Tailor-made plants using next-generation molecular scissors

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Since the practice of agriculture began around ten thousand years ago, man has always tried to adapt plants to his convenience, identifying and crossing varieties with traits that were beneficial to his wellbeing, a practice later named Plant Breeding. For a long time, this was achieved only by observing and selecting the diversity of plants that are available as natural resources, collecting the seeds of those that looked best and propagating them over generations. The variety of traits found in nature reflects the presence of one or multiple changes in certain genes, and these changes (i.e. naturally occurring mutations) arise as mistakes in the repair mechanism initiated after DNA damage. In the late 1920s, it was discovered that this natural variability could be increased by exposing plants to X-rays or chemicals which cause extensive DNA damage and therefore, as a DNA break is often repaired imprecisely, mutations. These findings considerably expanded the range of practically useful traits available for breeding and accelerated the establishment and release of new improved plant varieties. However, with this approach the genetic changes are induced casually, which means that one still needs to screen a large number of individuals to identify those carrying the mutation in the gene of interest, and it remains unclear if and which alterations all the other random-induced mutations may cause. The long-sought-after solution to this problem came about in the late 1990s with the discovery of site-specific nucleases (SSNs), a sort of sophisticated “molecular scissors” that can be programmed to cut the DNA precisely at a pre-determined site of choice, enabling the directed introduction of changes (i.e. a mutations) in the target gene. This technology is called Genome Editing. Interestingly, when a short piece of DNA is provided that serves as a patch (i.e. a template) to close the break, the outcome of the repair process can be directed at will, and not only the position but also the type of mutation can be controlled. Even more intriguingly, knowing where the break is going to occur, it is possible to design an *ad-hoc* large piece of DNA to be incorporated at the selected site, allowing the introduction of whatever new genetic information one desires. With these tools at hand, it is now feasible to generate tailor-made plants introducing mutations, e.g. to study the function of a particular gene in basic research, as well as increase the productivity of a crop by enlarging the grain size; change the flower colour of an ornamental plant, or make a tree resistant to a certain pathogen. With the more sophisticated approaches involving the delivery of a DNA template, one could introduce a whole new metabolic pathway to make a plant produce large amounts of a desired compound used for medical applications or create a ‘safe harbour’, an optimal position in the genome ensuring high levels of gene expression of any transgene that is inserted.

In this talk I will introduce you to the world of SSNs and especially describe the features, potentials and drawbacks of the latest and most promising of all, the CRISPR/Cas system. I will give an overview of the different applications of this technology in plants and stress the peculiarities of plants compared to other organisms with respect to genome editing.