Selection, plasticity and drift shape the life history traits in the crop pest *Tetranychus urticae* after a host-plant shift

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EVOLSEXALLOC Project

centre for ecology, evolution and environmental changes

General context

Degrees of host specialisation

Generalist

More than 3 different plant families

Specialist

One or a few closely related plant species

(Schoonhoven *et al.*, 2005)

General context

Degrees of host specialisation

Generalist

More than 3 different plant families

Specialist

One or a few closely related plant species

Less than 10% of herbivores

(Schoonhoven *et al.*, 2005)

General context

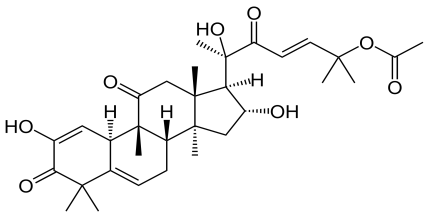
Host-plants and their defences (Fritz and Simms, 1992)

Physical, and…

Trichomes

…chemical defences

Systemin



Cucurbitacin

General context

Plasticity, a mechanism that may facilitate colonization

Genotypes adjust their phenotype in response to the environment (Bradshaw, 1965; Stearns, 1989)

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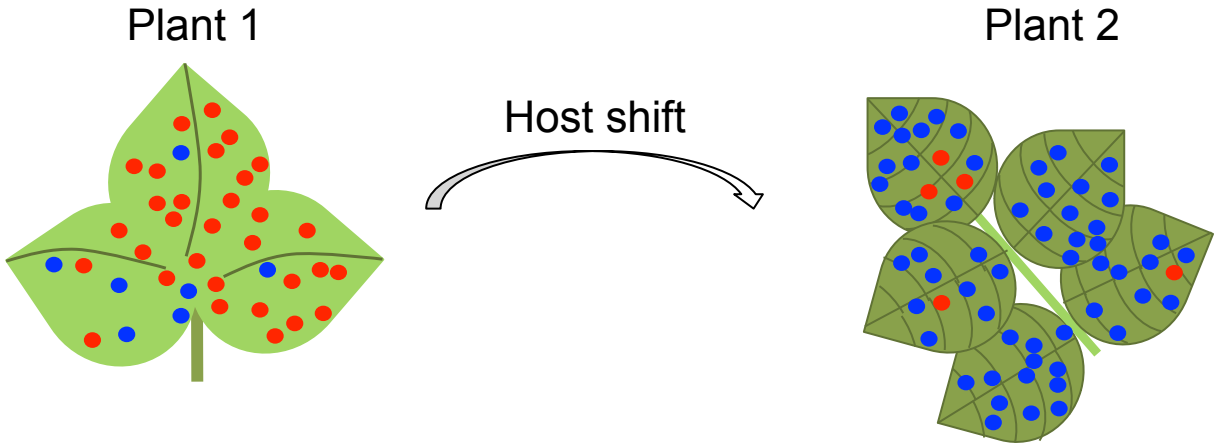
Plasticity, a mechanism that may facilitate colonization

Genotypes adjust their phenotype in response to the environment (Bradshaw, 1965; Stearns, 1989)

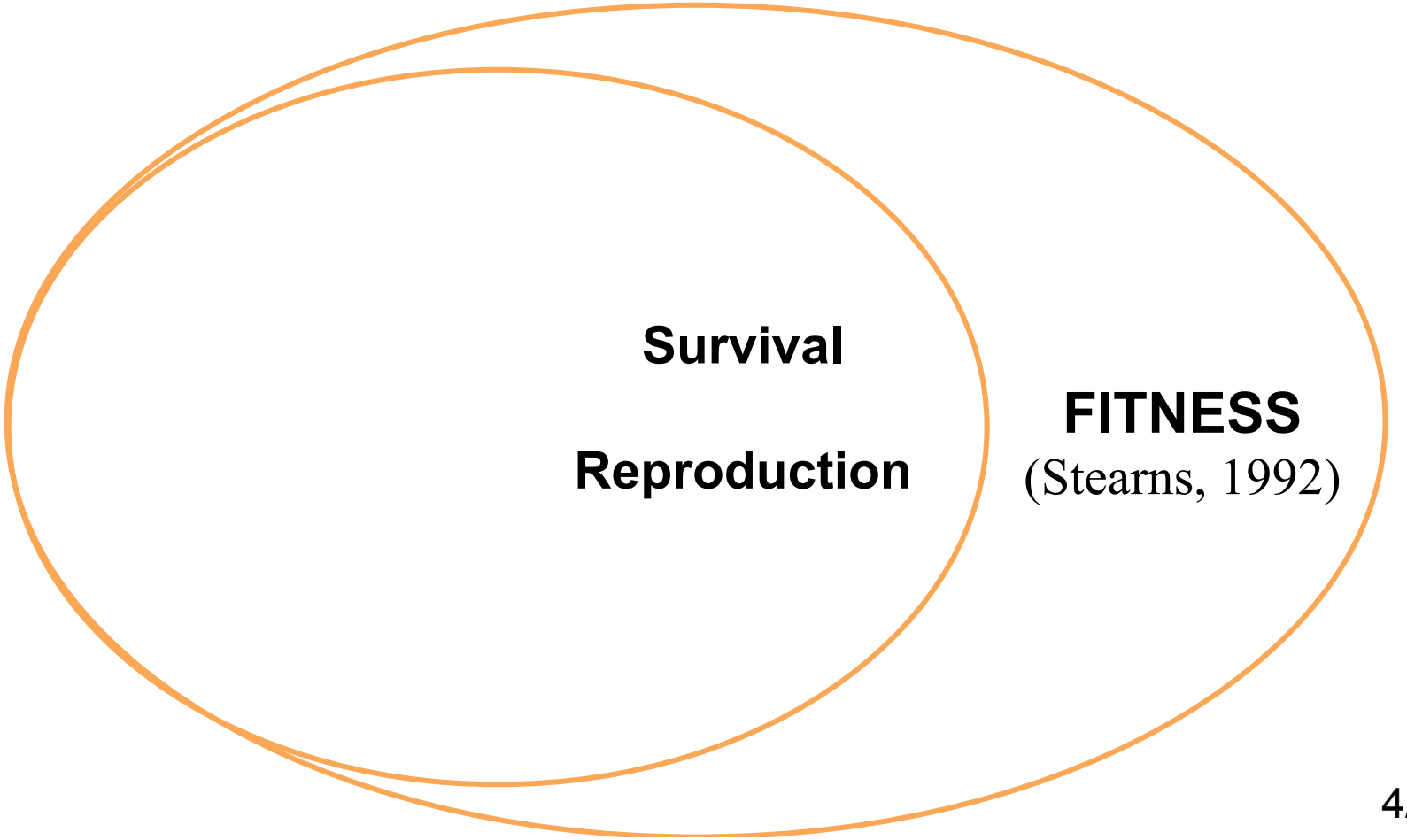
Host-plant adaptation, an evolutionary process

Environmental change selects genotypes with the highest fitness in this environment



Fitness and life-history traits

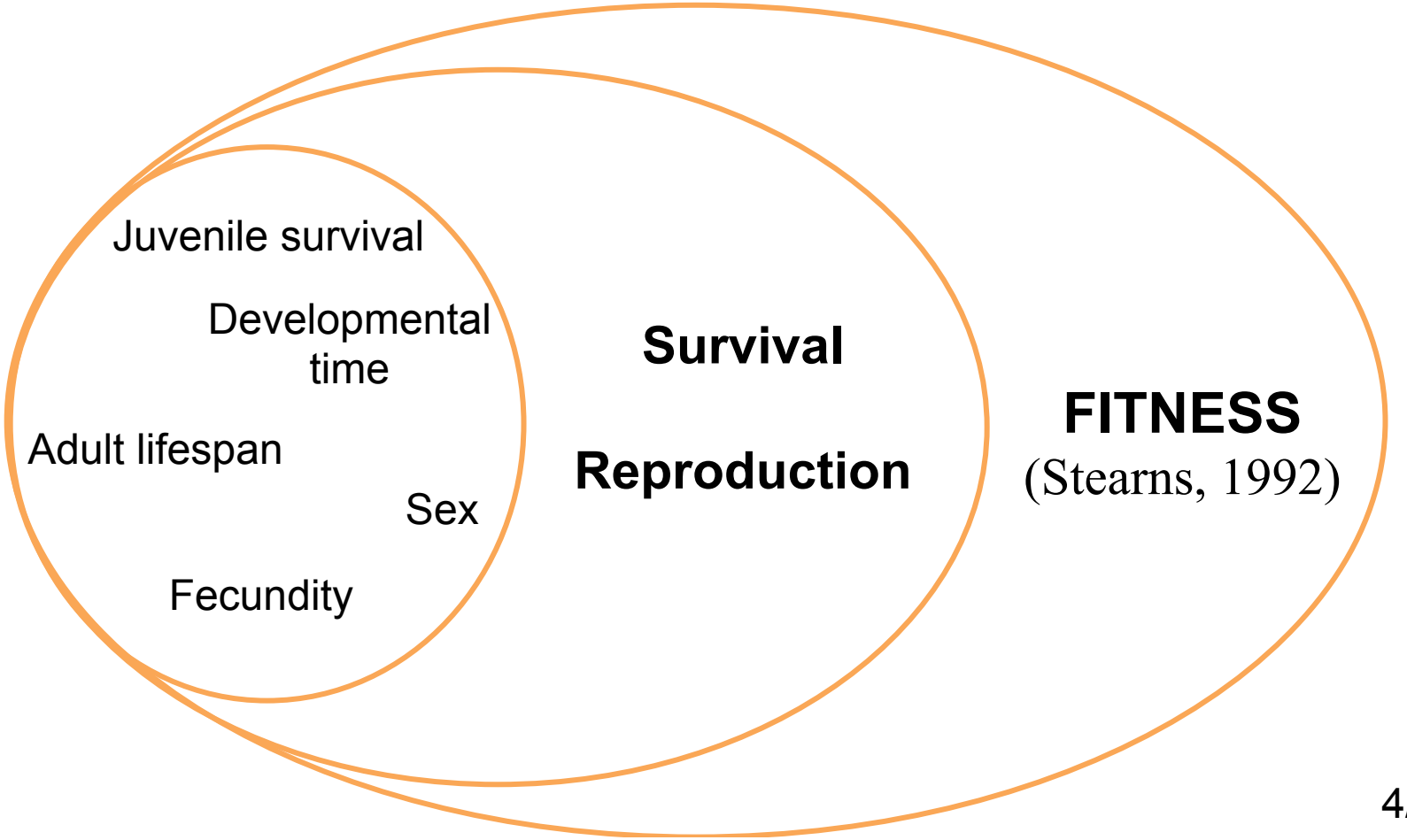
Fitness defined by two main components



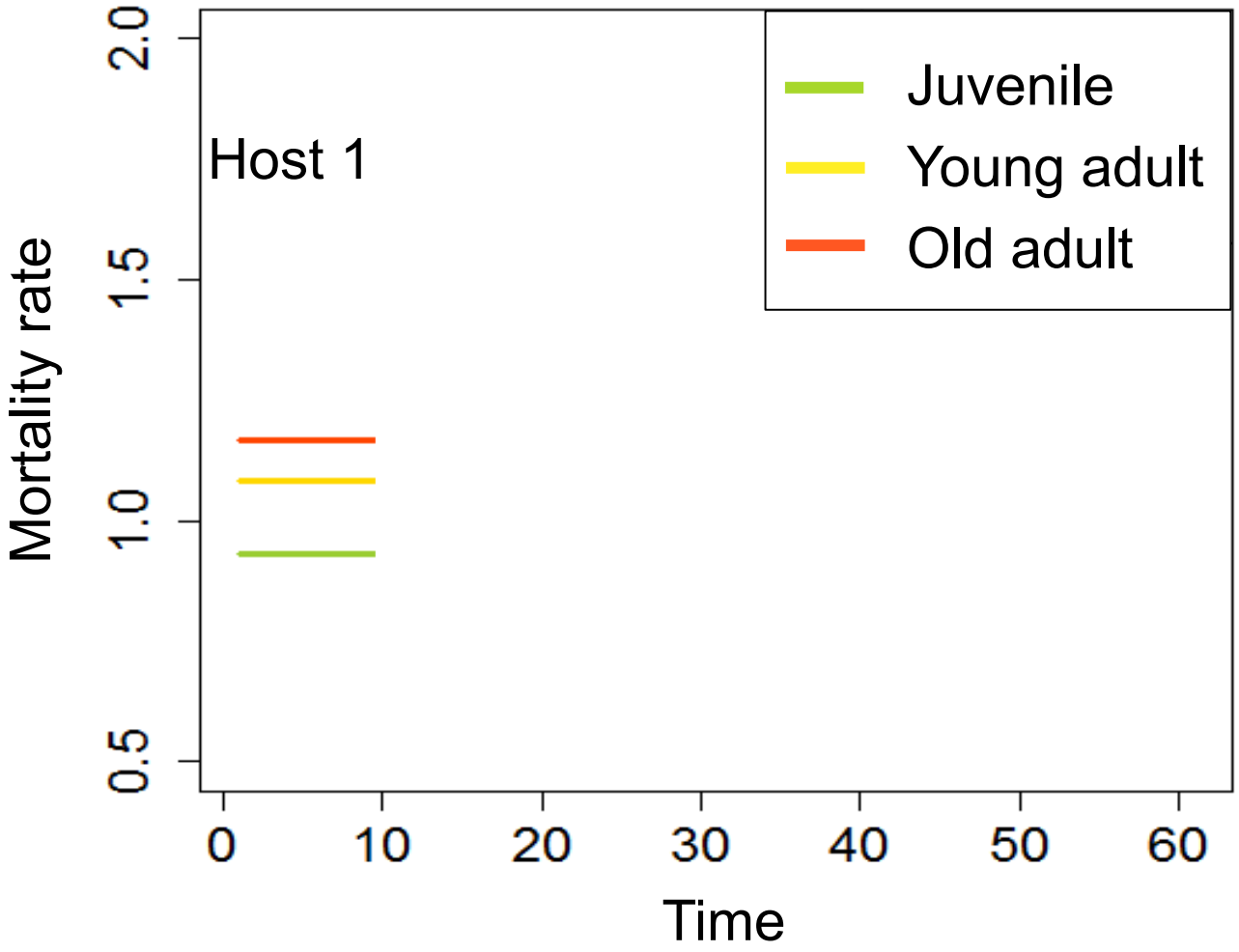
General context

Fitness and life-history traits

Biological traits at different ages characterizing life cycle of organisms



Evolution of life-history traits (Cotto and Ronce, 2014)



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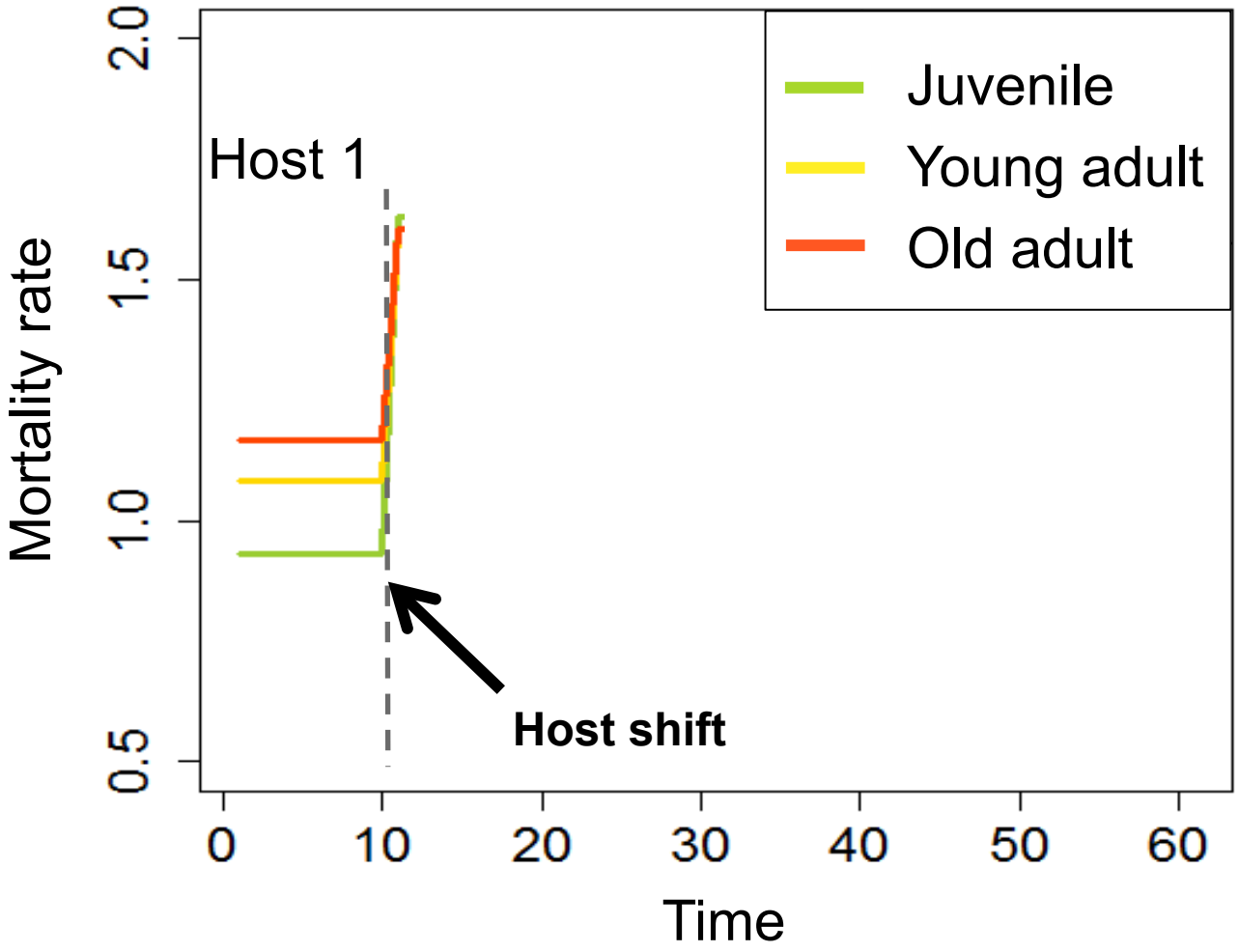

