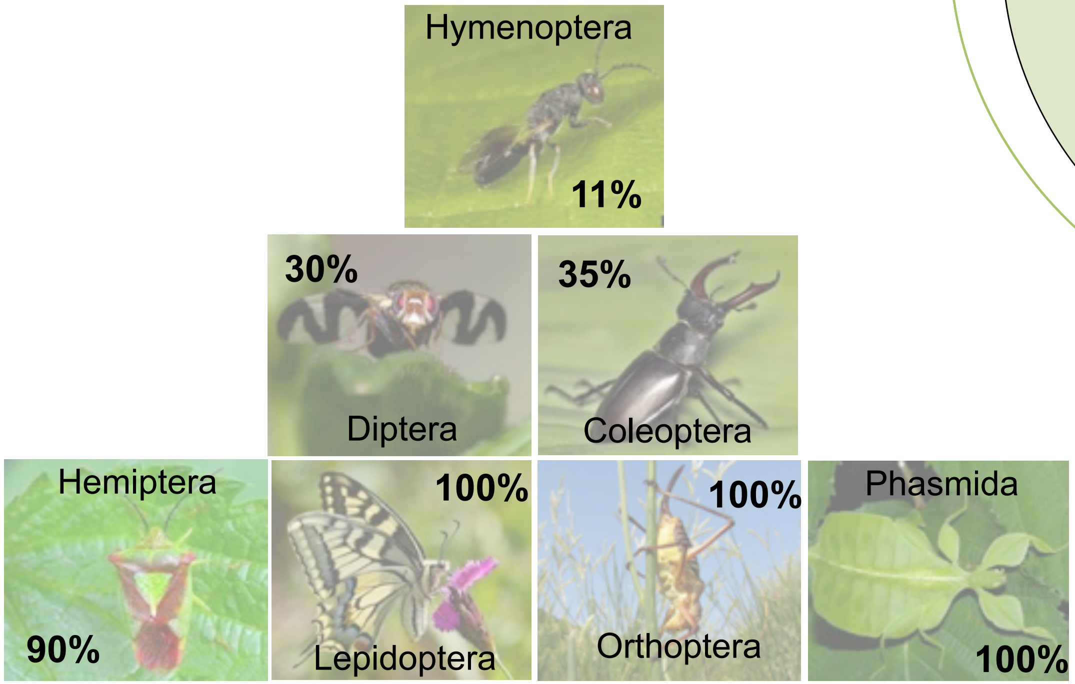
Host specialization in two sister species of moths: life history traits and differentially expressed genes

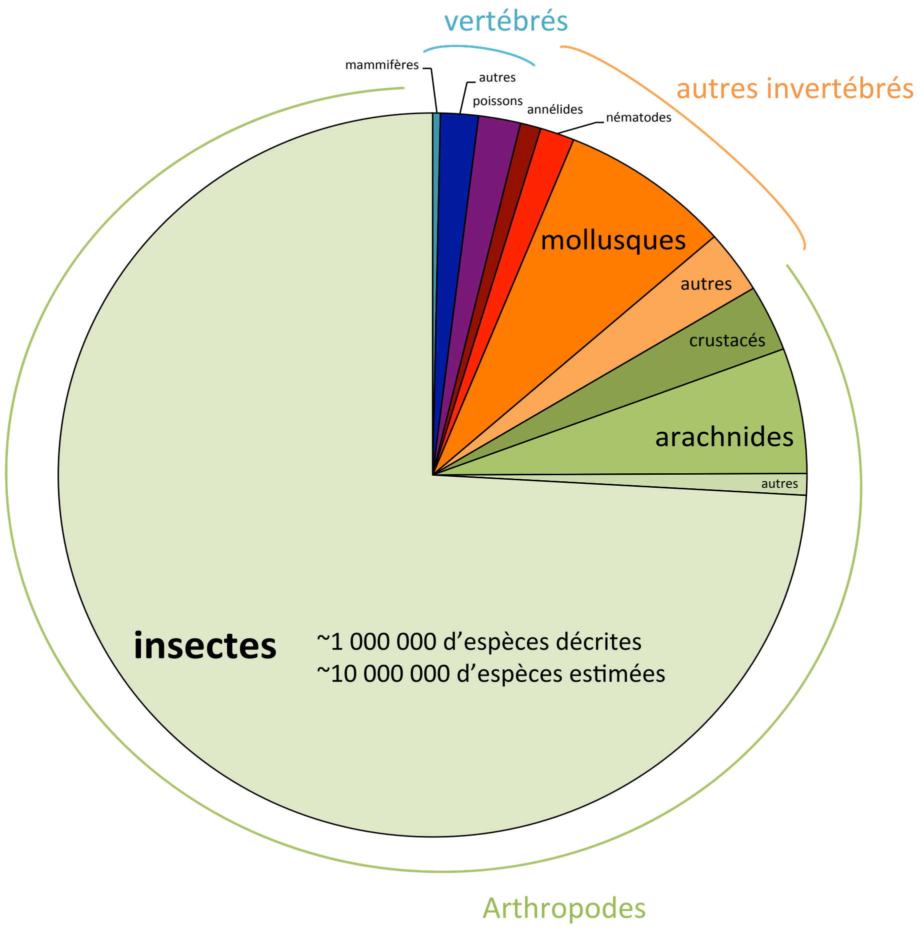
Marion Orsucci
Philippe Audiot
Louise Brousseau
Denis Bourguet
Franck Dorkeld
Bernhard Gschloessl
Sabine Nidelet
Réjane Streiff

Cbgp
Centre de Biologie pour la Gestion des Populations

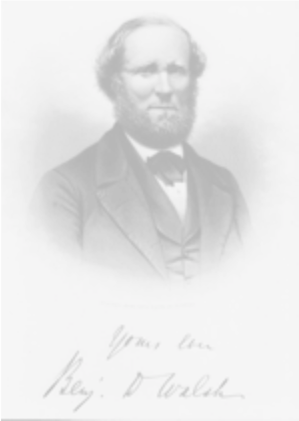
- **70% of animal species are insects**
- **A majority of insects is herbivorous**
- **A majority of the herbivorous insects are specialized to a limited number of host plants**



Herbivory level per insect family



The diversification of the phytophagous insects



- Coevolution
- Host shift
- Local adaptation
- Ecological speciation

372 Review TRENDS in Ecology & Evolution Vol.16 No.7 July 2001

Ecology and the origin of species

Dolph Schluter

Ecology Letters, (2005) 8: 336–352 doi: 10.1111/j.1461-0248.2004.00715.x

Ecological speciation

Howard D. Rundle[1]* and Patrik Nosil[2]

Genetica 116: 251–267, 2002.

Herbivorous insects: model systems for the comparative study of speciation ecology

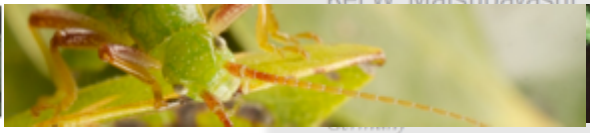
Daniel J. Funk[1], Kenneth E. Filchak[2] & Jeffrey L. Feder[2]

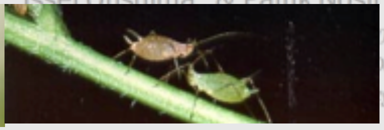
DOI: 10.1111/j.1570-7458.2009.00916.x

MINI REVIEW

Ecological speciation in phytophagous insects

Kei W. Matsubayashi[1], Issei Ohshima[2] & Patrik Nosil[3,4]*





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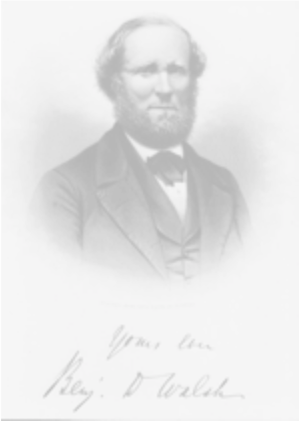
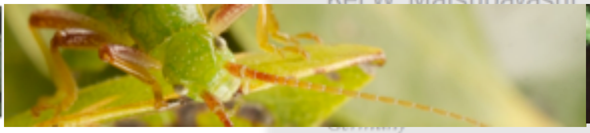
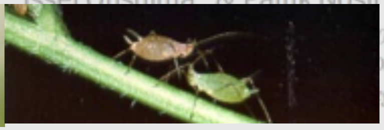


- **Coevolution**
- **Host shift**
- **Local adaptation**
- **Ecological speciation**

- **Pattern is not process. Ex: is specialization the cause or a consequence of species divergence?**





