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

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

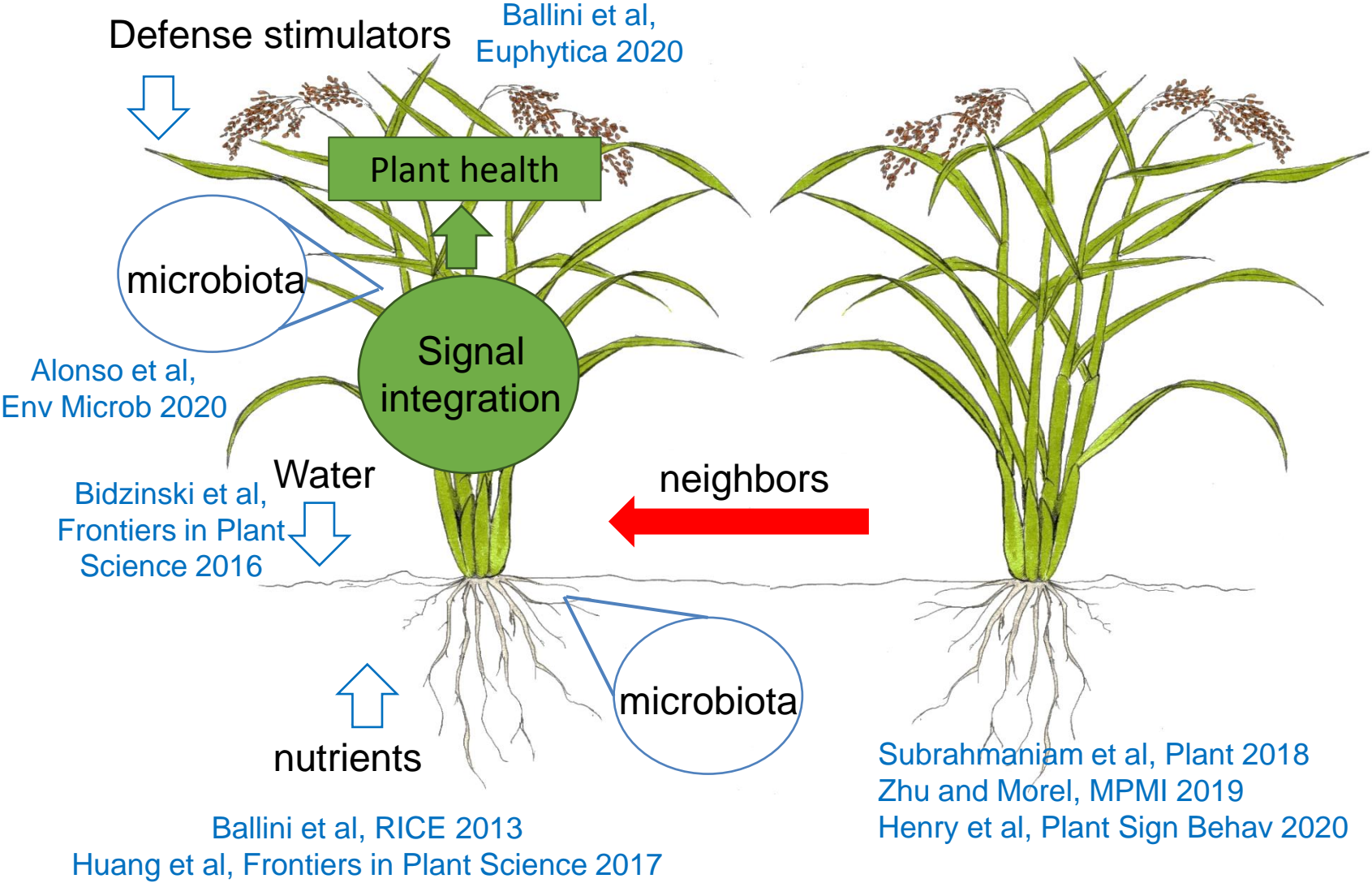


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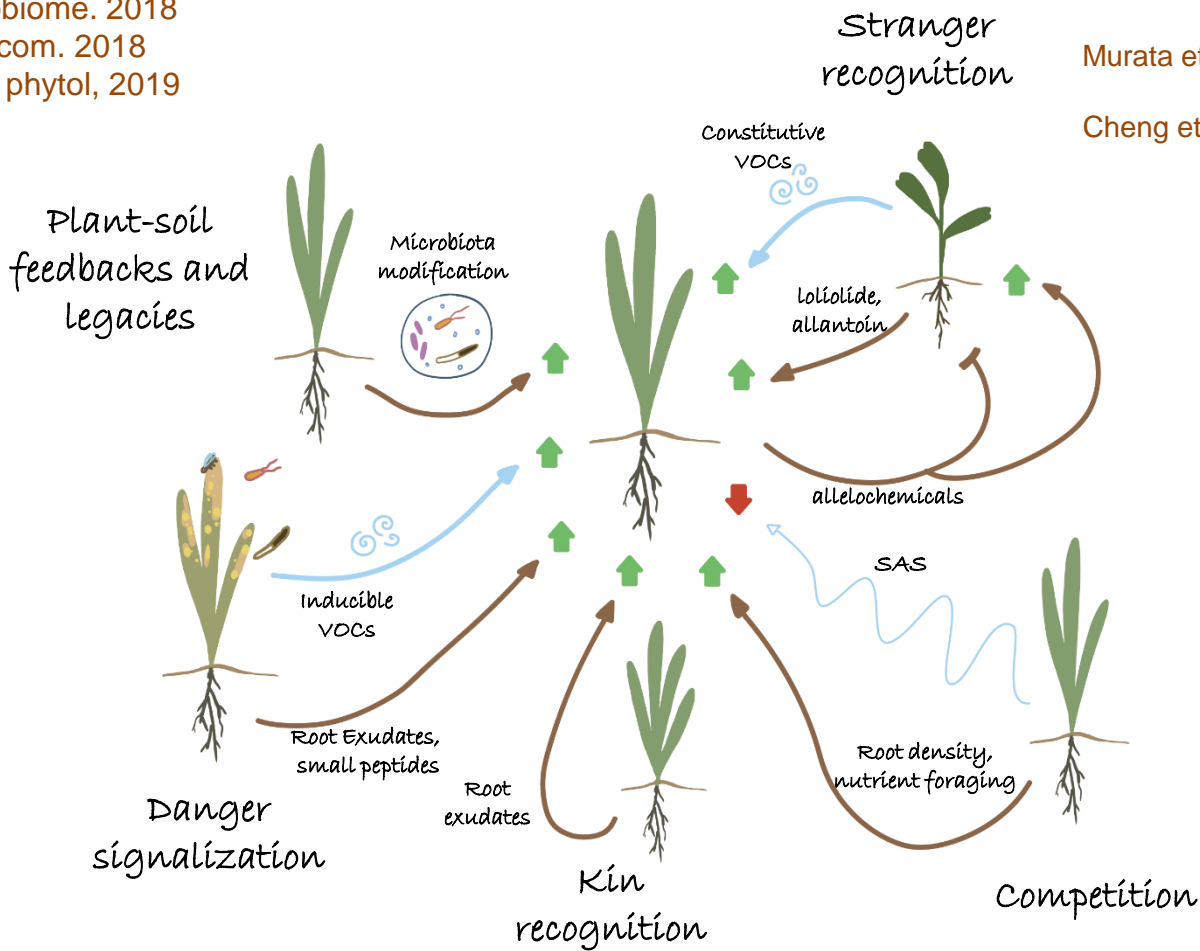
Plant immunity is modulated by the environment



Plants modulate immunity and susceptibility 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 physiology 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

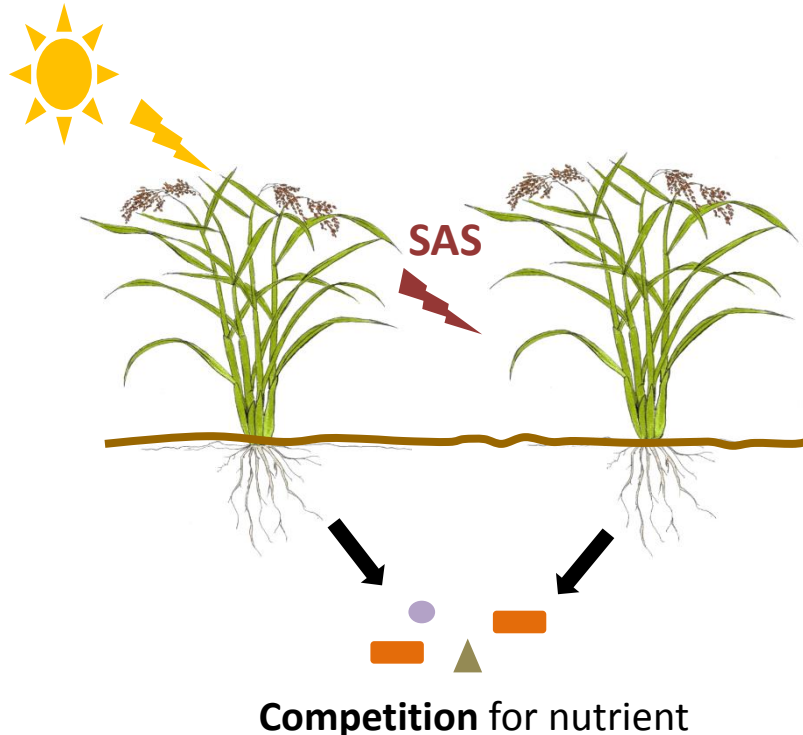
Wit et al, Plant Journal 2013
 Cerrudo et al, Plant Physiology 2012
 Ballaré, An. rev. of Plant biology 2014
 Chen et al. Frontiers in P. Science, 2019