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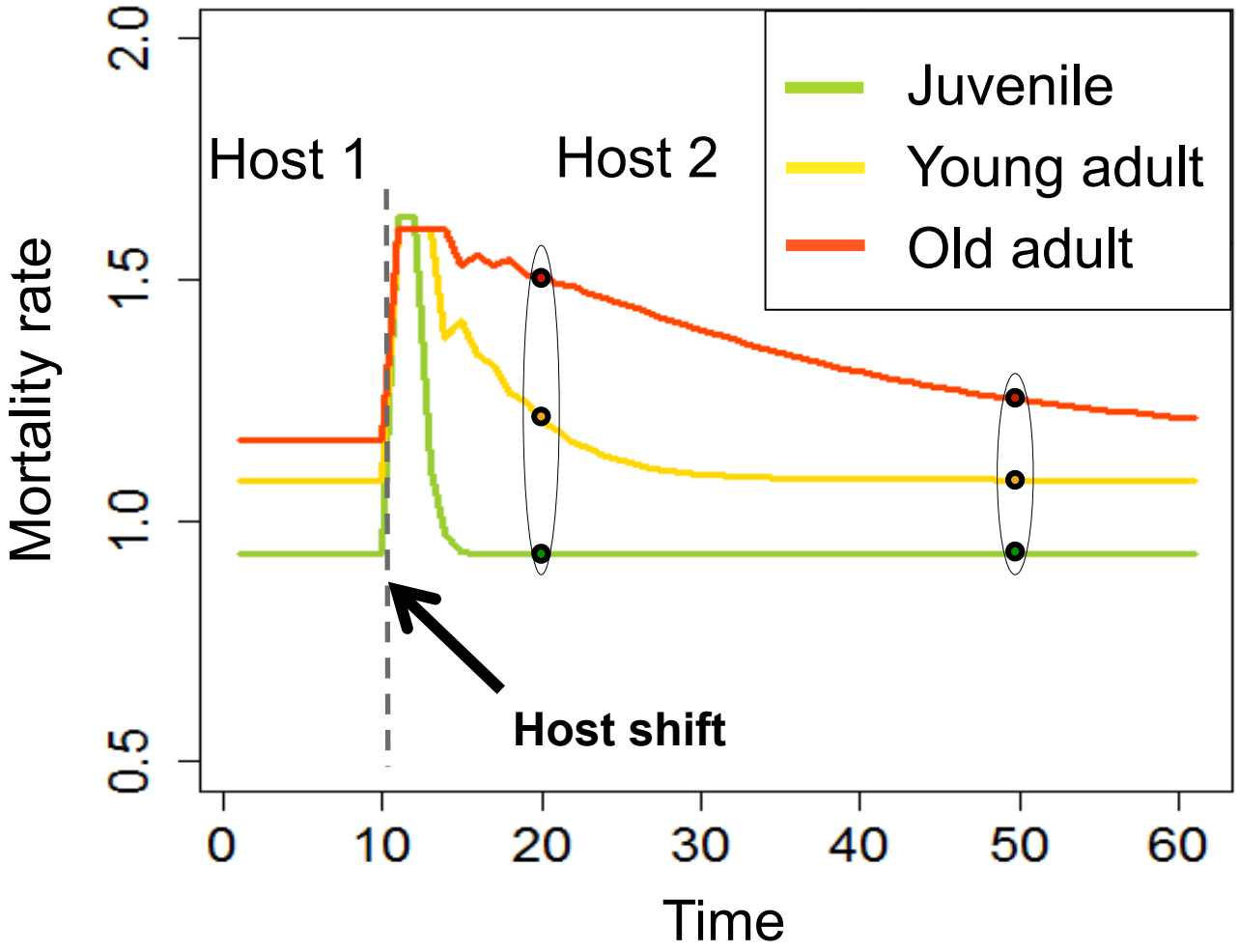
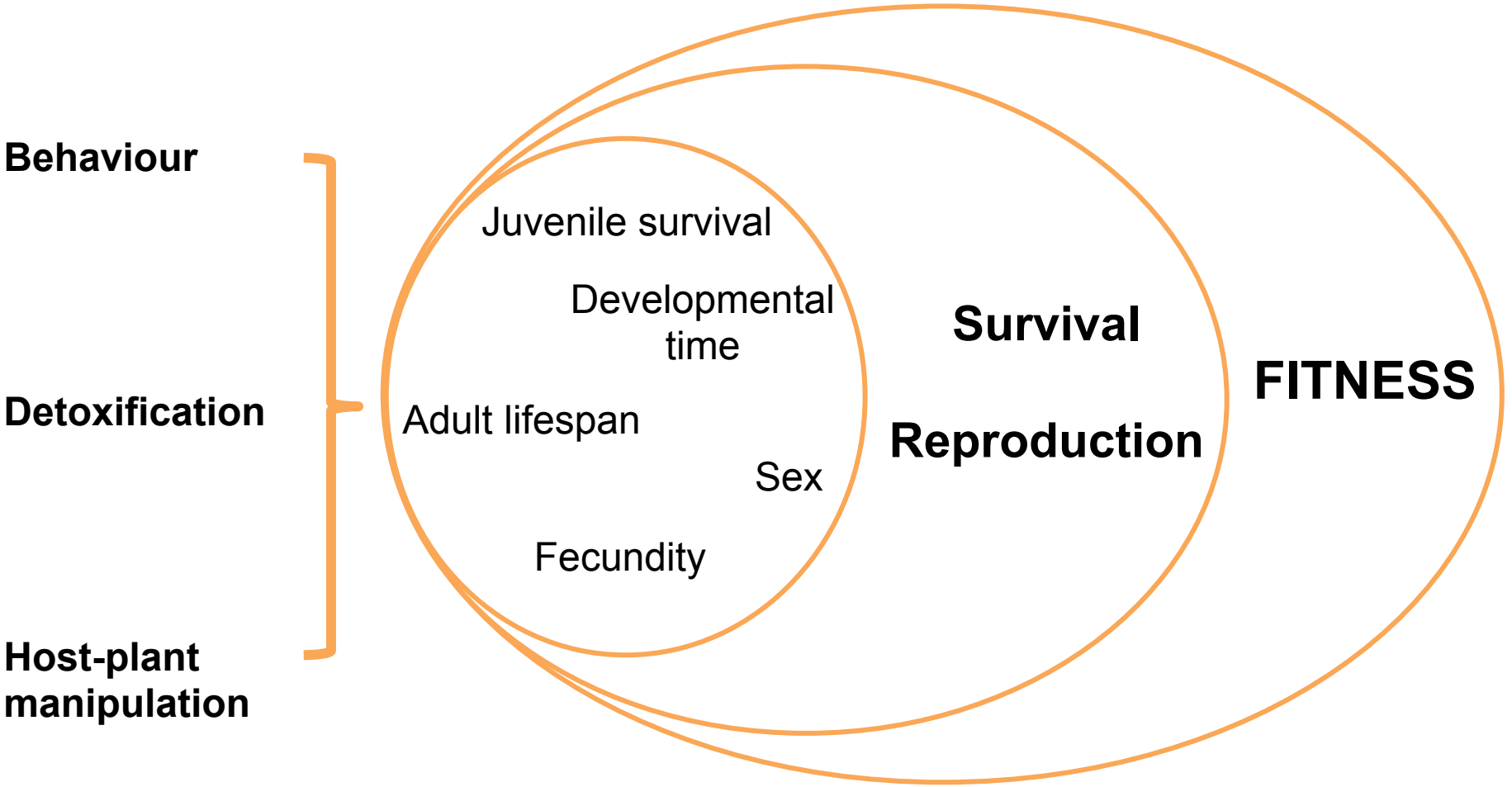


Late mortality evolves more slowly

General context

Underlying mechanisms of life-history trait evolution



General context

Main questions

To what extent are maternal effects involved in host plant exploitation after a shift?

Which life-history traits evolve after a host change?

Does it depend on the time spent on the novel host?

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To what extent are maternal effects involved in host-plant exploitation after a shift?

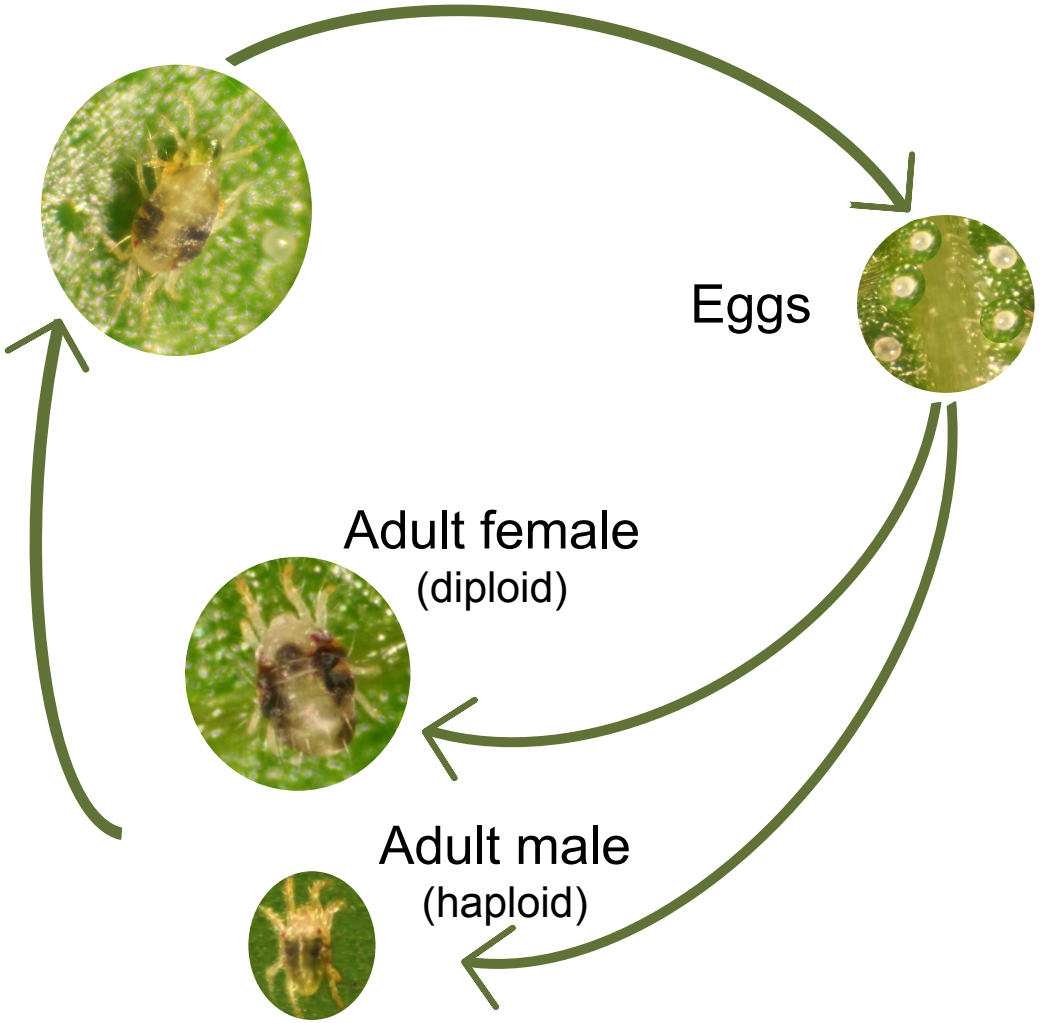
Which life-history traits evolve after a host change?

Does it depend on the time spent on the novel host?

Is evolution in response to a host shift mediated by the ability to manipulate host-plant defences?

General context

Biological model, *Tetranychus urticae* a polyphagous crop pest



- Short life cycle
  (~15 days ± 25°C)
- Haplodiploid species
- On more than 1100
  plant species
  (Grbic *et al.*, 2011)

1. Adaptation following host-plant colonization

1. Adaptation after a host shift – **Previous studies**

- Phenotypic plasticity for some traits (as dispersal, in Bitume *et al.*, 2013, 2014)

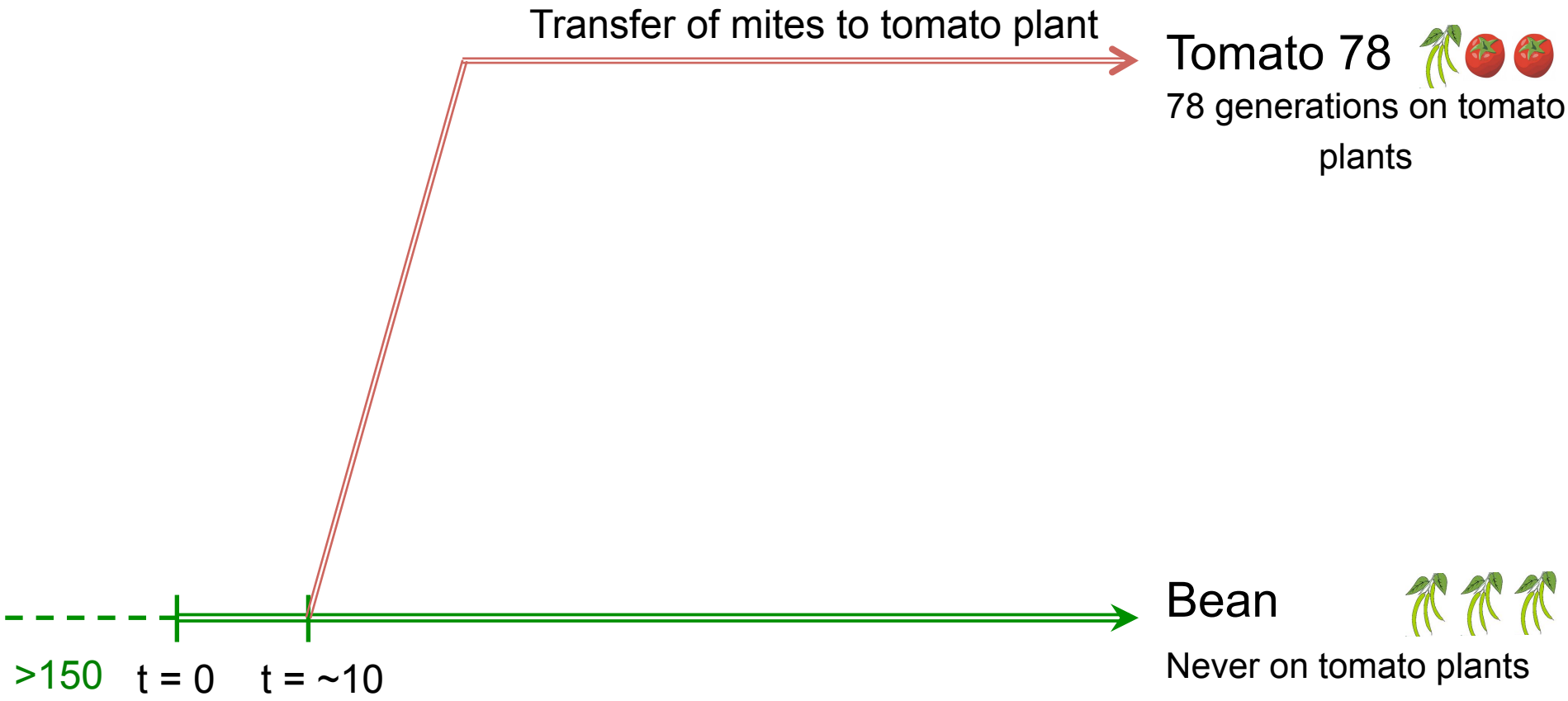
- Rapid adaptation to the host plant (Gould, 1979, Fry, 1990, Magalhães *et al*., 2007)

- But some populations can fail to adapt (Miyazaki *et al.*, 2015)

1. Adaptation after a host shift - **Mite populations**

Number of generations

1. Adaptation after a host shift - **Mite populations**



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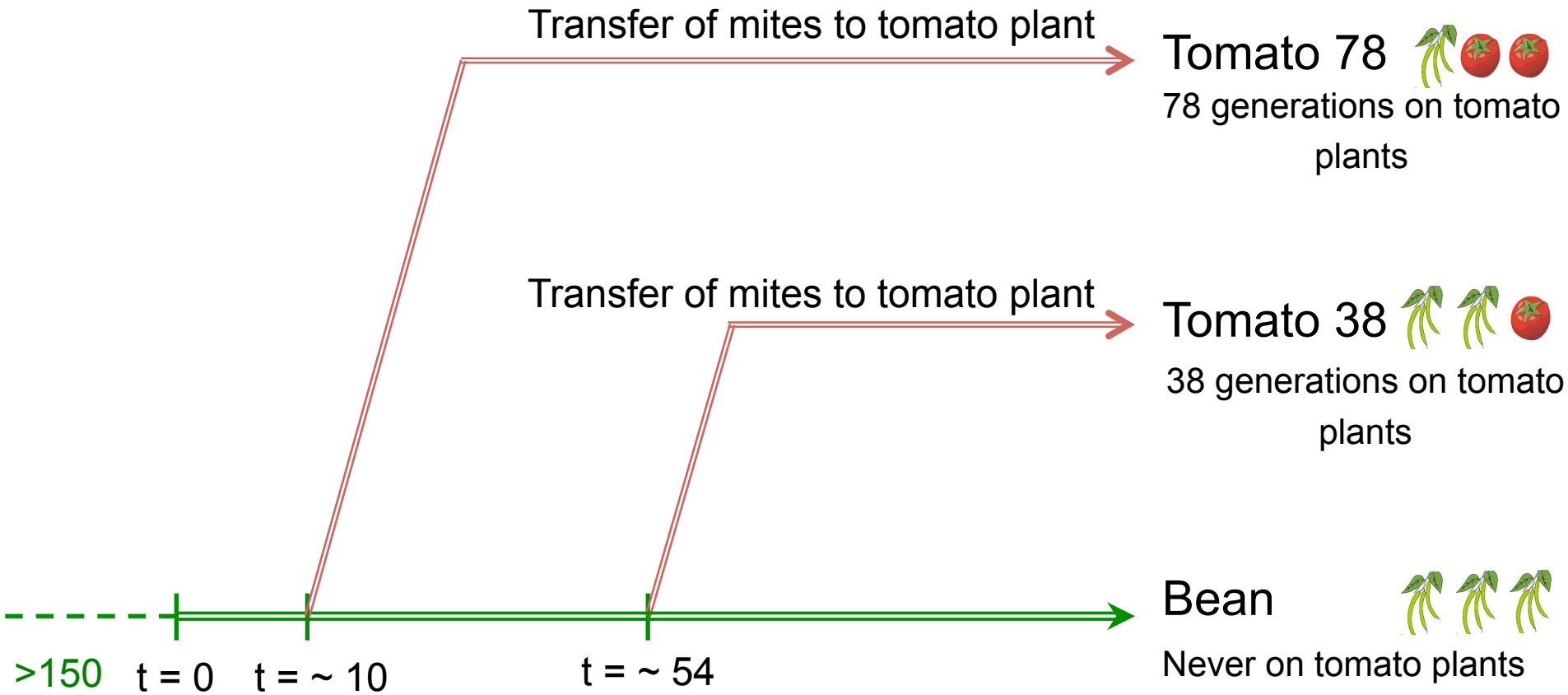
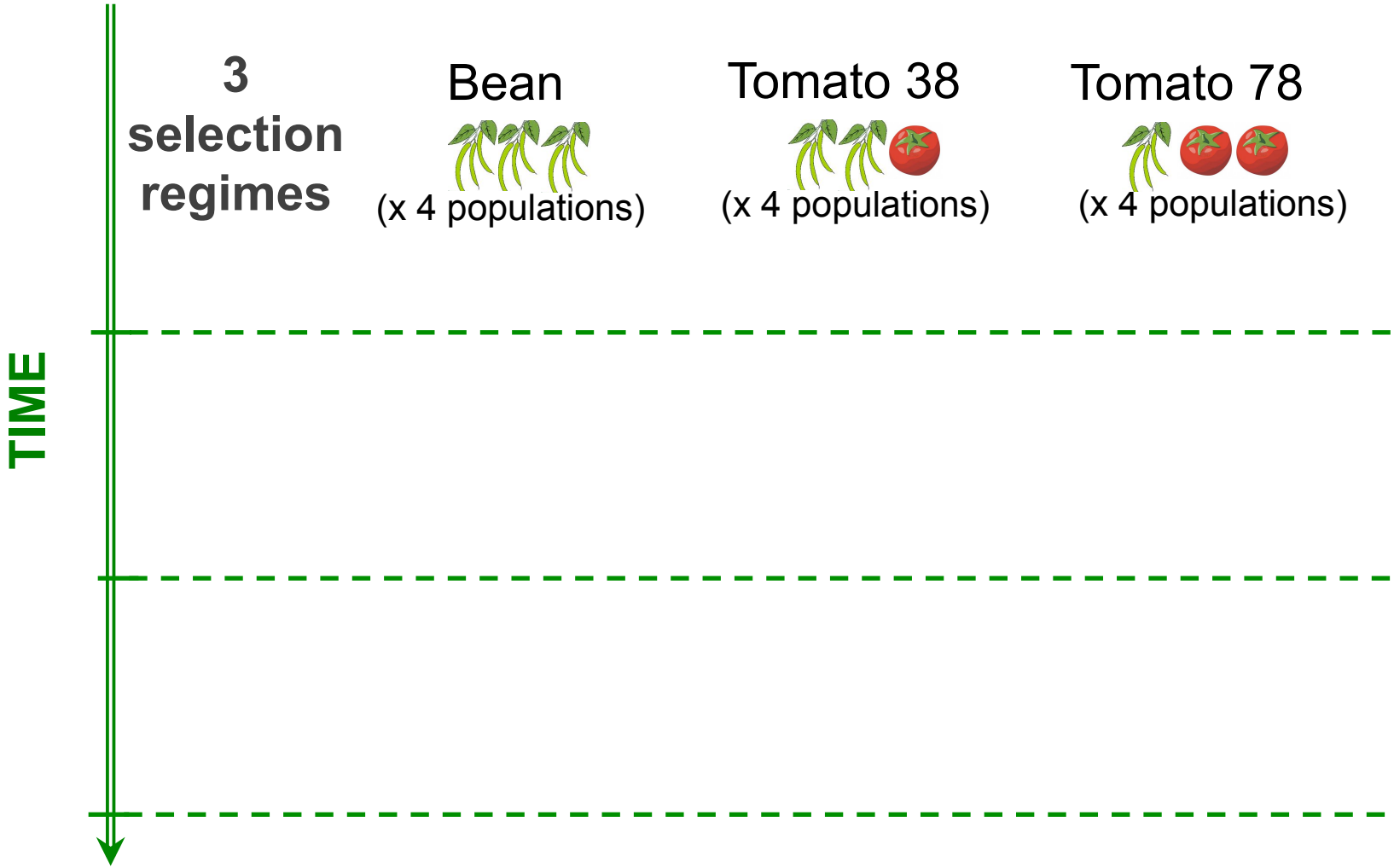


