Universidad Rey Juan Carlos

ÁREA DE BIODIVERSIDAD Y CONSERVACIÓN

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The GYPSEVOL project:
Phenotypic plasticity and natural selection on gypsum endemics and their role on a global change context

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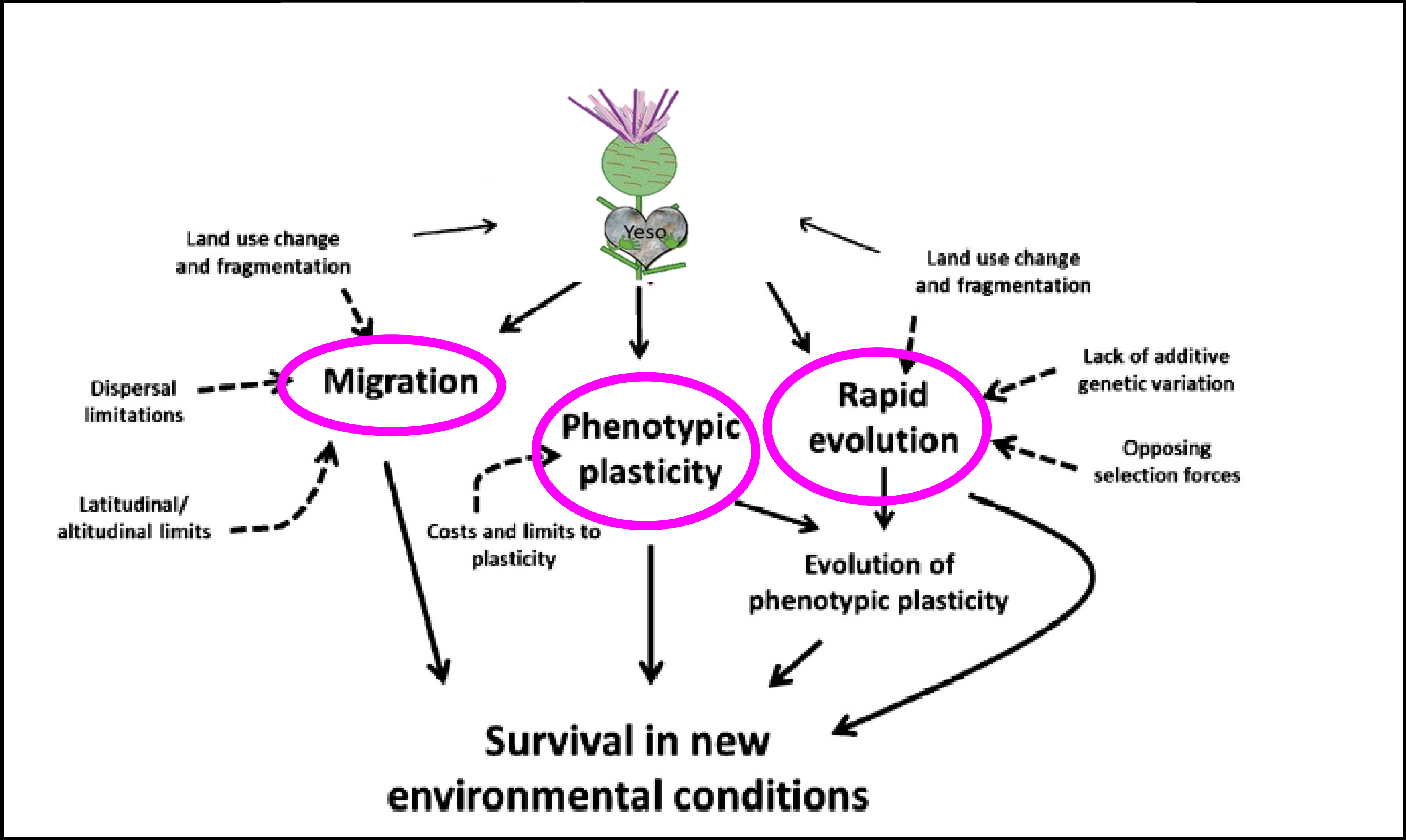
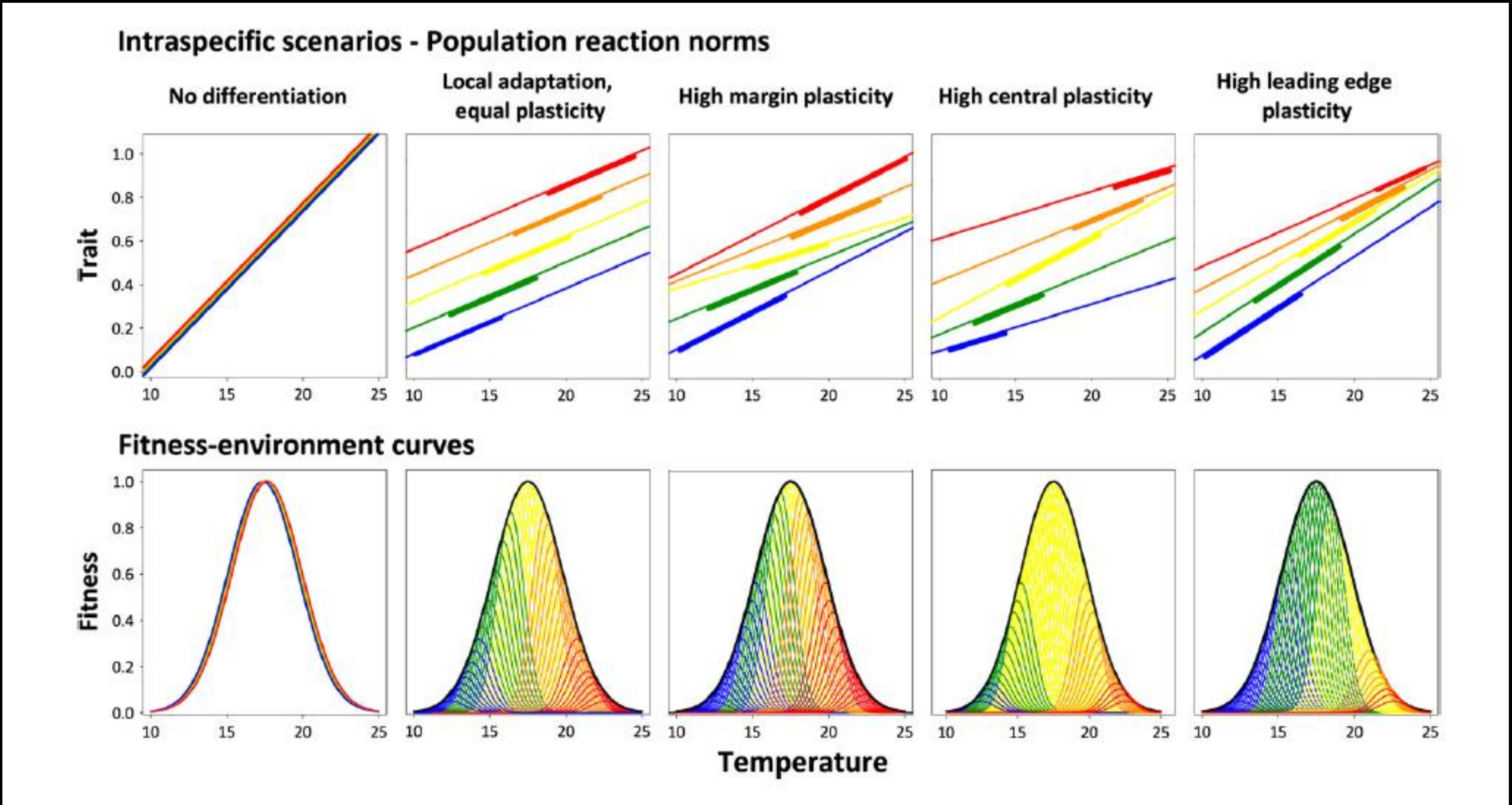
Plant responses to global change



