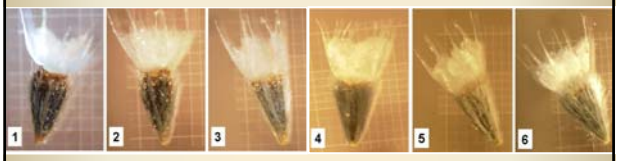
Anthropogenic Fires Shape Seed Traits in the Chilean Matorral



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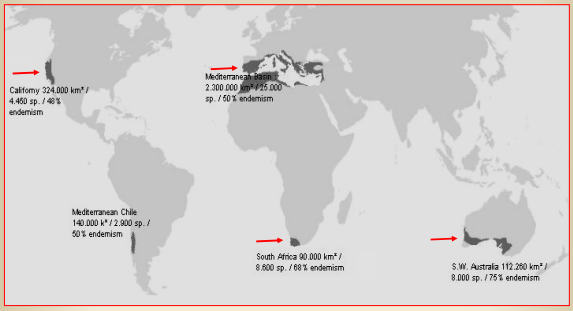
Mediterranean ecosystems



Summer drought + lightnings

Natural fire regime
(at least since the Pliocene)

→ Vegetation structure over evolutionary time

Plant species in these ecosystems have adaptive responses to fire

Flowering

Serotiny

Germination

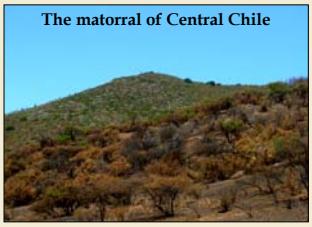
Resprouting

Seed persistence
(ability of seeds to resist fire) is considered to be adaptive because it allows plant establishment after fire under low competition and high resource availability

We still don´t know how fire acts as a selective pressure on the variability of seed traits among individuals to drive evolutionary changes

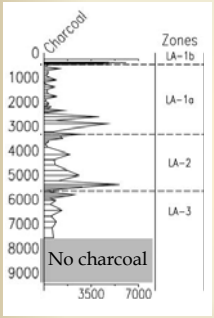
Ecosystems where fire is novel provide an **outstanding opportunity to explore the evolutionary ecology of seed traits in relation to fire**

The matorral of Central Chile



• Fire has not been as relevant in the evolution of the flora as in other Mediterranean-type ecosystems→ Little evidence of adaptive seed traits

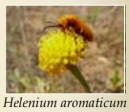
Anthropogenic fires have been present since the first human colonization, increasing their frequency in the last centuries



Aculeo lagoon (Central Chile)
(Villa-Martínez et al. 2003)

→ These fires might have selected favourable seed traits in native plant species, particularly on annual plants

Dichondra sericea



Helenium aromaticum

Plagiobothrys fulvus

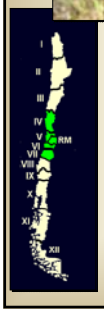
General objective:

We evaluated the role of fire in the evolution of seed traits from a microevolutionary perspective, using as study system a native forb from the Chilean matorral, where fire is a novel, anthropogenic disturbance.

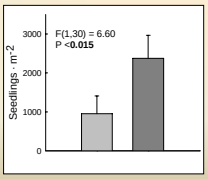
The model study: *Helenium aromaticum* (Asteraceae)

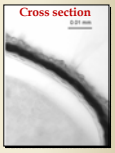
- Annual forb
- 20-60 cm tall
- Flowering = late spring
- Dispersal = summer

Bierner (1978)



- It has a Mediterranean distribution
- Evidence of fire-stimulated germination

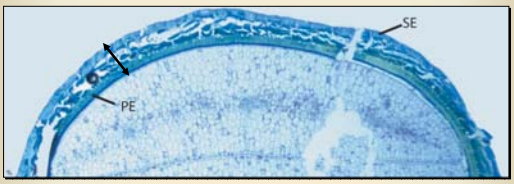




Seed coverings
testa
pericarp

What seed traits could be selected by fire?