Intraspecific competition for nutrients between conspecifics

Intraspecific competition



Intraspecific plant density



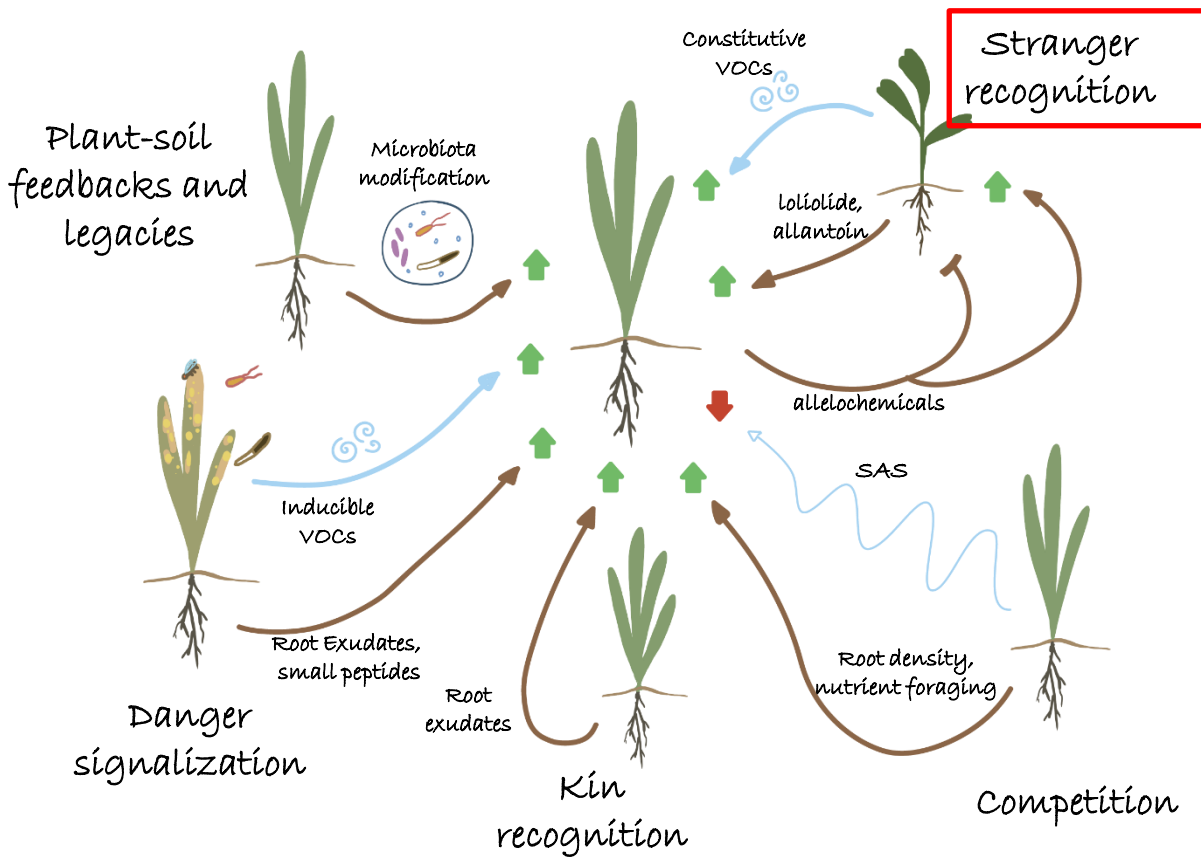
Shade Avoidance Syndrom
increases *A.thaliana* susceptibility
to pathogens

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

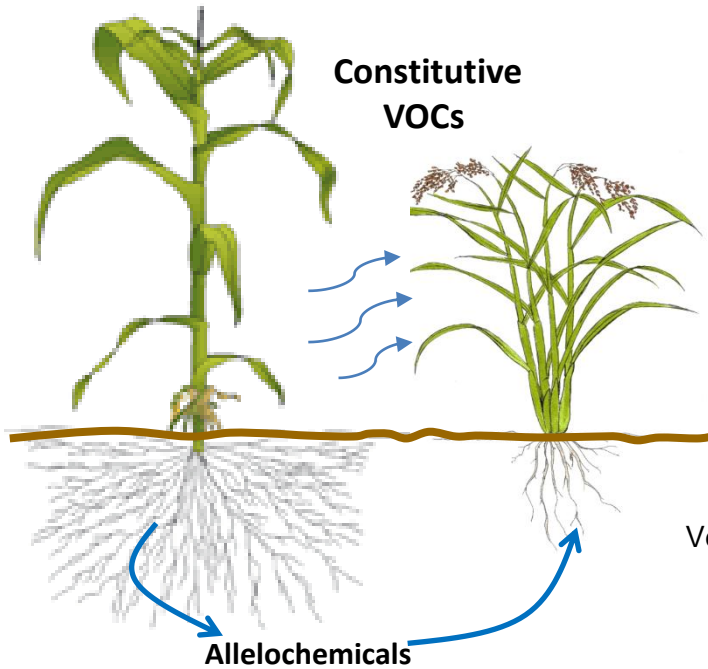
Chen et al. Frontiers in Plants Science, 2019

Plants modulate immunity and susceptibility in their neighborhood



Stranger's things from healthy neighbors

Sukegawa et al. Plant journal, 2018



Menthol
(cVOCs)

Modifying 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 physiology 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

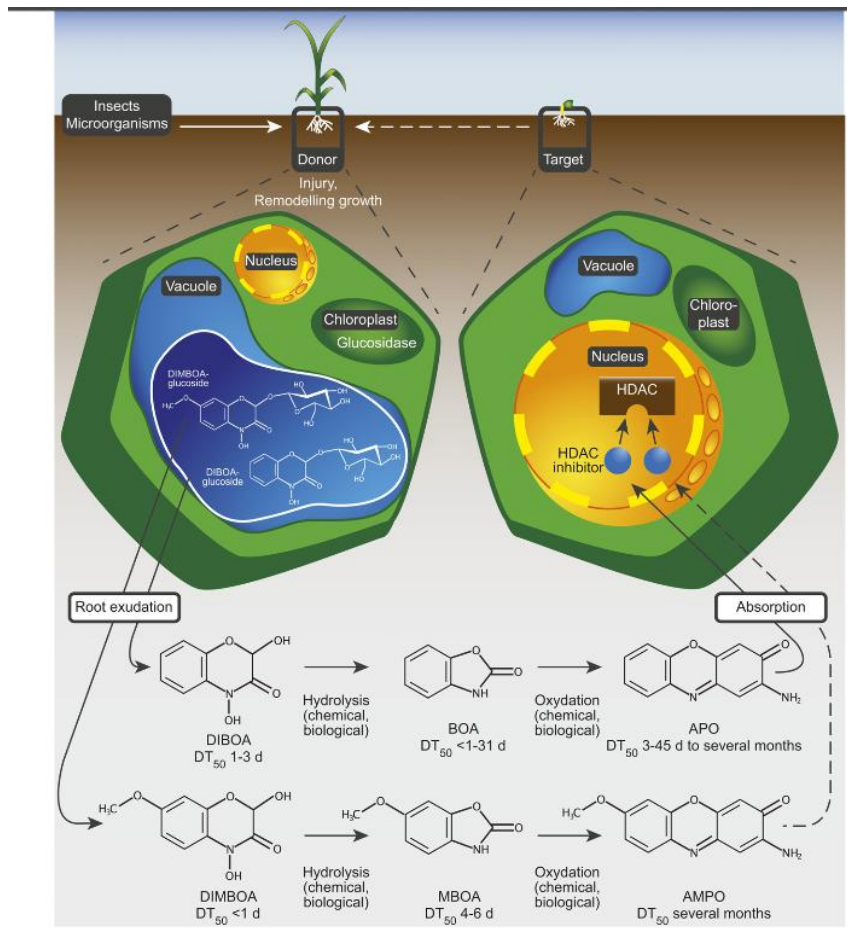
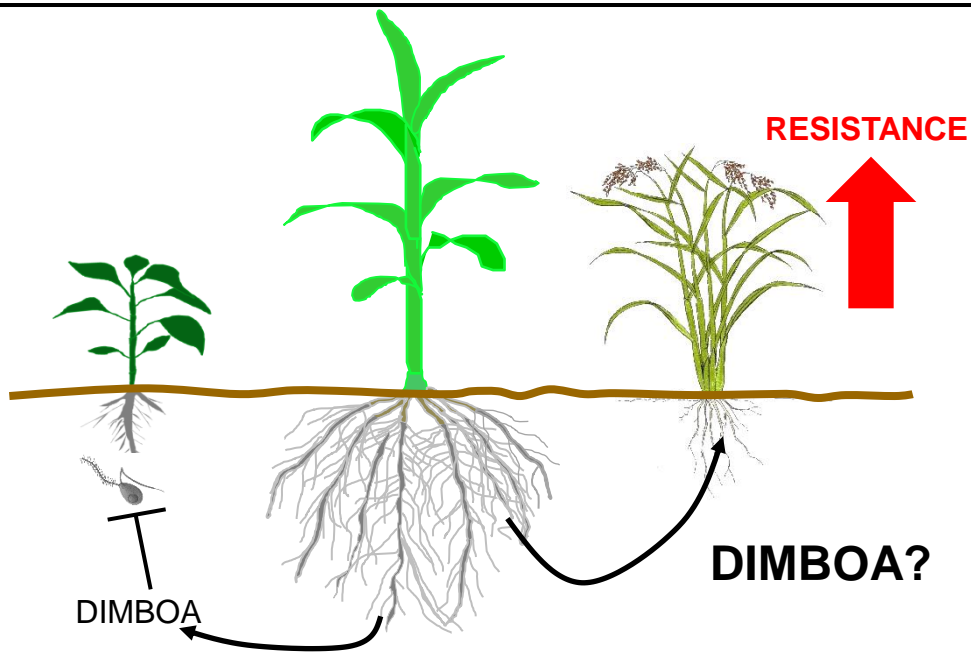


Figure 5. Model of a Chromatin-Based Mode of Action of the Allelochemicals APO and AMPO.