1. Adaptation after a host shift – **Experimental design**



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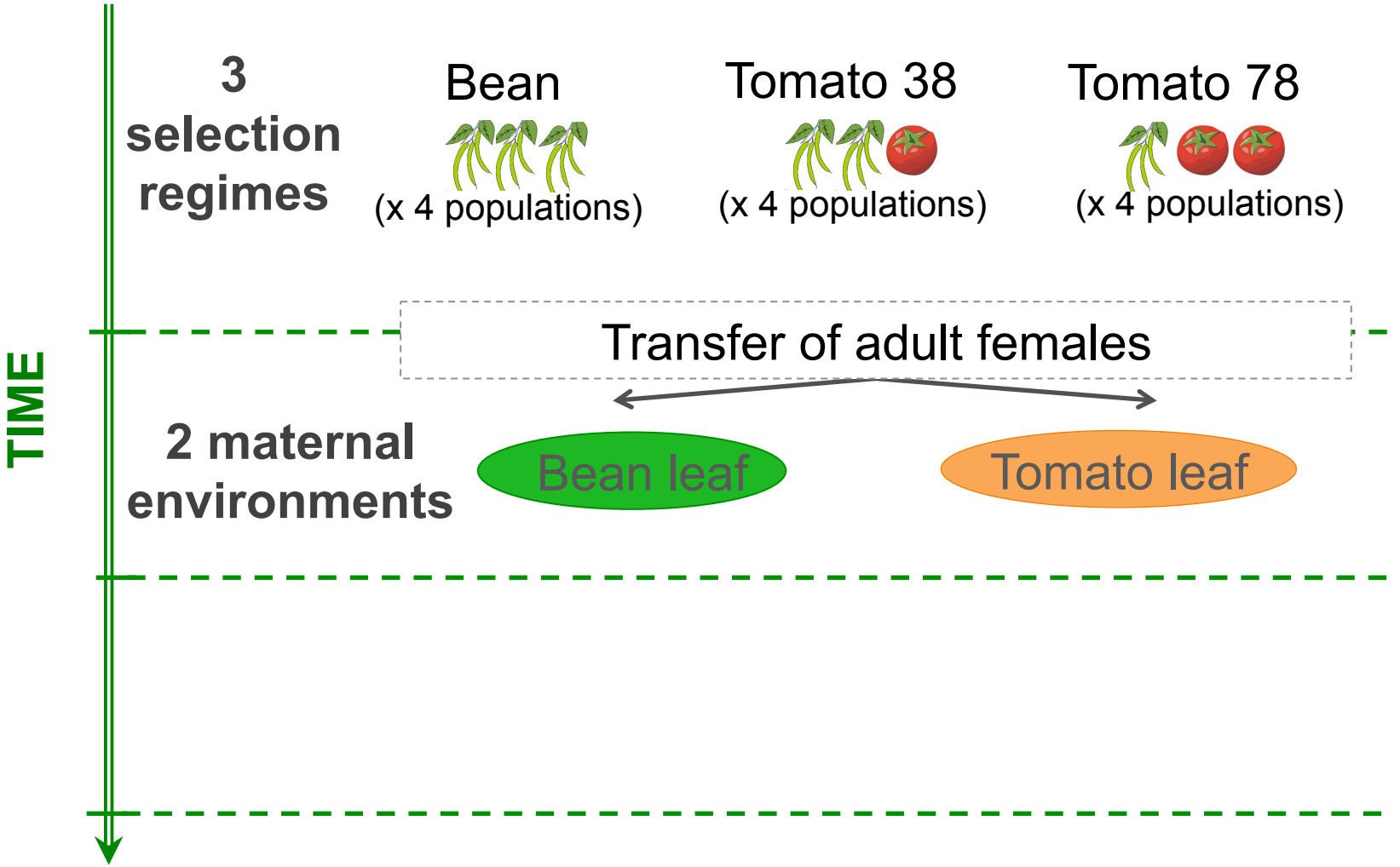

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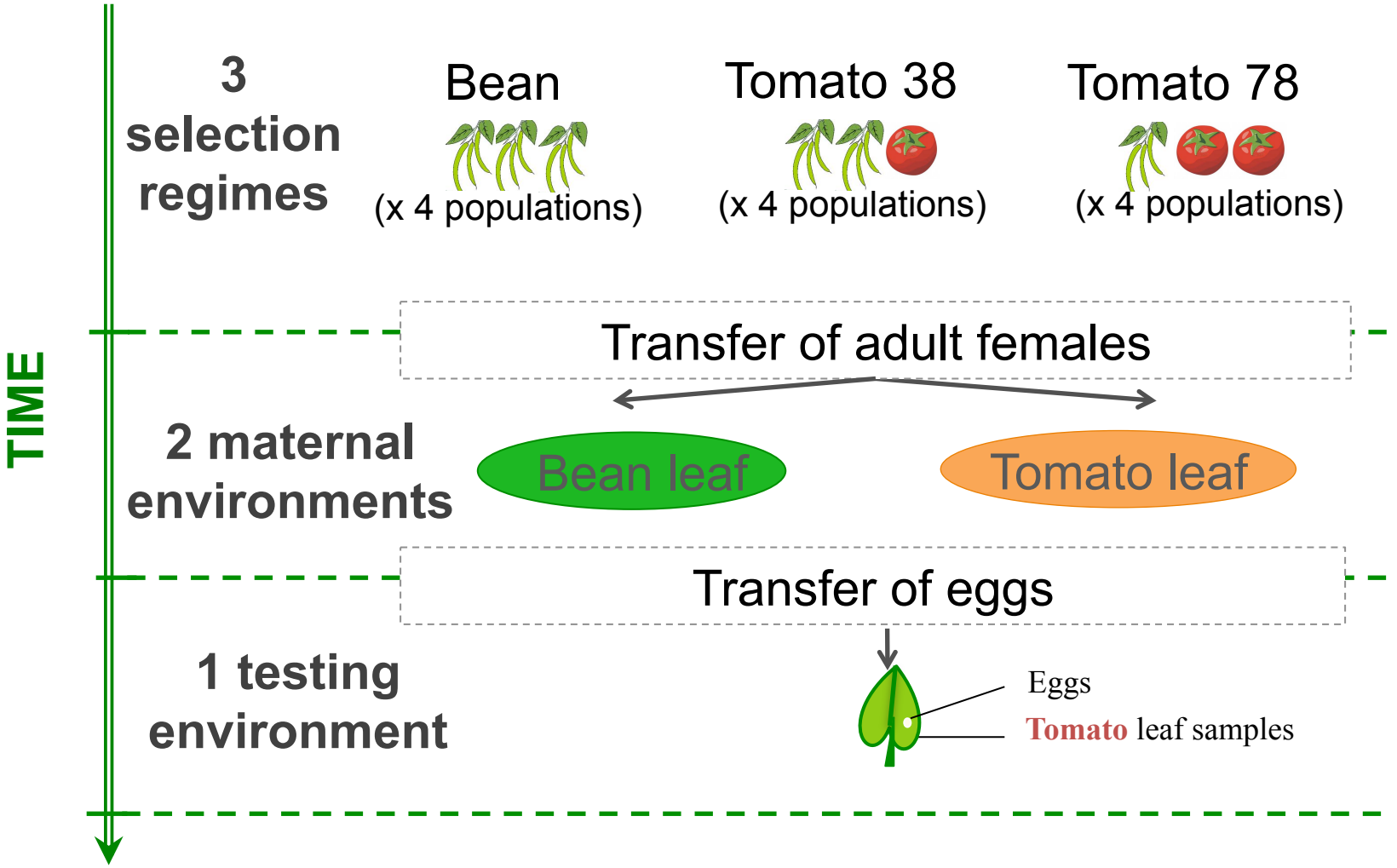


1. Adaptation after a host shift – **Experimental design**

TIME

3 selection regimes

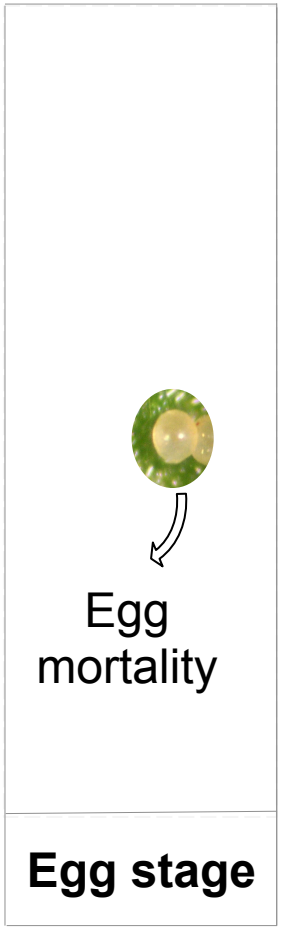
Bean (x 4 populations)

Tomato 38 (x 4 populations)

Tomato 78 (x 4 populations)

Measures of life history and behavioural traits

1. Adaptation after a host shift – **Individual monitoring**



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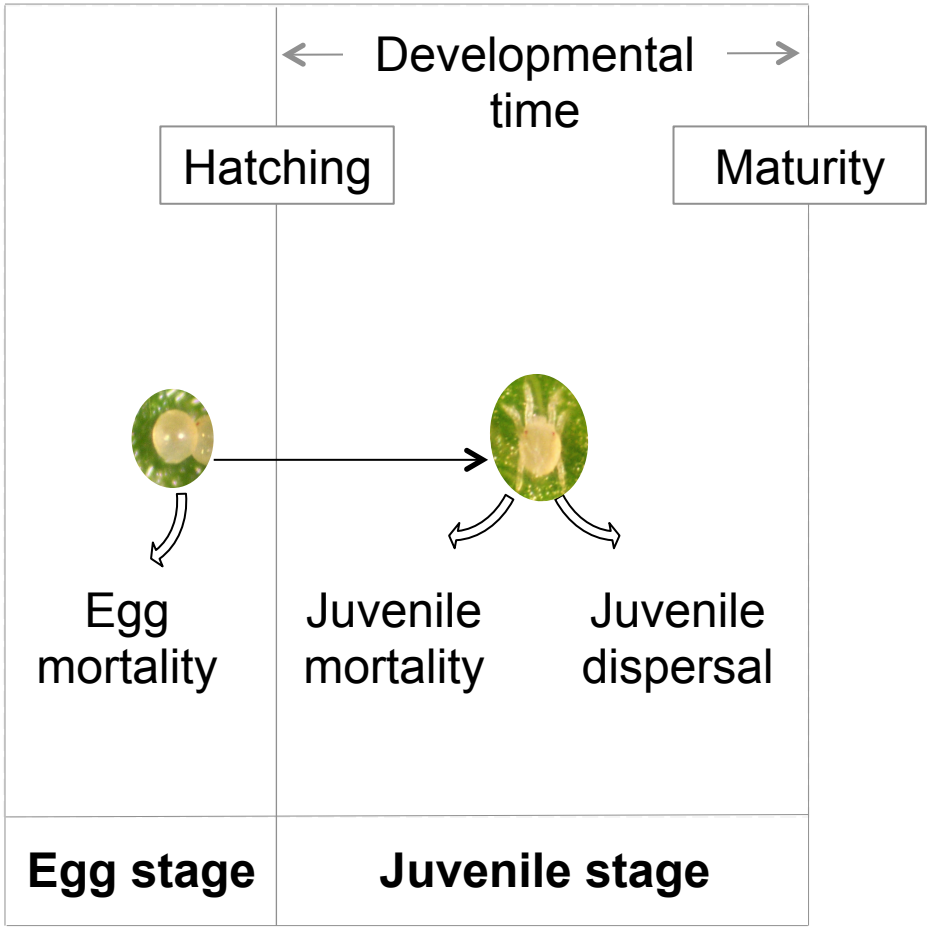

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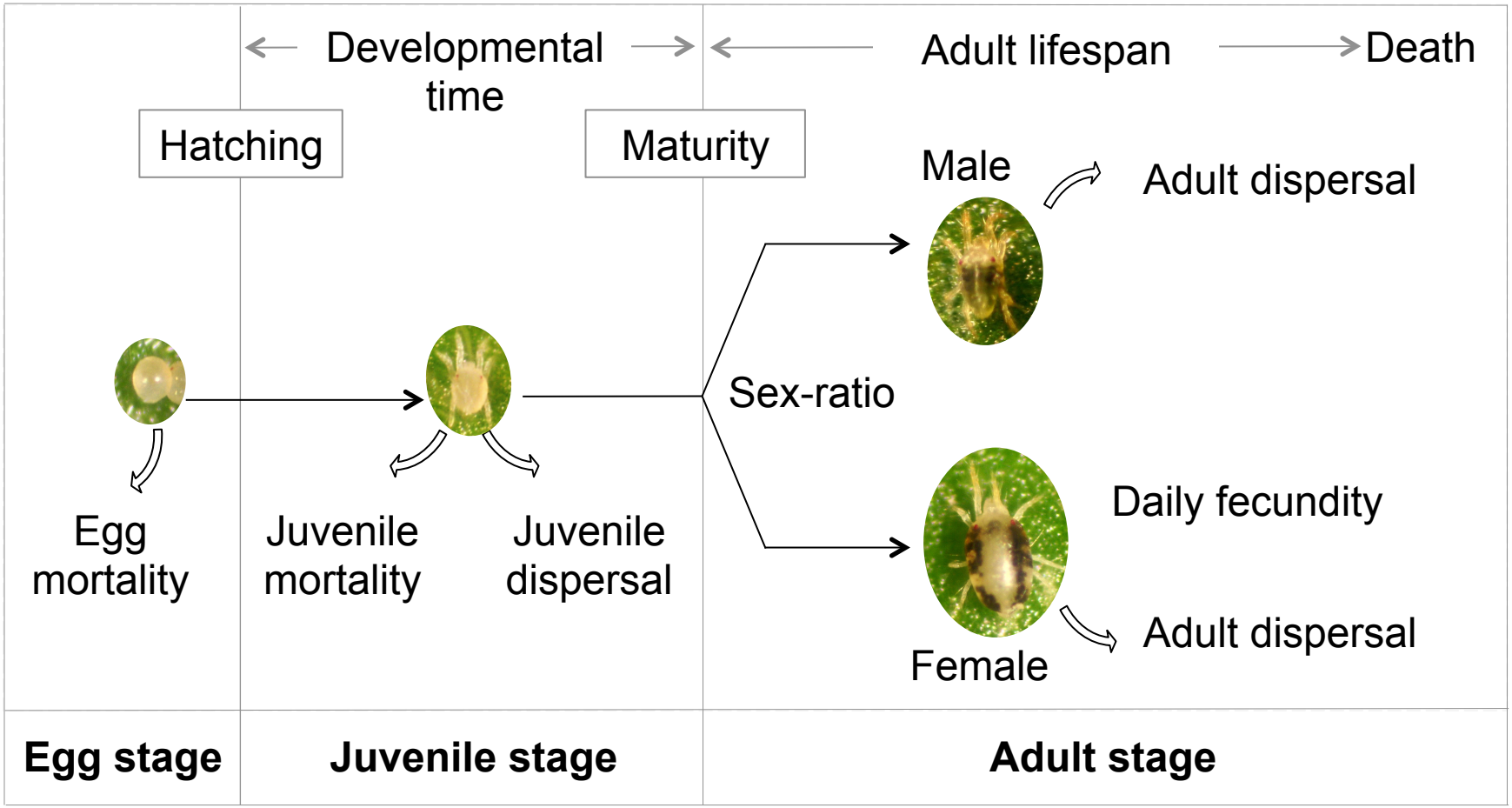