Seed persistence ⟷ Thickness of seed coverings (Brigs et al. 2005)

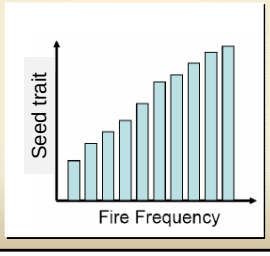


Seed persistence ⟷ Seed shape (Thompson et al. 1993)
(being small and rounded seeds easily buried)

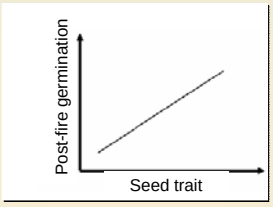
Thermal regulation ⟷ Seed pubescence (Barthlott 1981)

Hypotheses:

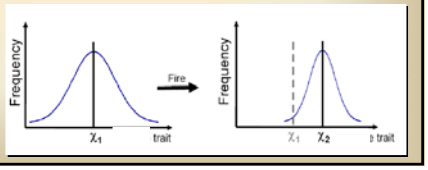
1. *Helenium aromaticum* populations from sites with high fire frequency will have smaller, more rounded and pubescent seeds, with thicker coverings (testa and pericarp), compared to populations from sites with low fire frequency **(Interpopulation level)**



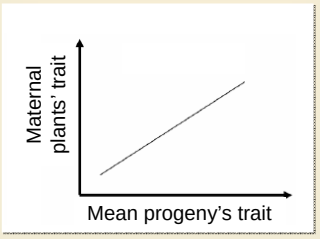
2. **Within a given population**, the probability of germination after fire will be associated with the expression of the traits



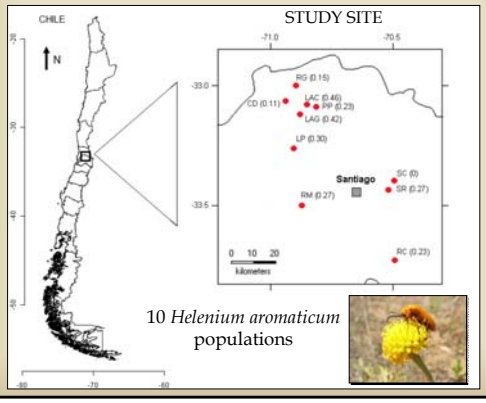
Directional selection



3. **Within a given population**, fire-selected seed traits will be heritable → Positive correlation beetween maternal plants and the progeny for the trait (potential of evolutionary change)



H1. Relationship between fire frequency and seed traits across populations

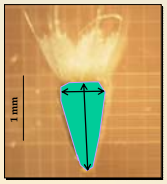


10 *Helenium aromaticum* populations

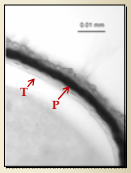
Seed trait measure

25 plants / population
5 seeds / plant

Seed size → seed area
Seed shape → width:lenght
Testa thickness
Pericarp thickness



Cross section

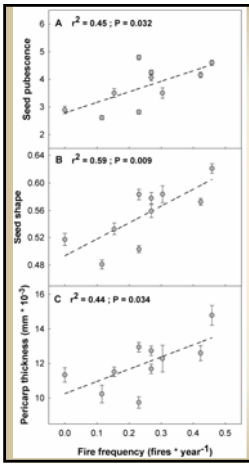


Pubescence → visually

Fire frequency

We constructed a fire scar chronology using the tree species *Acacia caven*

Mean annual ring increment as a proxy for **site productivity** (it could be a potential confounding factor affecting seed trait expression)

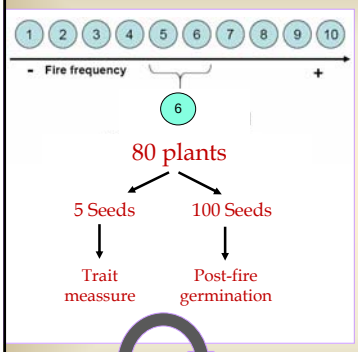


We found a positive relationship between fire frequency and seed pubescence, shape and pericarp thickness. No pattern for testa and size