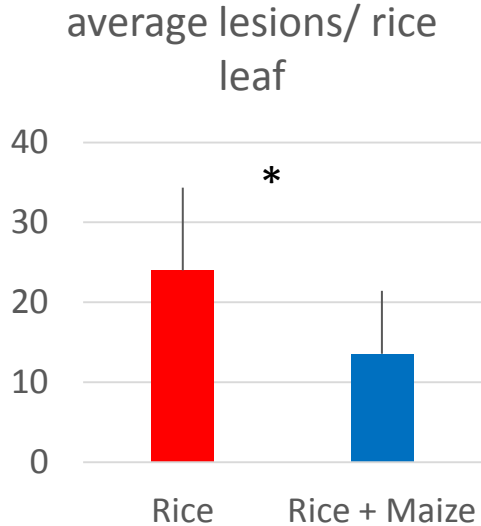
(Venturelli et al, 2015)



Intercropping rice and maize

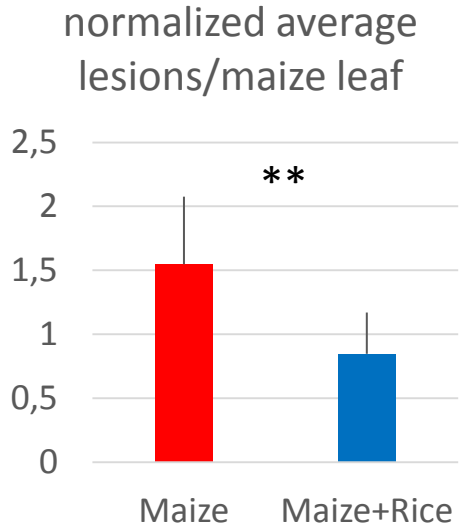


Rice blast disease (GY11)



(Nipponbare and B73)

Maize blast disease (2 isolates)



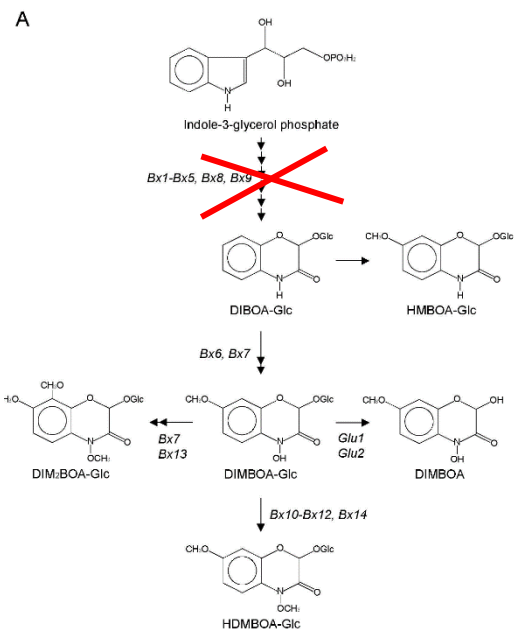
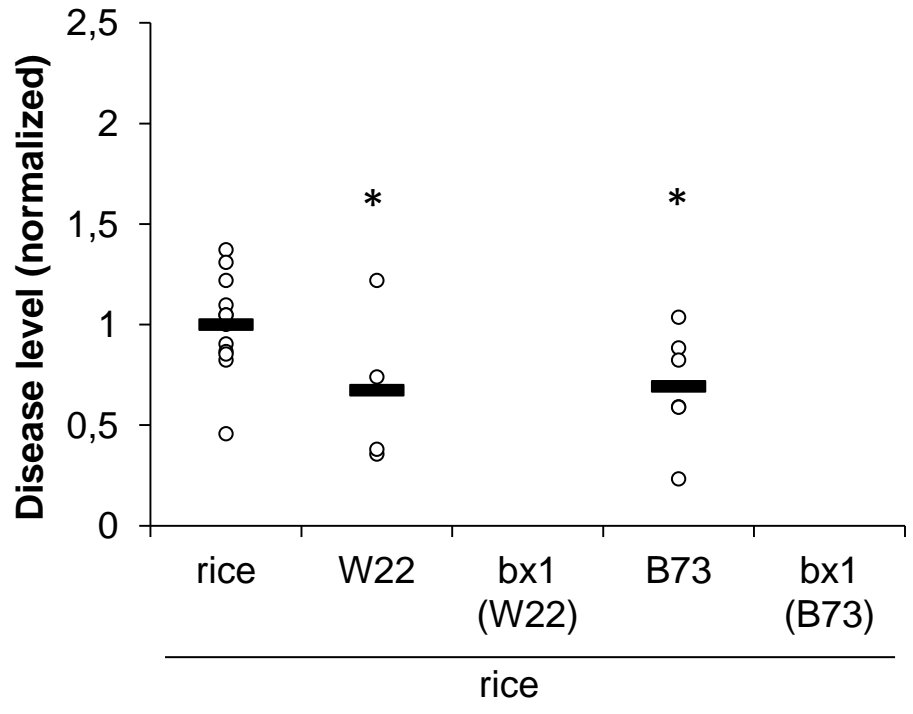
(B73 and Maratelli)

~40% reduction of symptoms

DIMBOA biosynthesis is required for protection in intercropping

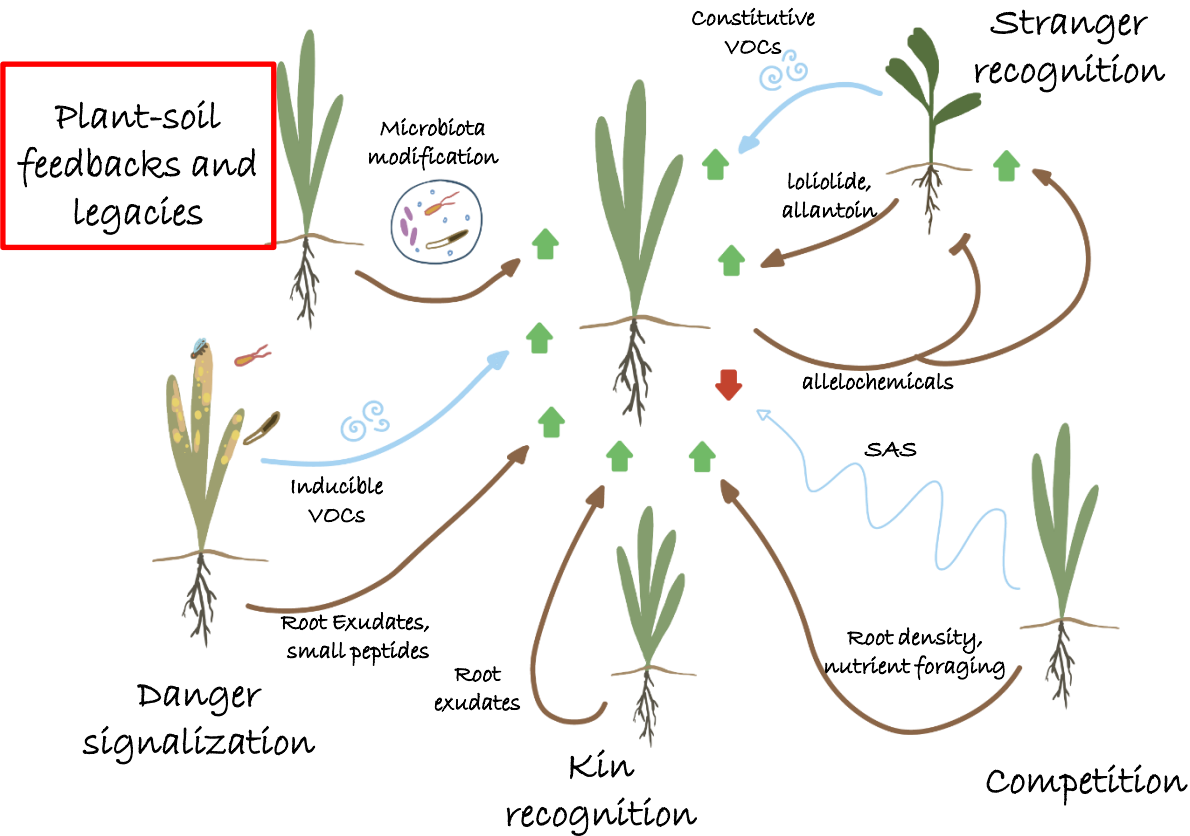


Rice blast disease (on rice)



neighbor
focal

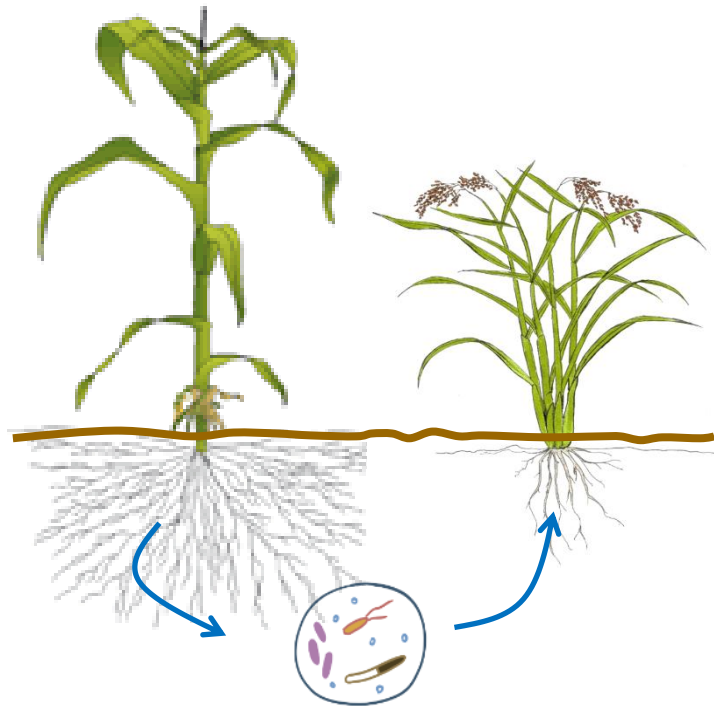
Plants modulate immunity and susceptibility in their neighborhood