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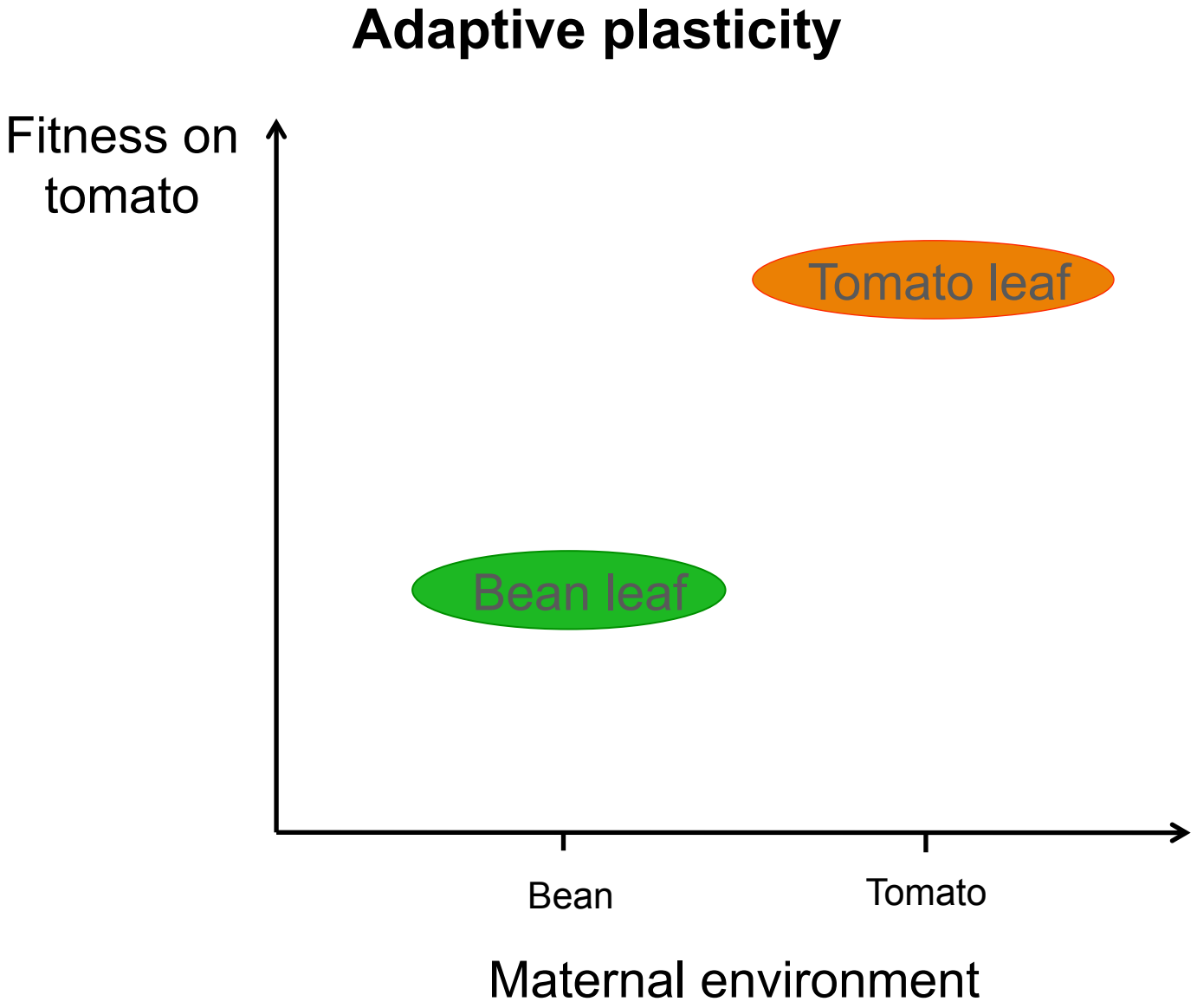

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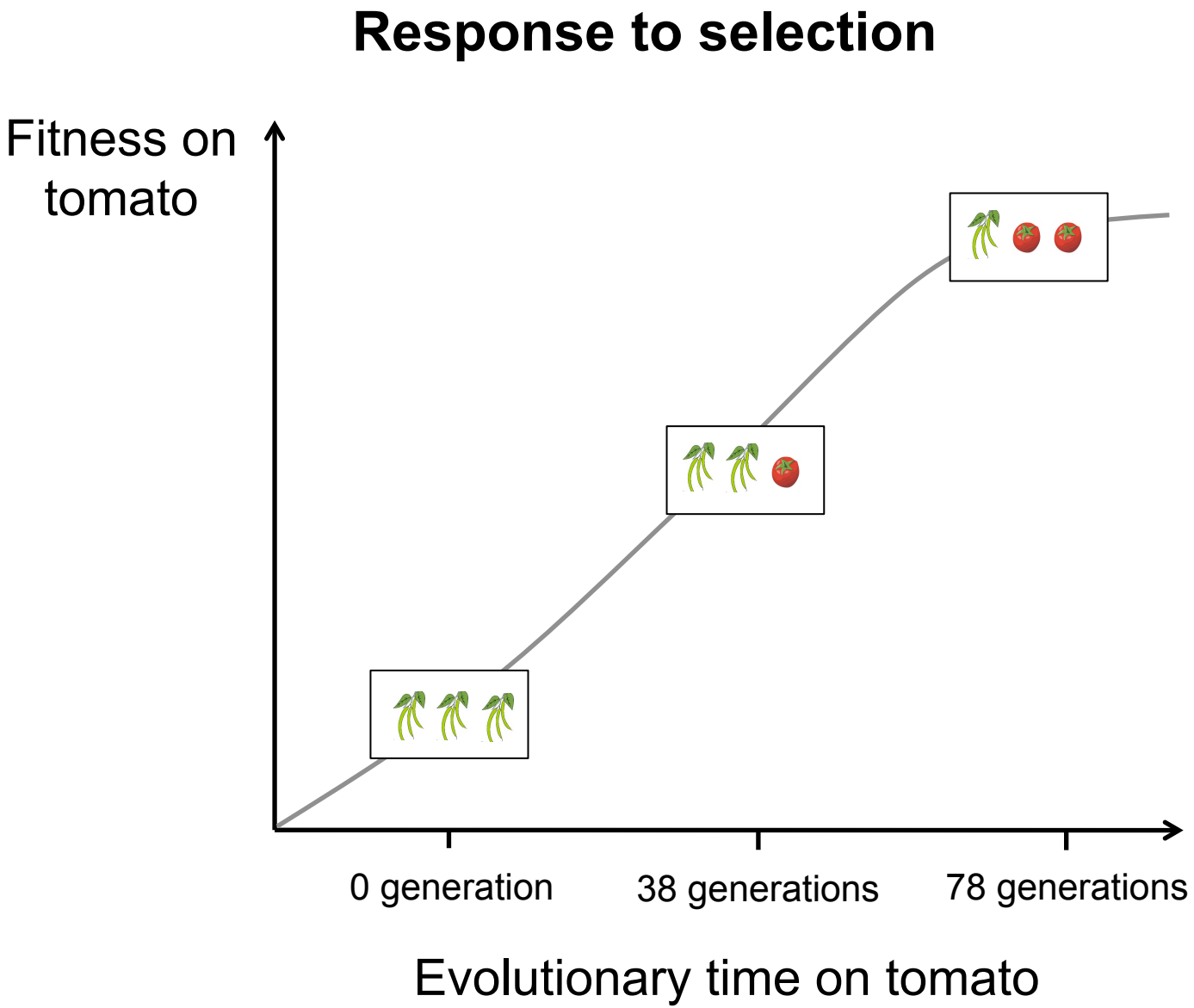
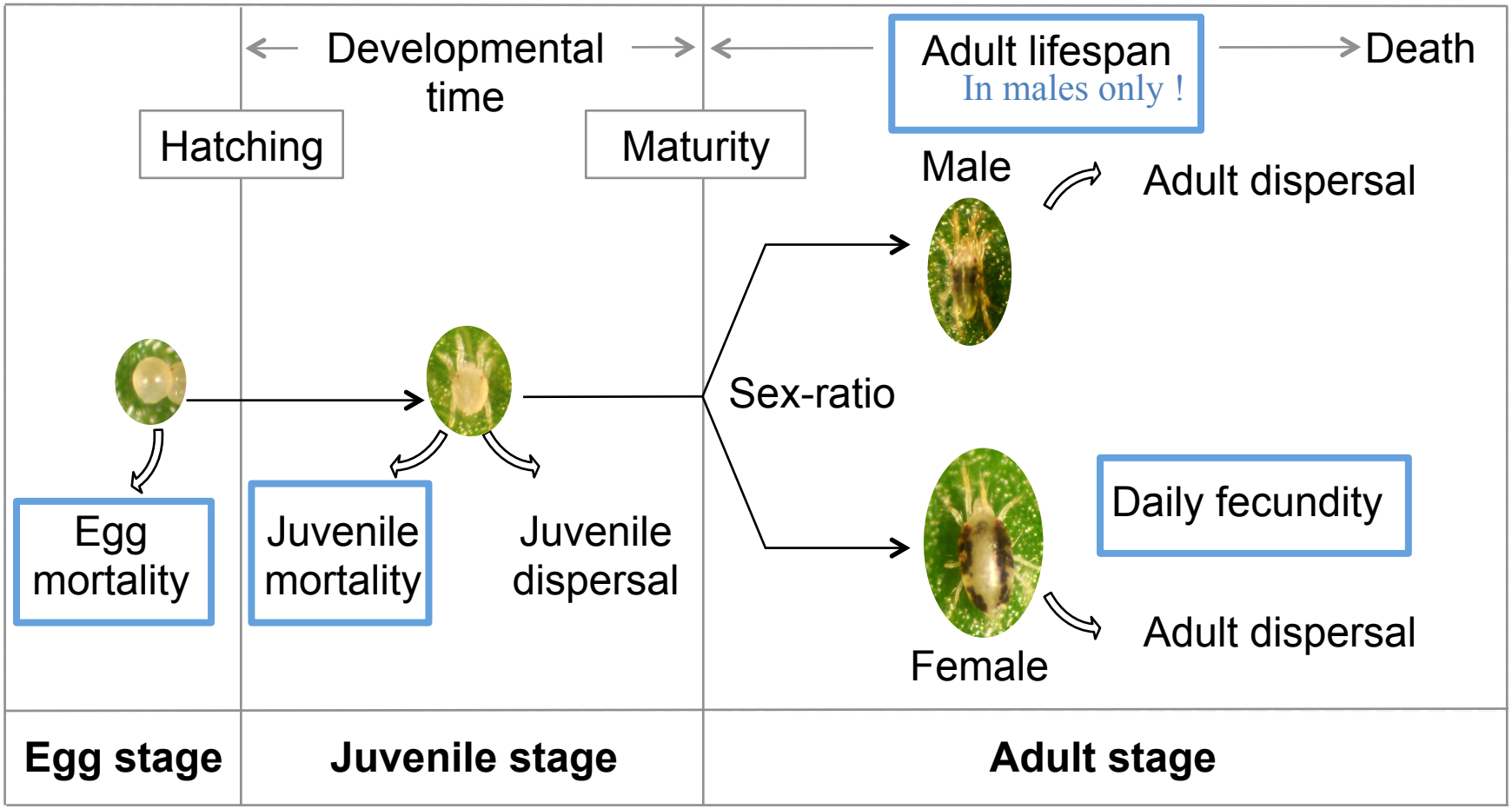
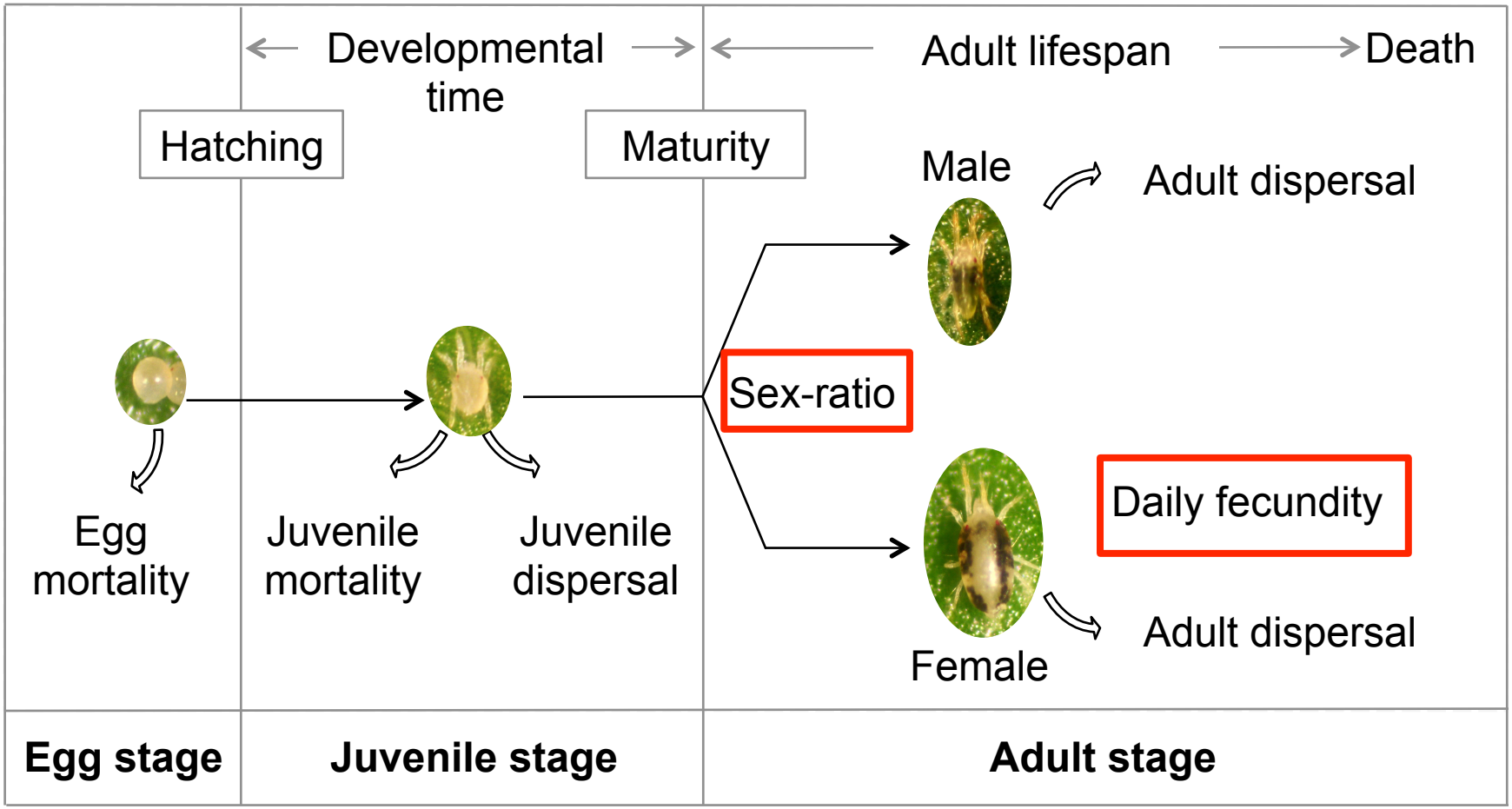


Which traits differed between selection regimes

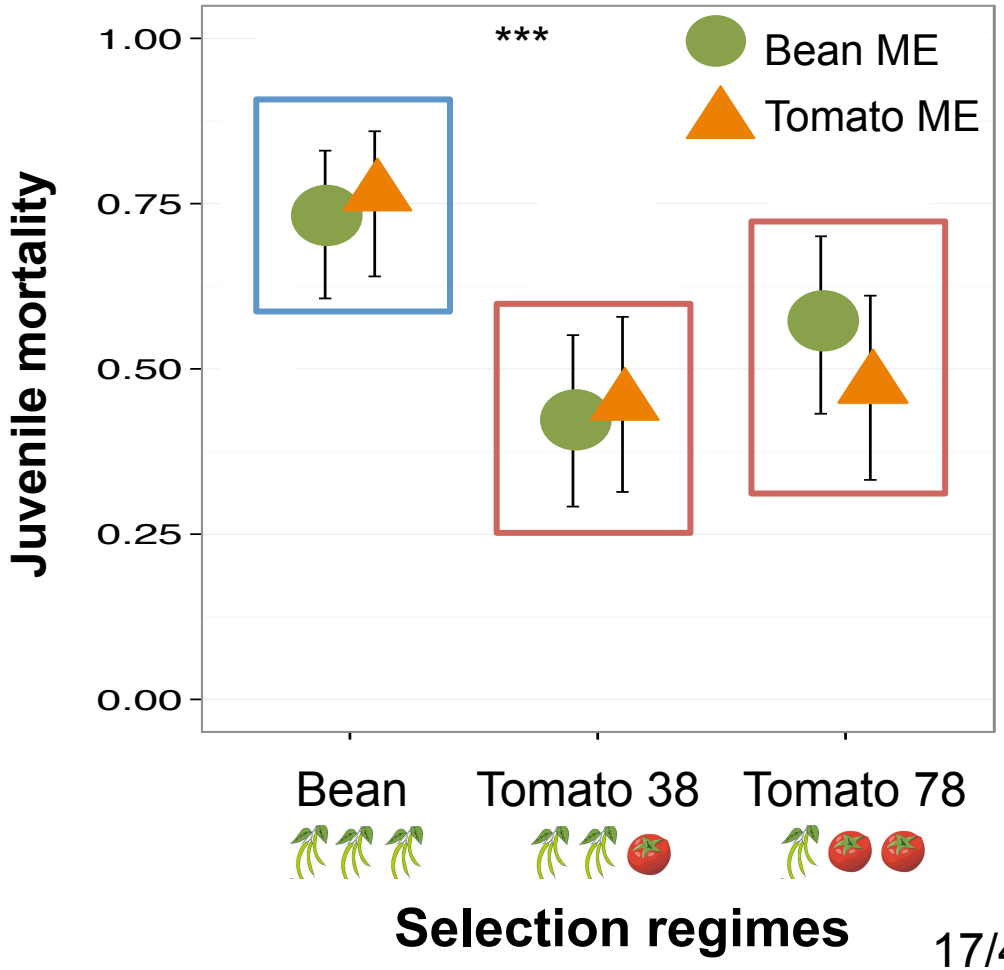


Which traits depend on maternal environment



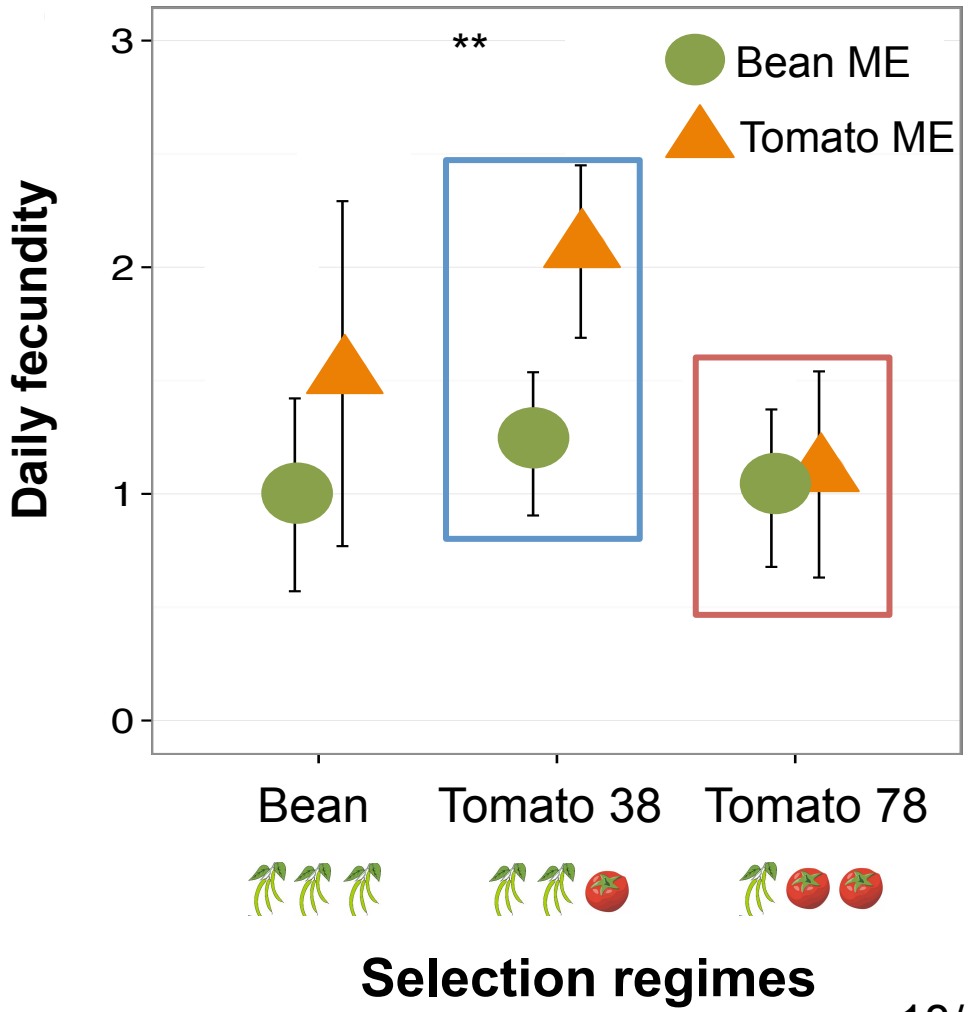
a) Juvenile mortality and selection regime