Matesanz & Valladares, *Environmental and Experimental Botany*, 2014

Species are composed of genetically different populations with differential plasticity



Valladares, Matesanz et al. *Ecology Letters,* 2014

Partitioning the phenotypic variance of functional traits

$$\sigma_P = \sigma_G + \sigma_E + \sigma_{G \times E}$$

Phenotypic variance

Genetic variance

Environmental variance

Interaction variance

The GYPSEVOL project

1. To assess neutral and quantitative genetic variation in populations of dominant gypsophiles σ_G

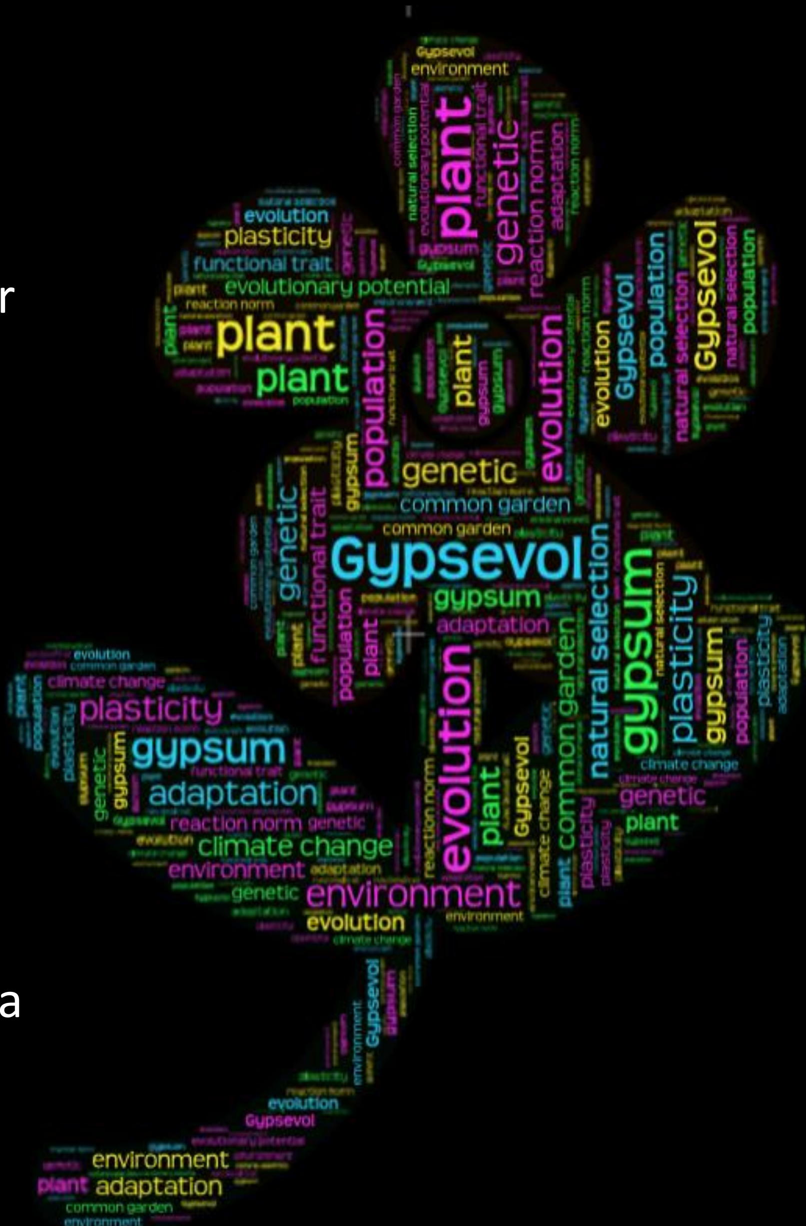
2. To test natural selection on relevant ecophysiological traits under field conditions for co-occurring gypsophiles and its genetic variation σ_P

3. To assess patterns of phenotypic plasticity and its evolutionary potential σ_E $\sigma_{G \times E}$

4. To evaluate the importance of neutral and adaptive processes in population differentiation σ_G $\sigma_{G \times E}$

5. To test for rapid, contemporary evolution on a common gypsophile σ_G $\sigma_{G \times E}$

6. To test the adaptive value of maternal effects σ_E



Our study organisms

Helianthemum squamatum (L.) Dum. Cours.