- **The case of insect pests**

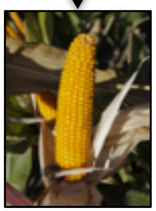




- **The case of insect pests**

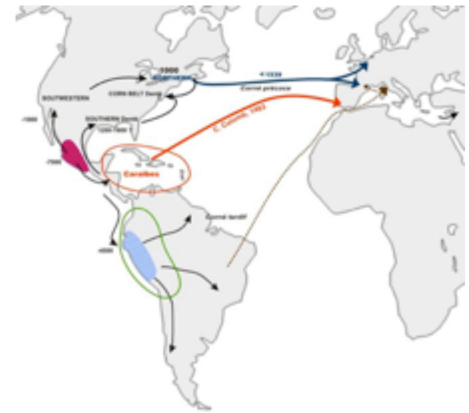
Domestication

teosinte



corn

Plant introduction

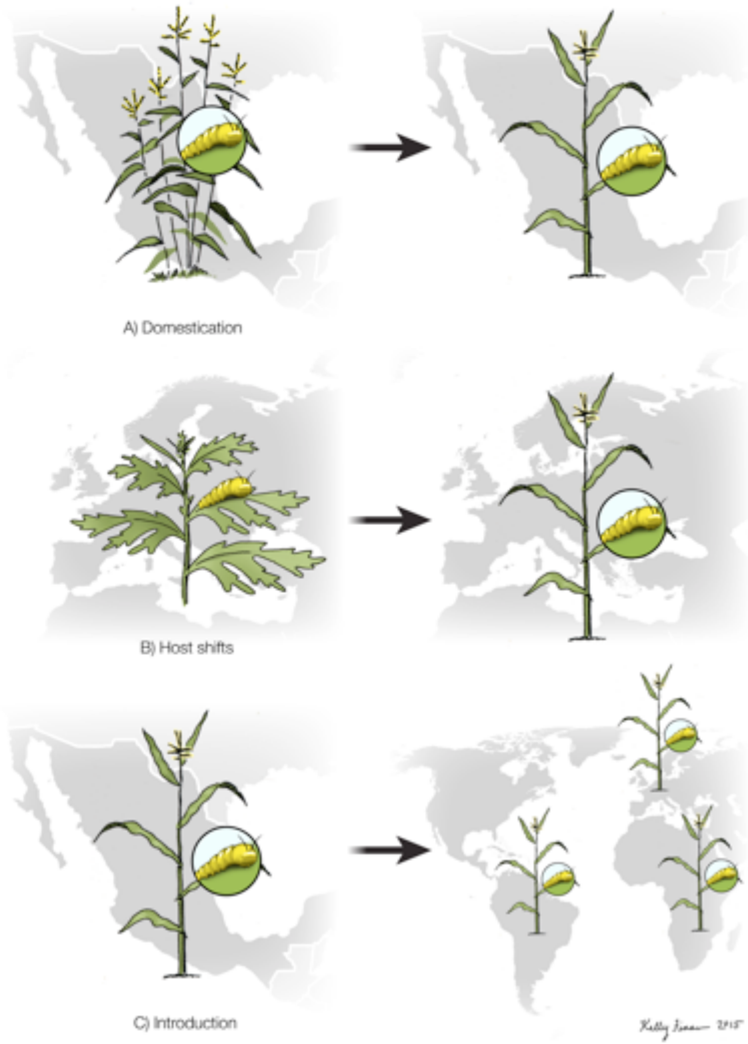


New niches

+

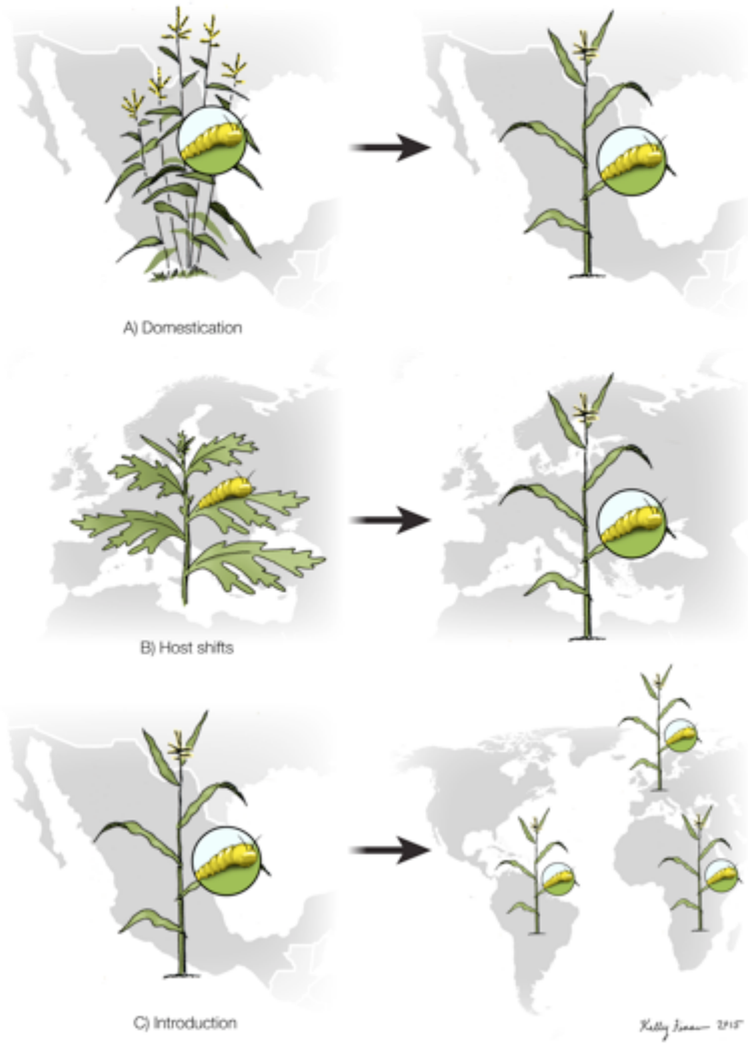
Crop intensification

Specialization to new habitats



Diatraea grandiosella : from the teosinte to maize

From Chen, Y. H. (2016). Journal elementa



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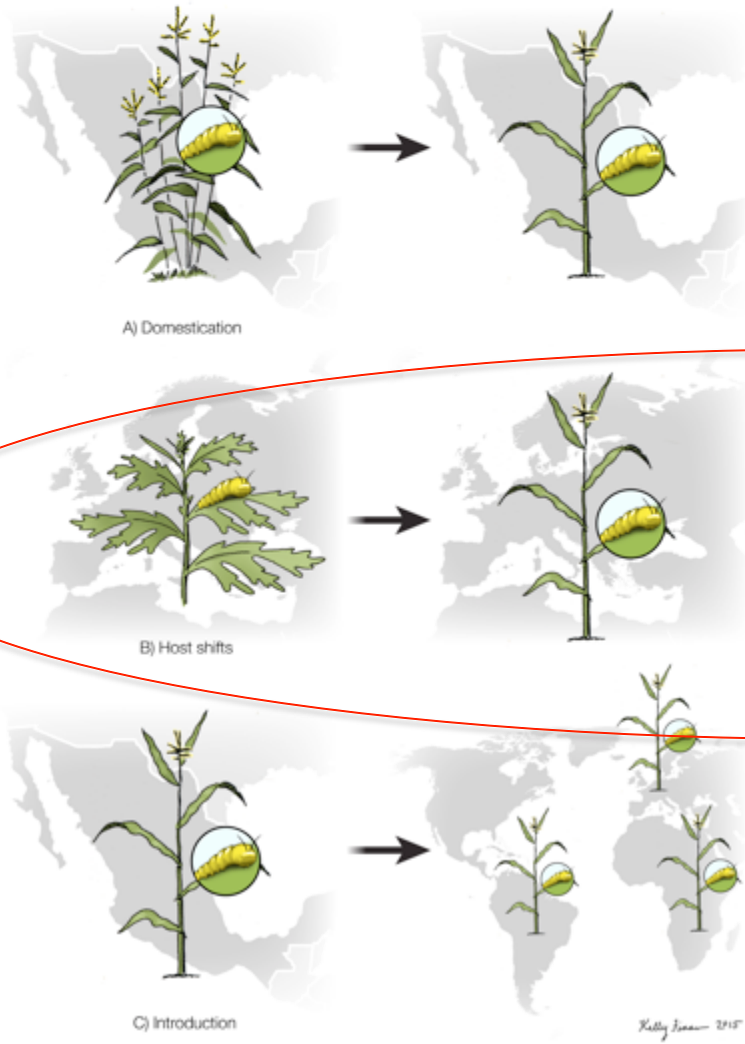
Diatraea grandiosella : from the teosinte to maize

Helicoverpa armigera and zea: from south america to worlwide



Diatraea grandiosella : from the teosinte to maize

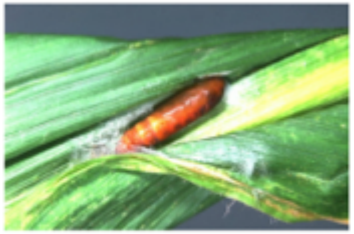
Ostrinia : from native host to introduced maize

Helicoverpa armigera and zea: from south america to worlwide

From Chen, Y. H. (2016). Journal elementa

- Context:
  Ostrinia genus, an eurasiatic origin and an exotic plant

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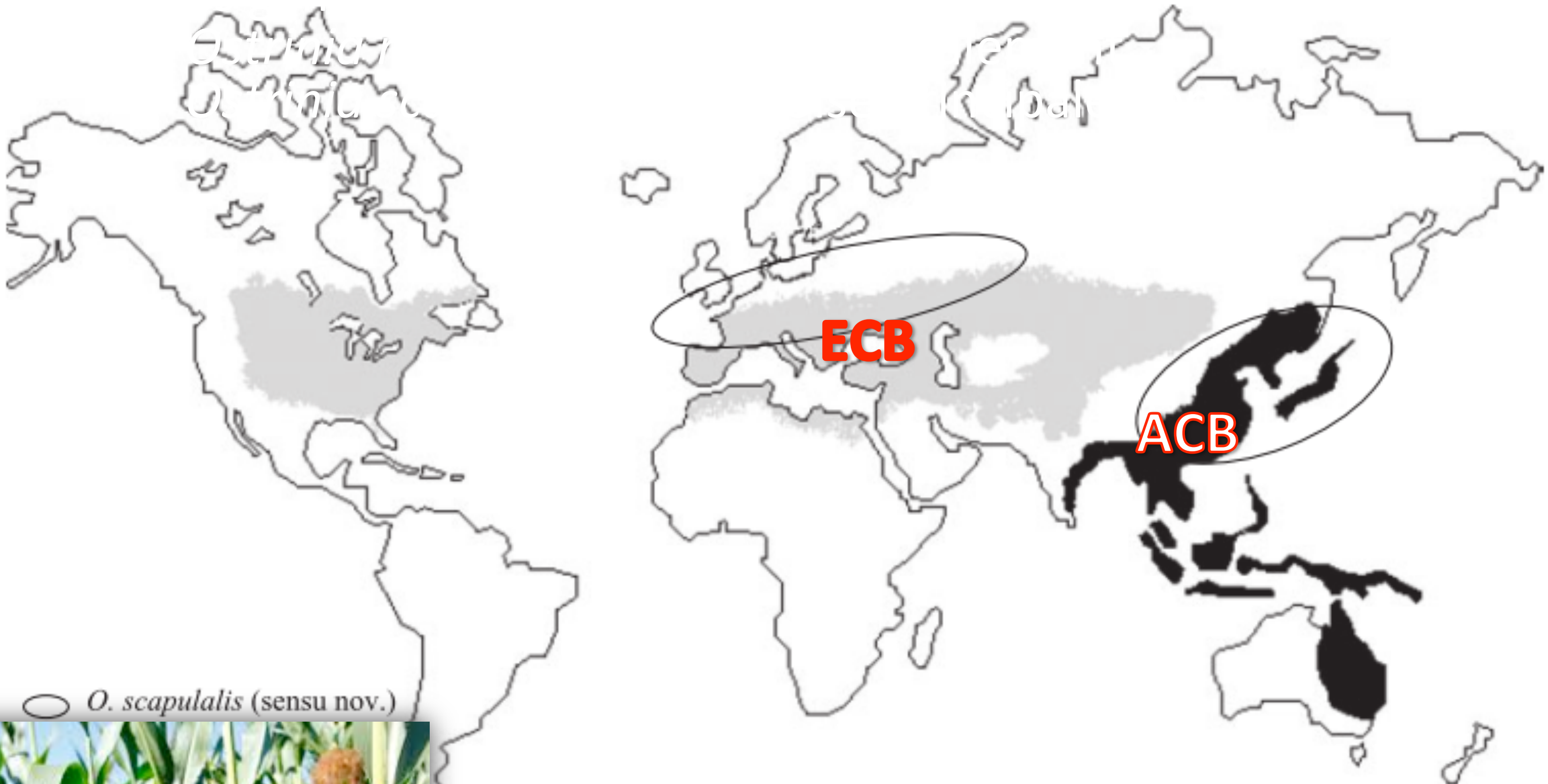

