

PHD PROPOSAL FOR THE DOCTORAL SCHOOL « Ecologie, Géosciences, Agronomie, ALimentation »

GENERAL INFORMATION

Thesis title: Genetic and PRI-induced resistance metabotyping and NIRS phenotyping to identify and monitor metabolites responsible for apple scab resistance
Acronym: MetaboNIRS
Disciplinary field 1: Agronomy Disciplinary field 2: Select an element
Three keywords: resistance mechanisms, mQTL mapping, phenomic prediction
Research unit : IRHS – Institut de Recherche en Horticulture et Semences
Name of the thesis director HDR (Habilitation thesis to supervise research) required: DUREL Charles-Eric Email address of the thesis director: charles-eric.durel@inrae.fr
Name of the thesis co-director (if applicable): HDR (Habilitation thesis to supervise research) required: Email address of the thesis co-director (if applicable):
Name of the thesis co-supervisor 1 (if applicable): MURANTY Hélène Email address of the thesis co-supervisor 1 (if applicable): helene.muranty@inrae.fr
Name of the thesis co-supervisor 2 (if applicable): Email address of the thesis co-supervisor 2 (if applicable):
Thesis grant (funding origin and amount): Contrat Doctoral Etablissement UA (100%)
Contact(s) (mailing address and E-mail): IRHS, Bat. B, 42 rue Georges Morel - CS 60057, 49071 BEAUCOUZE CEDEX, FRANCE
Recruitment process: Recruitment process depends on thesis funding. To select the corresponding recruitment process, please visit the EGAAL website here . This information is needed for proposal publication. <input checked="" type="checkbox"/> Doctoral school contest <input type="checkbox"/> Interview <input type="checkbox"/> Other (indicate) :

All sections must be filled. Once filled, please save the proposal form in pdf format using the following naming: Supervisor Name_Unit_Subject Acronym_EN.pdf

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SCIENTIFIC DESCRIPTION OF THE PhD PROJECT

Socio-economic and scientific context : (10 lines)

Controlling apple scab in commercial orchards requires a large number of chemical treatments (> 20 per year) with much concern for human health and environment. Increasing scab resistance, either through genetic (intrinsic) resistance or after induction by plant resistance inducers (PRI), is a major socio-economic challenge.

From a scientific point of view, knowing and quantifying the metabolic compounds actually responsible for apple scab resistance would represent a very significant gain in knowledge to understand the resistance mechanisms to be favoured by breeding or promoted by stimulation. Moreover, this knowledge is a key factor for the sustainable management of apple resistance. We therefore propose to the PhD candidate to explore this field using two complementary approaches: 1) genetic mapping of metabolite-amount QTLs (mQTLs) colocalizing with well-known scab resistance QTLs (rQTLs), and monitoring the induction of these metabolites by acibenzolar-S-methyl (ASM), and 2) phenomic prediction of these metabolites and of scab resistance by NIRS phenotyping (Rincent et al. 2018 ; doi: 10.1534/g3.118.200760).

Assumptions and questions (8 lines)

Q1: What are the metabolites associated with partial resistance (intrinsic or induced) to apple scab?

Combining genetic mapping and with-and-without-PRI defense induction should allow to focus on a few candidate metabolites to be validated in order to identify the causal 'effectors' of scab resistance.

Q2: How accurately can NIRS phenotyping predict scab resistance and the amount of associated metabolite compounds?

One hypothesis to explain the predictive power of phenomic prediction (based on NIR spectra) compared to genomic prediction is that these spectra reflect the amount of metabolites (here in the leaf) which ones are closer to the 'realisation' of an individual's phenotype than its genetic information (SNP markers), the latter being only at the beginning of the 'DNA - RNA - protein - metabolite' continuum.

The main steps of the thesis and scientific procedure (10-12 lines)

The PhD thesis work will rely on the study of a segregating F1 progeny in which scab resistance QTLs with-and-without defense induction by ASM have been identified (Bénéjam et al. 2020). During the thesis, HPLC-MS/MS metabotyping and near infrared absorbance spectra (NIRS) data will be obtained on leaves to :

- map mQTLs, study their colocalisation with rQTLs, and deduce positional and functional candidate genes explaining scab resistance mechanisms
- predict resistance levels and metabolite amounts using NIRS spectra

T1: mQTLs mapping after metabotyping the F1 progeny before and 3 (or 5) days after inoculation

T1bis: Metabotyping of ASM-induced resistance (subset of the progeny) and comparison to intrinsic resistance

T2: Search for the best positional/functional candidate genes underlying the m/rQTLs according to the metabolic pathways controlled, and exploration by qPCR of some of the most relevant genes (optional)

T3: NIRS phenotyping of the progeny at d0, d3, d5, d7 ... after inoculation, and after ASM-induction

T4: Construction of phenomic prediction equations for metabolic compound amounts and scab resistance levels and evaluation of prediction accuracy by cross-validation

Methodological and technical approaches considered (4-6 lines)

Metabotyping of an F1 progeny (267 individuals) resulting from the cross of the TN10-8 progenitor with the 'Fiesta' variety, and locating QTLs controlling the amount of metabolites ; study of their colocalization with the scab

resistance QTLs. Acquiring NIRS spectra from the leaves of the same plants and studying the accuracy of the phenomic prediction of metabolite amounts and resistance levels in comparison with genomic prediction.