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

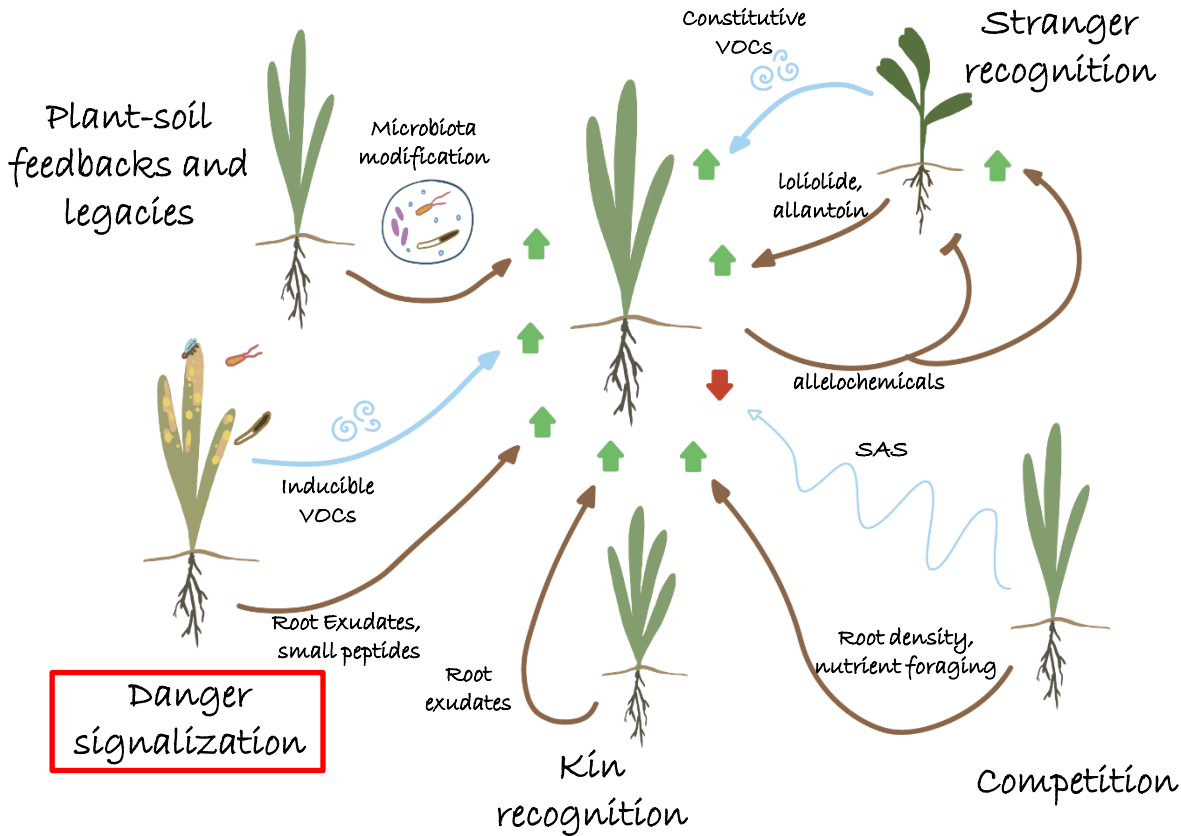
→ **Induces defense genes, pathogen and herbivory resistance**

Hu et al, Nature com. 2018

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

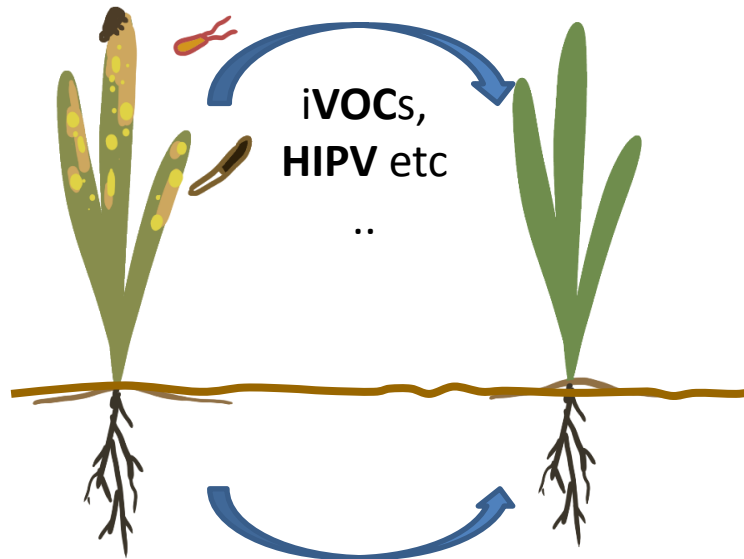
Wang et al. New phytol, 2019

Plants modulate immunity and susceptibility in their neighborhood



The neighbor watch, Signalisation of danger between plant

Disease / attack
plant



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

Inducible VOCs

Markovic et al, JEBX. 2019

→ Can be triggered by touch
in maize

Monoterpene

Wenig et al, Nature com. 2019

→ Propagation of SAR
(Systemic acquired
Resistance) between
neighbor plants

Unknown root
signal

Orlovskis et al, New phytol. 2020

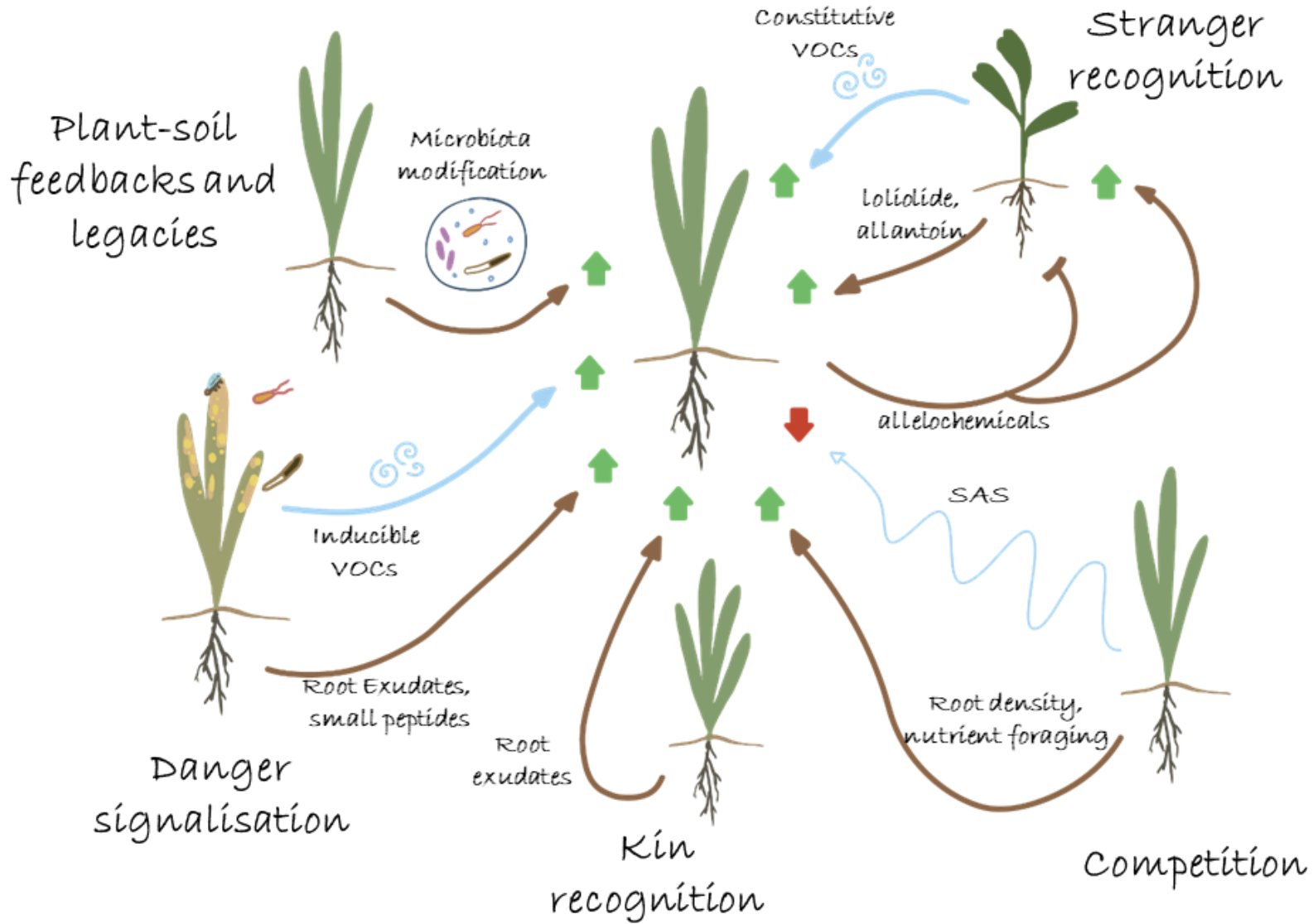
Systemin

Coppola et al, Scientific reports. 2017

→ Excreted soil peptide
(18 AA) by tomato roots

Plants modulate immunity and susceptibility in their neighborhood

Pelissier, Violle and Morel, review submitted

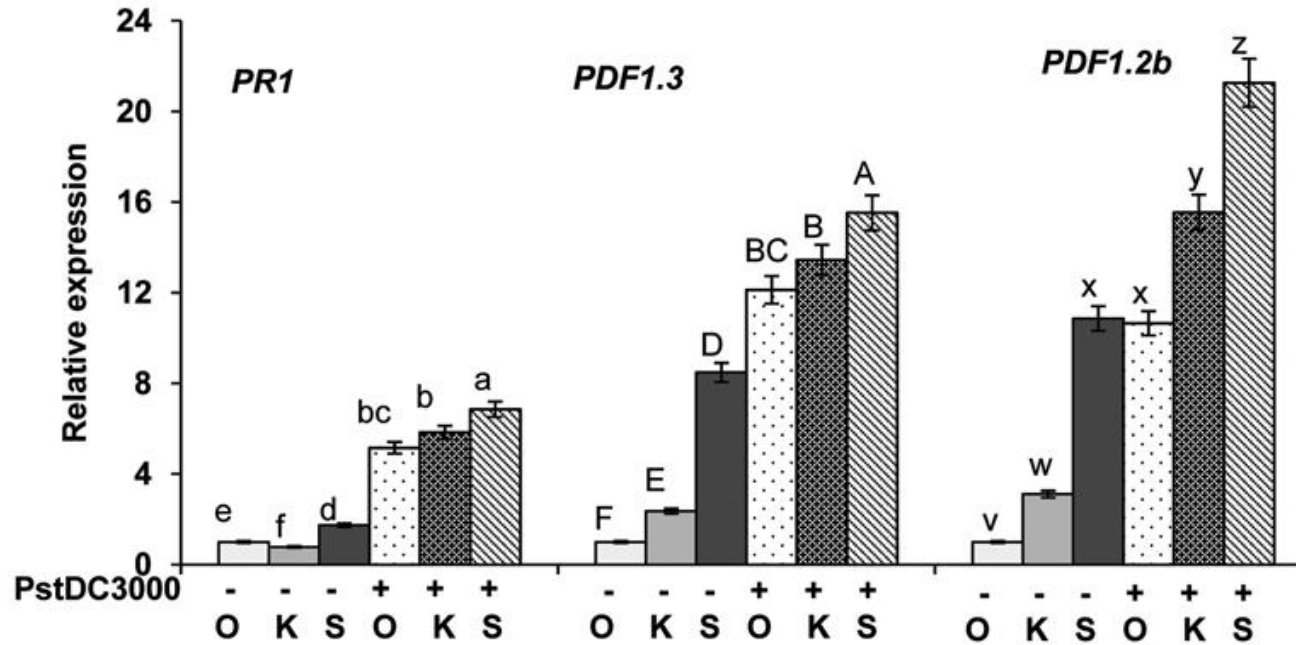


Can kins/conspecifics modulate susceptibility in their neighborhood?