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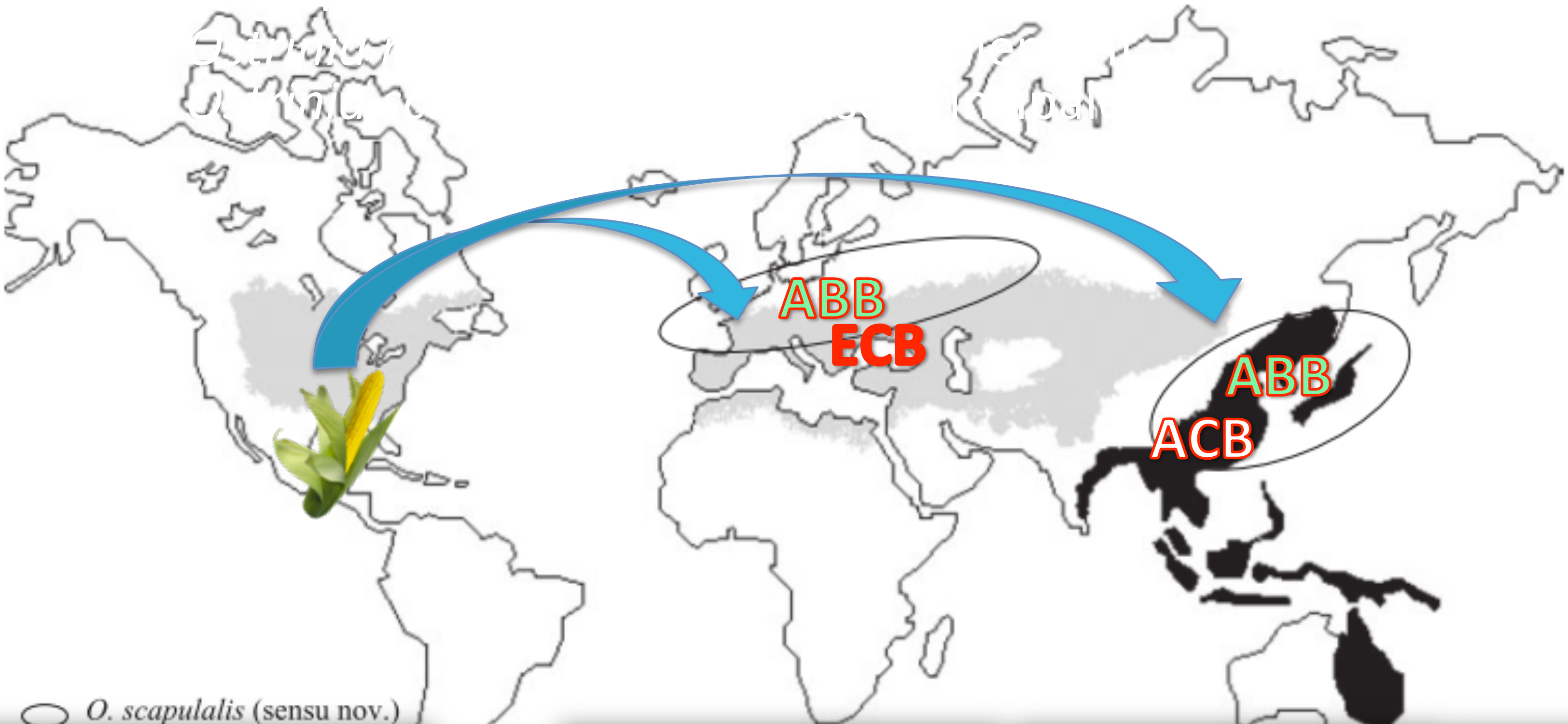

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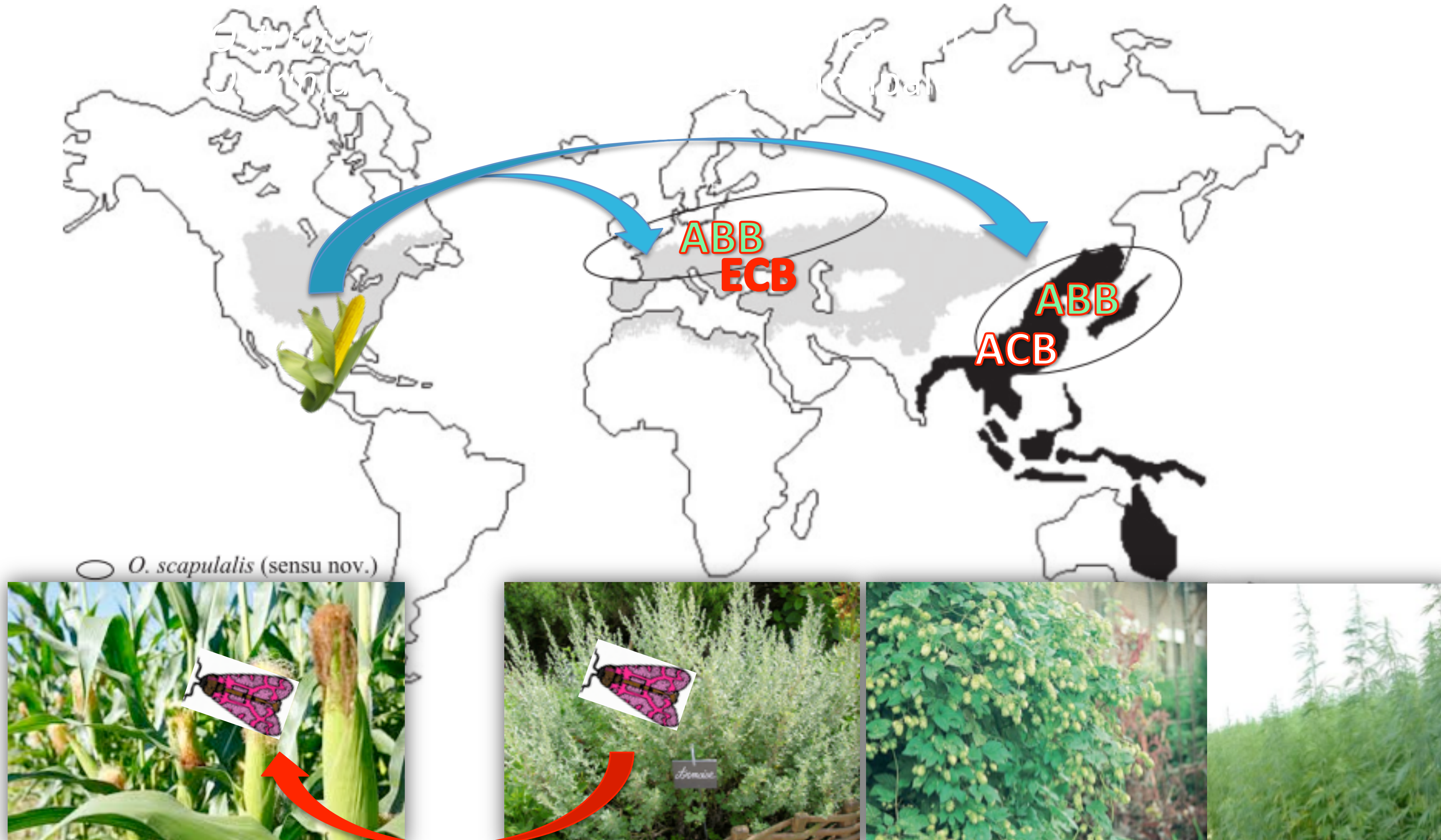
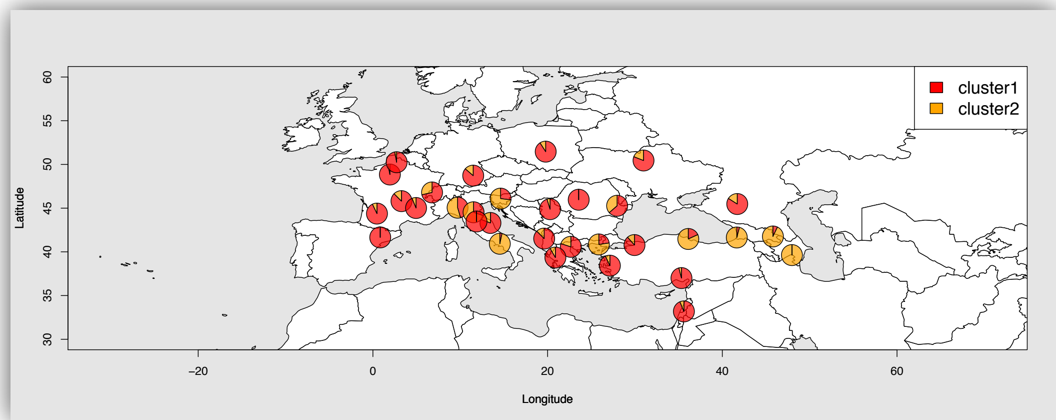


Objectives:

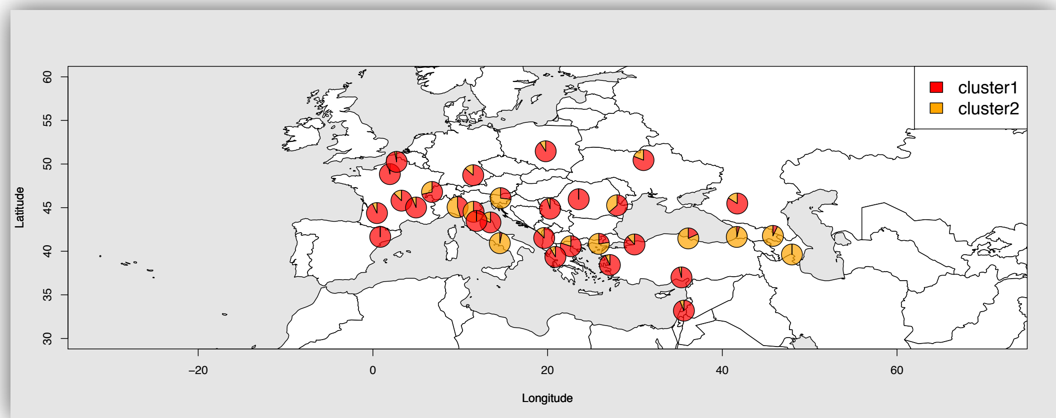
* Evolutionary history of the populations and species of the *Ostrinia* genus



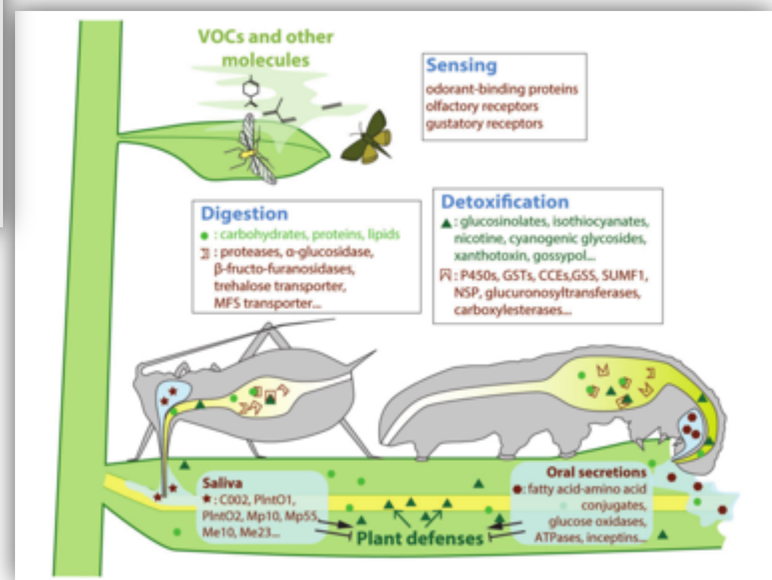
Genetic differentiation and association to the host plant

Objectives:

* Evolutionary history of the populations and species of the *Ostrinia* genus
* Mechanism involved in the specialization to the host plant (phenotypic, molecular, genomic)