Cistaceae

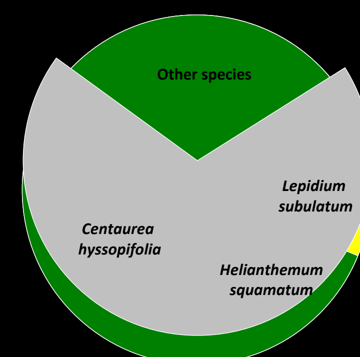
Centaurea hyssopifolia Vahl

Asteraceae

Lepidium subulatum L.

Brassicaceae

- Dominant in gypsum plant communities in the Iberian Peninsula



Matesanz et al. 2009

1. To assess neutral genetic variation in populations of dominant gypsophiles

σ_G

Family	Species	Distribution	Functional group	Sample	Marker	Results	Reference
Apiaceae	*Ferula loscosii*	Ebro Valley (Iberian Peninsula)	Shrub	12-30 plants from 12 pops	AFLP	Hs = 0.171 (0.129-0.226)	Pérez-Collazos et al., 2009
Caryophyllaceae	*Gypsophila struthium subsp. hispanica*	NE Iberian Peninsula	Shrub	11-12 plants from 7 pops	AFLP	Hs = 0.200 (0.159-0.199)	Martínez-Nieto et al., 2013
Caryophyllaceae	*Gypsophila struthium subsp. struthium*	C, E, S Iberian Peninsula	Shrub	11-12 plants from 16 pops	AFLP	Hs = 0.160 (0.129-0.174)	Martínez-Nieto et al., 2013
Cistaceae	*Helianthemum squamatum*	Iberian Peninsula, Magreb	Camaephyte	19-20 plants from 20 pops	Microsatellites (8 loci)	H_E = [illegible]	Matesanz et al. [illegible]npublished
Comp[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
Cruci[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]ez et
Fouq[illegible]	[illegible]	[illegible]	[illegible]	[illegible] from de 5 posp	[illegible] markers (5)	[illegible] (0-0.648)	[illegible]et al.,
Onagraceae	*Oenothera gayleana*	New Mexico, Texas, OK (USA)	Camaephyte	8-29 plants from 3 pops	Microsatellites (11 loci)	H_E = 0.269 (0.198-0.322)	Lewis et al., 2016
Onagraceae	*Oenothera hartwegii subsp. filifolia*	C, S USA	Camaephyte	24-29 plants from 2 posp	Microsatellites (11 loci)	H_E = 0.561 (0.520-0.597)	Lewis et al., 2016
Papaveracea	*Arctomecon humilis*	Utah (USA)	Perennial herb	24-30 plants from 6 poblaciones	Isozymes (10 loci)	H_E = 0.103 (0.042-0.172)	Allphin et al., 1998
Papaveracea	*Arctomecon humilis*	Utah (USA)	Perennial herb	26-49 plants from 10 pops	Microsatellites (16 loci)	H_E = 0.531 (0.413-0.606)	Simpson, 2014

- Moderate-high genetic variation
- Do gypsophiles really have low genetic variation because of substrate specialization?