Kin recognition: when plants recognize conspecifics

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

Wikipedia

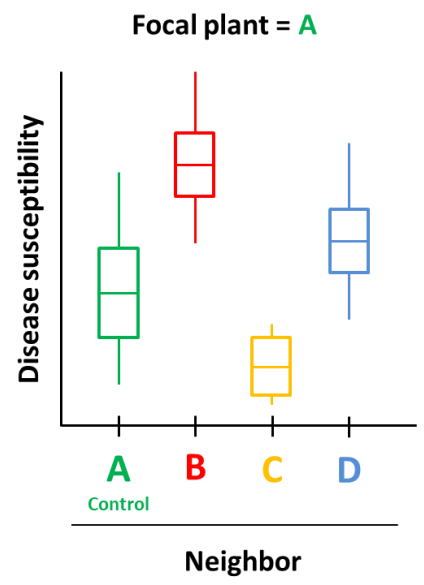
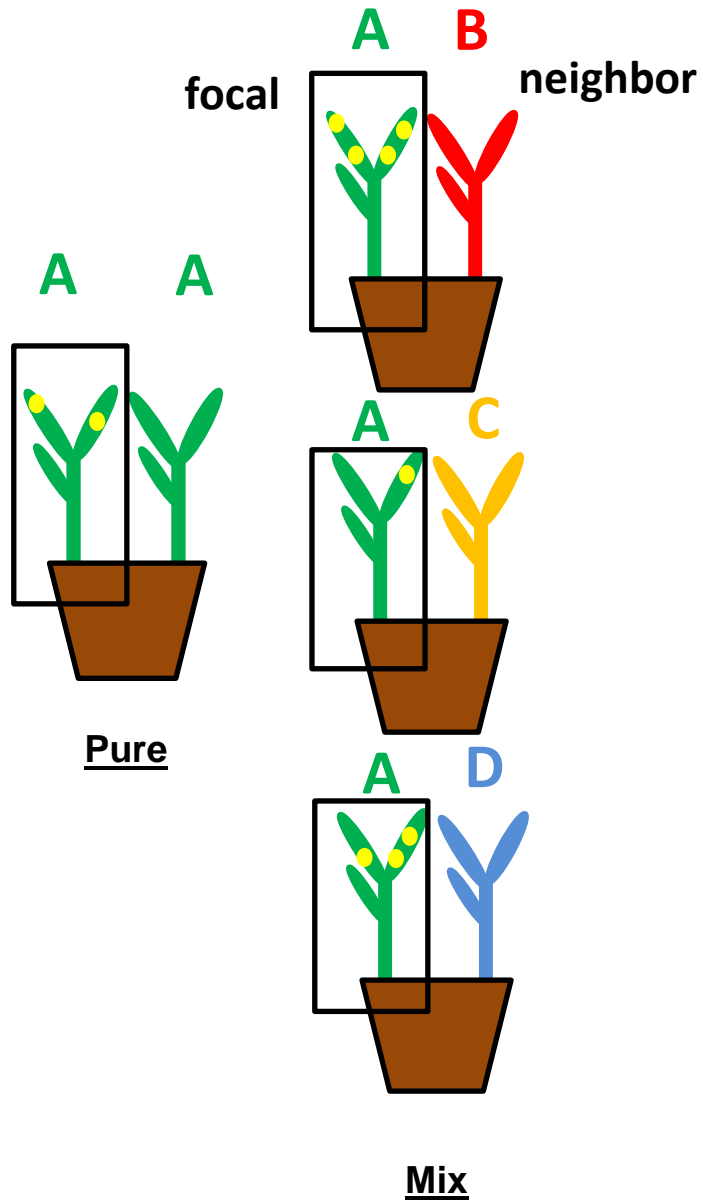


O= Own= plant alone
K= Kin= 2 plants together
S= Stranger= different ecotype

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 susceptibility



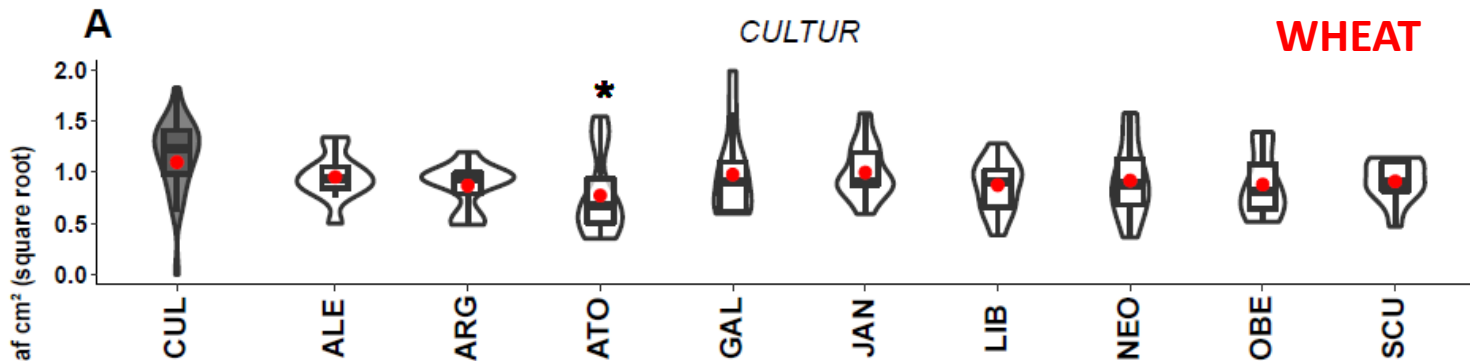
Specific ability of a given neighbor to modulate susceptibility of focal A (« good » or « bad » neighbor)