- Decrease of juvenile mortality for populations previously transferred on tomato



b) Daily fecundity and selection regime

- Higher daily fecundity in populations recently transferred to tomato plants than populations on this host for a longer time



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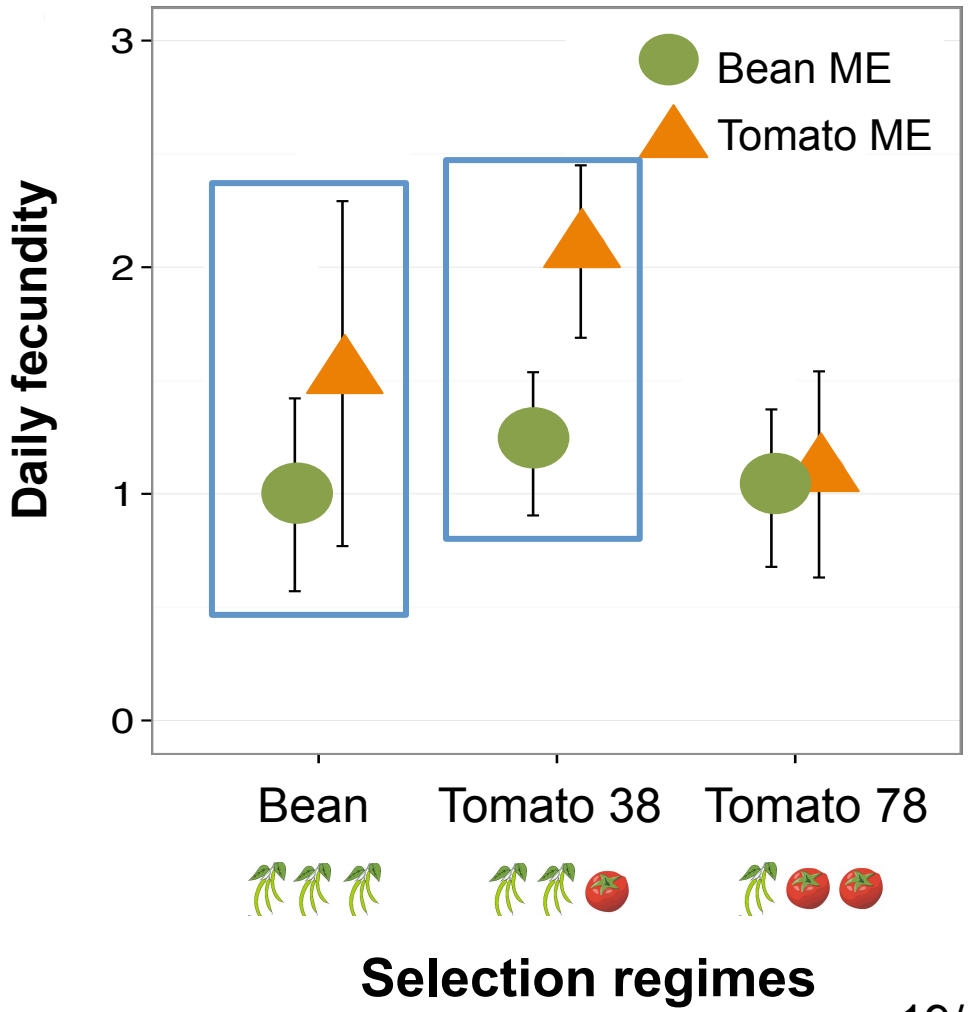
- No difference in fecundity



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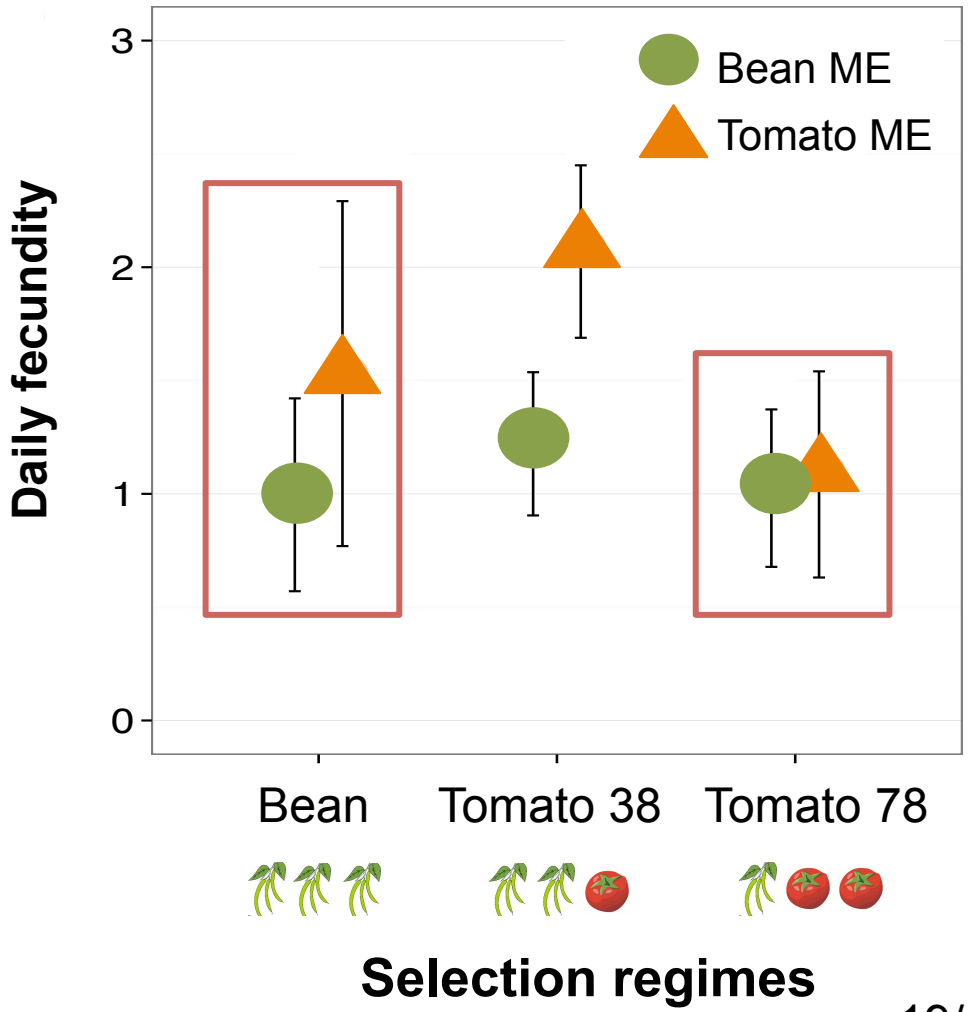
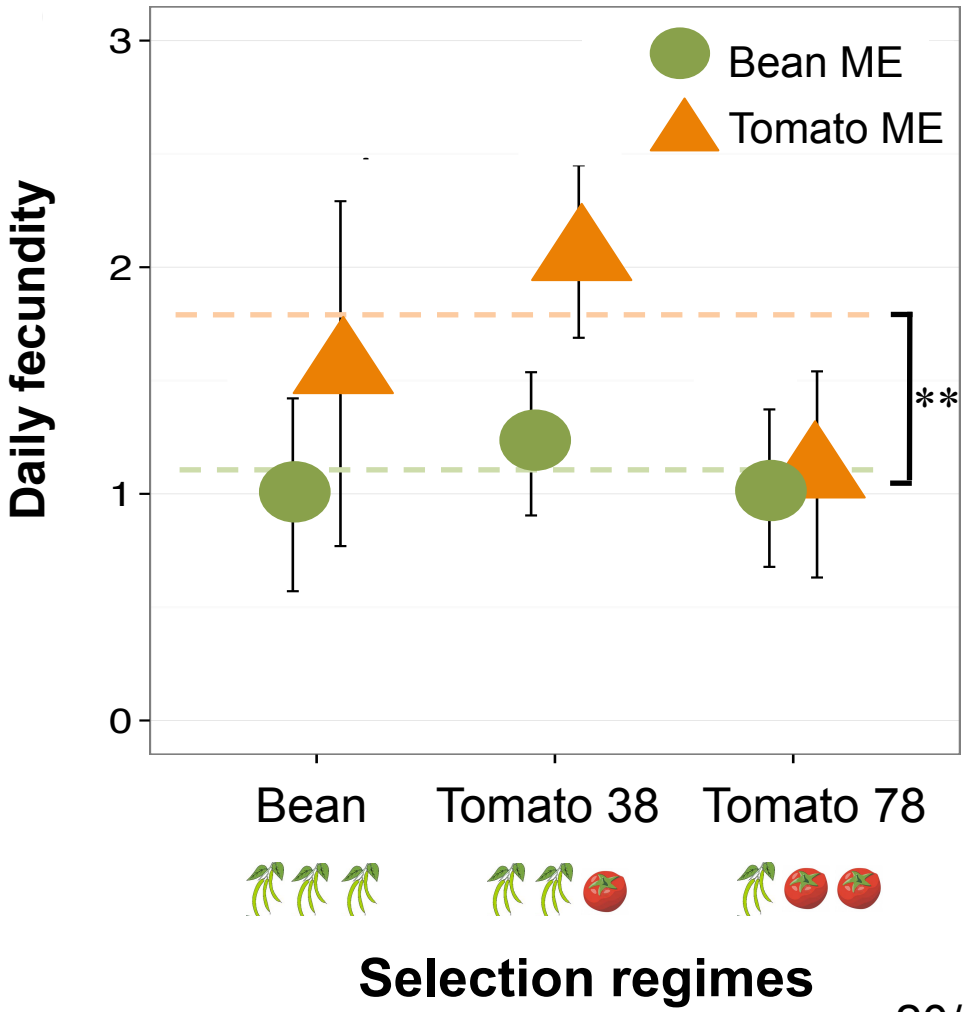


c) Daily fecundity and maternal effect

- Mothers grown on tomato produced adult daughters with a higher daily fecundity than mothers on bean



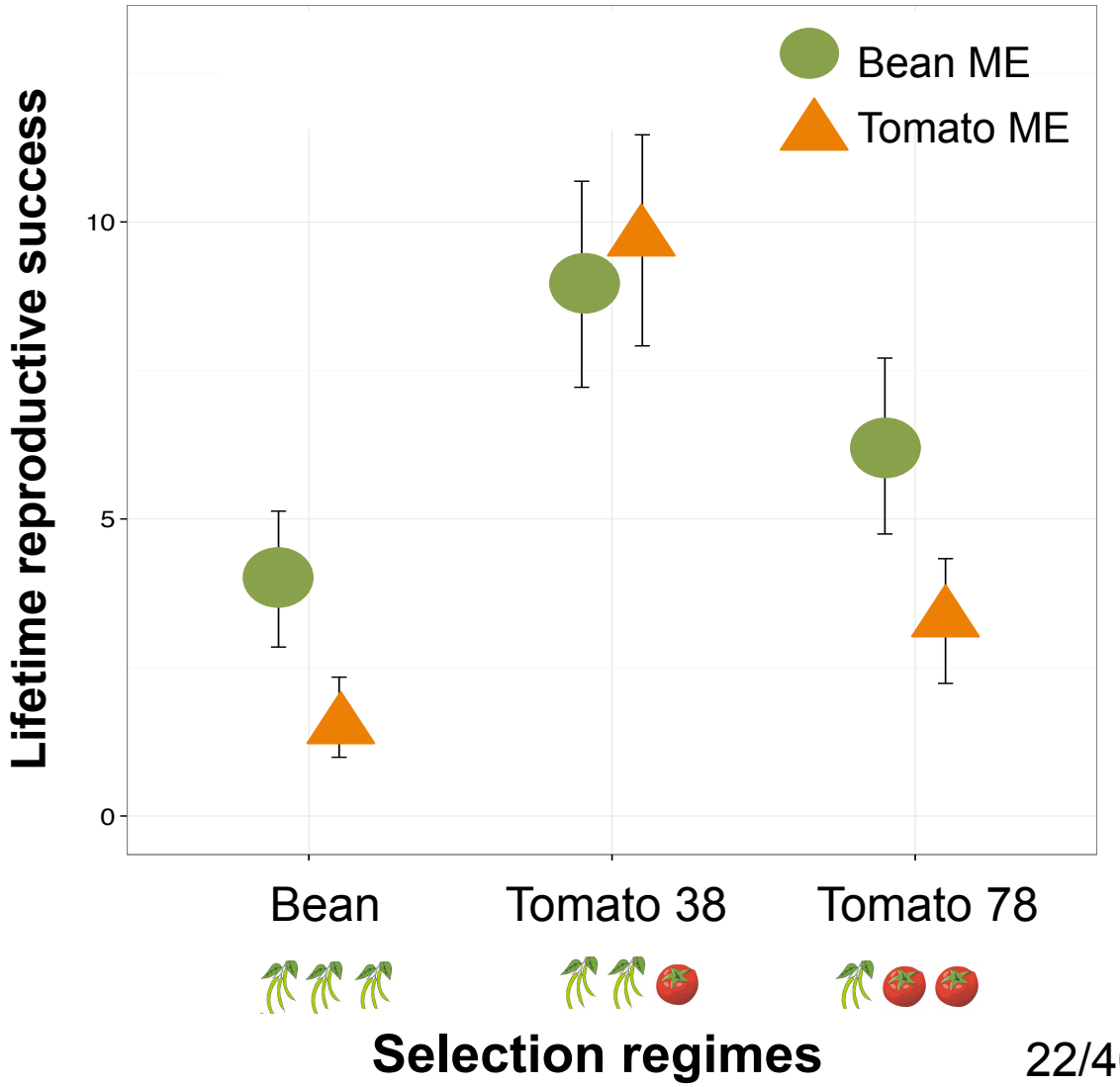
Individual life history traits

- When comparing with control populations (bean), populations previously transferred to the tomato host plant had:
  - a higher juvenile survival, but
  - no difference in daily fecundity

- Lower daily fecundity for populations transferred to tomato for the longest time

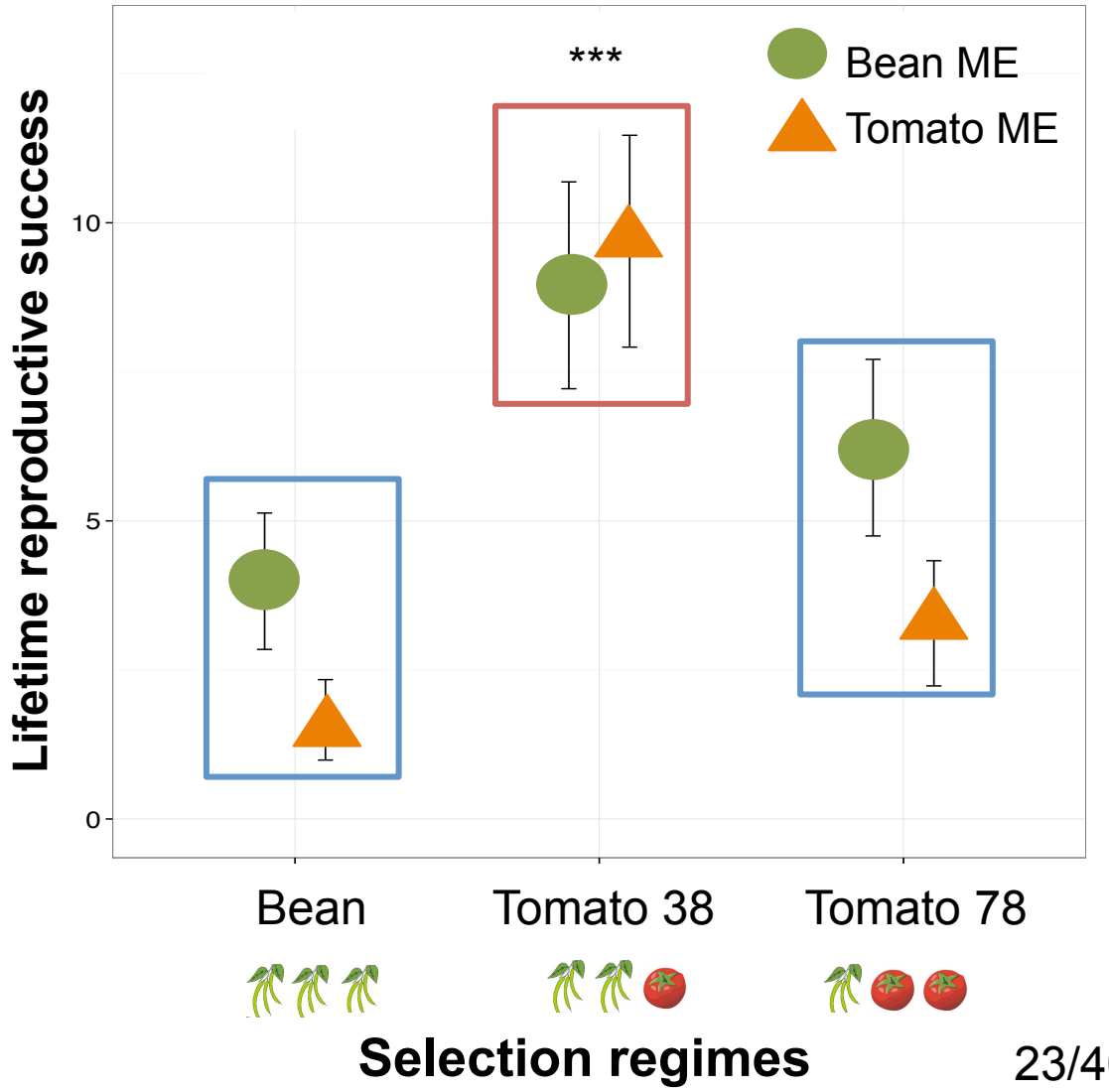
a) Lifetime reproductive success and maternal effect