Moore et al. 2014, Matesanz et al. Ecosistemas, accepted

Natural habitat fragmentation

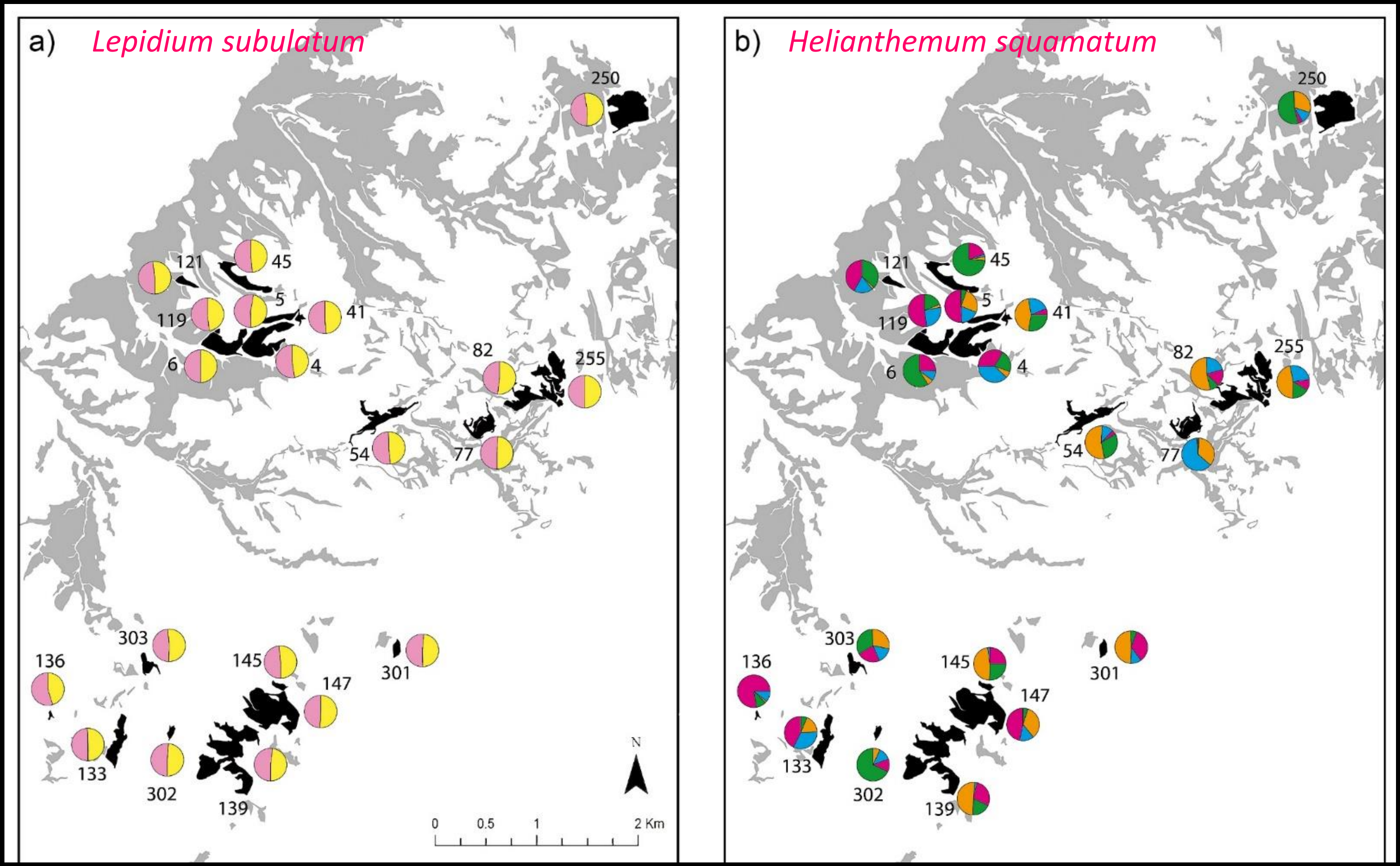
From Escudero et al. 2015

Photo credit: S Matesanz

Anthropogenic habitat fragmentation

Matesanz et al. 2009

σ_G

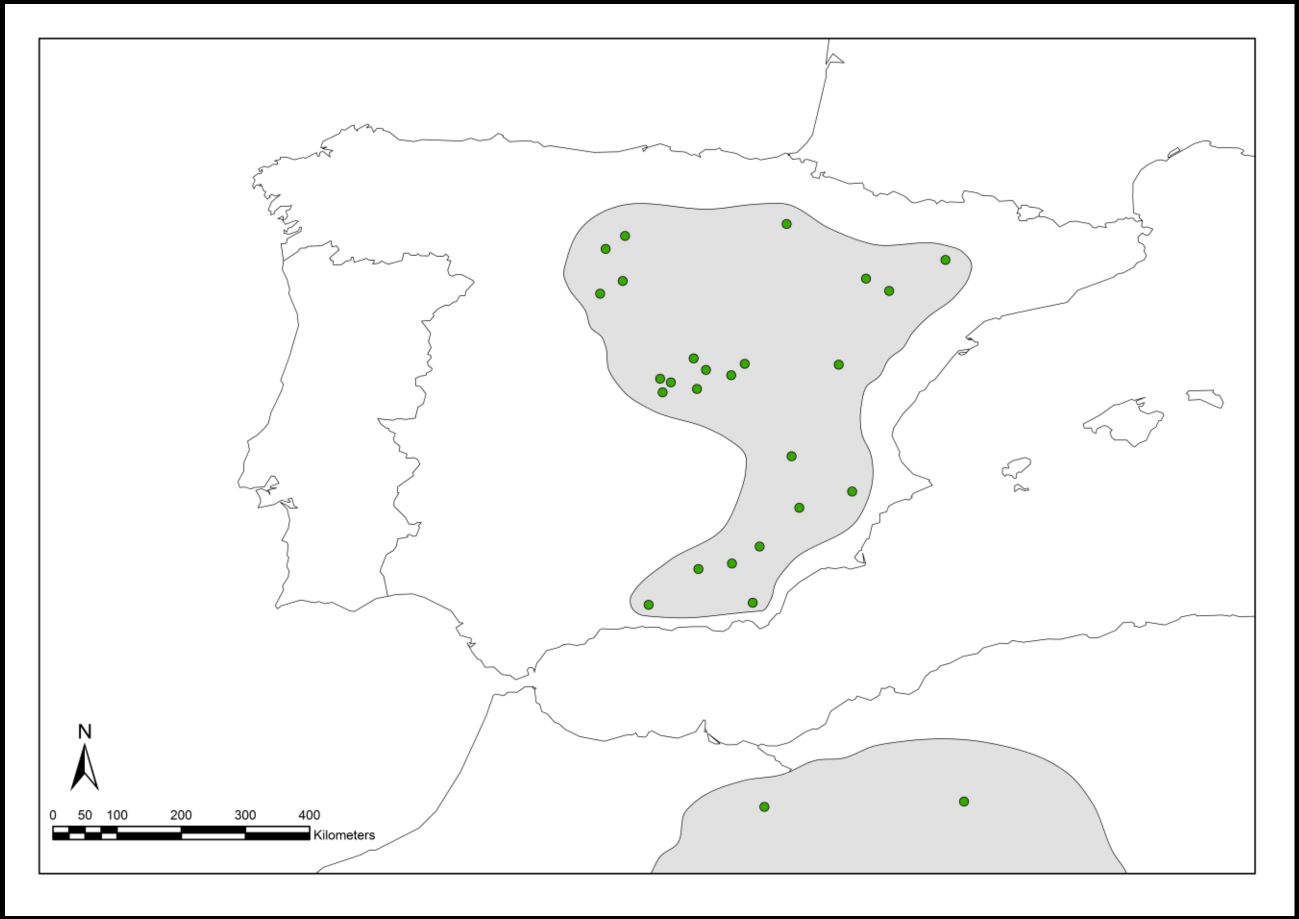


- High genetic diversity despite strong natural and anthropogenic habitat fragmentation
- Co-occurring species may differently experience the landscape

Matesanz et al. *Perspectives in Plant Ecology, Evolution and Systematics*, in 3rd revision

Population structure and phylogeography of a gypsophile across its entire distribution range

- 26 populations across 1000 Km geographical gradient
- 10 microsatellite markers
- 2 cpDNA markers (matK, trnL) 1 nuclear marker (ITS) and 1 coding region (PISTILLATA)