Neighbor-modulated susceptibility (NMS) in rice and wheat

Pelissier et al, submitted

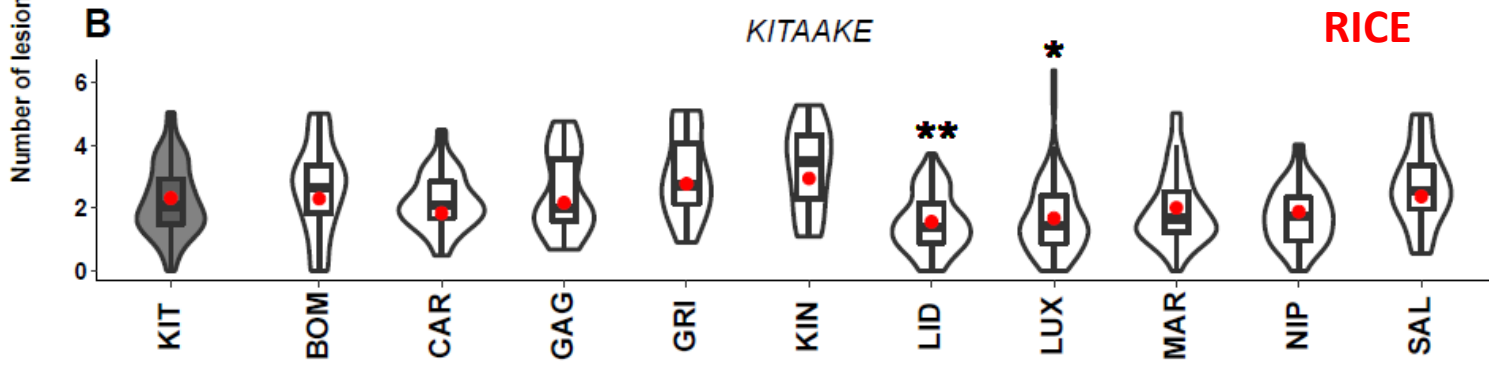
Leaf rust susceptibility



Puccinia triticina



Blast susceptibility



Magnaporthe oryzae

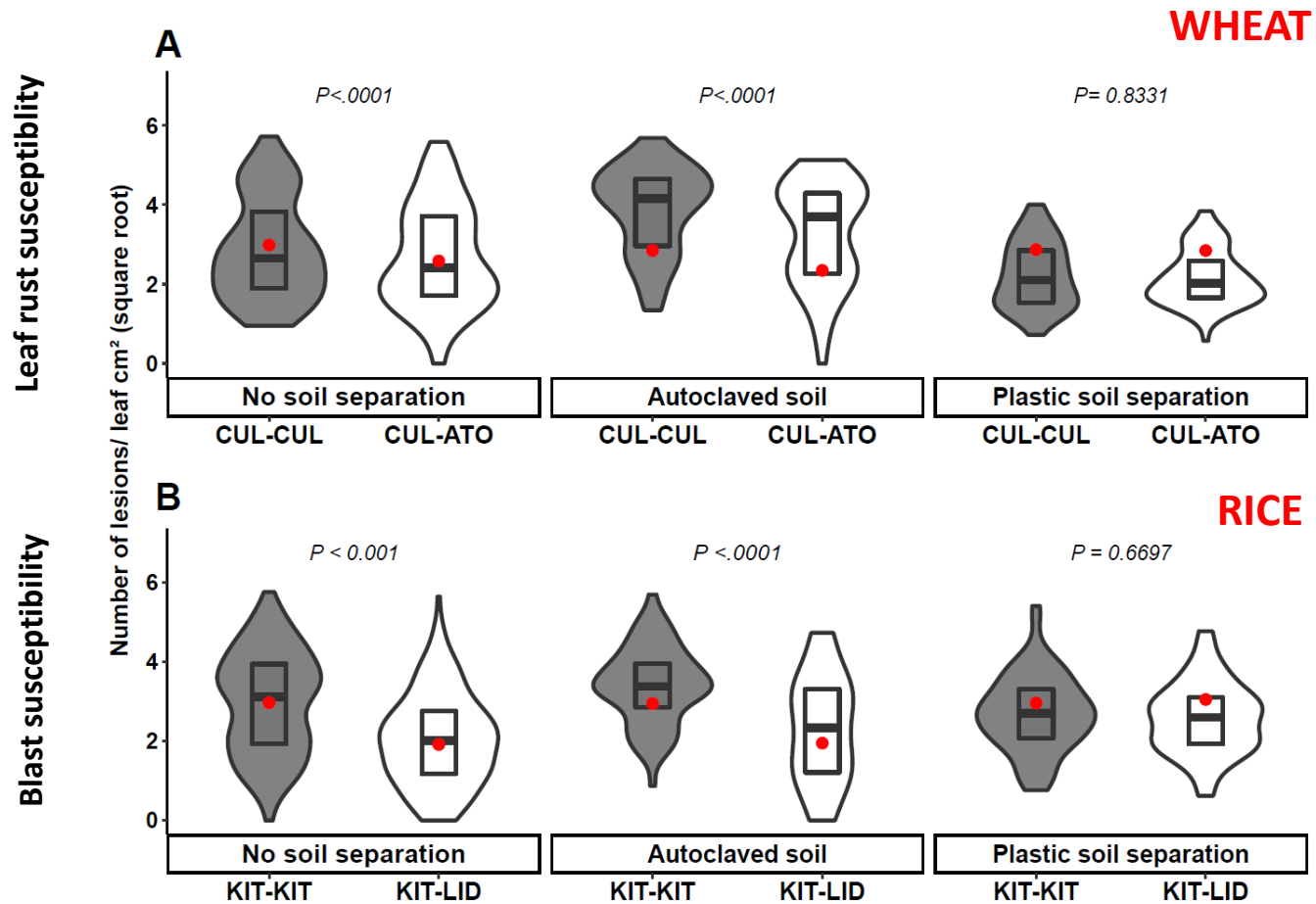


Pure

Mixes

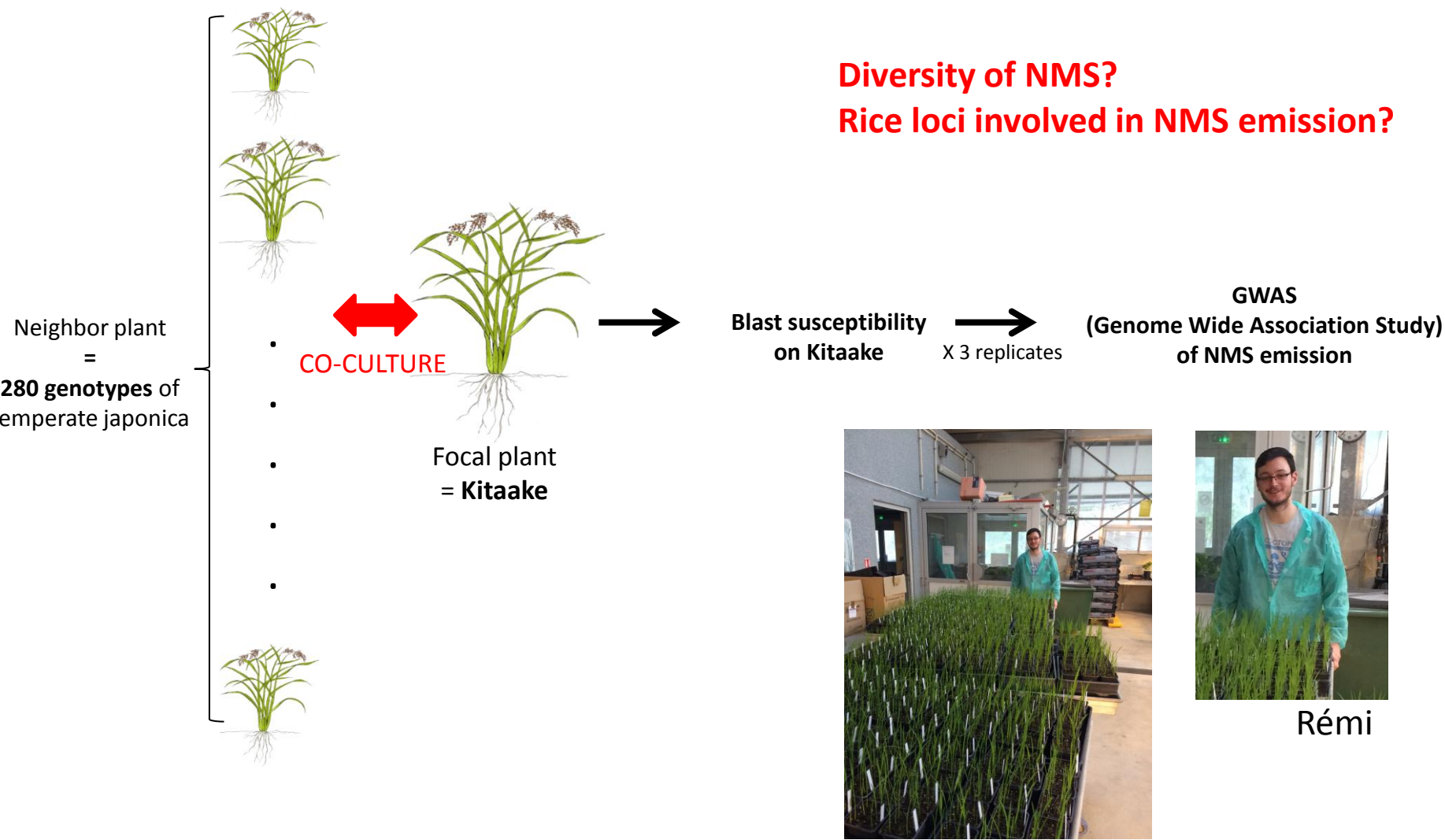
Some kins can modulate susceptibility in their neighborhood (NMS)

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



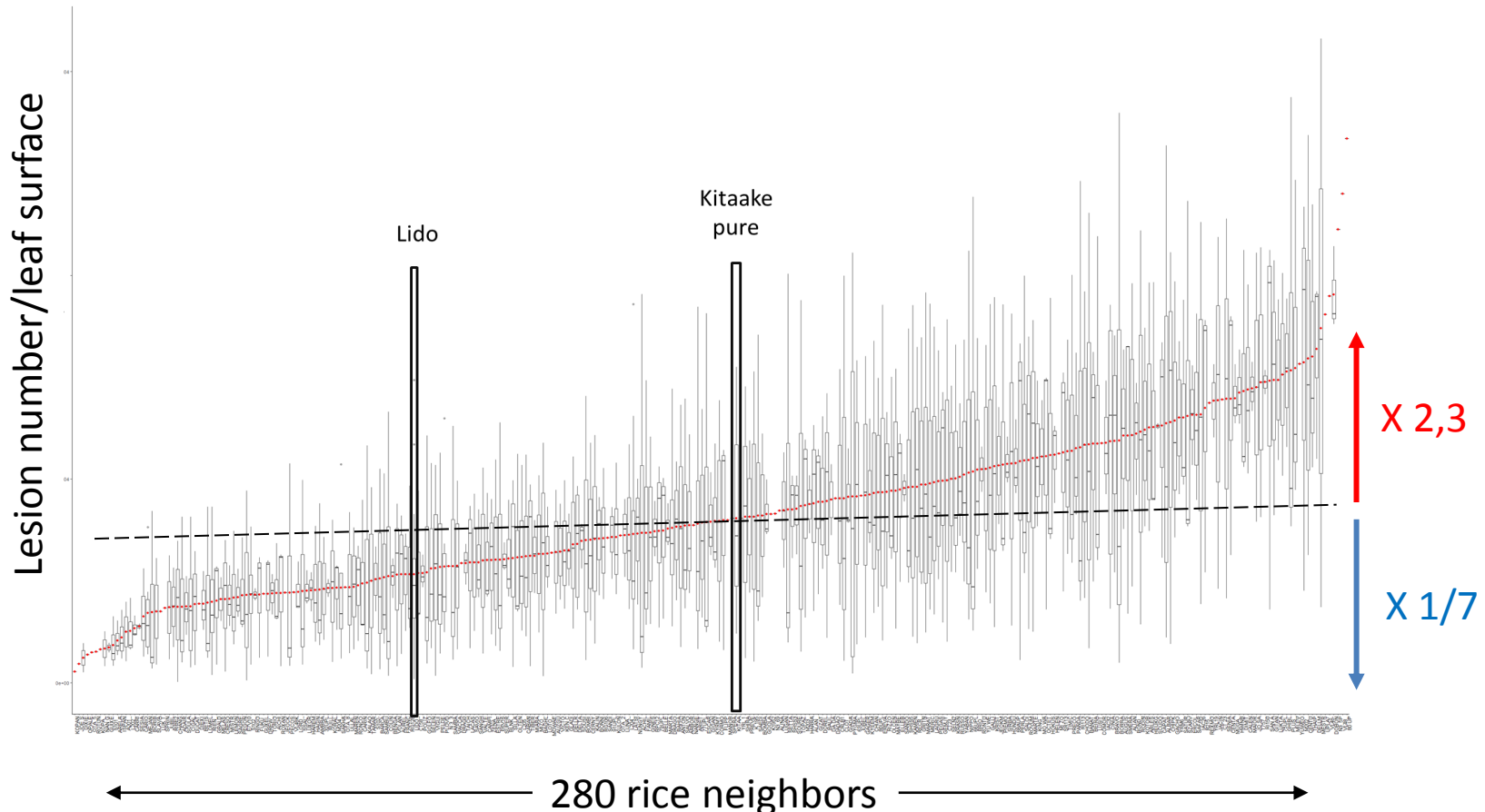
NMS takes place in the soil and does not require microbiome
(nor an infected neighbor)

Mapping rice ability to modulate susceptibility in its neighborhood



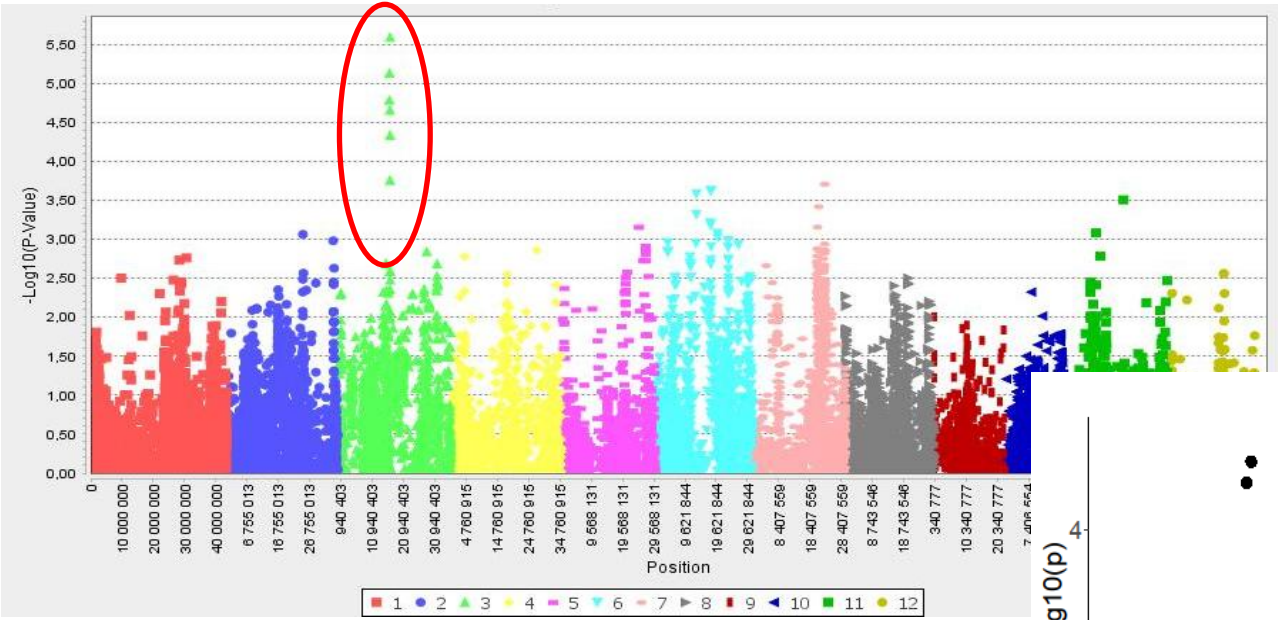
Diversity of NMS?
Rice loci involved in NMS emission?