These traits were **not associated with site productivity**:
Pubescence: $r^2 < 0.001$, P = 0.98
Shape: $r^2 = 0.18$, P = 0.22
Pericarp: $r^2 = 0.07$, P = 0.45

Fire is more relevant in explaining their regional variation compared to other environmental factors related to site quality

H2. Relationship seed trait-fitness (directional selection)



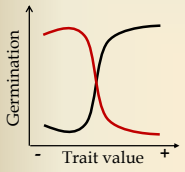
Multiple regression approach (Lande & Arnold 1983)

Selection experiment

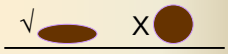
Burning litter on seeds located in clay pots with sterile sand

Mean T_{max} 91.6°C

Seed pubescence and pericarp thickness were positively associated with post-fire germination (+ directional selection), while seed shape was negatively associated (-directional selection)



Pubescence β = 0,69 P = 0,03
Pericarp β = 0,89 P = 0,01
Shape β = -0.68 P = 0.03



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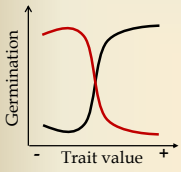

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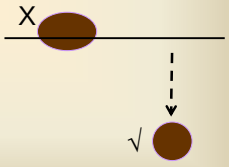


Adaptive traits to fire

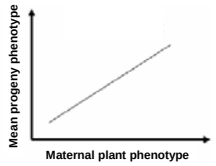
H3. Heritability of the fire selected traits

6 → Seed traits maternal plants
5 seeds x 25 plants

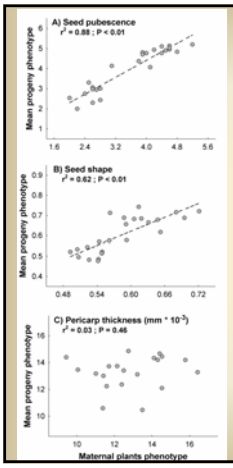
Seed traits 2nd generation
5 seeds x 3 plants x 25 families

Plants grown in a common environment

Seeds from self-pollination



Heritable trait → b > 0

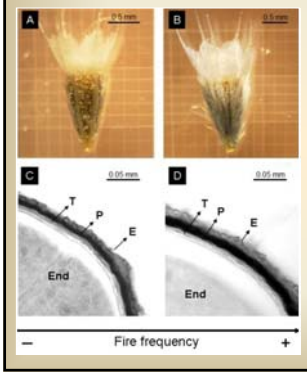


Pubescence and shape were heritable, but not pericarp thickness

There was a significant positive relationship between the expression of these traits in maternal plants and their progeny.

There is a potential of evolutionary change

Fire is a selective pressure that shapes adaptive seed traits



- In *H. aromaticum* populations, fire is selecting more pubescent, thicker-coated (thermal resistance) and rounded seeds (easily buried).
- Heritability of traits → conditions are given for **evolution by natural selection to occur**.

Our results challenge the widespread assumption that native matorral species don't have adaptive traits to fire

Source of variation	Factor	Vegetation χ^2	Vegetation P
Native perennials			
Species richness	Fire	0.01	0.925
Abundance	Fire	1.28	0.256
Native annuals			
Species richness	Fire	4.24	0.039

Gómez-González et al. 2011

Dichondra sericea

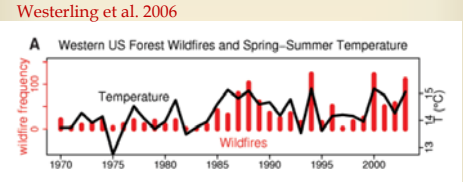
Helenium aromaticum

Plagiobothrys fulvus

Adaptive traits might be rather common among matorral species

Since fire frequency is increasing due to human activities and global warming

Westerling et al. 2006



The role of anthropogenic fire as a selective agent in ecosystems worldwide is probably being underestimated