Genetic differentiation and association to the host plant

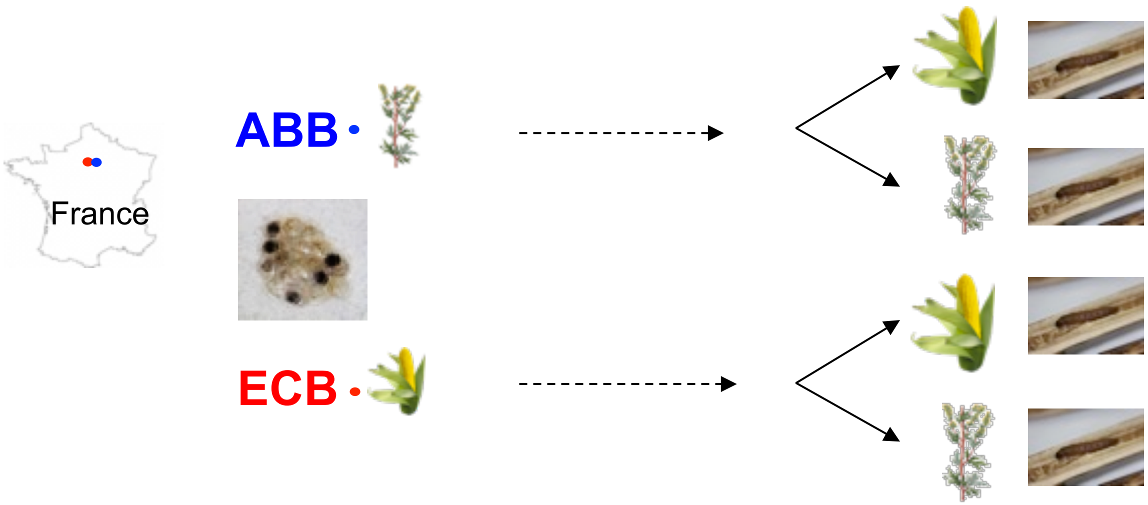


Mechanisms: recognition, digestion, detoxification (Simon et al 2015)

- methods:
complementary approaches in natural and experimental populations

- Specialization and gene expression

Specialization at the larval stage

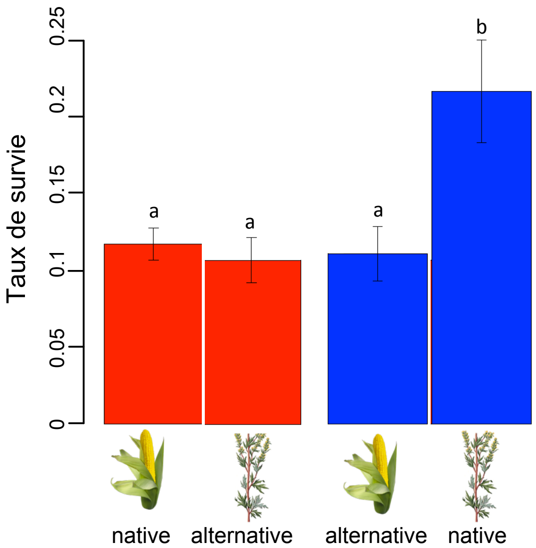


- Count (~ survival)
- Weight
- Developmental time

Specialization at the larval stage

ECB

ABB

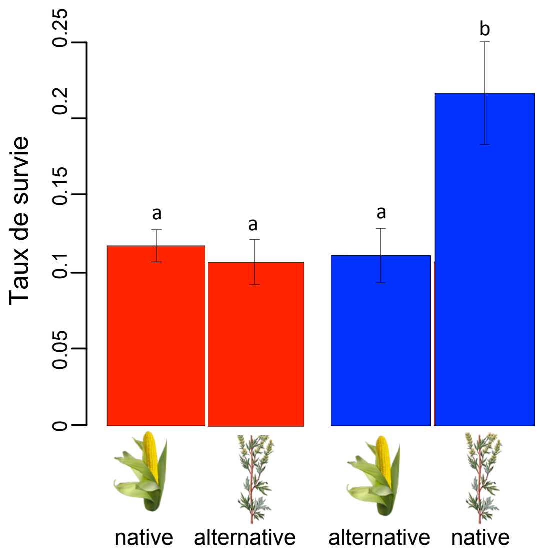


Survival

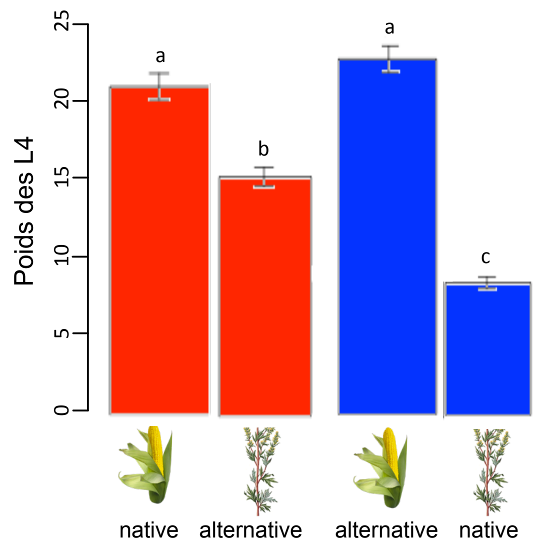
Specialization at the larval stage


ECB


ABB

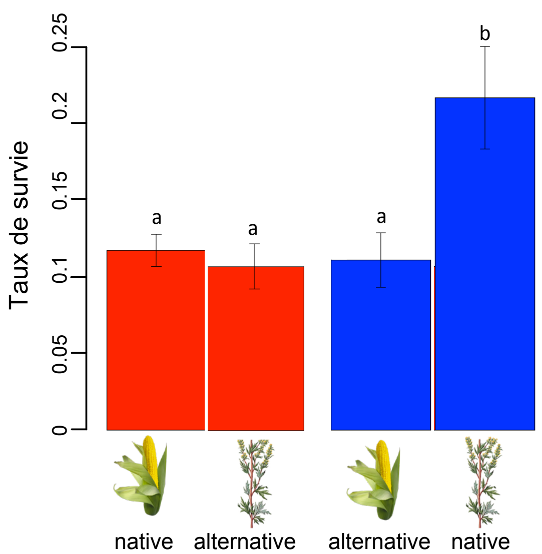


Survival

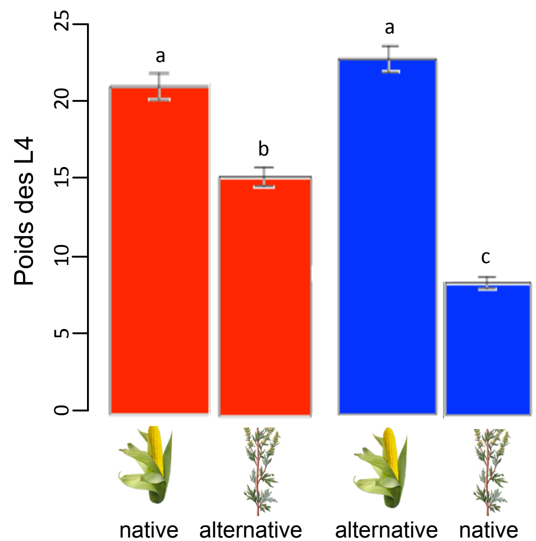


Weight

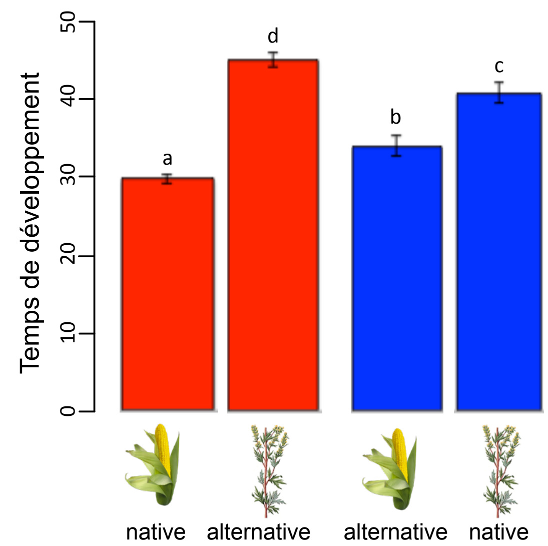
Specialization at the larval stage



Survival



Weight



Developmental time

Gene expression at the larval stage

RT

↓

ADNc sequencing, Hiseq

↓

De novo transcriptomic reference

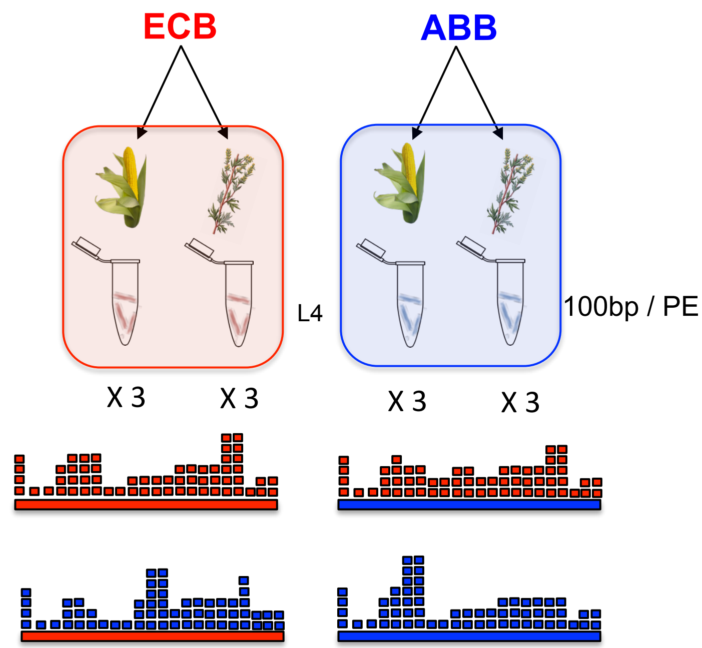
↓

Reads mapping

↓

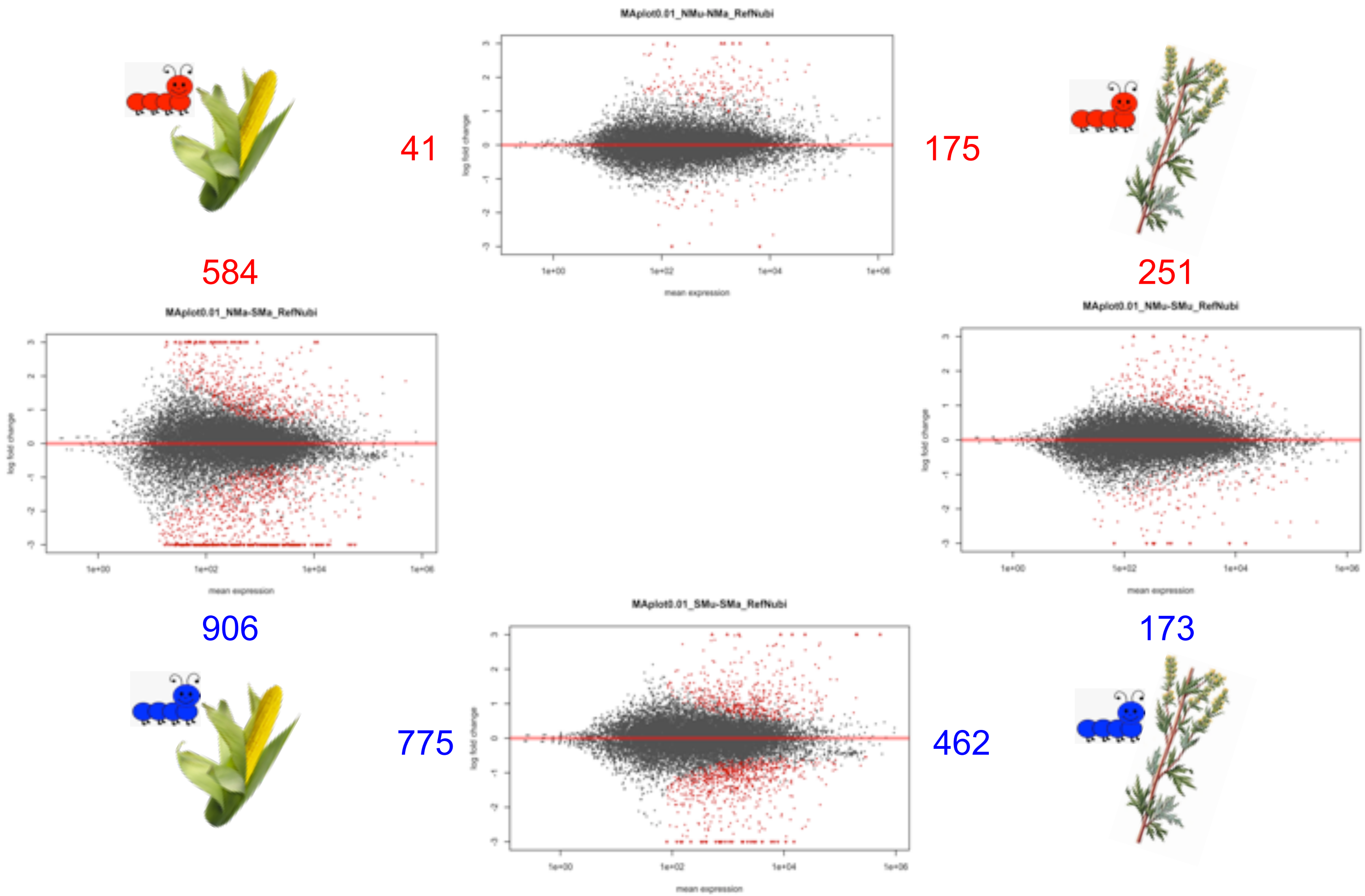
Analyses → DE genes

→ Functions (automatic annotations)