Blanco-Sánchez et al. in preparation

2. To test natural selection on relevant ecophysiological traits under field conditions for co-occurring gypsophiles

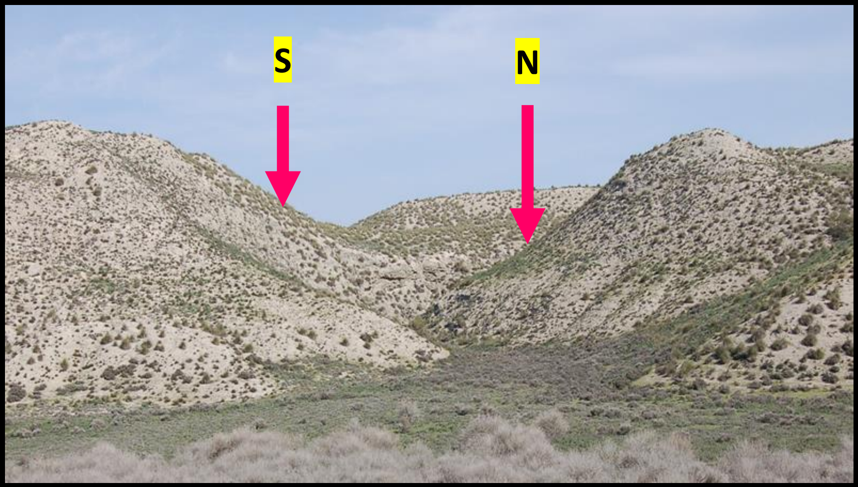


Photo: Ana M. Sanchez

H. squamatum

C. hyssopifolia

2 spp, 2 years

6 plots, **3 North, 3 South**

480 plants

Blanco-Sánchez et al. in preparation

σ_P

Microsite

- Soil water content
- Slope
- Microhabitat → Cover % / # conspecifics / Bare soil % …

Functional traits

- Phenology
- Plant size
- Photochemical efficiency
- Leaf thickness
- Leaf area
- LMDC
- SLA
- Leaf C
- Leaf N
- δ 13 C

Fitness traits

- # inflorescences
- Viable seeds per inflorescence
- Seed set
- Fruit set
- Seed mass
- Survival

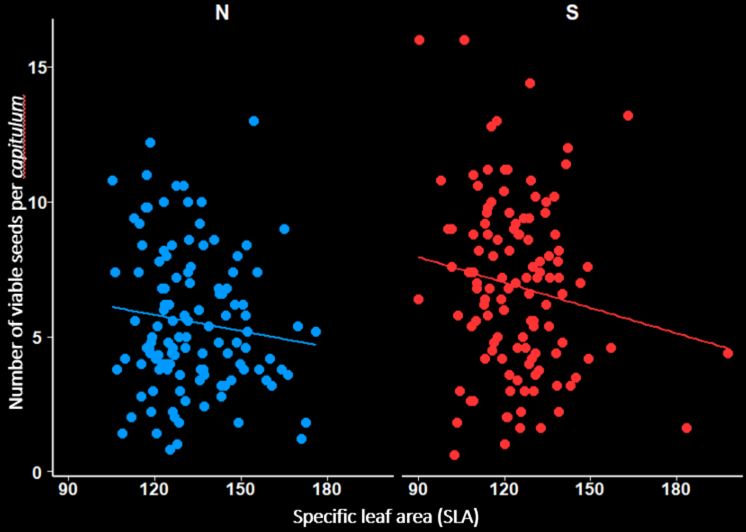
Phenotypic selection analyses

Selection differentials *S'*
Selection gradients β

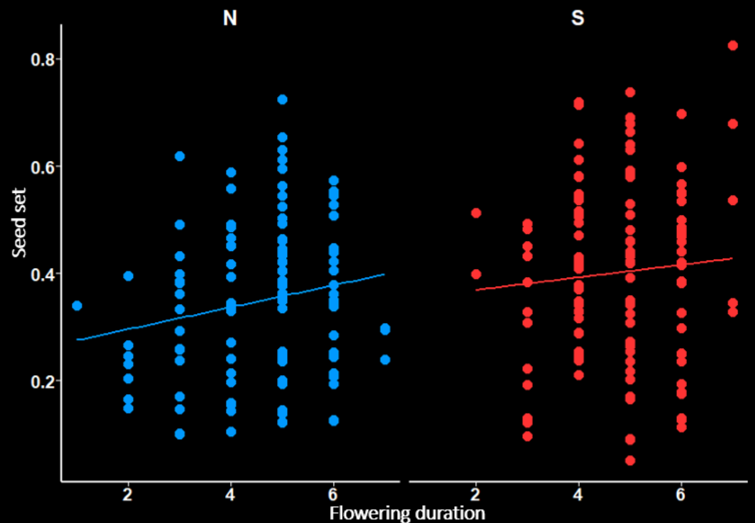
Blanco-Sánchez et al. in preparation

Selection on functional traits in *Centaurea hyssopifolia*

σ_P



P = 0.035*



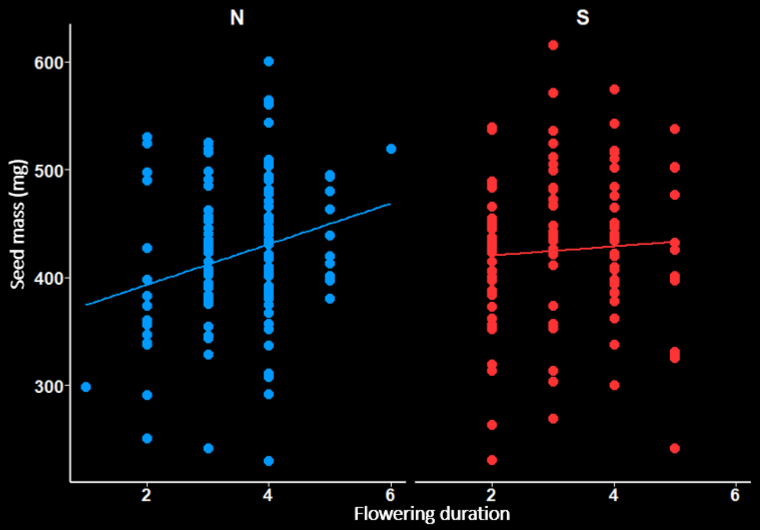
P = 0,067

- **Selection on Specific leaf area.** Plants with lower SLA had higher fitness
- **Selection on flowering duration.** Plants with open flowers for longer periods have higher seed set