Blast susceptibility of Kitaake cultivated with 280 different neighbors

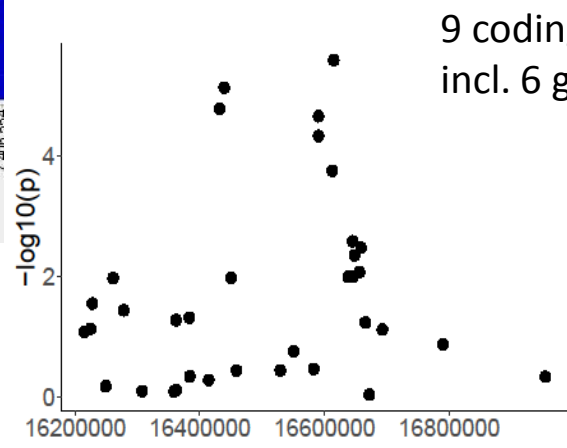


Neighbors can reduce but also increase disease susceptibility of Kitaake

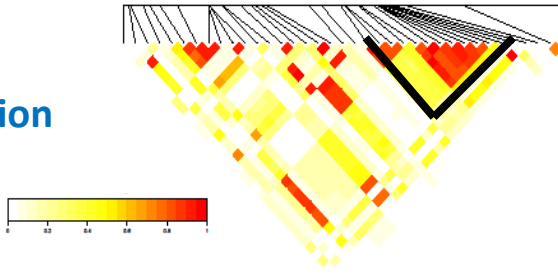
GWAS of the emission of NMS



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

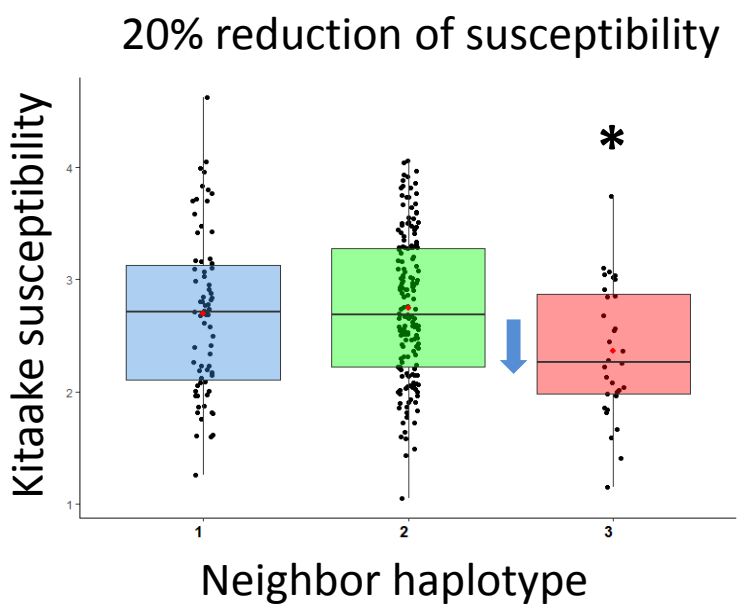


One region on rice chromosome 3 controls NMS emission



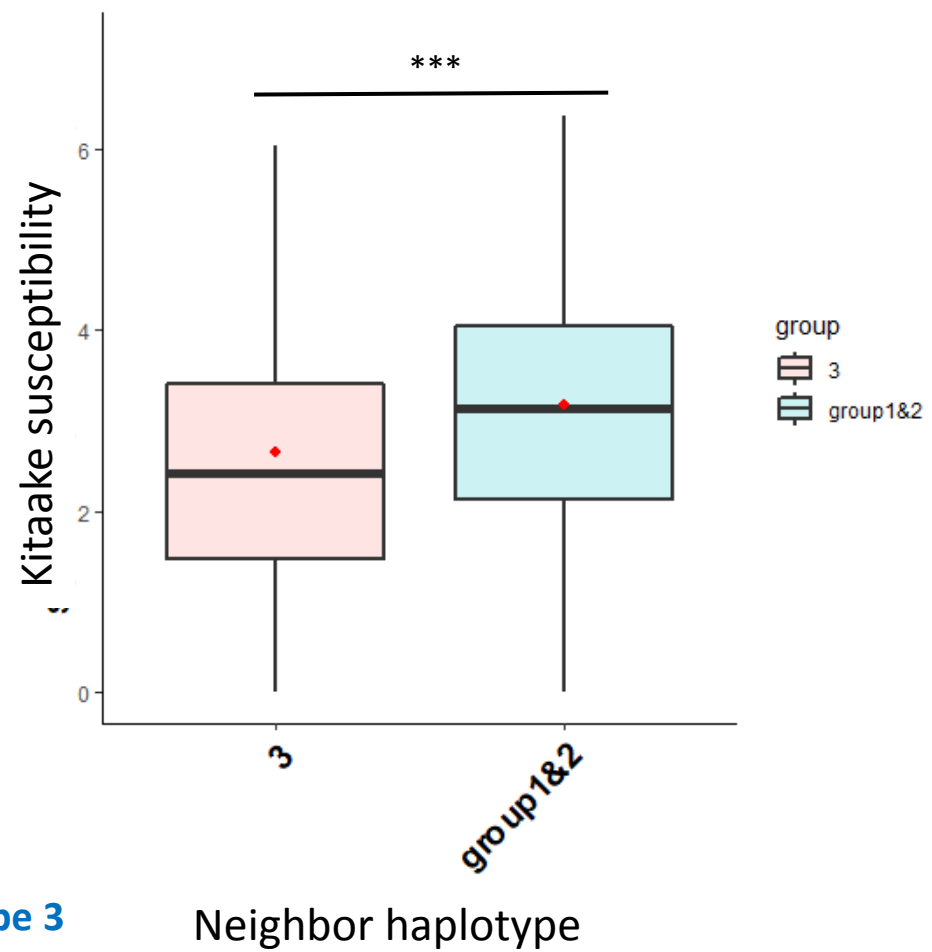
Test of GWAS prediction for emission of NMS

Susceptibility data from GWAS



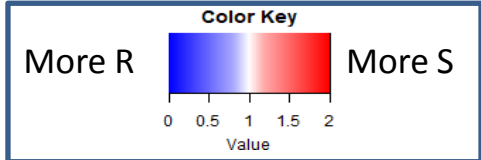
GWAS predicts that neighbors with haplotype 3 reduce susceptibility in focal kitaake

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



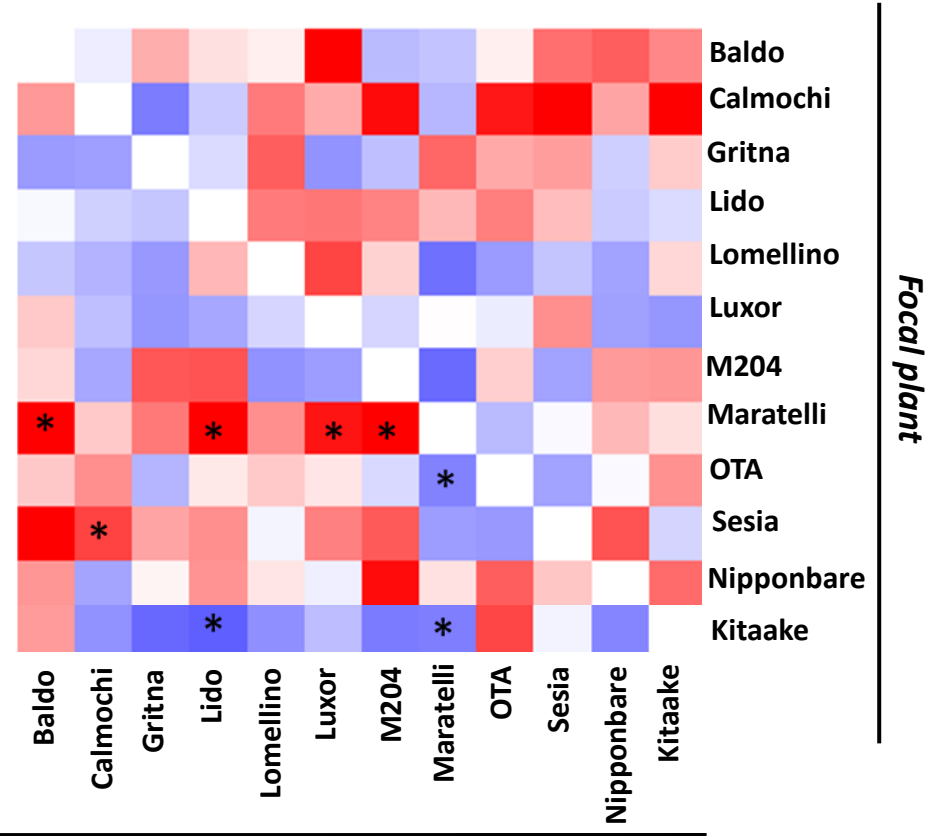
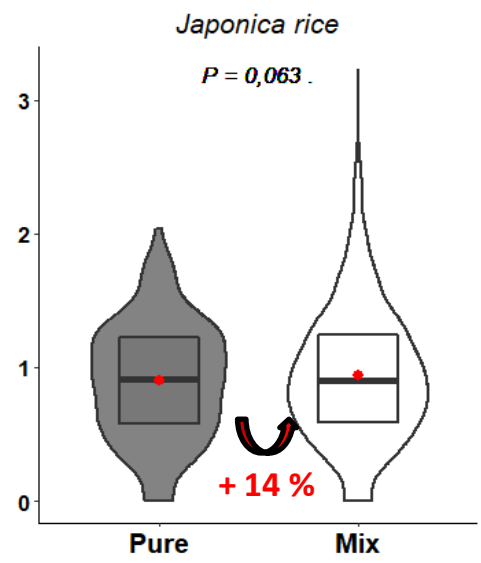
NMS at the species level: the case of temperate japonica rice

Rice
Blast fungus



Temperate japonica rice

Susceptibility (norm.)



