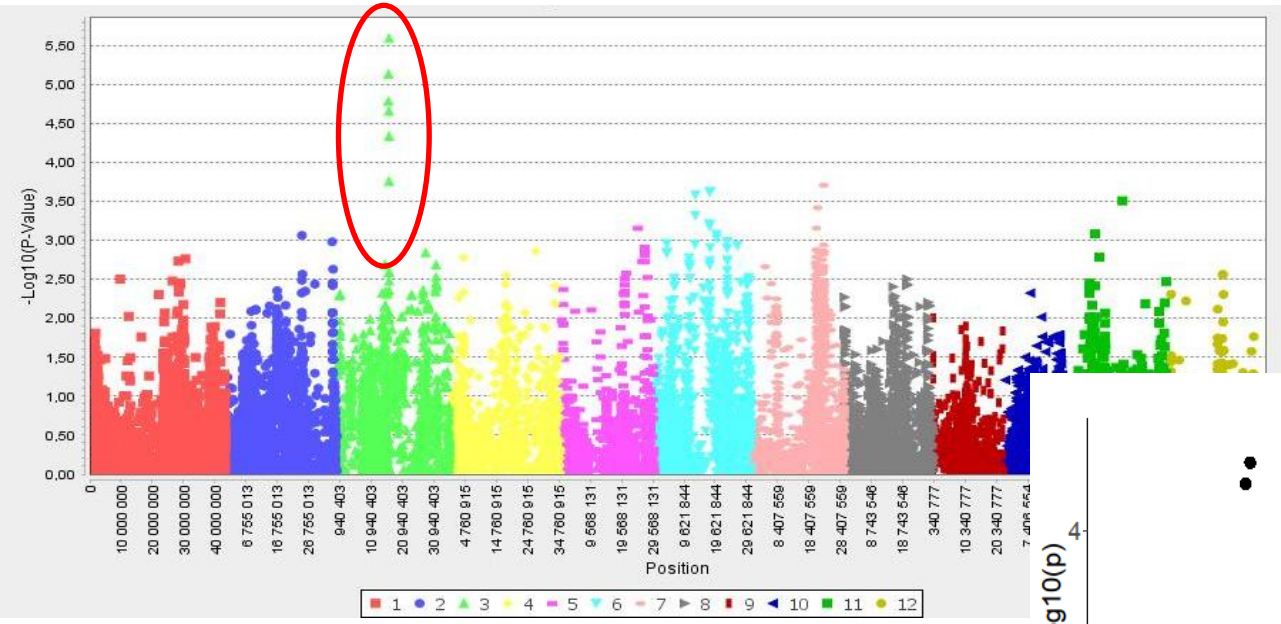
Blast susceptibility of Kitaake cultivated with 280 differents neighbors