Blanco-Sánchez et al. in preparation

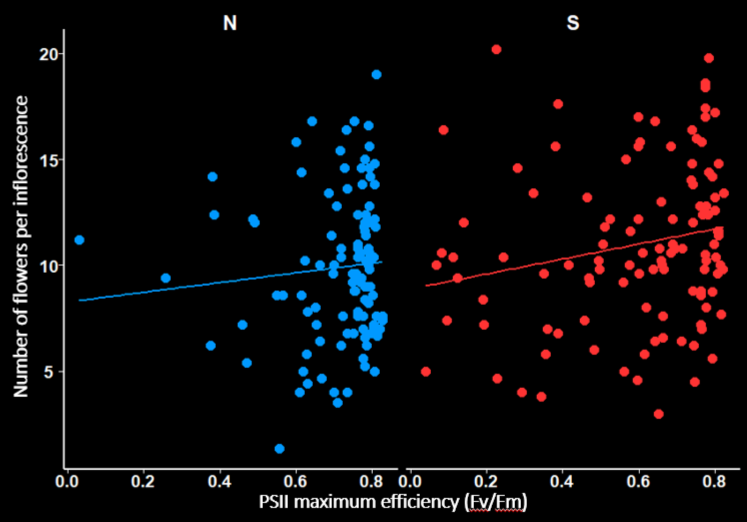
Selection on functional traits in *Helianthemum squamatum*

σ_P



P = 0.023

- **Selection on flowering duration**. Plants with open flowers for longer have higher seed mass



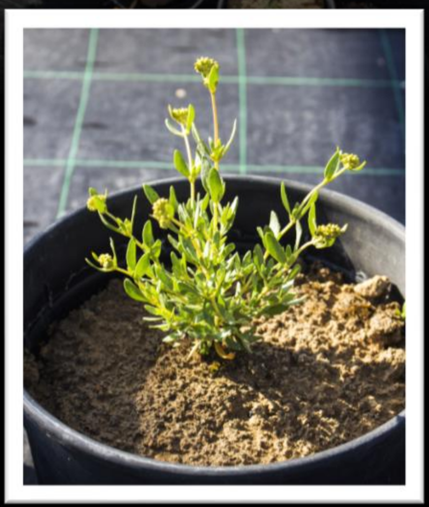
P = 0.060

- **Selection on PSII efficiency**. Plants with higher efficiency had higher number of flowers.

Blanco-Sánchez et al. in preparation

Can adaptive traits evolve by natural selection?

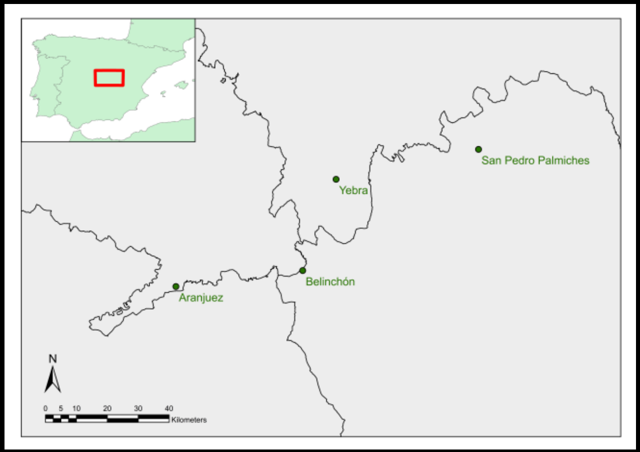
σ_G



A common garden to detect intrapopulation genetic variation (heritabilities, additive genetic variation etc.)

3. To assess patterns of phenotypic plasticity and population differentiation

σ_E $\sigma_{G \times E}$



- 4 populations along a climatic gradient
- Maternal families nested within populations

Matesanz et al. in preparation

Adaptive plasticity to drought

σ_E $\sigma_{G \times E}$

Plant Biomass	++	-
Leaf area	+	-
RGR	+	-
Flowering onset	late	early
Root allocation	-	+

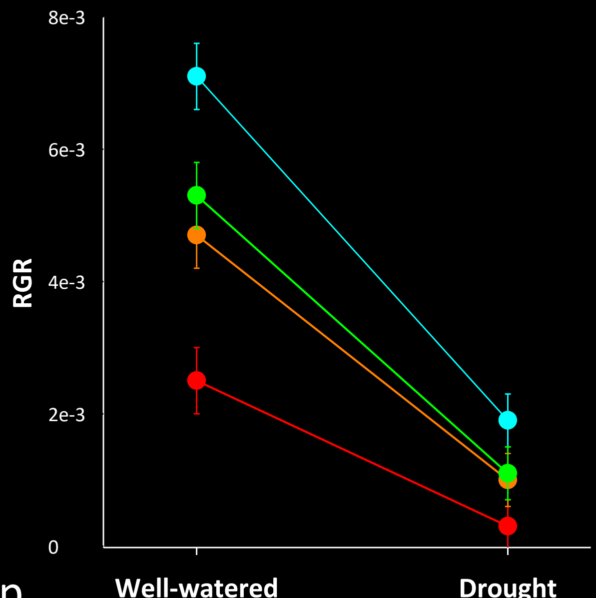
Matesanz et al. in preparation

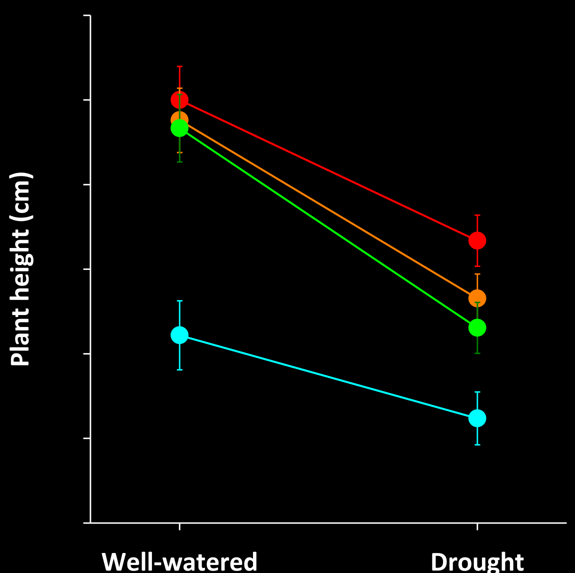
Adaptive population differences

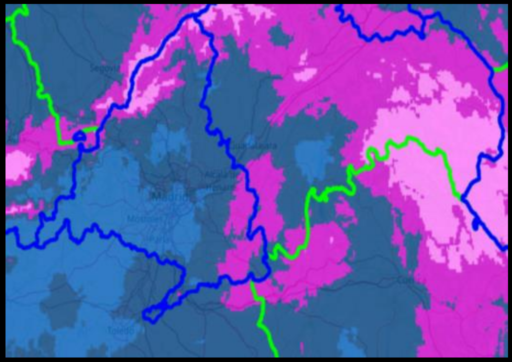
σ_E $\sigma_{G \times E}$

<Temp
>Prec

>Temp
<Prec







Minimum winter temps

Matesanz et al. in preparation

4. To evaluate the importance of neutral and adaptive processes in population differentiation

F_{ST}-Q_{ST} comparisons

•F_{ST}: population differentiation in neutral markers due to neutral processes (drift, migration)