Comptage des reads / transcrit / référence

Gene expression at the larval stage



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- General mixed model:

Counts gene *i*= Species + Plant + Species x Plant

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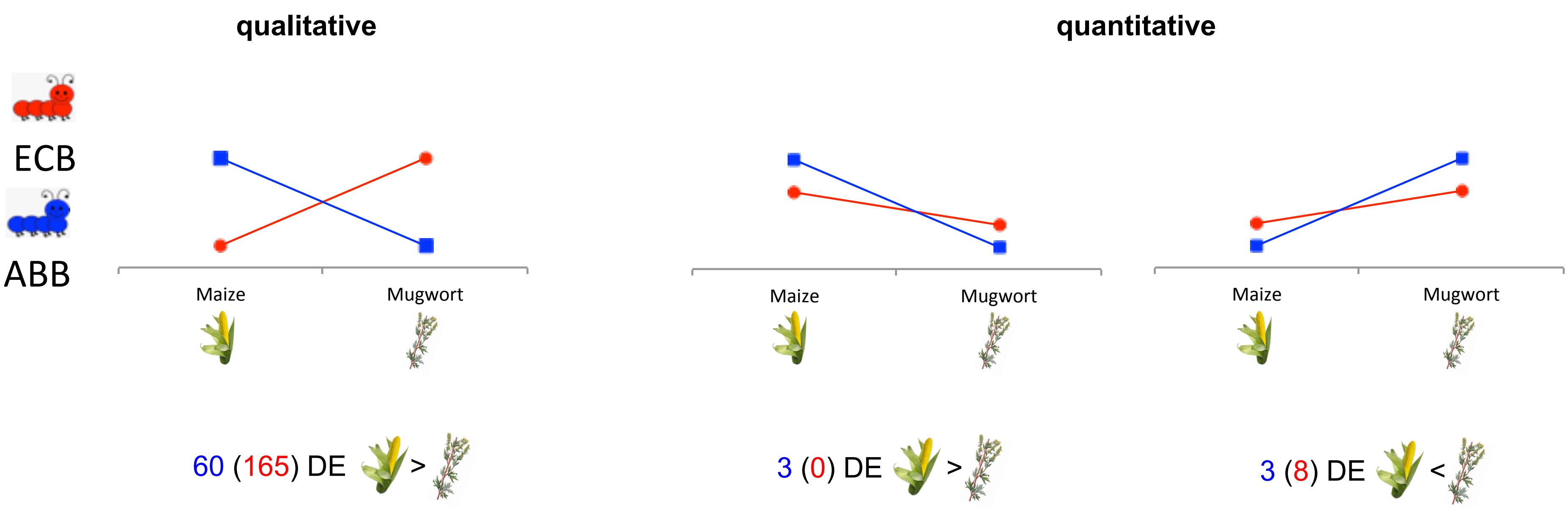

Gene expression at the larval stage

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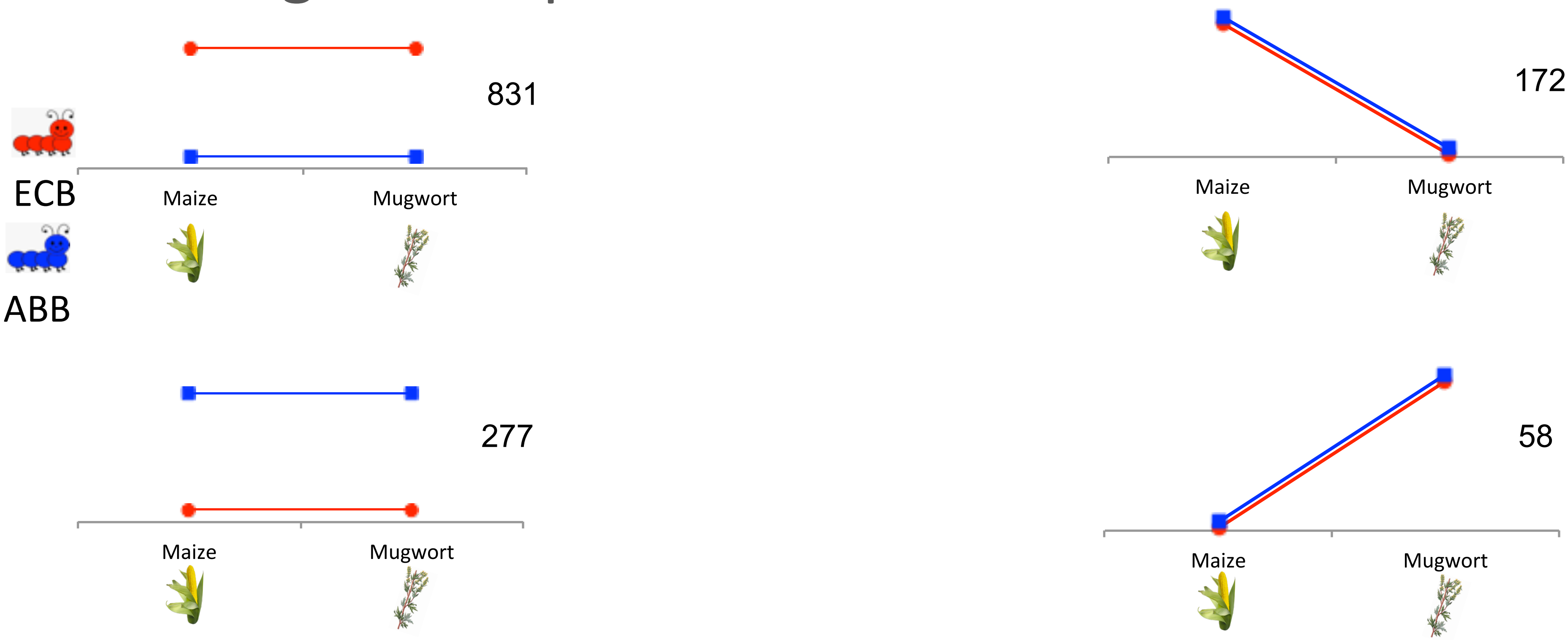

Over-represented functions in DE genes

- Development (ECB et ABB)
- Digestion (ECB et ABB) : serine endopeptidases, alpha-amylase, fatty acyl-CoA reductase
- Olfaction (ECB et ABB) : ORfur12 et 19 ; ORfur44; OnubOR5ag
- Detoxification (ABB) : Glutathione S-transferase, P450

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- Inmmunity (ABB) : PGRP, CTL, Serine Protease, Serine protease inibitor, immunlectin, chitinase

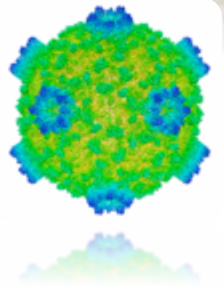
Over-represented functions in DE genes

➔ plant

Over-represented functions in DE genes

➔ plant

➔ virus

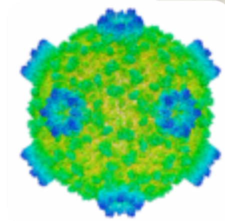


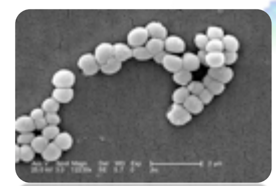
Over-represented functions in DE genes

→ plant

→ virus

→ bactéries





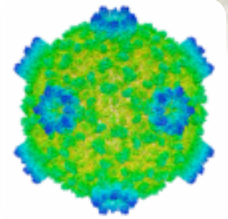
Over-represented functions in DE genes

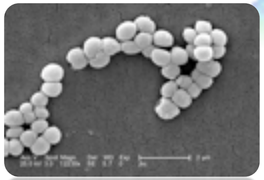
→ plant

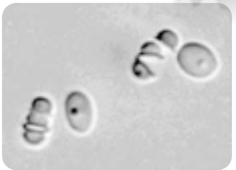
→ virus

→ bactéries

→ levures







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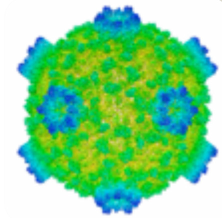

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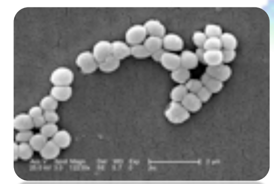
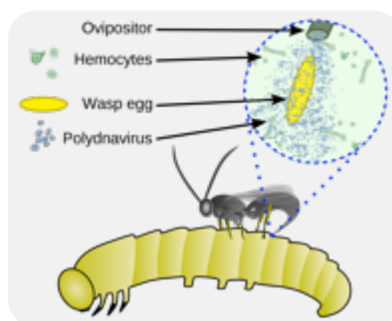


→ levures

→ parasitoïdes et virus associés



Over-represented functions in DE genes

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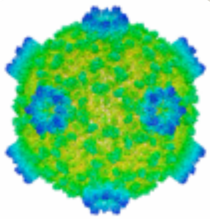
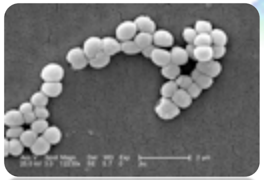
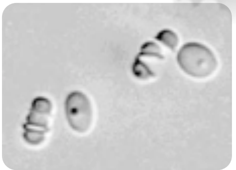
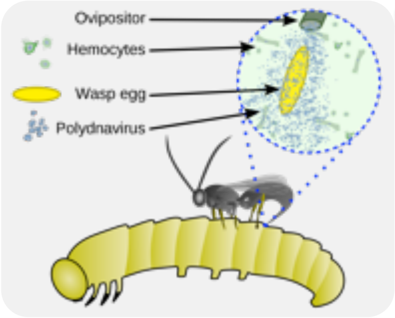