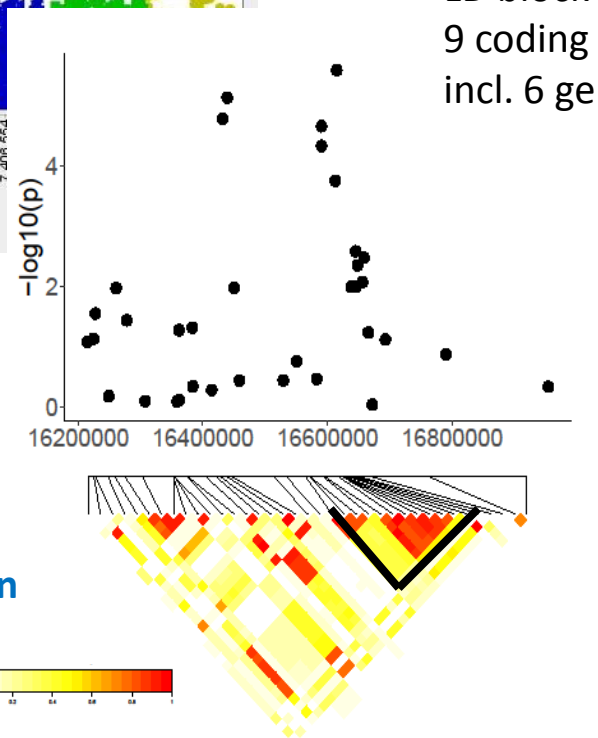


Neighbors can reduce but also increase disease susceptibilty of Kitaake

Pelissier et al, unpublished

GWAS of the emission of NMS





LD block= 250kb
9 coding sequences,
incl. 6 genes

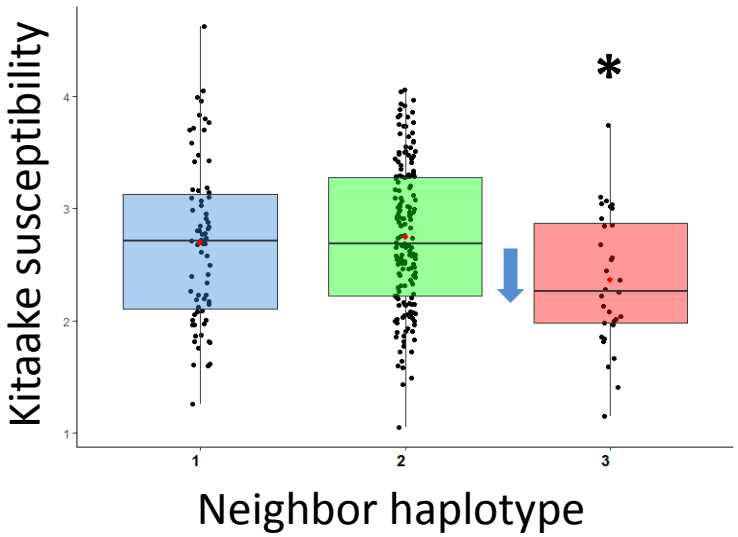
One region on rice chromosome 3 controls NMS emission

Pelissier et al, unpublished

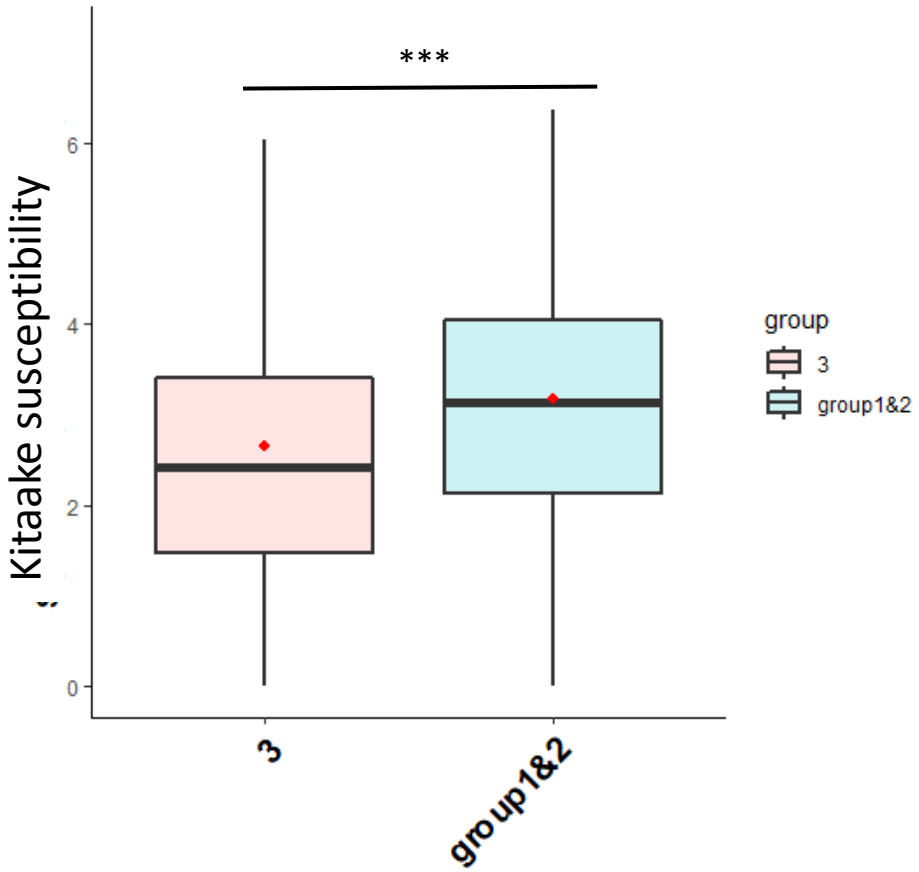
Test of GWAS prediction for emission of NMS

Susceptibility data from GWAS

20% reduction of susceptibility



Independent validation
(6 haplotype 3 vs 6 haplotypes 1 or 2)

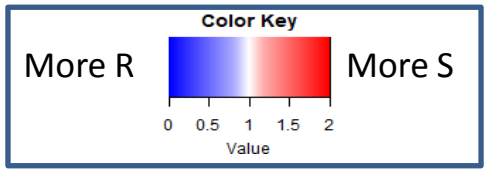


GWAS predicts that neighbors with haplotype 3 reduce susceptiblity in focal kitaake