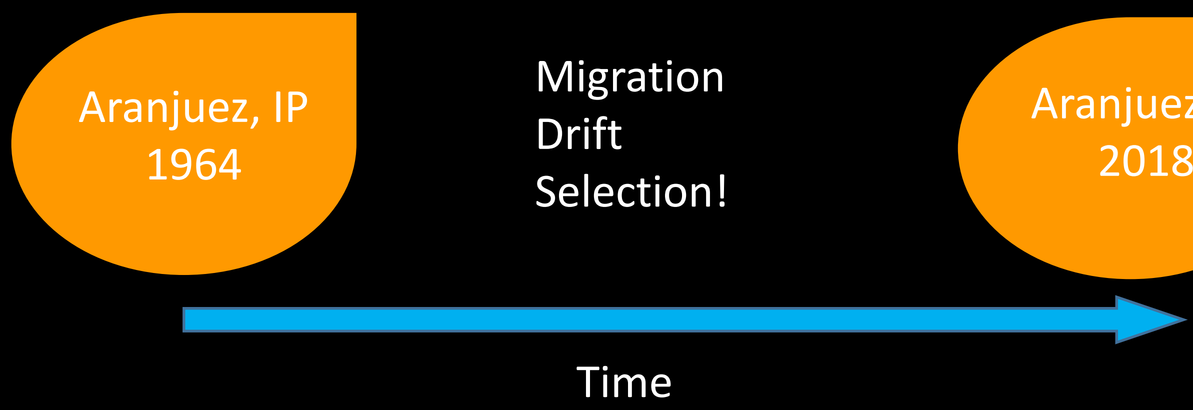
•Q_{ST}: population differentiation in quantitative traits (% phenotypic variance among pops)

- $Q_{ST} > F_{ST}$: spatially divergent selection
- $Q_{ST} < F_{ST}$: spatially homogenizing selection
- $Q_{ST} \approx F_{ST}$: population differences in quantitative traits could be attributed to neutral evolutionary processes

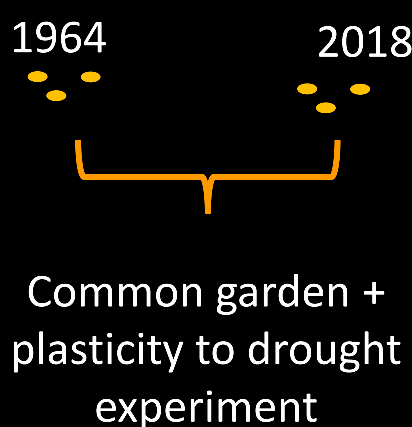
Common garden experiment + molecular analyses
to tease apart neutral and adaptive processes

σ_G $\sigma_{G \times E}$

5. To test for rapid, contemporary evolution on a common gypsophile



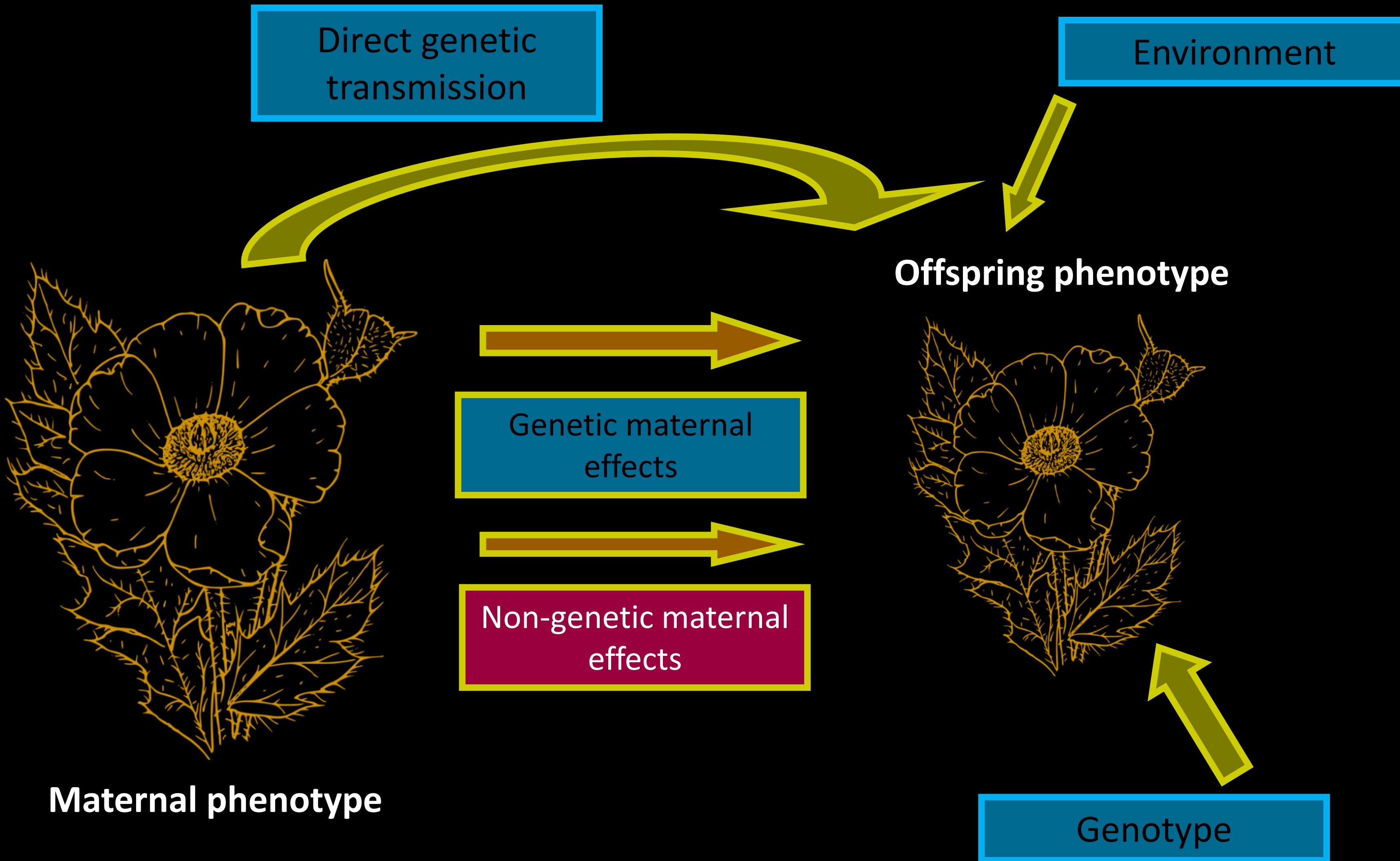
A resurrection experiment to detect natural selection in action!