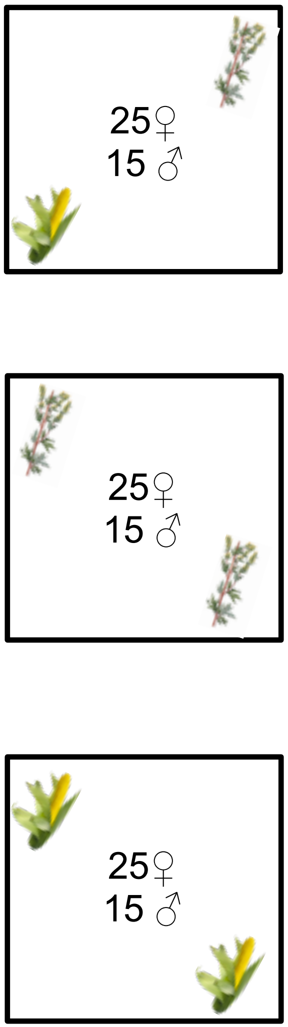




ECB		ABB	
maize	mugwort	maize	mugwort
cypoV +	cypoV +	cypoV+	--
Symbiont +	--	Symbiont +	--

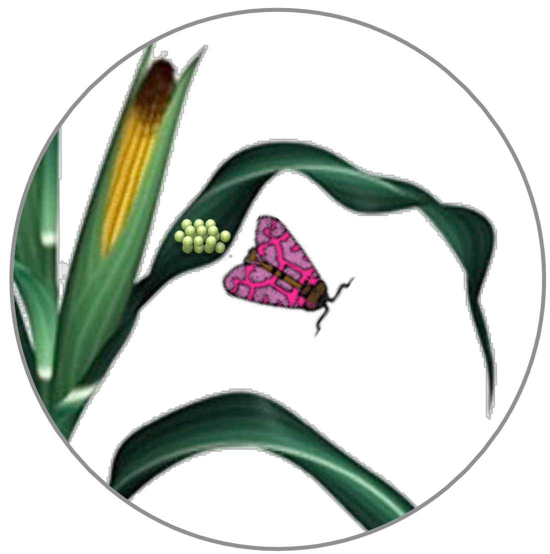
Plante hôte ➡ **Plante + faune associée**

Specialization at the adult stage



→ 72 h (3 nights)

→ virgin adults



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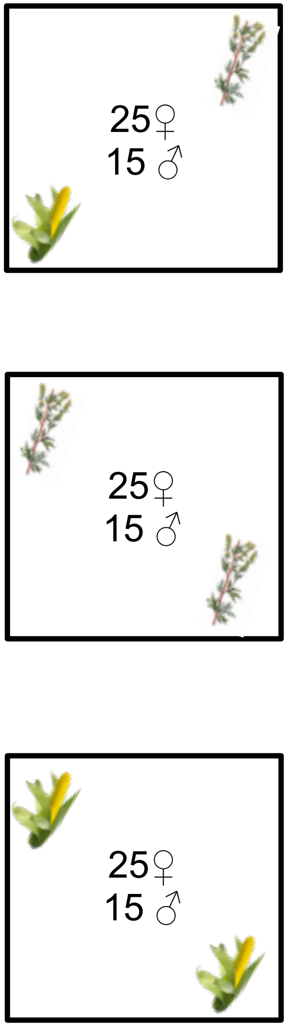

→ 72 h (3 nights)

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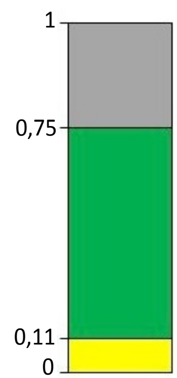
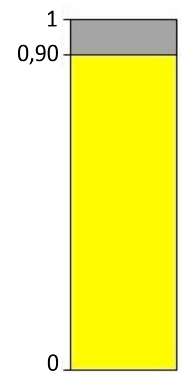
Species	ABB	ECB
(no) choice conditions		
Oviposition site	maize mugwort net	maize mugwort net
% eggmasses laid per site		

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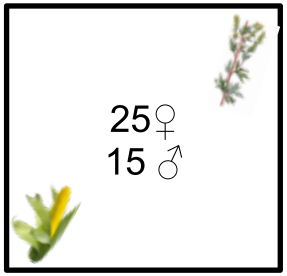

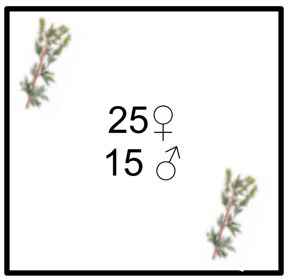

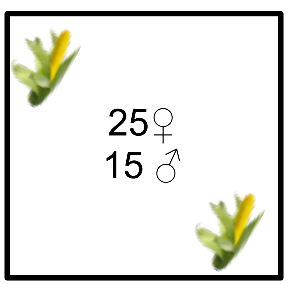

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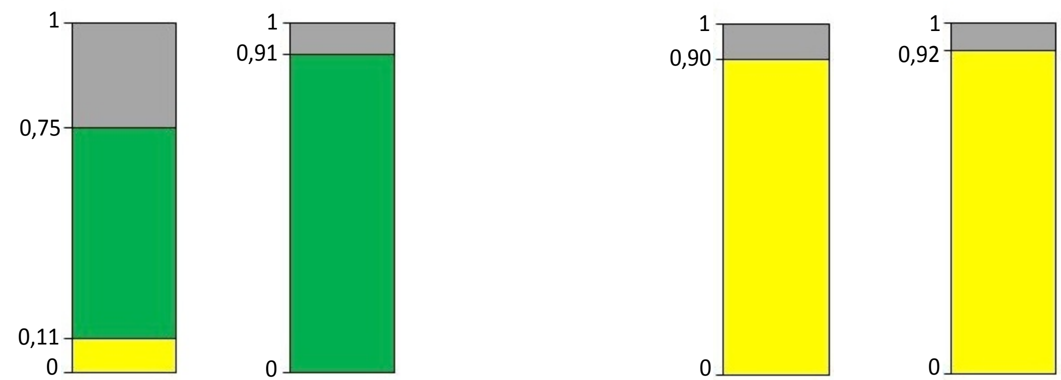
Species	ABB			ECB		
(no) choice conditions						
Oviposition site	maize mugwort net	mugwort net		maize mugwort net	maize net	

% eggmasses laid per site



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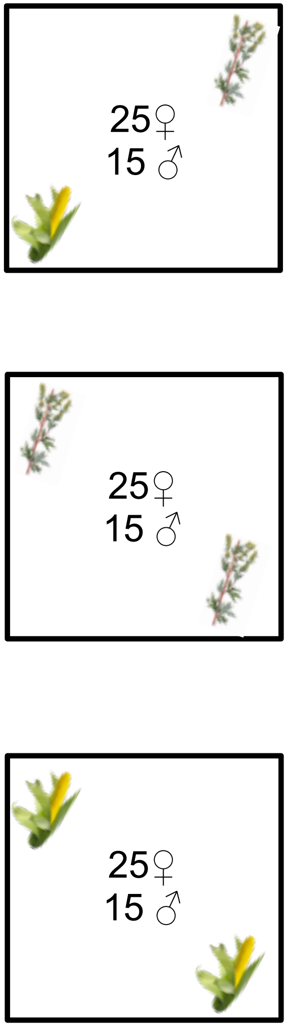

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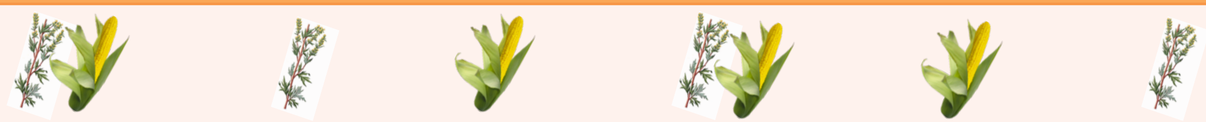
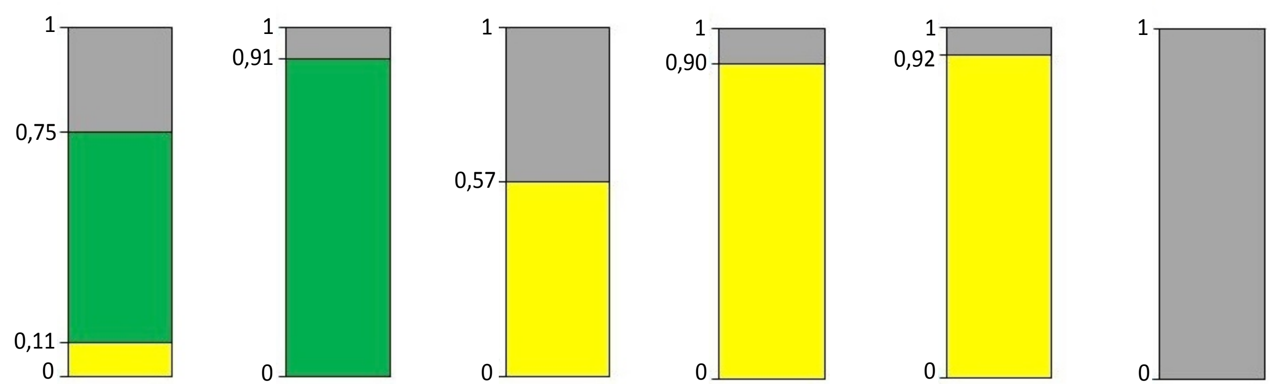
(no) choice conditions						
Oviposition site	maize, mugwort, net	mugwort, net	maize, net	maize, mugwort, net	maize, net	mugwort, net
% eggmasses laid per site						

Gene expression at the adult stage

Ostrinia spp.

Expérience

↓

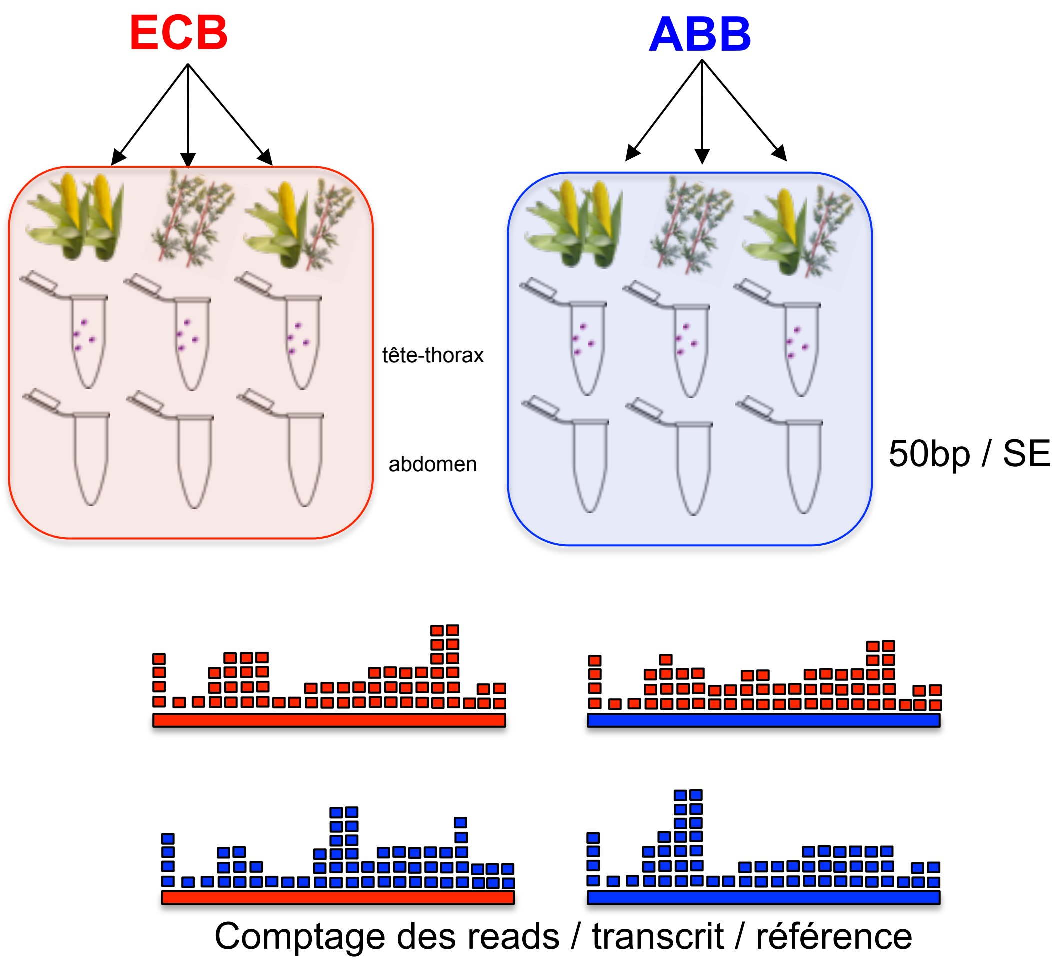
Séquençage ADNc

↓

Construction de références *de novo* (~12 000)