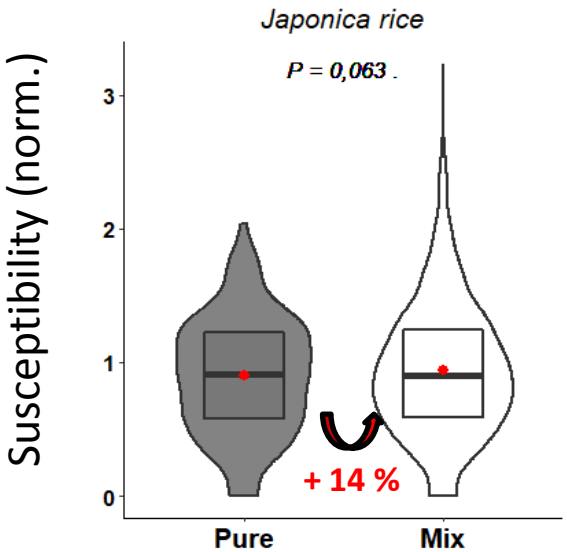
Pelissier et al, unpublished

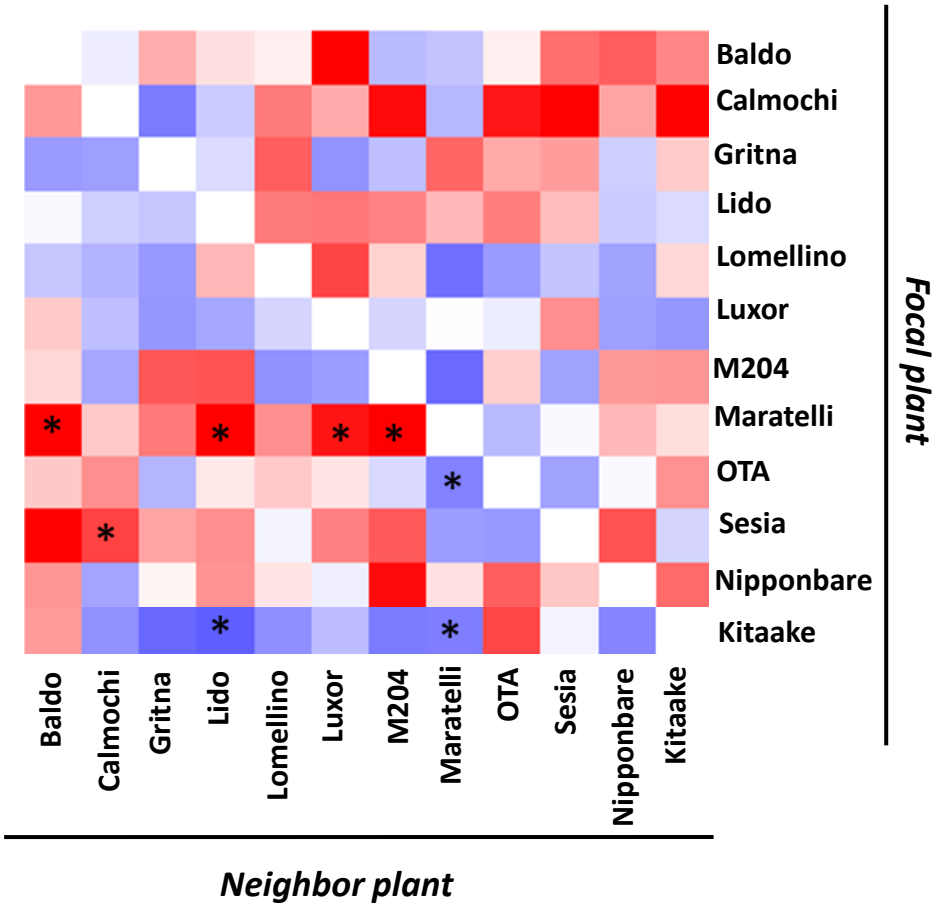
NMS at the species level: the case of temperate japonica rice

Rice
Blast fungus



Temperate japonica rice





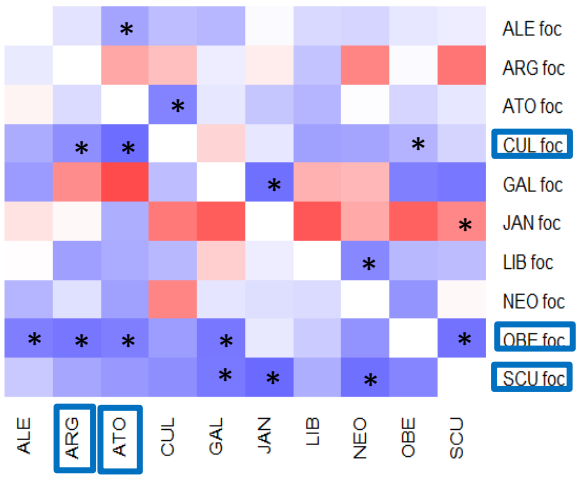
Intra-specific interactions are not favorable to rice blast resistance

