The secret of short stems

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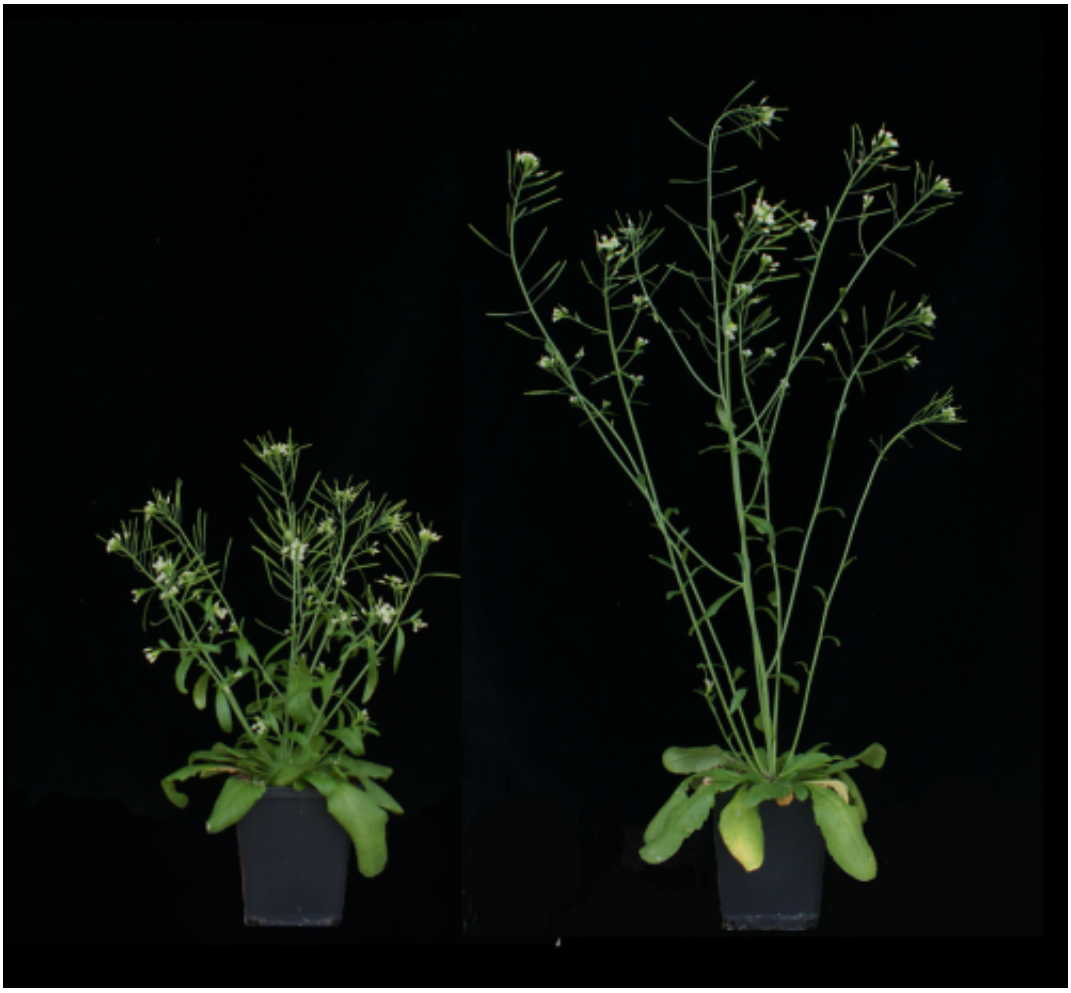

This shows different forms of growth of *Arabidopsis thaliana*: on the left, a plant with a mutation of the GA20ox1 gene, on the right, a plant without mutation. Credit: MPI f. Plant Breeding Research

The normal height to which plants grow is a critical trait. In the wild

Arabidopsis thaliana uses the same genetic changes in the biosynthesis of the growth factor gibberellin to cut its size in half as found in semi-dwarf varieties of rice and barley that have been bred by people. When expressing the same phenotype, various plant species apparently fall back on the same genes in their genotype. There must therefore be so-called "hot spots" whose repeated mutation produces the same traits that are beneficial in some conditions.