Metabotyping carried out in collaboration with the LAE platform in Nancy (R. Larbat, partner in the CapZeroPhyto project) and with SONAS (A. Schinkovitz). NIRS phenotyping in collaboration with ImHorPhen team.

Consummable budget for the PhD work is already acquired in the CapZeroPhyto project of the French Priority Research Programme "Protéger et Cultiver Autrement".

Scientific and technical skills required by the candidate

Quantitative genetics

Metabolomics

Plant biology

Statistics

THESIS SUPERVISION¹

Unit name: IRHS	Team name: ResPom
Unit director name: RENOU Jean-Pierre	Team director name: DUREL Charles-Eric
Mailing address of the unit director: jean-pierre.renou@inrae.fr	Mailing address of the team director: charles-eric.durel@inrae.fr
<p>Thesis director</p> <p>Surname, first name: DUREL, Charles-Eric</p> <p>Position: Directeur de Recherches</p> <p>Obtained date of the HDR (Habilitation thesis to supervise research): December 2006</p> <p>Employer: INRAE</p> <p>Doctoral school affiliation: EGAAL</p> <p>Rate of thesis supervision in the present project (%): 50%</p> <p>Total rate of thesis supervision in ongoing theses (supervisions and co-supervisions) (%): 50%</p> <p>Number of current thesis supervisions/co-supervisions: 1 (thesis defense in late 2021)</p>	
<p>Thesis co-supervisor 1 (if applicable)</p> <p>Surname, first name: MURANTY, Hélène</p> <p>Position: Chargée de Recherches</p> <p>Habilitation thesis to supervise research <input type="checkbox"/> yes <input checked="" type="checkbox"/> no If yes, date diploma received:</p>	

¹ In EGAAL Doctoral School, if only one scientist in thesis supervision = 100% of supervision rate; if 2 people involved in thesis supervision = from 50% to 70% of supervision rate for the director; if 3 people involved in thesis supervision = 40% / 30% / 30% of supervision rate distribution among supervisors.

Employer: INRAE

Doctoral school affiliation: EGAAL

Rate of thesis supervision in the present project (%): 50%

Total rate of thesis supervision in ongoing theses (supervisions and co-supervisions) (%): 50%

Number of current thesis supervisions/co-supervisions: 1 (thesis defense in late 2021)

Professional status of previous PhD students supervised by both director and co-supervisors (from 5 years)

Please provide the following information for each PhD students supervised

Surname, first name: Bénéjam, Juliette

Date of PhD beginning and PhD defence: 01/11/2017 – 12/02/2021

Thesis supervision: Durel Charles-Eric

Professional status and location: post-doc, UR GAFL, INRAE Avignon

Contract profile (post-doc, fixed-term, permanent): post-doc

List of publications from the thesis work:

Bénéjam J, Ravon E, Gaucher M, et al. (2020) Acibenzolar-S-methyl and resistance QTLs complement each other to control apple scab and fire blight. Plant Disease. <https://doi.org/10.1094/PDIS-07-20-1439-RE>

Five main recent publications of the supervisors on thesis subject:

Bénéjam J., Ravon E., Gaucher M., Brisset M.N., **Durel C.E.**, Perchepied L. (2020) Acibenzolar-S-methyl and resistance quantitative trait loci complement each other to control apple scab and fire blight. Plant Disease (in press). <https://doi.org/10.1094/PDIS-07-20-1439-RE>

Roth M., **Muranty H.**, Di Guardo M., Guerra W., Patocchi A., Costa F. (2020) Genomic prediction of fruit texture and training population optimization towards the application of genomic selection in apple. Horticulture Research 7:148. <https://doi.org/10.1038/s41438-020-00370-5>

Jung M., Roth M., Aranzana M.J., Auwerkerken A., Bink M., Denancé C., Dujak C., **Durel C.-E.**, Font i Forcada C., Cantín C.M., Guerra W., Howard N., Lewandowski M., Ordidge M., Rymenants M., Sanin N., Studer B., Zurawicz E., Laurens F., Patocchi A., **Muranty H.** (2020) The apple REFPOP—a reference population for genomics-assisted breeding in apple. Horticulture Research 7:189. <https://doi.org/10.1038/s41438-020-00408-8>

Lasserre-Zuber P., Caffier V., Stievenard R., Lemarquand A., Le Cam B., **Durel C.E.** (2018) Pyramiding quantitative resistance with a major resistance gene in apple: from ephemeral to enduring effectiveness in controlling apple scab. Plant Disease 102:2220-2223. <https://doi.org/10.1094/PDIS-11-17-1759-RE>

Laloi G., Vergne E., **Durel C.E.**, Le Cam B., Caffier V. (2017) Efficiency of pyramiding of three quantitative resistance loci to apple scab. Plant Pathology 66:412-422. <https://doi.org/10.1111/ppa.12581>

THESIS FUNDING

Origin(s) of the thesis funding: Contrat Doctoral Etablissement UA (grant requested, 100%)

Consummable budget for the PhD work is already acquired in the CapZeroPhyto project of the French Priority Research Programme "Protéger et Cultiver Autrement" : 25 k€ acquired.

Gross monthly salary: ~1770 €

Thesis funding state : Non acquired

Funding beginning date/Funding ending date: 01/11/2021 - 3 years

Date: 25/03/2021

Name, signature of unit director: J.P. Renou



Name, signature of team director: C.E. Durel



Name, signature of thesis project director: C.E. Durel