Pelissier et al, unpublished

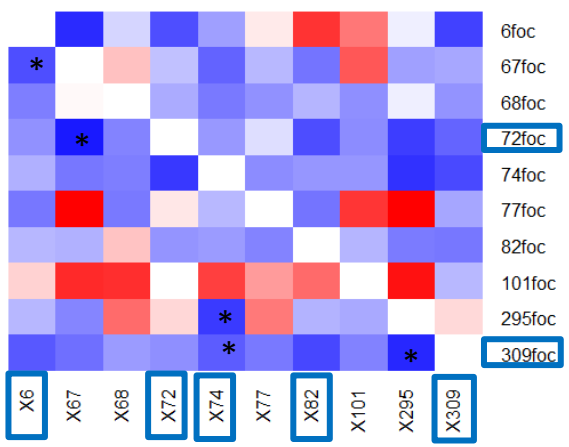
NMS: good neighbor and good focal plants

Wheat X leaf rust

Cultivated durum wheat

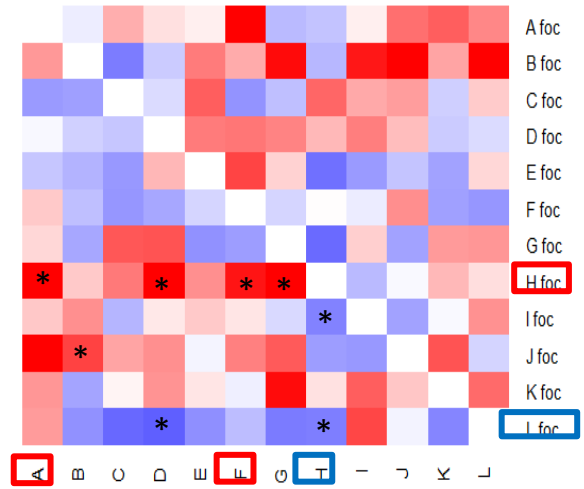


EPO Wheat

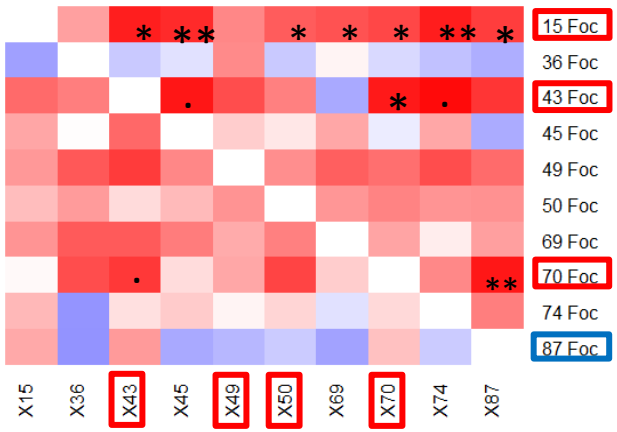


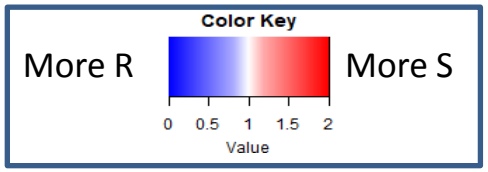
Rice X Blast fungus

Japonica Rice



Acuce rice





Focal plant

Neighbor plant

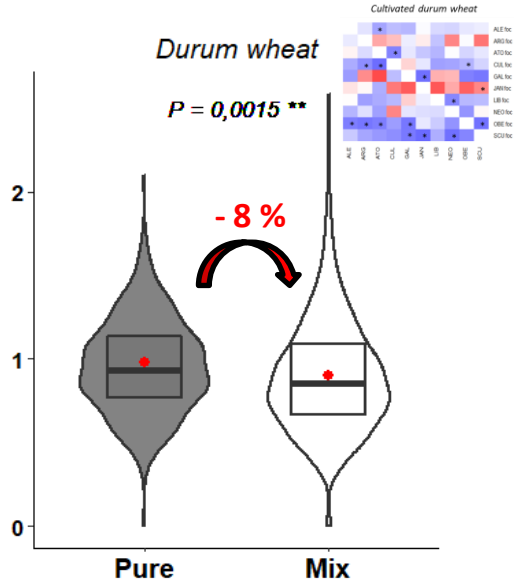
Pelissier et al, unpublished

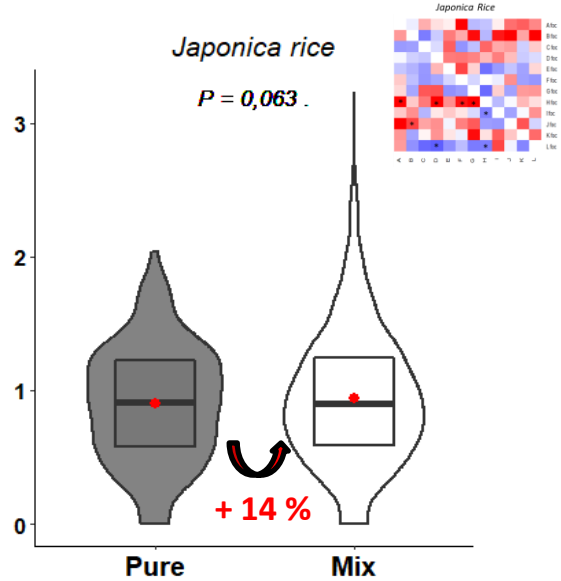
NMS and breeding

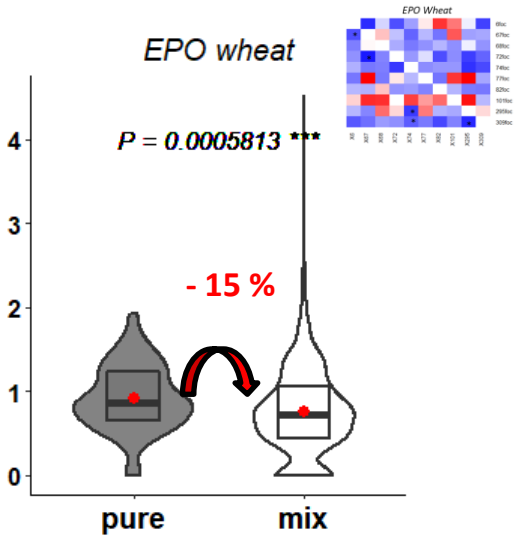
Wheat
(leaf rust)

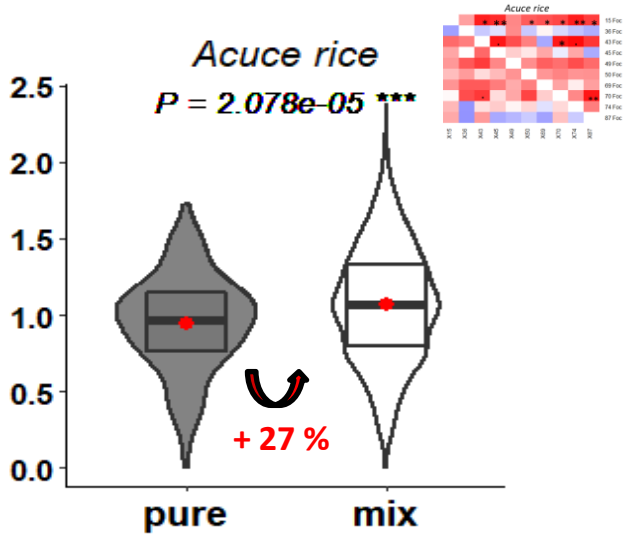
Rice
(Blast fungus)

Pathogen susceptibility

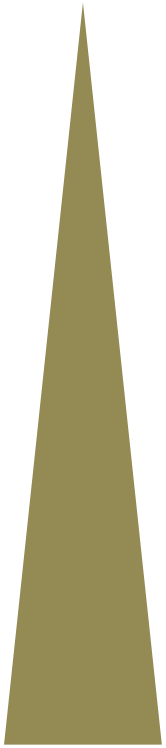








Historical
within-field
co-existence



Pelissier et al, unpublished

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Yunnan Agricultural University

Huichuan Huang
Jingjing Liao
Baihui Jin
Xiahong He
Chenyung Li
Youyong Zhu

Cyrille Violle
Centre d'Ecologie Fonctionnelle & Evolutive

Hélène Fréville
agap

International joint Lab PLANTOMIX

jean-benoit.morel@inrae.fr

Rémi Pélissier
Elsa Ballini
Luis Buendia
Aurélie Ducasse
Andy Brousse

Funding
French ANR
INRAE Crop protection
CASDAR

QUESTIONS?

+ projet thèse (Inrae-ANR Mobidiv)
Génétique et physiologie des interactions blé-blé modulant la sensibilité aux agents pathogènes
(Sept 2021-2024)