- No effect



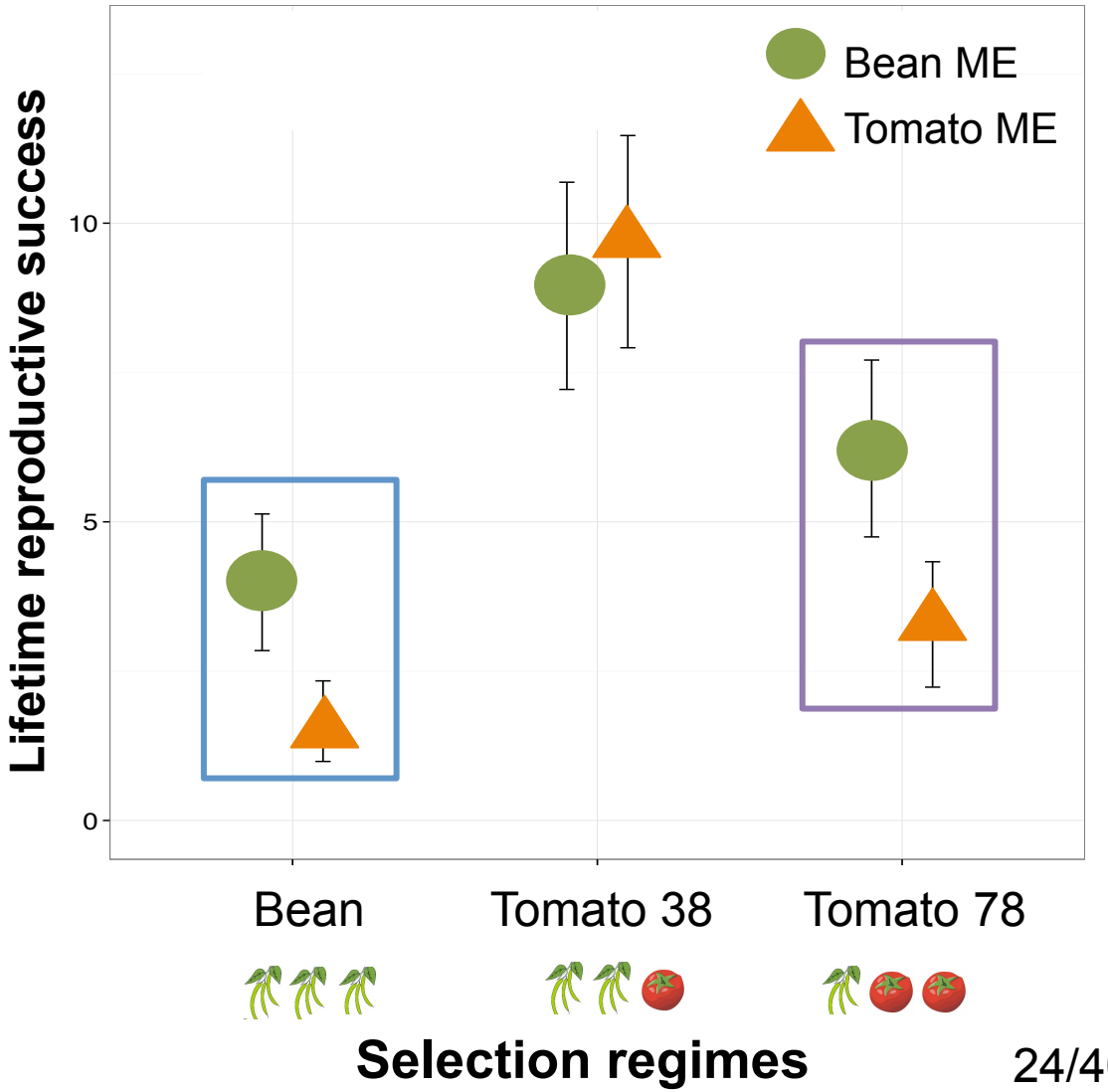
b) Lifetime reproductive success and selection regime

- Increase of LRS for populations recently transferred on tomato

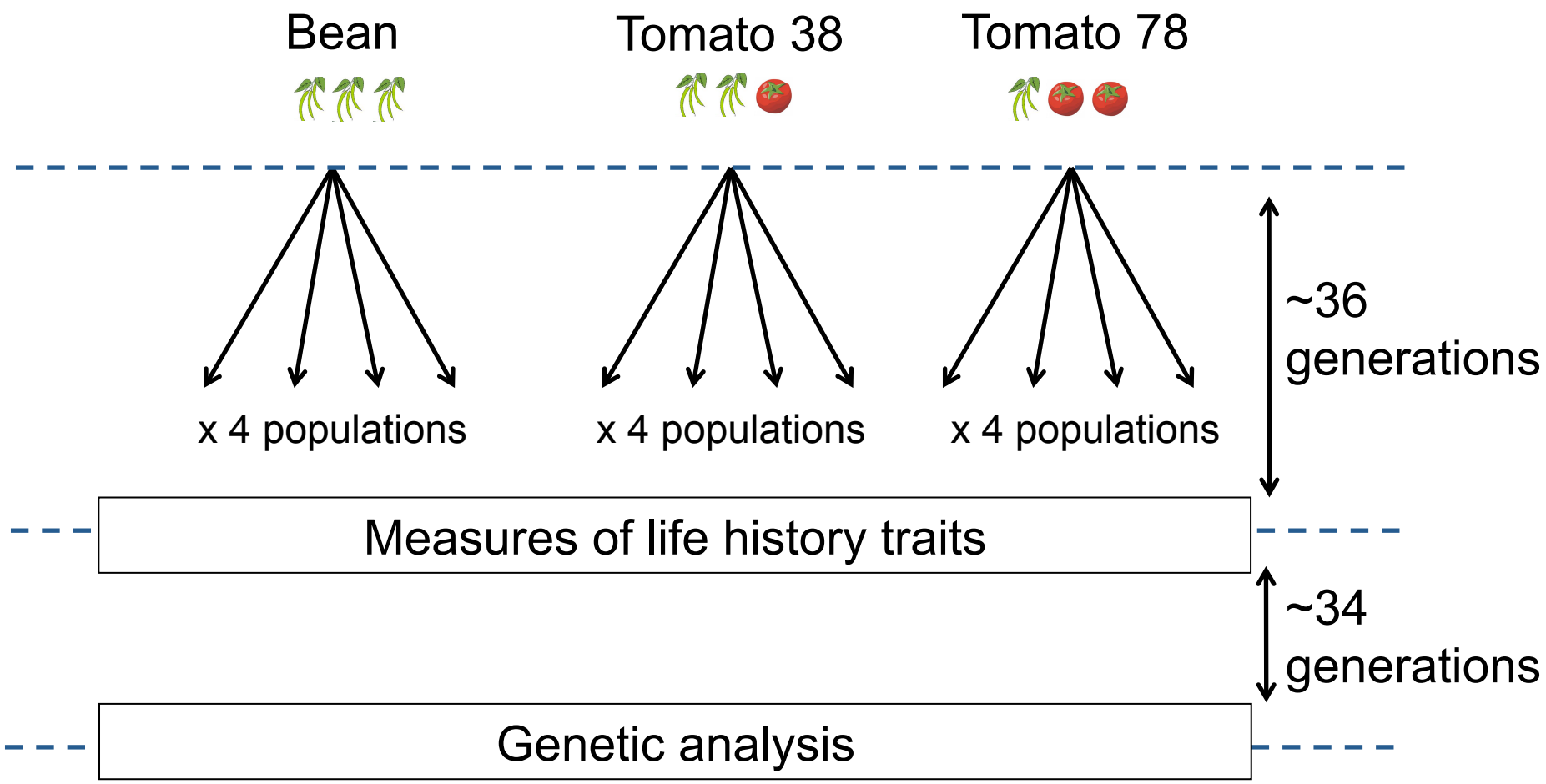


b) Lifetime reproductive success and selection regime

- Increase of LRS for populations recently transferred on tomato
- LRS marginally different

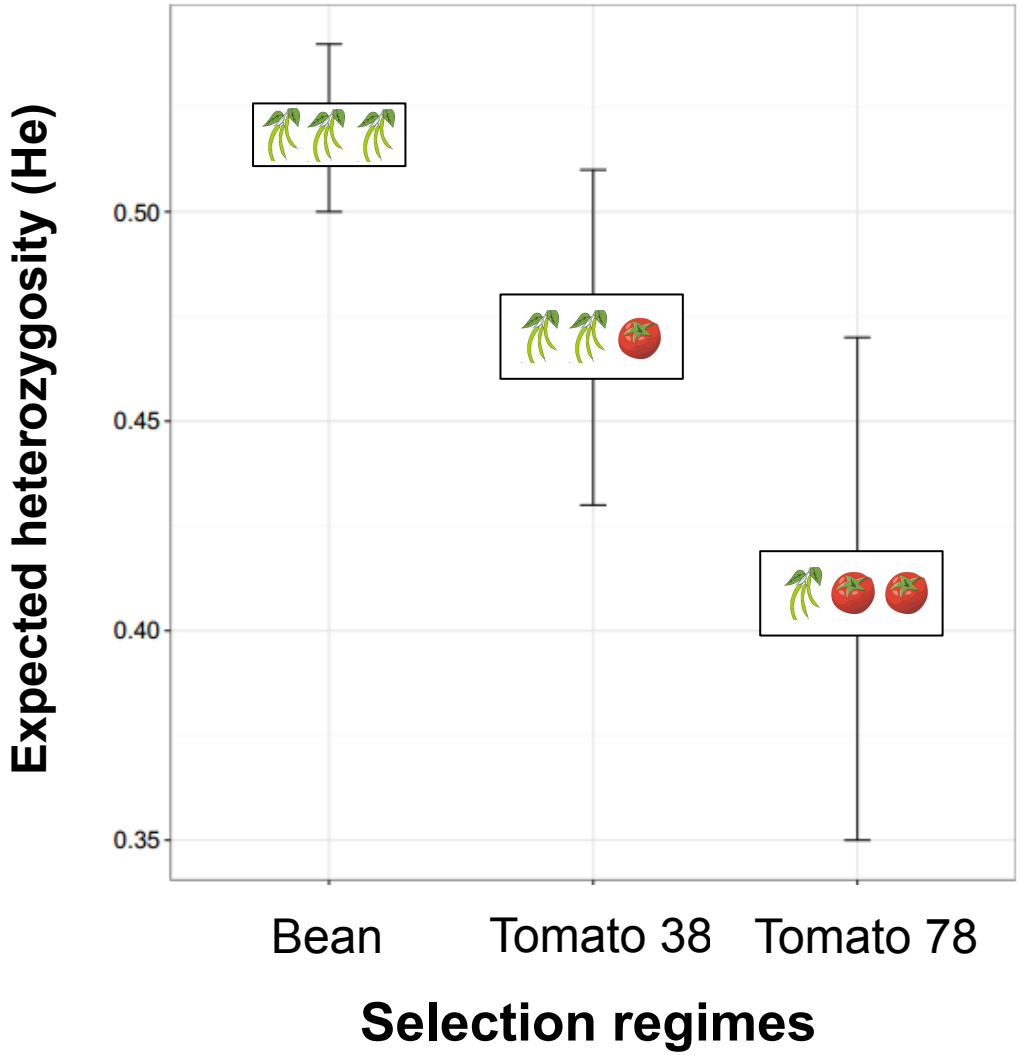


1. Adaptation after a host shift – **Genetic analysis**



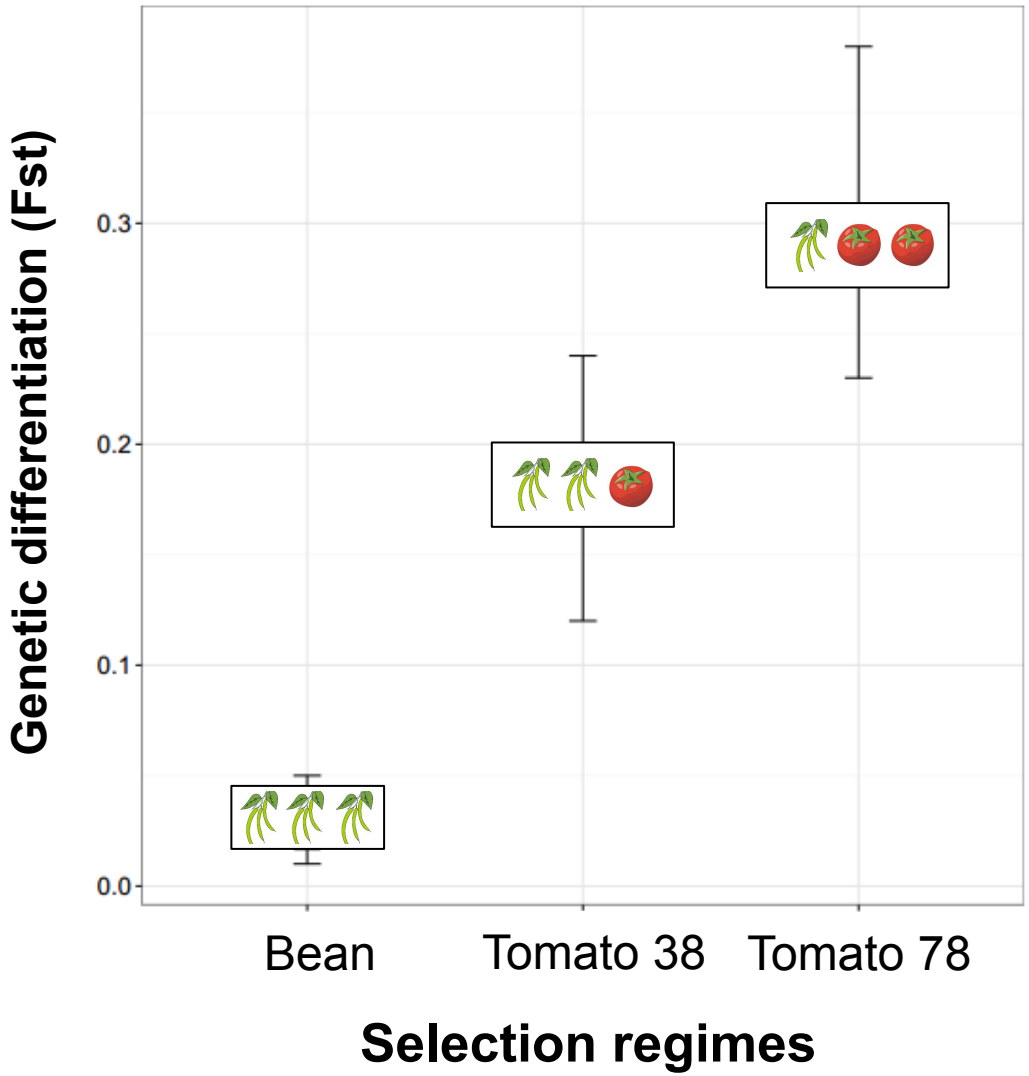
- 15 microsatellite markers / 24 individuals collected by population

a) Expected heterozygosity



- Genetic diversity decreases from bean to populations transferred to tomato for the longest time

b) Genetic differentiation



- Increase in genetic differentiation within selection regime from bean to tomato 78

1. Adaptation after a host shift – **Main conclusions**

- Possibly populations evolved on tomato plants experienced bottlenecks and evolved by genetic drift

- Extinction of populations evolved on tomato plants for the longest time

2. Effects of host-plant pre-infestation on herbivore performance

Is evolution in response to a host shift mediated by the ability to manipulate host-plant defences?

