The High Life: Alpine Dwarfism in Arabidopsis

Visiting high altitudes or latitudes, it is easy to marvel at the tiny survivors that green the ground. Plants in such habitats face many challenges, including freezing and fluctuating temperatures, strong winds, and, at high altitudes, increased UV radiation and low partial pressure of carbon dioxide (Billings and Mooney, 1968). There are many interesting adaptations in tundras, but one of the most universal is dwarfism (Billings and Mooney, 1968), which has captivated plant biologists for decades. Clausen et al. (1948) considered alpine and lowland variants of *Achillea* spp. and showed in classic experiments that differences in stature have a genetic basis. There have been hints that the stature of alpine plants can arise from hormonal differences, such as altered sensitivity to GA_3 and endogenous ethylene (Kurepin et al., 2006), but the causal genes have remained unknown.

A recent study of dwarf stature in alpine colonists of the molecular model Arabidopsis (*Arabidopsis thaliana*) provides intriguing new hints to the genetic basis of that most ubiquitous of tundra adaptations (Luo et al., 2015). The authors identified dwarf plants common in two high-altitude populations in the Swiss Alps. They showed, with transplant experiments, that dwarfism indeed appears to be locally adaptive at high altitudes. They found that a mutation in the gene encoding an important enzyme in the GA_3 pathway, GA 20-oxidase (*GA5*), was responsible for dwarfism (Luo et al., 2015). This particular mutation was common in two geographically proximal high-altitude sites in the Alps and was not found in 855 other Arabidopsis strains sampled from the 1001 Genomes Project (Cao et al., 2011), suggesting that it arose and persisted locally.

The study by Luo et al. (2015) places this potential alpine adaptation firmly in the realm of our knowledge of plant physiology. In agriculture, the Green Revolution of the 1960s and 1970s was facilitated by the development of crop strains with increased grain yield at the expense of biomass production. Dwarf plants in wheat (*Triticum aestivum*) and maize (*Zea mays*) are defective for a transcription factor that regulates GA_3 signaling (Peng et al., 1999), while the rice (*Oryza sativa*) Green Revolution dwarfing gene *Semidwarf* corresponds to the GA 20-oxidase (Spielmeyer et al., 2002), the homolog of the gene affected in the high-altitude Arabidopsis strains (Luo et al., 2015). Mutations in GA5 have been reported to sporadically cause semidwarf stature in Arabidopsis strains worldwide (Barboza et al., 2013), although without obvious association with altitude or other habitat factors. However, like the Green Revolution mutations, the Arabidopsis *ga5* mutants cause reduced stature without decreasing yield. This suggests that their spontaneous occurrence may be tolerated; thus, in Switzerland, one allele may have become fortuitously advantageous because it occurred in a population that colonized a high-altitude environment (Luo et al., 2015). This work provides an important inroad to begin understanding the genetic basis of alpine dwarfism and to begin extending this to other species to ask if GA_3 modulation is a common cause of dwarfism in alpine plants.

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