↓

Alignement des reads sur transcriptomes *de novo* (~70%)



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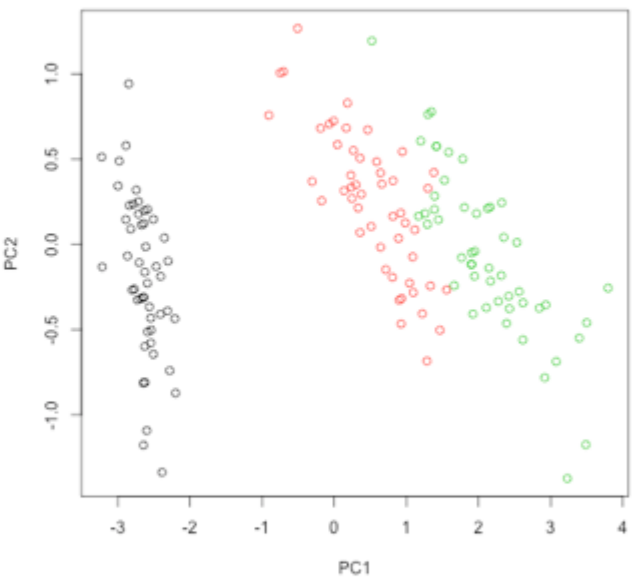

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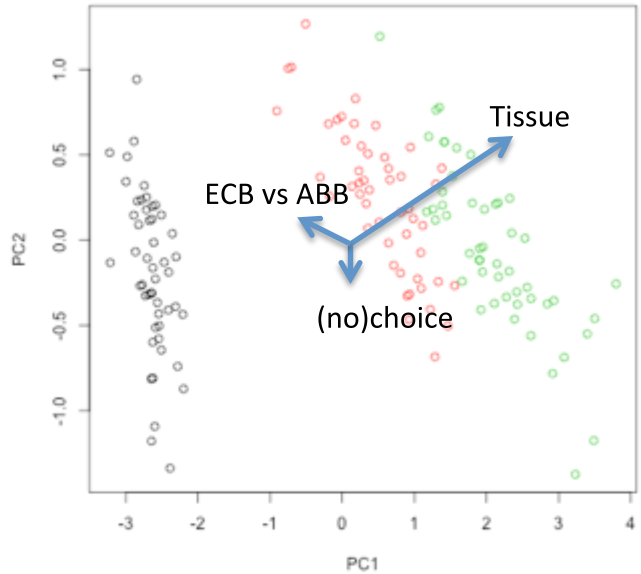
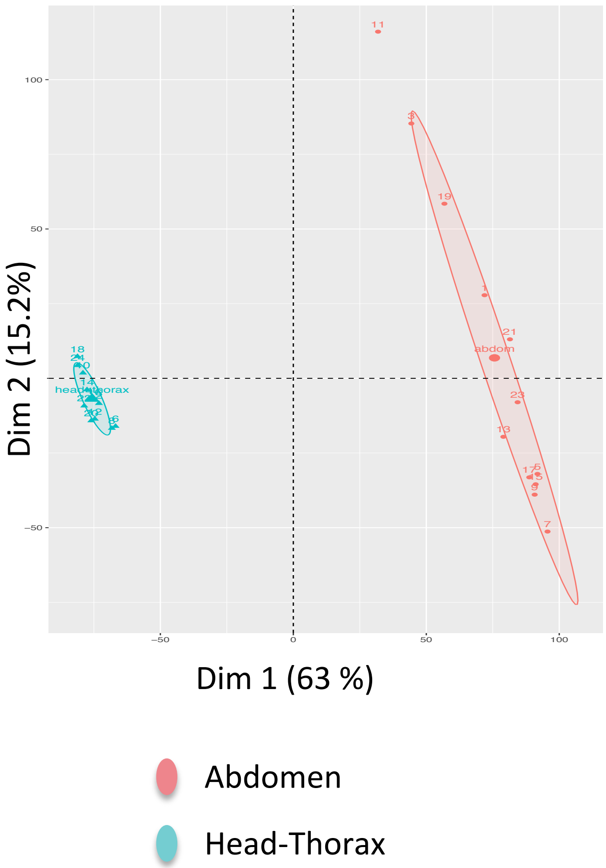
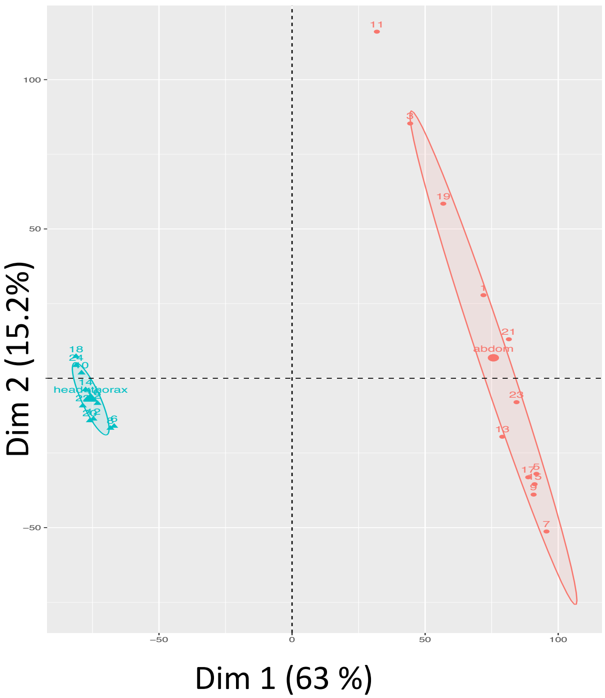
- General Mixed Model: Counts gene *i*= Species + (no) choice set-up + Species x Set-up
- PCA analysis on normalized counts: another way of classifying Species/Choice/ No choice effects