2. A mechanism allowing adaptation? **Previous studies**

Induction →

(Kant *et al.*, 2008)

Tomato plants

No induction →

2. A mechanism allowing adaptation? **Previous studies**

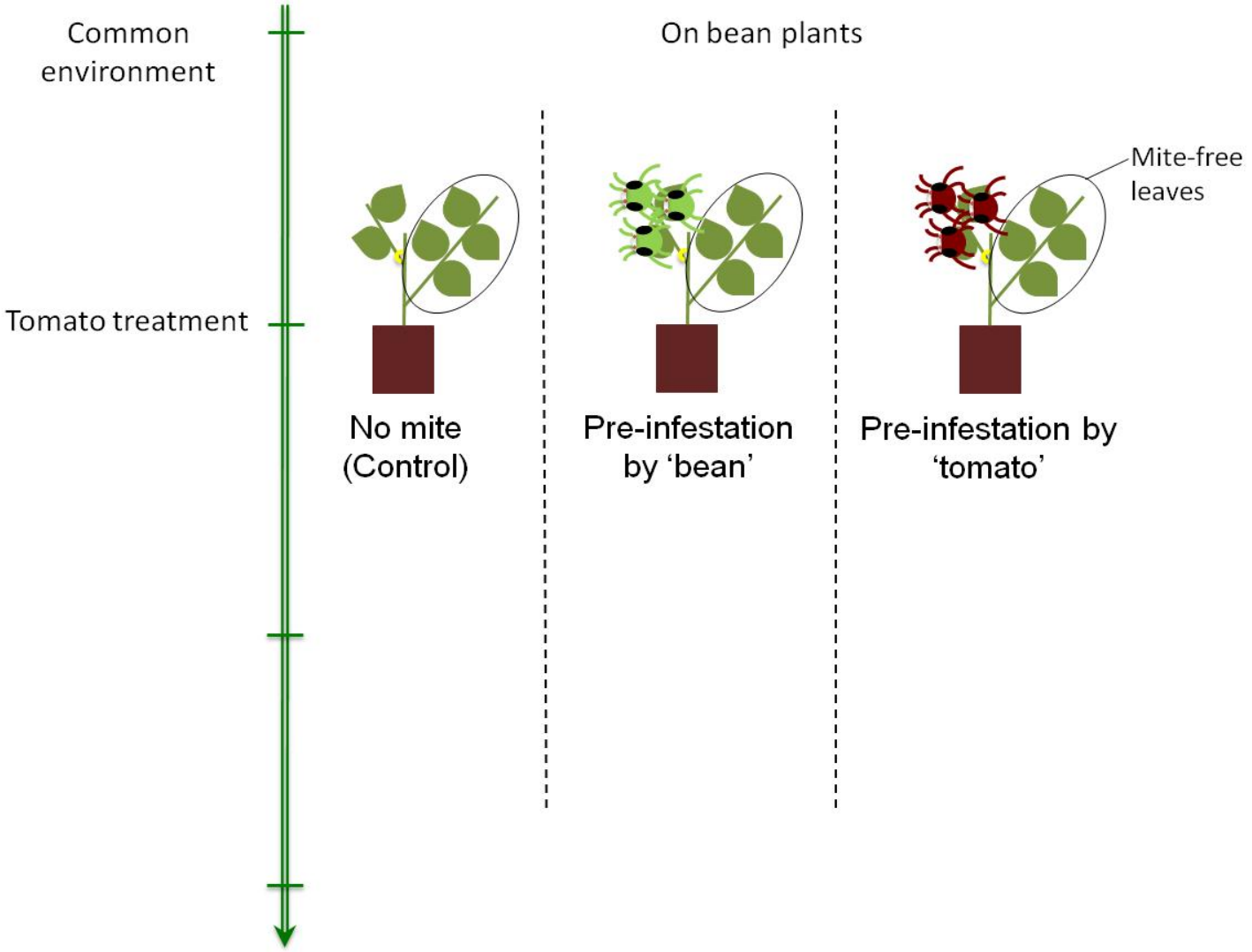
- Strains that are susceptible or resistant to induced defences (Kant *et al*., 2008)

- Populations adapted to tomato modify gene expressions involved in plant defences (Wybouw *et al*., 2015)

↓

But no link between adaptation to tomato and effect on mite performance after tomato pre-infestation

2. A mechanism allowing adaptation? **Experimental design**



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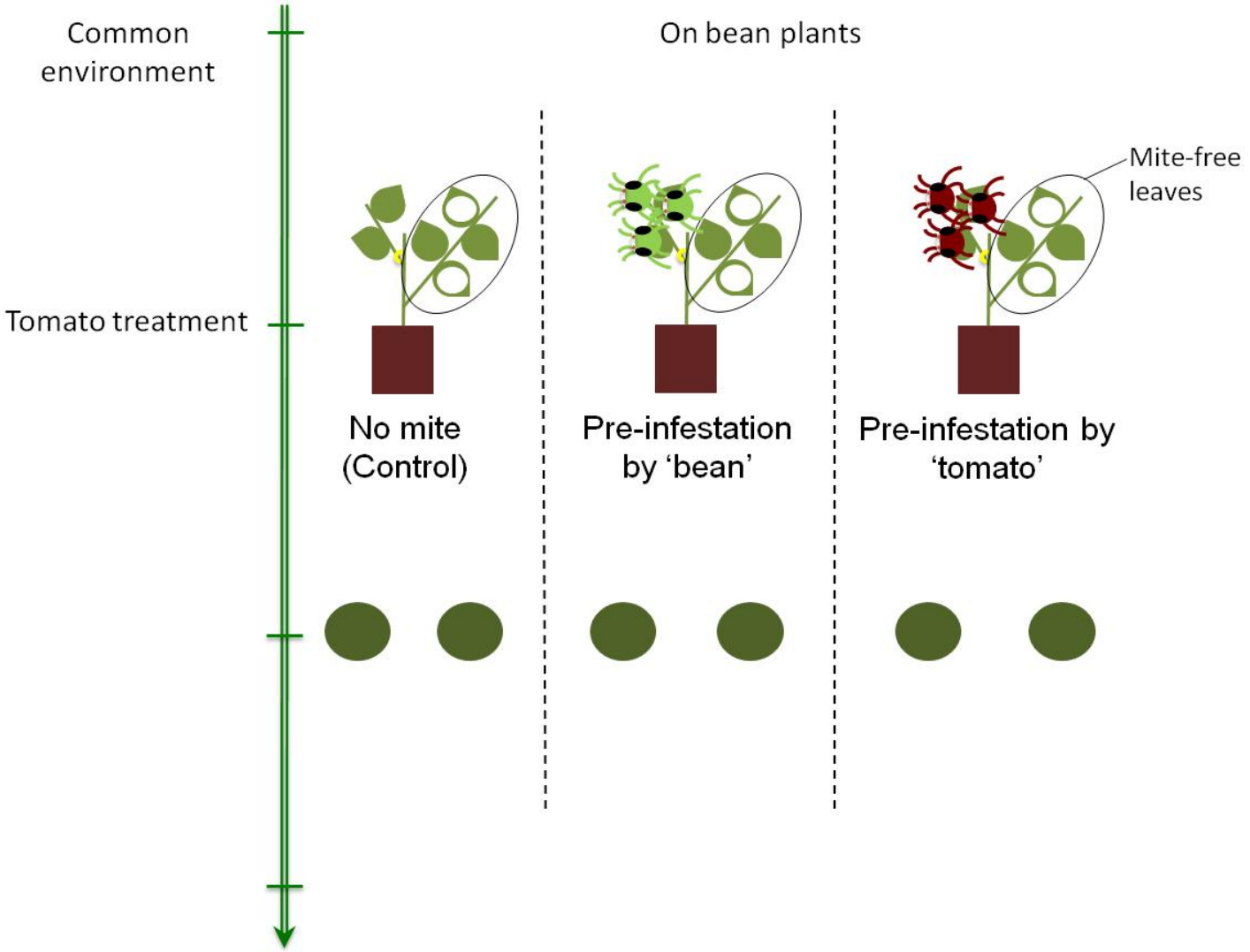

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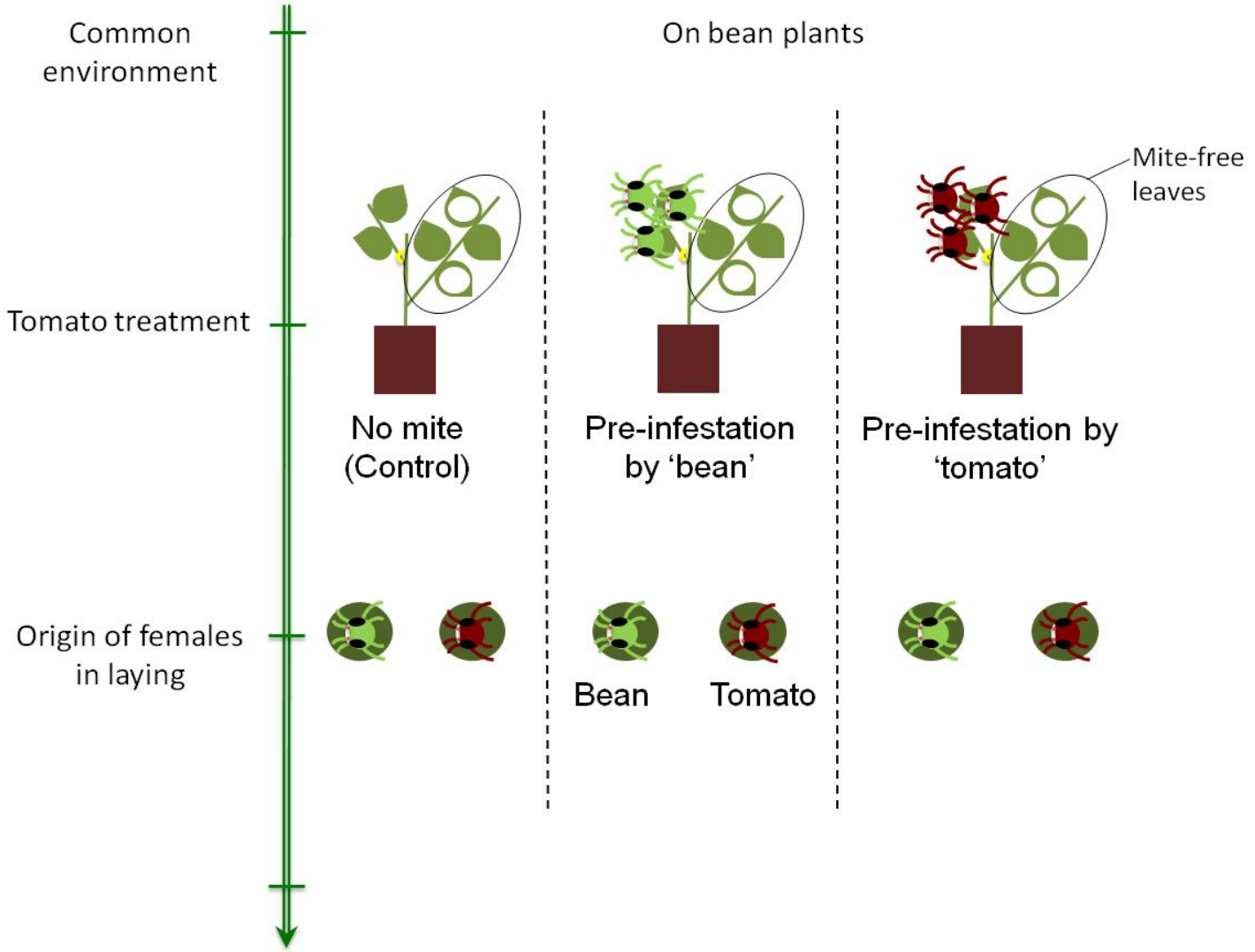

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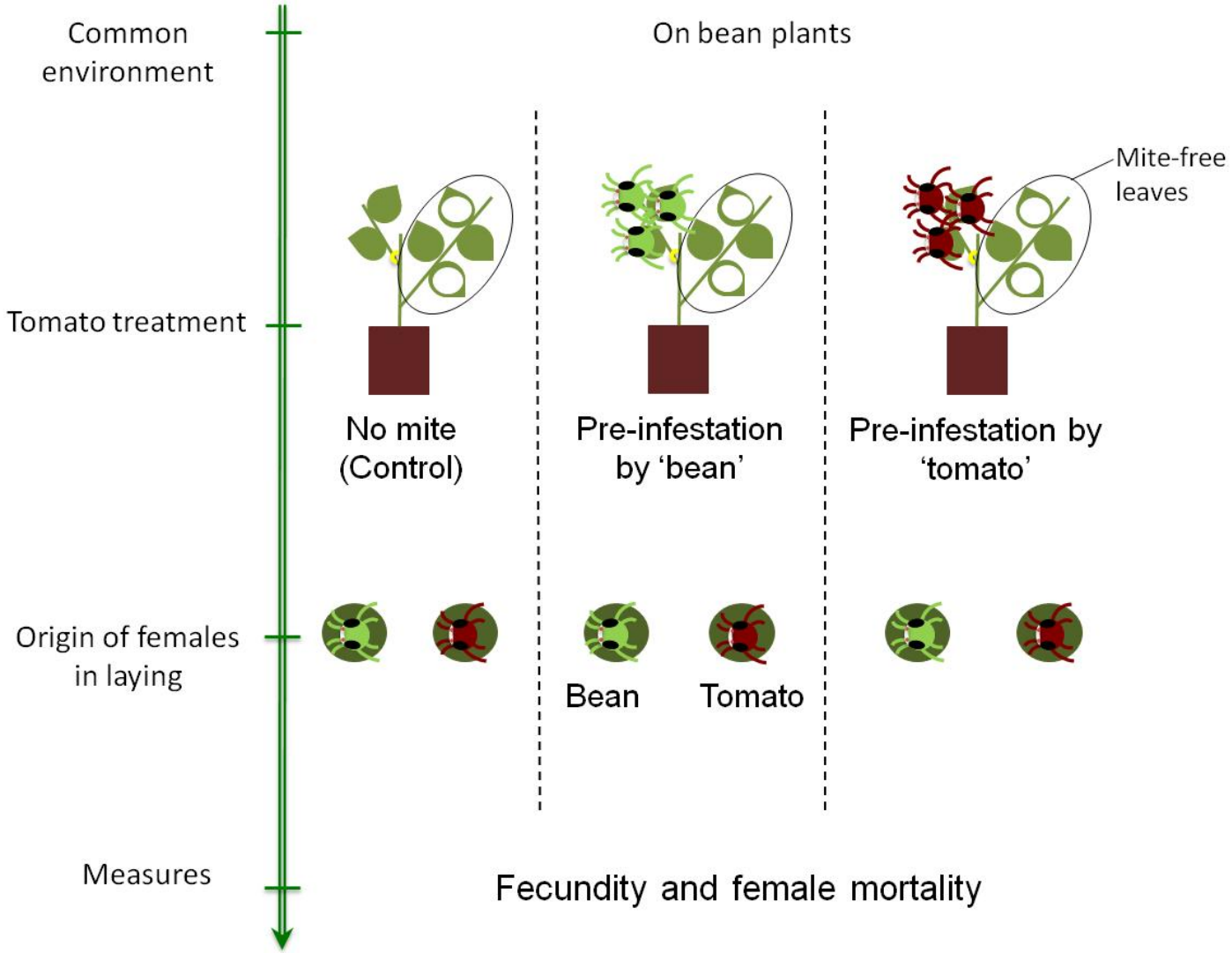
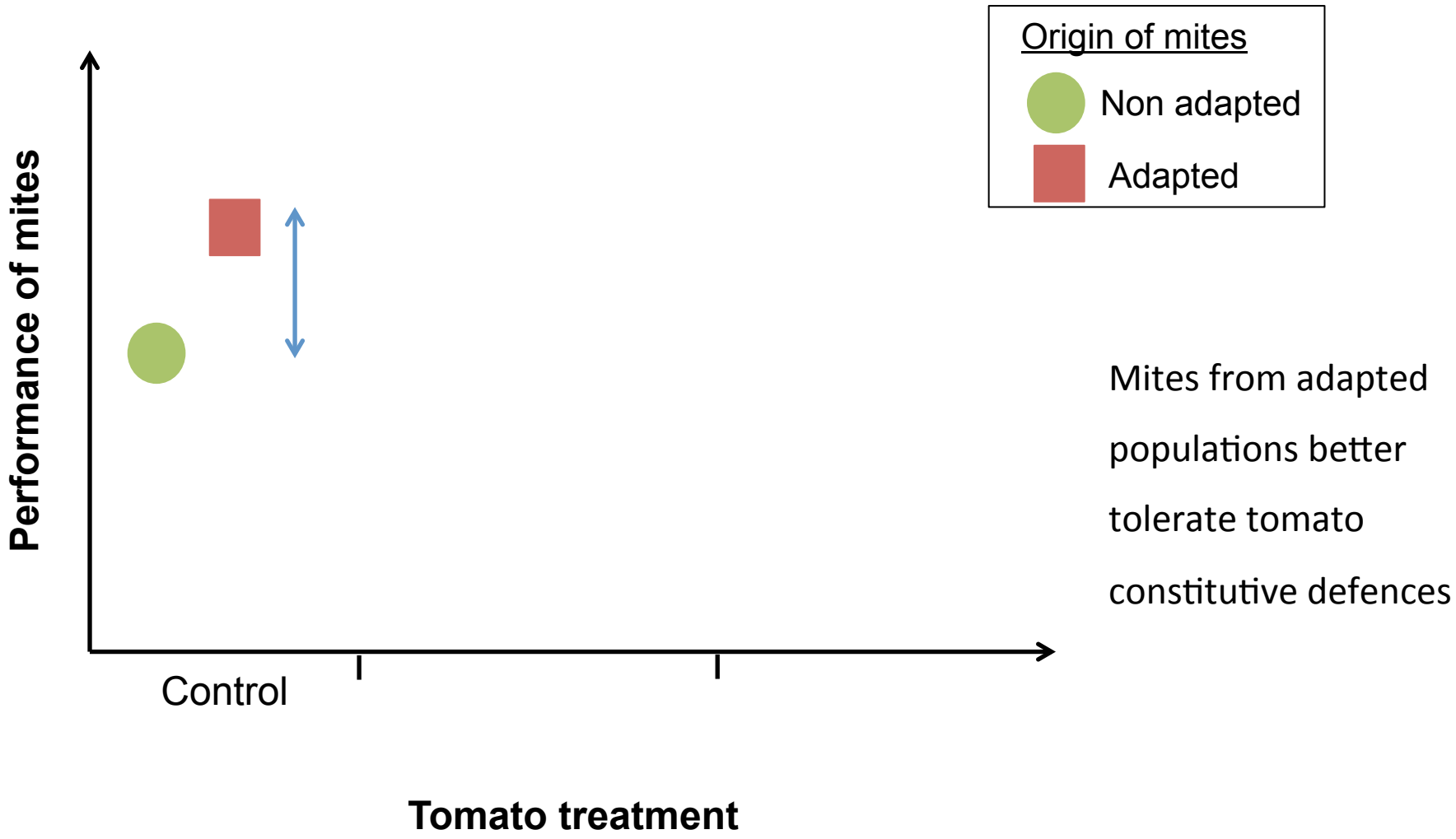
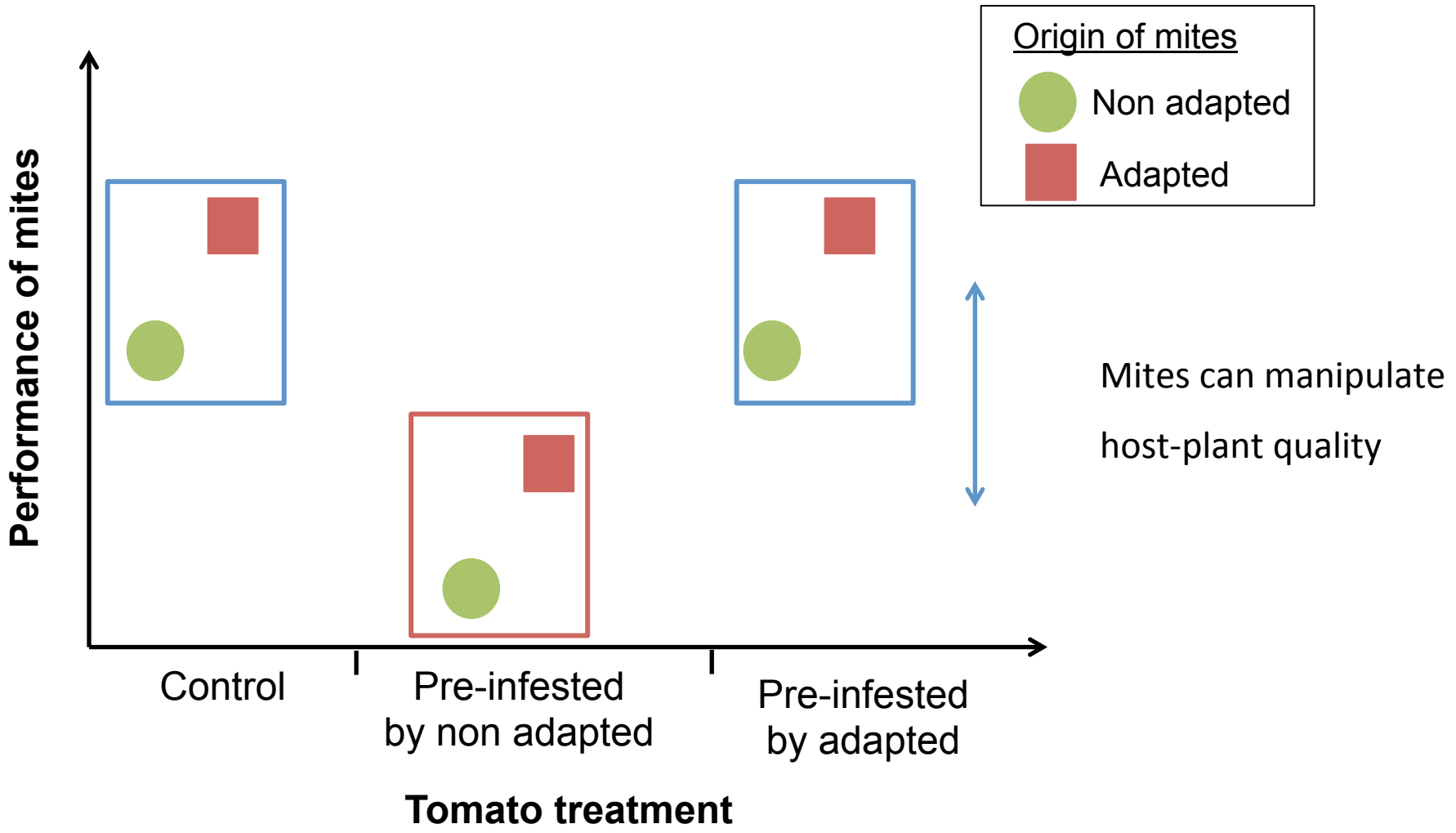


