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IT PAYS OFF TO FLOWER EARLY, BUT NOT TOO EARLY WHEN THE SOIL GETS WARMER

Johan Ehrlén, Alicia Valdés, Vigdís F. Helmutsdóttir, and Bryndís Marteinsdóttir

Study Description

In seasonal environments, phenotypic plasticity of phenology to spring temperature can increase fitness by increasing season length and minimizing exposure to cold air temperatures. In geothermally heated areas, the optimal plasticity might change because soil temperatures are higher and decoupled from air temperatures. Along a natural warming gradient, *Cerastium fontanum* flowered earlier and had lower fitness on warmer than on colder soils in 2 years. In 1 year, selection favored earlier flowering on colder soils, but later on warmer soils, suggesting that plasticity evolved on unheated soils is suboptimal on warmer soils, and might be selected against in some years.

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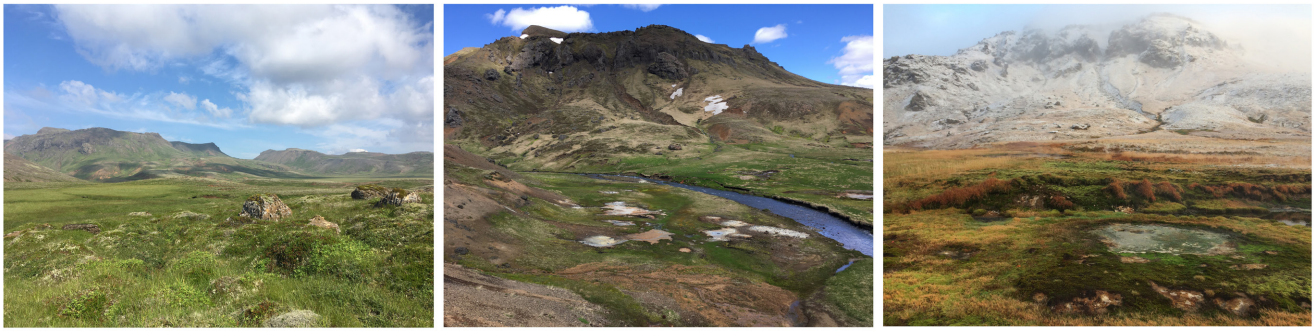


Photo 1. Our study site was located in the Hengill geothermal area, located 40 km east of Reykjavik, Iceland, (64°03′N; 21°18′W, ~360 m.a.s.l.), at the base of the Hengill volcanic system. The study area, comprising ~1 km^2, includes the Fremstidalur (left) and Miðdalur valleys (center and right), and the main vegetation type consists of unmanaged, but grazed, subarctic grassland. There are large differences in soil temperature over distances of only a few meters (see Photo 2), but very small differences in other abiotic factors such as soil chemistry, elevation or vegetation type. Photo credit: Vigdís F. Helmutsdóttir.



Photo 2. Bedrock of the Hengill geothermal area contains geothermal channels originating from high volcanic activity, which warm the water and soil through radiative heating. Geothermally heated water (left) or steam (center) reaches the surface in some places, and there is a large variation in soil temperatures across the study site, ranging from no geothermal heating to more than 20°C above ambient temperature over short distances (10–20 m), with little to no warming on the air temperature. This system has been heated for over 50 years or longer, offering a unique natural laboratory for studying the long-term effects of warming. In our study, soil temperature was measured in May each year, at 10 cm depth in the immediate vicinity (<2 cm) of each individual plant, using a digital thermometer (right). Photo credit: Vigdís F. Helmutsdóttir (left and right) and Katarina Fast Ehrlén (center).



Photo 3. Our study species, *Cerastium fontanum* (Caryophyllaceae) is a perennial herb that is common in subarctic and arctic ecosystems. Individuals produce 1–30 stems that are 10–30 cm long, with small, hairy leaves. Each stem carries 1–6 flowers with 5–7 mm long petals. This species flowers in June and July in the study area and it is self-compatible, but can also be cross-pollinated by insects. Fruits mature from July to August, and seeds show unspecialized seed dispersal. We used data from two growing seasons to assess how flowering time, fitness, and phenotypic selection on flowering time in this species vary with soil temperature along a natural soil warming gradient in the Hengill geothermal area. We found an earlier flowering time and a lower fitness on warmer soils in both study years. In one of the 2 years, natural selection favored earlier flowering on colder soils and later flowering on warmer soils. Photo credit: Vigdís F. Helmutsdóttir (left and right) and Katarina Fast Ehrlén (center).

These photographs illustrate the article "Maladaptive plastic responses of flowering time to geothermal heating" by Johan Ehrlén, Alicia Valdés, Vigdís F. Helmutsdóttir, and Bryndís Marteinsdóttir published in *Ecology*. https://doi.org/10.1002/ecy.4121