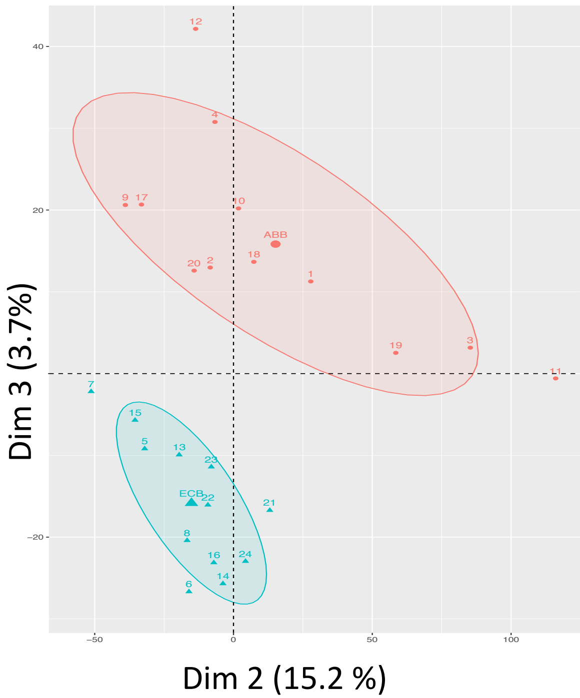


Gene expression at the adult stage



Gene expression at the adult stage





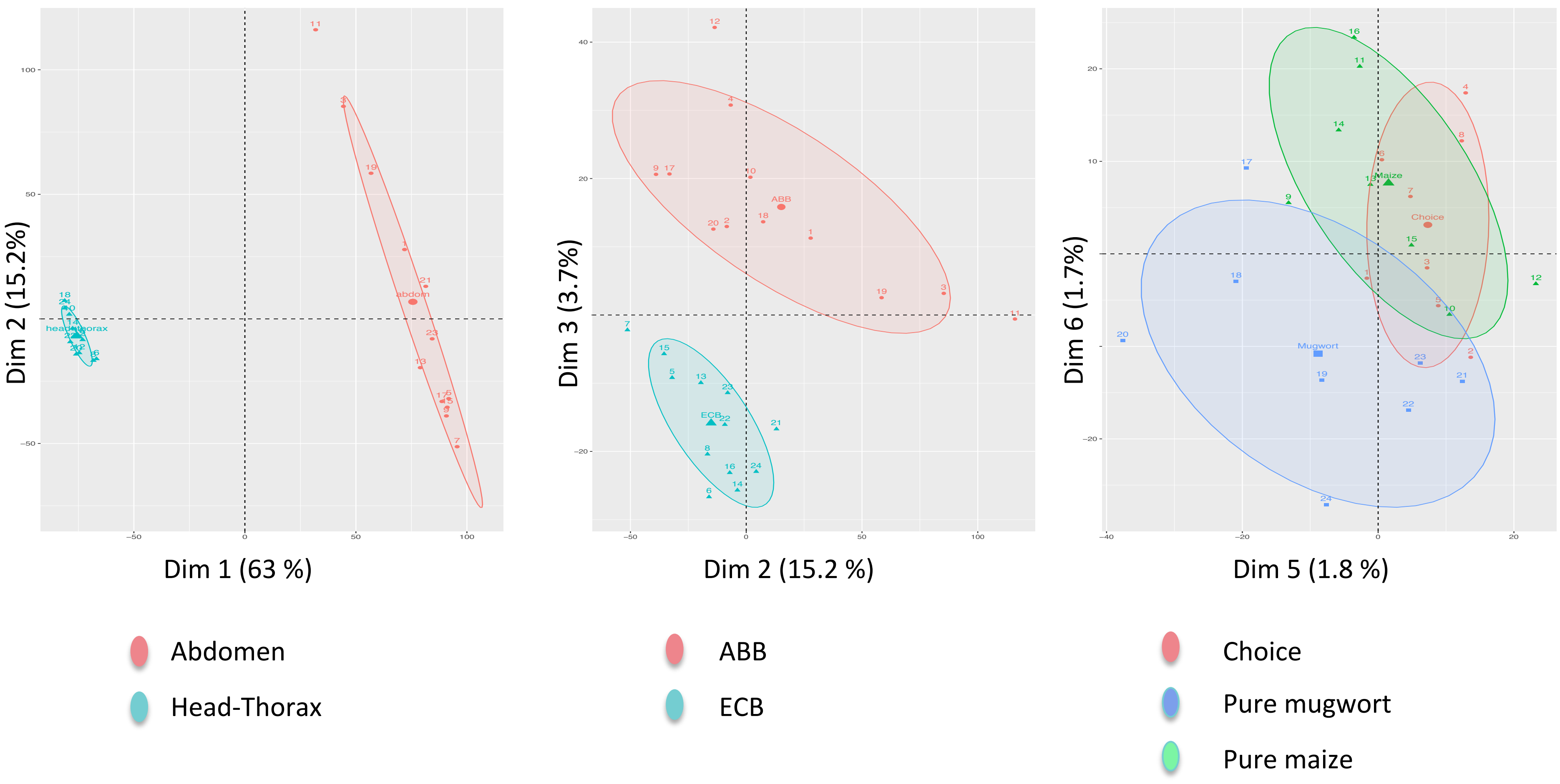
Abdomen

Head-Thorax

ABB

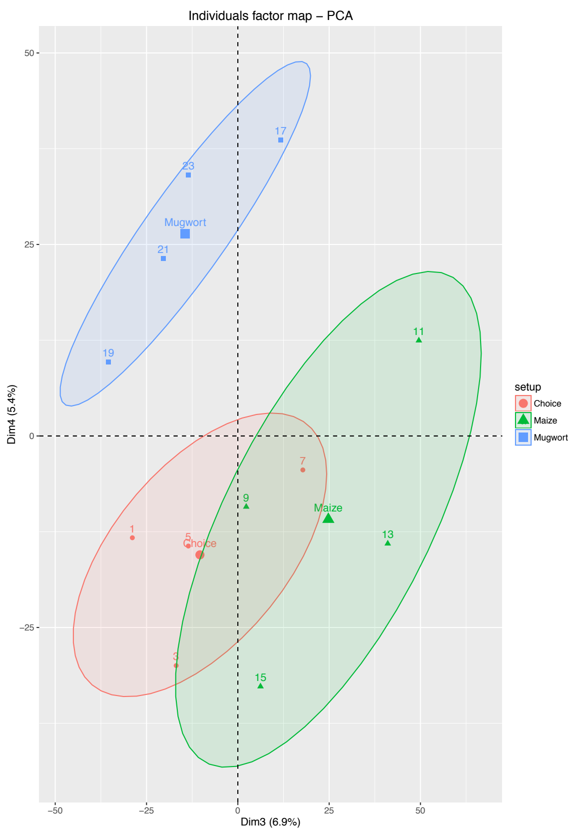
ECB

Gene expression at the adult stage



Gene expression at the adult stage

- Abdomen only



Axes 3-4: mugwort effect

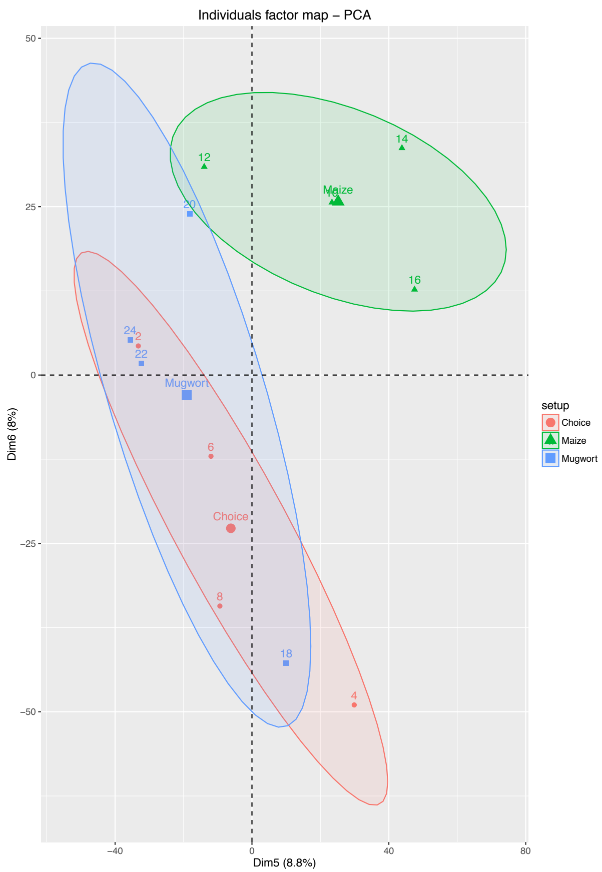
```
isotig01215  -0.7462918 5.307489e-03
isotig04501  -0.7612812 4.023504e-03
isotig05508  -0.7614681 4.009152e-03
isotig08305  -0.7621112 3.960054e-03
isotig08789  -0.7652629 3.726008e-03
isotig03495  -0.7664987 3.637162e-03
isotig04815  -0.7668057 3.615342e-03
isotig03046  -0.7803249 2.748908e-03
isotig04748  -0.7857541 2.449615e-03
isotig04964  -0.7933184 2.074869e-03
isotig04001  -0.8066352 1.523328e-03
isotig05092  -0.8174815 1.163832e-03
isotig10481  -0.8178808 1.151979e-03
isotig11212  -0.8182348 1.141548e-03

$quali
           R2     p.value
setup 0.6930558 0.004917763

$category
        Estimate      p.value
Mugwort 26.40022 0.0008750745
```

Gene expression at the adult stage

- Head-Thorax only



Axes 5-6: maize effect

isotig01427	-0.7799042	0.0027732078
isotig07806	-0.7839070	0.0025484930
isotig05820	-0.7856138	0.0024570182
isotig03971	-0.7881675	0.0023248625
isotig07757	-0.7963768	0.0019364964
isotig10392	-0.8013399	0.0017271133
isotig03368	-0.8088253	0.0014446649
isotig09939	-0.8143705	0.0012594186
isotig08136	-0.8236766	0.0009901817
isotig01928	-0.8279819	0.0008818027
isotig01183	-0.8352600	0.0007196502
isotig07846	-0.8385420	0.0006545692
isotig00683	-0.8399198	0.0006286475
isotig01679	-0.8401764	0.0006239101
isotig02186	-0.8445209	0.0005477992
isotig08910	-0.8601840	0.0003311712

$quali

	R2	p.value
setup	0.4184365	0.08723425

$category

	Estimate	p.value
Maize	25.19092	0.03132546

Annotated functions and DE genes at the adult stage

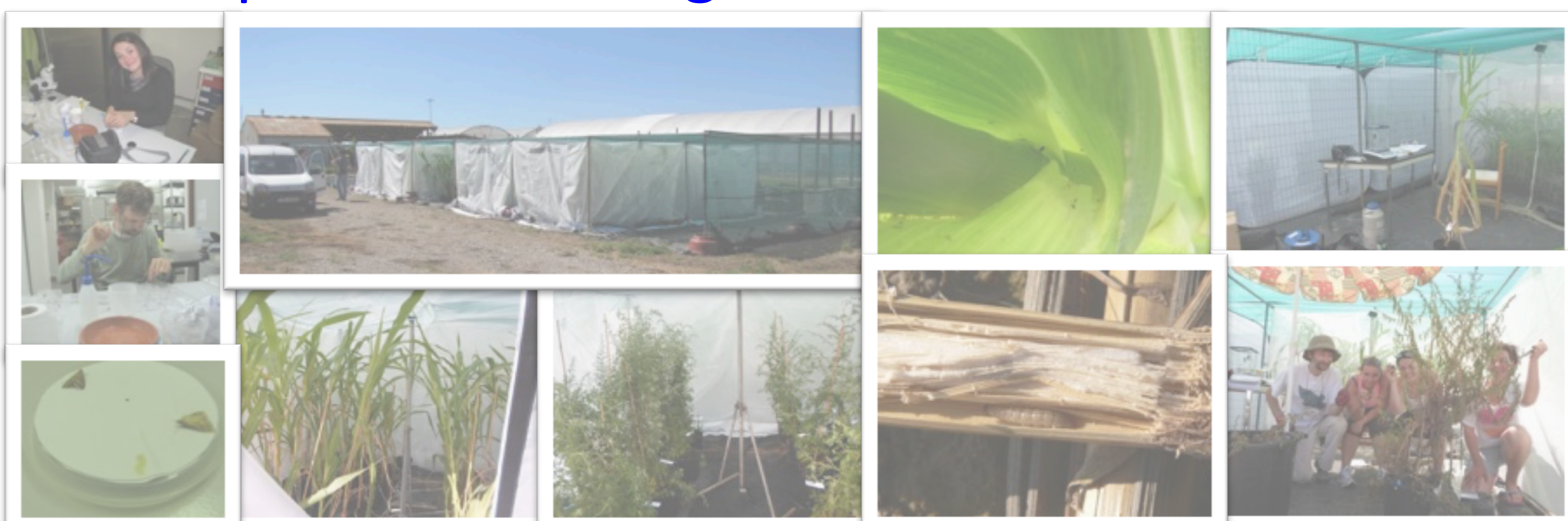
For the plant effect (choice versus no choice effect):

- Development (muscle development, oogenesis, neurones)
- Digestion/ detoxification
- Inmmunity
- Chemosensory??

For the species effect (choice versus no choice effect) : to be done

Conclusions

- Specialization at the larval stage and adult stage for ECB: survival, preference, and avoidance
- Specialization at the adult stage for ABB: preference
- Host pecialization higher in ECB than in ABB



Conclusions

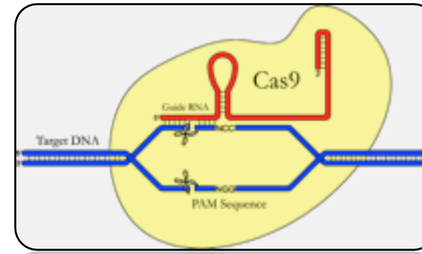
- DE genes at the larval stage:
  - Species >> interaction >> plant effect
  - Candidates genes to host specialization and their relative pattern in ECB and ABB: evolutionary history
  - Host specialization uncovers various biological functions: development, digestion, detoxification, sensing and IMMUNITY

Conclusions

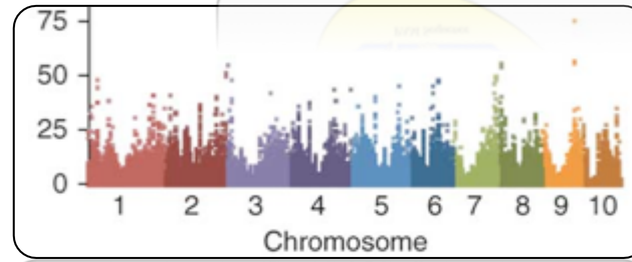
- DE genes at the adult stage:
  - Tissue >> Species >> plant effect
  - Candidates genes to host specialization and their relative pattern in ECB and ABB: evolutionary history
  - Host specialization uncovers various biological functions: development, digestion, detoxification, and IMMUNITY

Perspectives

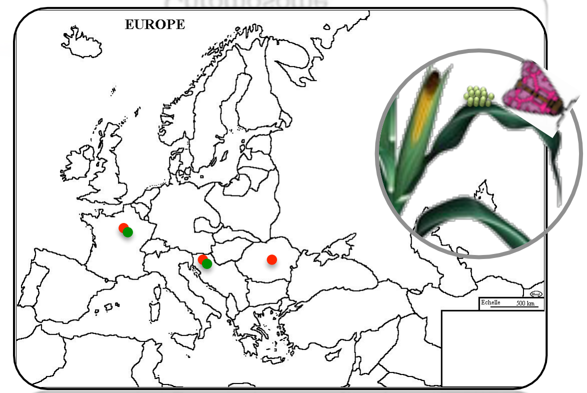
- Validation
  qPCR, functional genomics



- Cross validation
  Population genomics



- Generalization
  THV in various European populations



- Evolutionary history
  Phylogeography with neutral markers and candidate genes