2. A mechanism allowing adaptation? **Expectations**



Mites from adapted populations better tolerate tomato constitutive defences

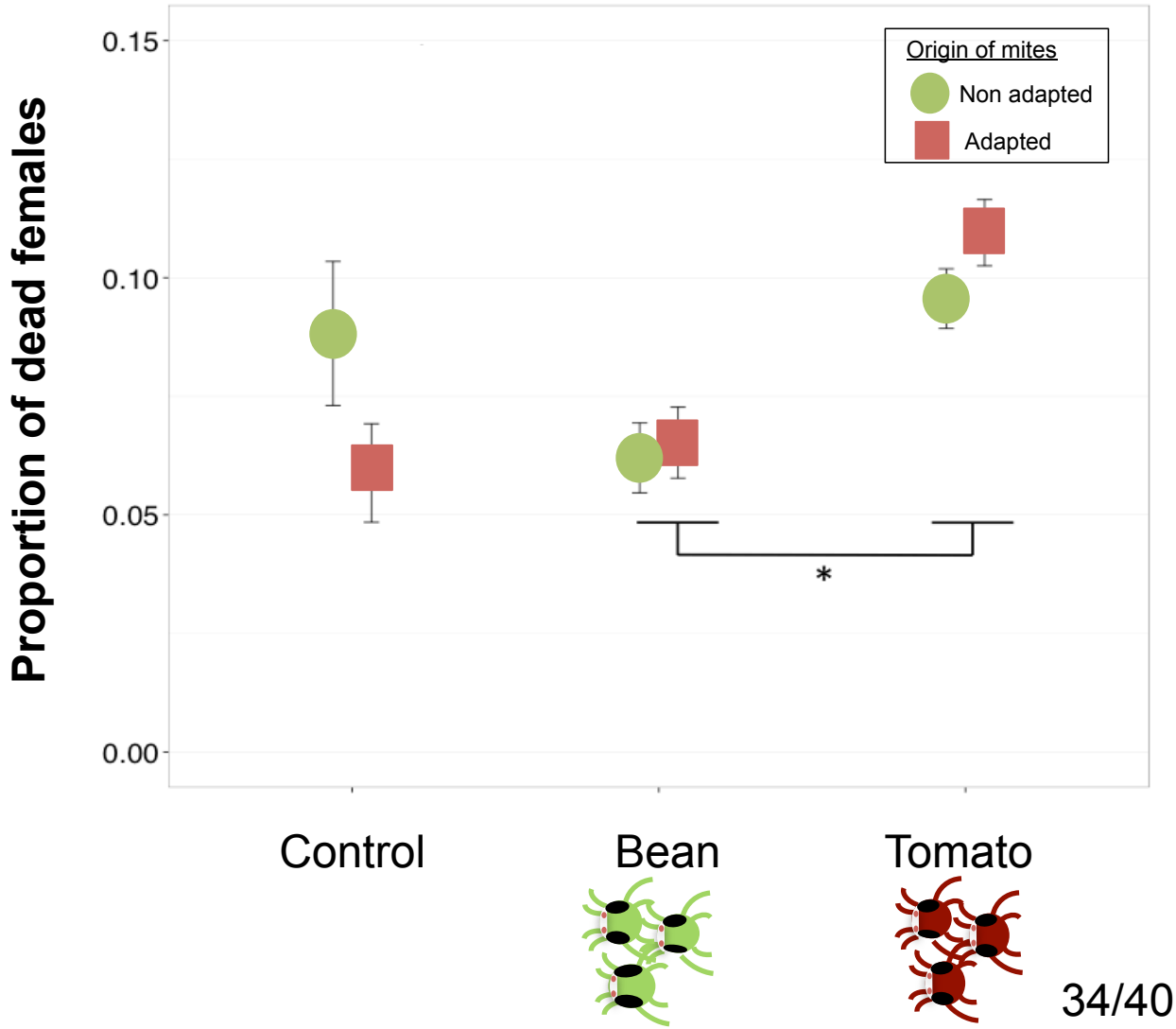
2. A mechanism allowing adaptation? **Expectations**



2. A mechanism allowing adaptation? **Results**

a) Female mortality

- Higher on plants pre-infested by tomato-adapted populations



2. A mechanism allowing adaptation? **Results**

a) Female mortality

- Higher on plants pre-infested by tomato-adapted populations

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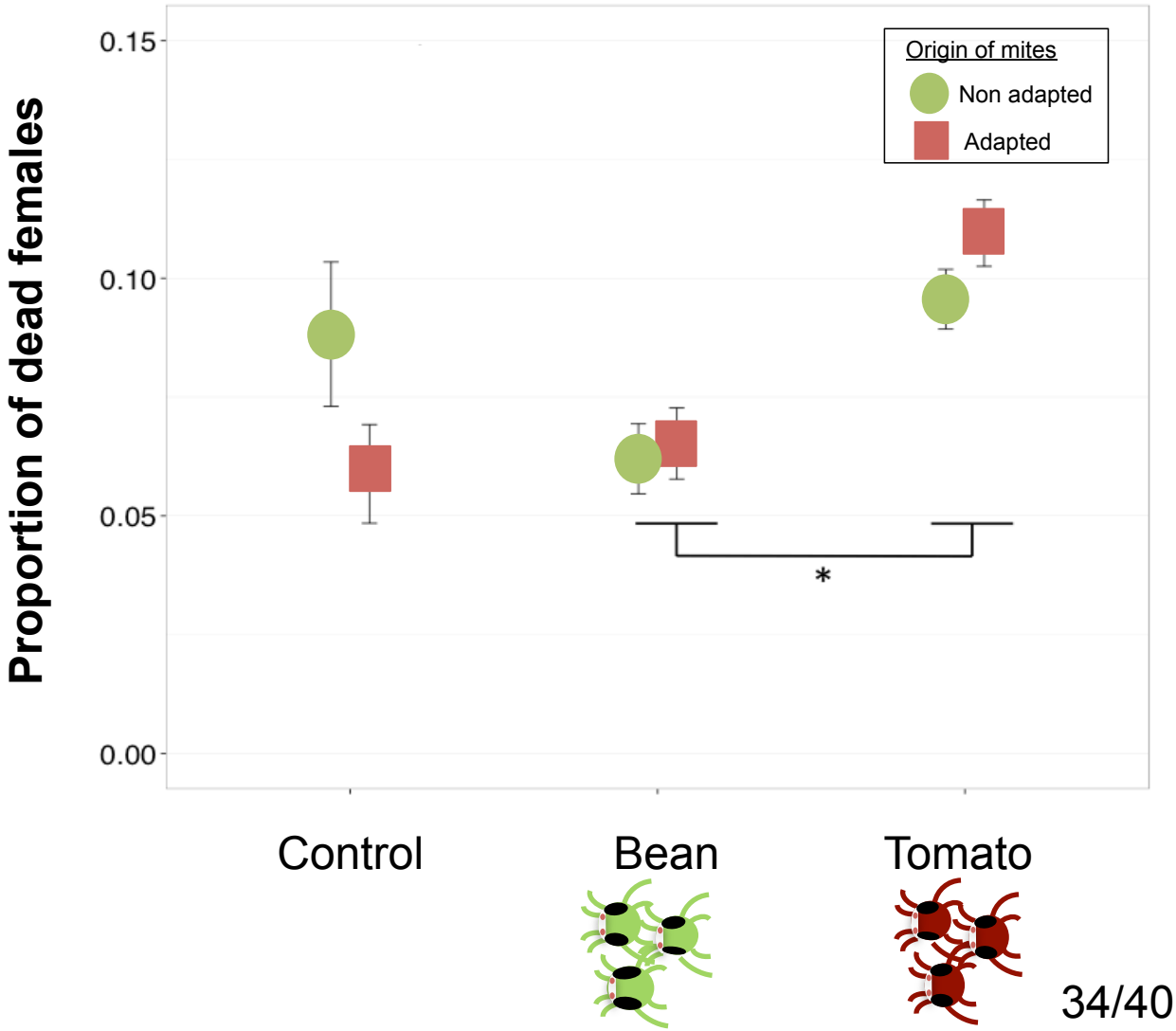
Do ‘tomato-adapted’ mites degrade host-plant quality?

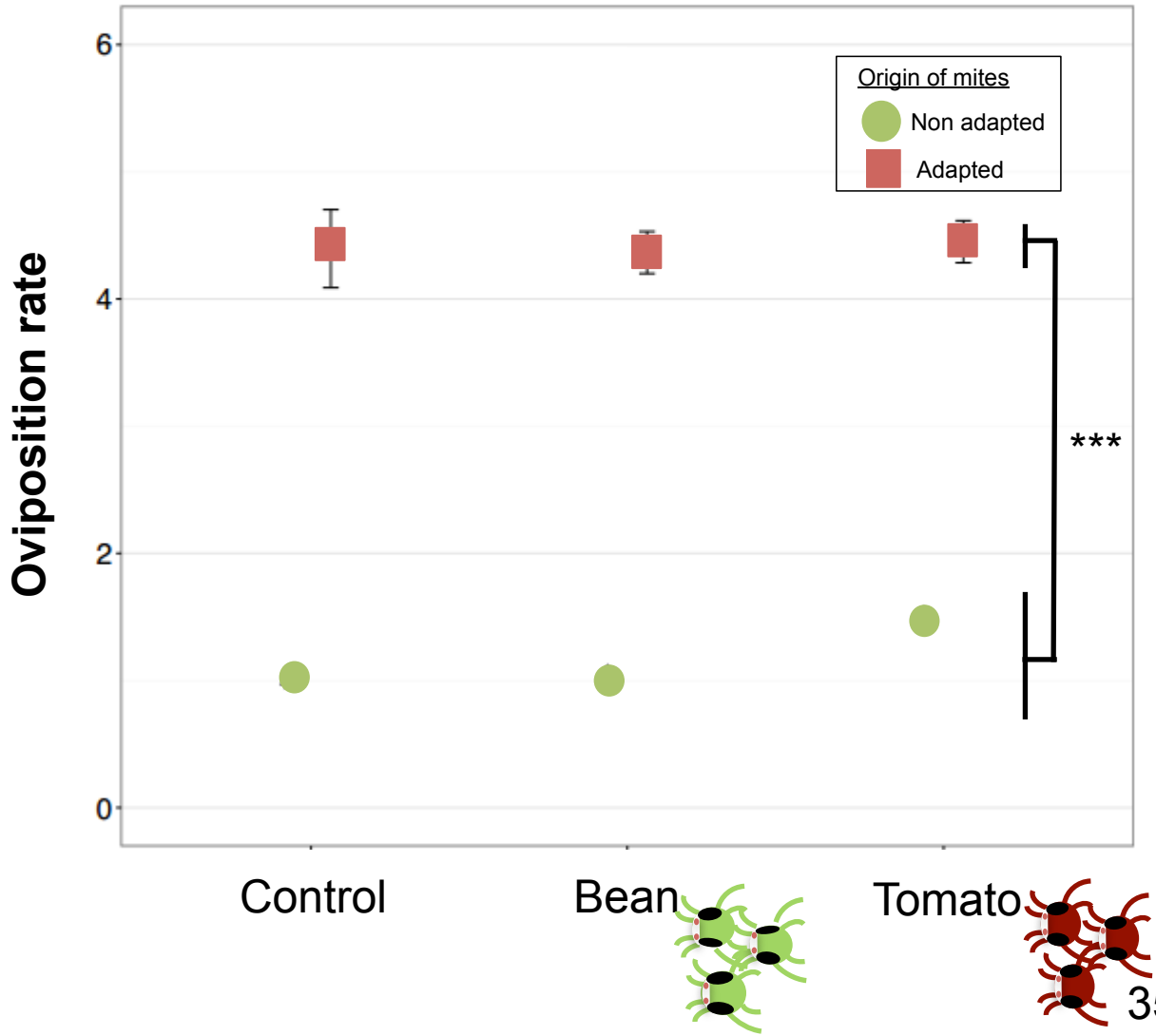
(Li *et al.*, 2002; Kant *et al.*, 2004)



2. A mechanism allowing adaptation? **Results**

b) Fecundity

- Higher for females from tomato-adapted populations



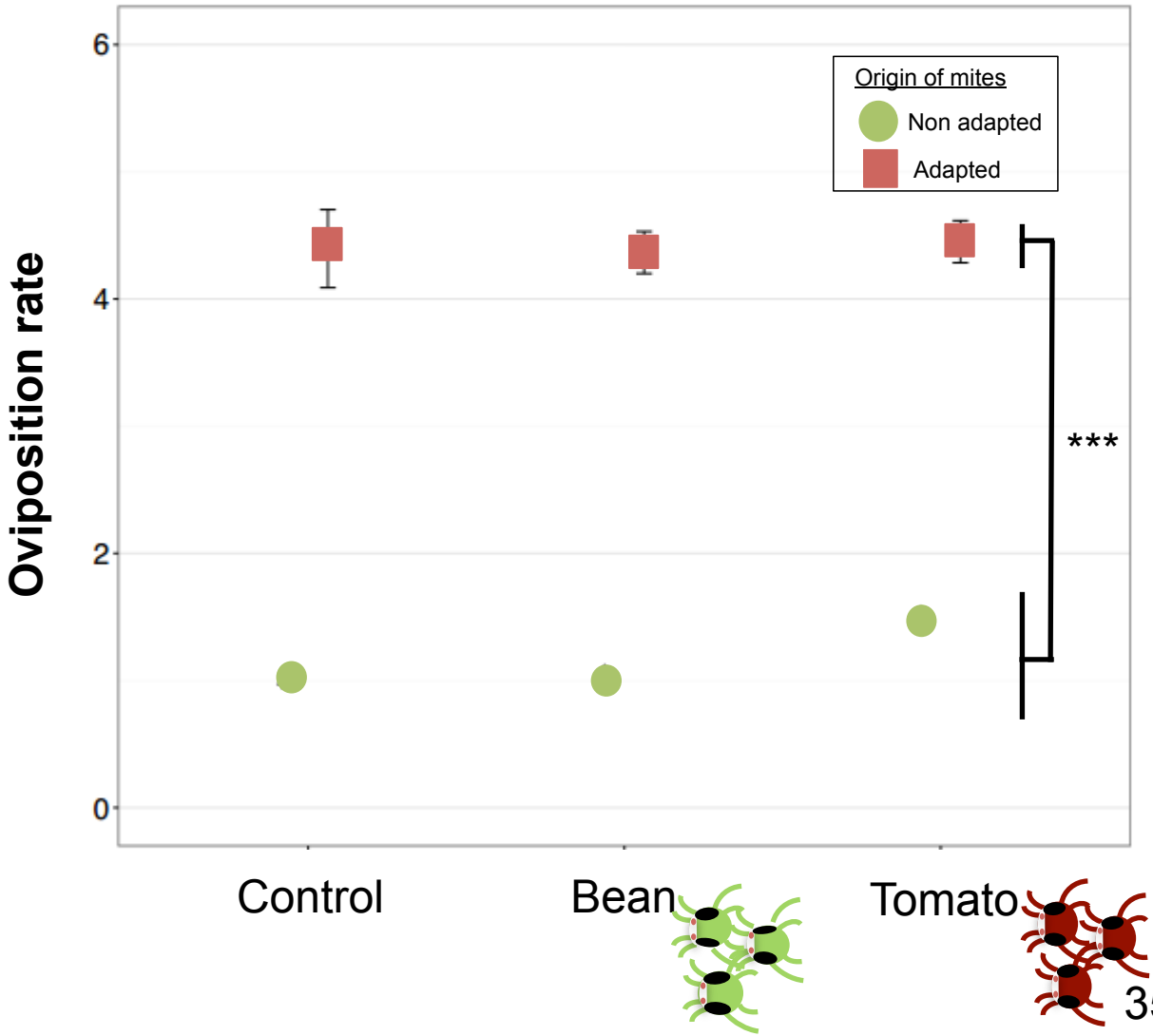
2. A mechanism allowing adaptation? **Results**

b) Fecundity

- Higher for females from tomato-adapted populations

↓

Evolution of higher female tolerance?



2. A mechanism allowing adaptation? **Main conclusions**

- Female mortality suggested that host-plant quality is degraded in plants pre-infested by tomato-adapted populations

- Female fecundity evolved in response to the origin of laying females

2. A mechanism allowing adaptation? **Perspectives**

- Pre-infestation induced the expression of toxic components specifically affecting female mortality?

- Limits competition?

General conclusions and perspectives

General conclusions and perspectives

- Maternal effects

  - Improve daily fecundity

  - But reduce the proportion of daughters produced

To what extent do maternal effects limit host-plant adaptation?

General conclusions and perspectives

- Selection regime

  - Repeatable evolution of some traits (juvenile survival, developmental time) (Magalhães *et al.*, 2007)

  - but not others (daily fecundity)

  - Overall, juvenile traits evolved more than adult traits (confirming Cotto and Ronce, 2014)

  - Daily fecundity differently evolved according to the time spent on tomato

General conclusions and perspectives

- Aster analysis did not integrate relevant variables such as:

  - male reproductive success
  - male longevity
  - fecundity of fertilized females

Consequences for fitness?

- Adaptation may be limited because of bottlenecks following a host colonization

General conclusions and perspectives

- Manipulation of host-plant
  - Previous infestation with mites from different regimes affected mortality

    Expression of plant defences?

- Consequences for herbivore communities?

Thanks

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- Joanne Griffin
- Students
- Julien Delnatte

David Carbonell

Denis Orcel

Sophie Lefèvre

Alison Duncan

Emilie Macke

AGENCE NATIONALE DE LA RECHERCHE ANR EVOLSEXALLOC Project