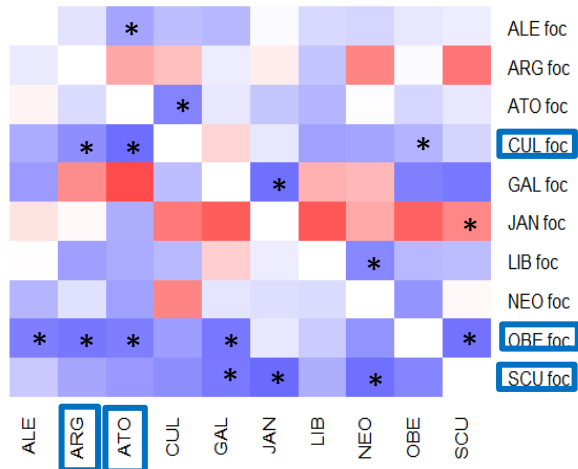
Neighbor plant

Intra-specific interactions are not favorable to rice blast resistance

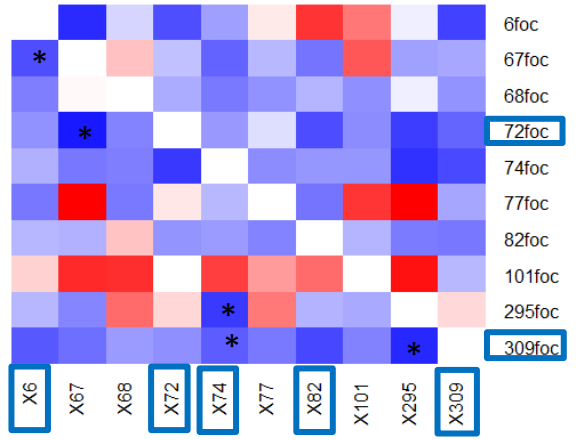
NMS: good neighbor and good focal plants

Wheat X leaf rust

Cultivated durum wheat

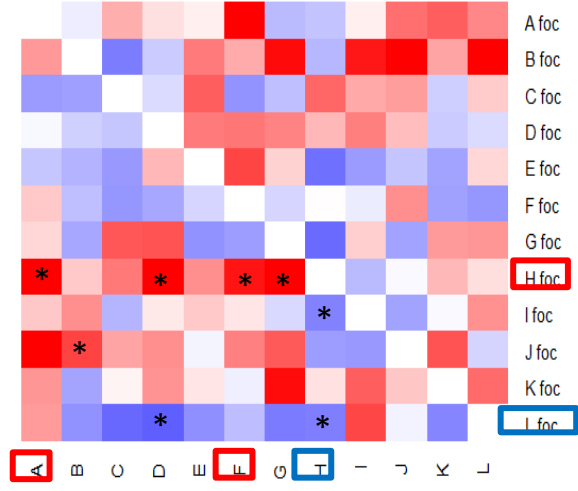


EPO Wheat

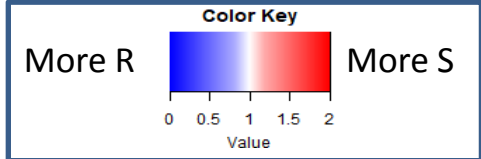
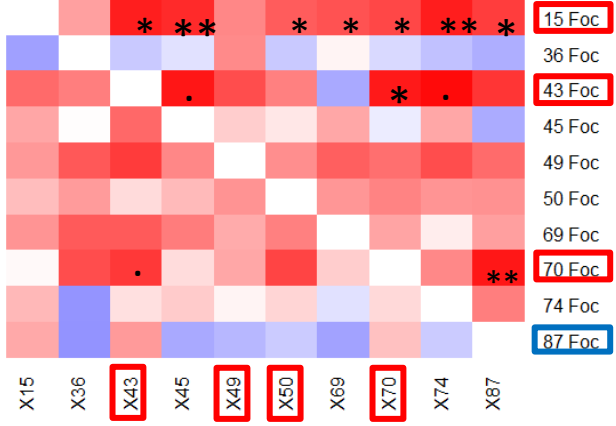


Rice X Blast fungus

Japonica Rice

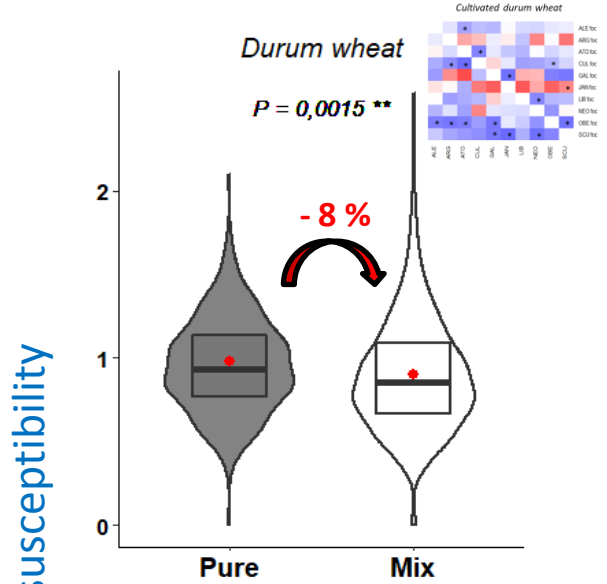


Acuce rice

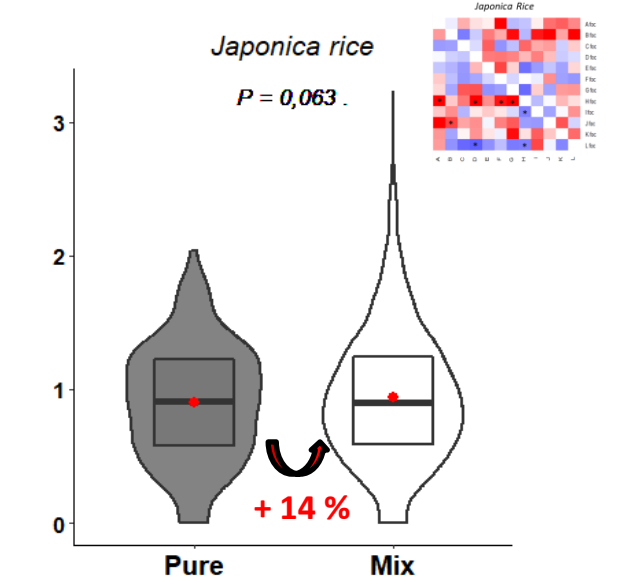


NMS and breeding

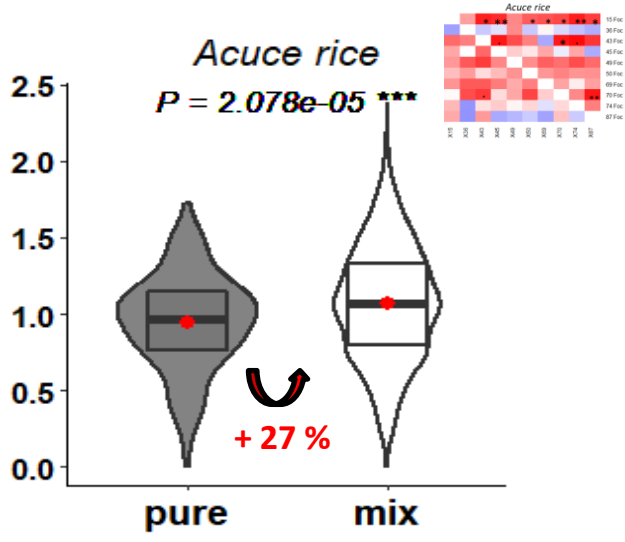
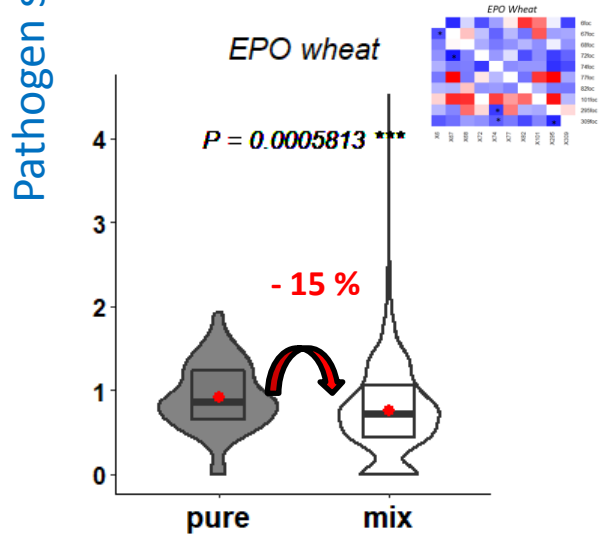
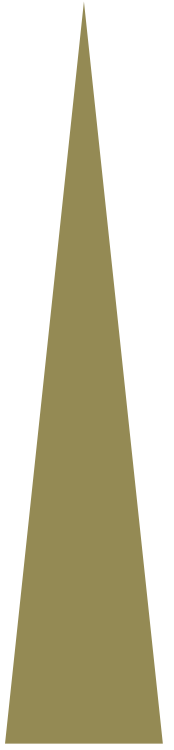
Wheat (leaf rust)



Rice (Blast fungus)



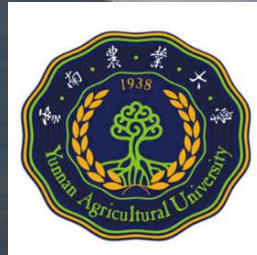
Historical within-field co-existence





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Luis Buendia

Aurélie Ducasse

Andy Brousse

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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)