Long-stem plants may well be a splendorous in flowerbeds. However, long stalks in a grain field present a danger to the yield. Tall rice or barley varieties buckle over too easily under the load of their heavy panicles or ears. During the green revolution in the 1960s, numerous high-yield varieties with half the normal height were produced for agriculture in developing countries. Many of the rice and barley varieties owe their short stature to a gibberellin deficiency. Besides linear growth, this plant growth factor promotes seed germination and the development of the blossoms. The genetic changes in the semi-dwarf rice and barley varieties of the green revolution prevent a final step in the biosynthesis of gibberellin. The mutated gene carries the cryptic name GA20ox1.

Maarten Koornneef and his colleagues from the Max Planck Institute for Plant Breeding Research in Cologne have now examined whether *Arabidopsis* plants in the wild that grow to only half the height as other members of their same species also have a mutated GA20ox1 allele as the short rice and barley varieties of the green revolution do. "We would like to know whether the same genetic causes are found for the same phenotype through natural selection in the wild as are found through the artificial selection of plant breeding", explains Koornneef.

Arabidopsis only occurs in the northern hemisphere. The researchers in Cologne together with their colleagues in other countries have found samples of semi-dwarf *Arabidopsis* in 23 locations throughout Europe, Asia, and Japan. Using genetic crossbreeding experiments, they have

shown that this characteristic can be traced back to a change in the GA20ox1 gene in most of the plant specimens gathered. This gene is especially interesting in *Arabidopsis*, as mutations only cause the semi-dwarfism and have no further negative effects on the performance of the plants, even though gibberellin is an important plant growth factor. "The reason for this", according to Koornneef, "is that *Arabidopsis* possesses other additional genes for gibberellin biosynthesis. These genes jump in if GA20ox1 does not function. They apparently can compensate for all of the effects of the loss, except for the semi-dwarfism."

What changes cause *Arabidopsis* to switch the GA20ox1 gene off in the wild? Koornneef and his colleagues have identified six different genetic causes for the semi-dwarfism. These include mutations that the prevent the growth factor from being formed with the correct size, mutations that replace especially important amino acids with useless ones, as well as mutations that prevent the proper splicing of messenger RNA prior to the protein biosynthesis. In addition, the scientists have also found mutations that alter the reading frame of the GA20ox1 gene by removing part of the gene, then lengthening the gene sequence through insertion of foreign DNA, a so-called transposon.

Moreover, Koornneef and his colleagues were able to show that *Arabidopsis* only rarely displays semi-dwarfism in the wild. They describe the frequency of this trait as between one and five per cent. "If the frequency fluctuates in this way depending on the part of the world, there cannot be just one factor leading to the formation of this phenotype", says Koornneef. "One of these factors is the local environment.

Koornneef's investigations also prove that semi-dwarfism has arisen independently in every location. "The semi-dwarf *Arabidopsis* plants always had different genetic backgrounds", explains the geneticist, "and were actually related to their fellow *Arabidopsis* plants at the same sites.

This means that a mutation occurring at one location did not propagate." The trait also did not spread over a larger region, except in The Netherlands. The DNA sequence shows that a few plants attempted to rid themselves of the semi-dwarfism again. However other plants at some sites have selected for this dwarf phenotype because it apparently brought them advantages. The GA20ox1 gene is therefore one of these "hot spots" in the plants' genome becoming repeatedly mutated if a certain phenotype is beneficial at least under some specific conditions.

More information: Luis Barboza et al. Arabidopsis semidwarfs evolved from independent mutations in GA20ox1, ortholog to green revolution dwarf alleles in rice and barley *PNAS* DOI: 10.1073/pnas 1314979110

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