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All things dwarfed and beautiful

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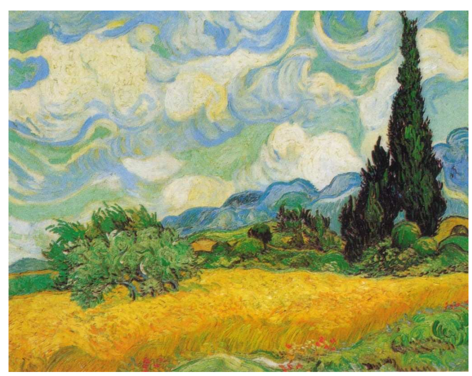
The world population increases daily, and with it the number of mouths to feed. As a consequence, finding ways to improve crop yield has become a major issue. Since the 1960s, grain production has grown exponentially. And while it took 10 000 years to produce the first billion tons of grain, it has only taken 40 years to produce the second, thanks to fertilisers, pesticides and intensive cross-breeding. As is frequently the case, the molecular mechanisms underlying the commercially improved phenotype are largely unknown. However, it appears that hormones known as gibberellins – along with the proteins they stimulate – have a central role in plant growth and development, and could be the molecules upon which to act in the future, to design cereals – or indeed other plants – that are favourable in terms of agronomy and economy.

In the 1950s, the use of fertilisers and pesticides on wheat produced varieties which bulged with grain but bowed under its weight – or were flattened in strong winds and rain – making it difficult to harvest. Japan presented the United States of America with a dwarfed version of wheat, whose stalks were short. The drawback though was that it did not produce so much grain and tended to be sterile. The Americans then crossbred the variety with another, and managed to create wheat that not only produced plenty grain but was fecund and did not fall over. Further crossbreeding was performed to design yet another variety that was plump with grain, short-stalked and could grow in tropical or subtropical conditions, such as Mexico. And this novel Mexican wheat received the Nobel Prize in Peace in 1970.

Fertilisers, pesticides and crossbreeding increased grain production not only drastically but also worldwide within only a few decades. And in 1968, the term 'Green Revolution' was coined to illustrate just this. But what were the genes that were being altered and spread from one variety into another? What were the genes that had such an effect on plant growth and development? The gene that was bred from the Japanese variety into the American and then the Mexican variety is known as Rht, i.e. 'reduced height'. Rht is a gene which causes wheat to be undersized. And currently, almost all – over 70% – of the commercial wheat is grown with an Rht mutant. Similar mutants are found in maize and vine, and are known as Dwarf-8 and Gai respectively. They are Rht orthologues and also produce plants with shorter stems.



'Wheat Field with Cypresses'
Vincent Van Gogh

On the molecular level, Rht, Dwarf-8 and Gai are all three involved in the gibberellin signaling pathway. Gibberellin is a plant hormone, which has a direct role in plant growth and development, such as stem elongation, flowering, pollen tube growth, seed germination and fruit development. Gibberellins are tetracyclic diterpenoids and over 120 have been discovered to date – in higher plants and fungi – although only a few are biologically active. Along with Rht and its orthologues, gibberellins produce the much sought after dwarfed stems.

How? Rht, Dwarf-8 and Gai are known as DELLA proteins because they all own a same stretch – DELLA – of conserved amino acids. And this domain is seemingly involved in the gibberellin response. The DELLA proteins are probably transcriptional regulators. Wild type Rht, Dwarf-8 and Gai repress plant development; in the presence of gibberellin, they are degraded and plant development is no longer checked. Mutant Rht can no longer respond to the gibberellin signalling pathway probably because it has been locked into a conformation that cannot respond to the plant hormone anymore and, as a result, plant growth is modified and dwarfed stems appear.

Besides knowing that the DELLA proteins probably act as transcriptional repressors, which are in turn controlled by the plant hormone gibberellin, much has still to be understood – not only on gibberellin signal transduction but also on the 3D structure of the wheat Rht protein, and consequently that of other DELLA proteins. Such knowledge would help to design proteins that would have an effect on gibberellin response, which in turn could improve – by way of genetic engineering – a number of plant characteristics of agronomical and commercial interest. And not only in wheat, but also in other types of cereal, such as rice for instance. Surprisingly, a grapevine cultivar – the champagne cultivar Pinot Meunier known to make excellent red wine – did not wait for the 1960s to introduce an Rht mutant orthologue – known as Vvgai1 – into its genome. The cultivar dates back to the 1500s, and the introduction of the mutation into the vine's genetic heritage at one point between then and now, also introduced a dwarfed phenotype of the grapevine… that has since given great pleasure to the taste buds of many a wine connoisseur.

Cross-references to Swiss-Prot

DELLA protein Rht-1, *Triticum aestivum* (Wheat): Q9ST59
DELLA protein dwarf-8, *Zea mays* (Maize): Q9ST48
DELLA protein Gai1, *Vitis vinifera* (Grapevine): Q8S4W7

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