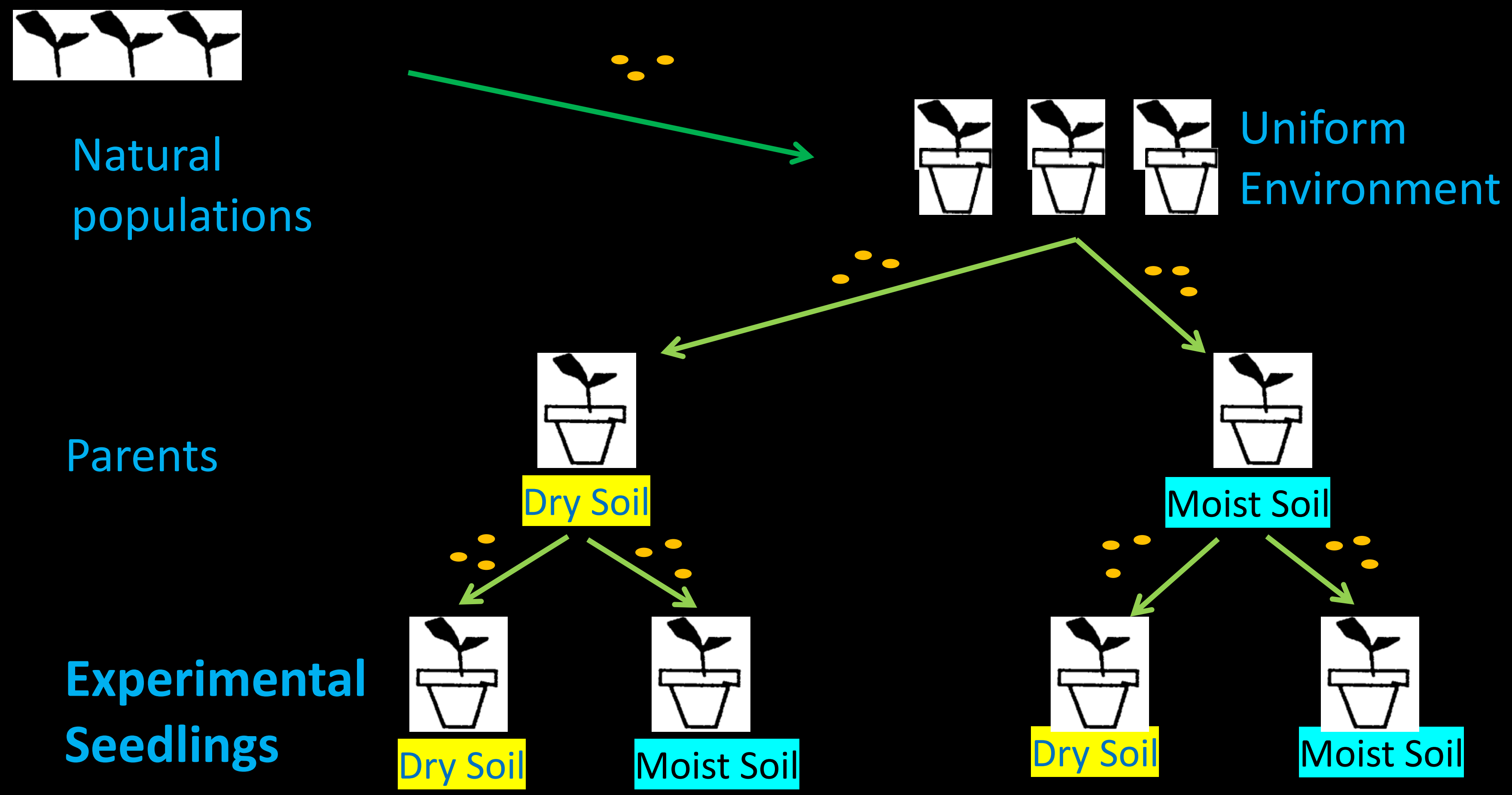


σ_G $\sigma_{G \times E}$

6. To test the adaptive value of maternal effects

σ_E




Natural
populations
Uniform
Environment
Parents
Dry Soil
Moist Soil
Experimental
Seedlings
Dry Soil
Moist Soil
Dry Soil
Moist Soil

Conclusions

- Gypsophiles such as *Centaurea hyssopifolia*, *Helianthemum squamatum* and *Lepidium subulatum* have substantial neutral genetic variation
- Historical evolution on a fragmented landscape may preadapt gypsophiles to the effects of further anthropogenic fragmentation, but still, gypsophiles may strongly differ in their migration ability
- Both phenological, morphological and physiological traits are under selection on gypsum environments. So far, no evidence of different phenotypes being selected in different slopes
- Gypsophile populations are able to express adaptive phenotypic plasticity as well as adaptive differentiation as a response to a key environmental factor
- It is likely that both genetic (adaptation) as well as environmental (plastic) components will modulate the response of gypsophile populations to environmental change

The GYPSEVOL team





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Check our latest news on twitter.com/gypsevol

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Working in gypsum is FUNtastic!