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Introducing New Varieties of Food through "New Breeding Techniques"

In previous years, most of the genetically modified crops are mainly designed to tolerate certain herbicides and resist diseases and insect infestations to benefit farmers, or have additional health and nutritional benefits for consumers. Recently, scientists have started introducing some plants as new varieties of food by using different genetic engineering techniques to modify the gene expression or genetic make-up of plants.

For examples, edible cottonseeds have been developed by gene silencing to selectively silence the expression of an enzyme involved in the biosynthesis of toxic compounds in the seed of the cotton plant. Wild plants such as wild tomato and groundcherry have also been domesticated for food use by introducing mutations at several genes associated with the desirable traits, through genome editing. These techniques are some of the so-called "new breeding techniques" developed in recent years. Let's take a look at these examples in this article.

Edible cottonseeds

Cottonseeds are rich in oil and proteins. However, they are unfit for direct human consumption because they contain a toxic compound called gossypol, which is produced naturally by the cotton plant for defense against insects and diseases. Gossypol causes heart and liver damage in humans, and also infertility in male by inhibition of sperm production and motility. Therefore, although a significant amount of cottonseeds is produced as a by-product of cotton fiber production for textiles, they have limited uses in food production due to the presence of gossypol, e.g. only for the production of edible oil with gossypol removed during the oil refining process.

Hence, attempts were made to mitigate the toxic effects of gossypol in cottonseeds. Recently, a type of low gossypol cottonseeds has been developed by selectively silencing the expression of an enzyme involved in the biosynthesis of gossypol and related compounds in the seed of the cotton plant. This reduced the gossypol levels in the seed by 97% without affecting the levels of gossypol and related compounds in the rest of the plant where they are needed for defense against insects and diseases. The low gossypol cottonseeds can be potentially utilised directly for human consumption, e.g. as cottonseed kernels and defatted cottonseed flour, apart from being used for the production of cottonseed oil, hence improving the utility and overall economic value of the cottonseeds.

The U.S. Food and Drug Administration (FDA) completed its evaluation for the cotton with reduced levels of gossypol in seed in October 2019. Pertaining to human food uses, the FDA concluded that human food from the cotton is as safe as and, with the exception of reduced levels of gossypol in seed, does not differ in composition from cotton-derived human food currently on the market.

Domesticated tomato and groundcherry

Wild plants often have certain undesirable characteristics for large-scale agricultural production. For example, wild tomato and groundcherry have a sprawling growth habit and produce small fruits dropping to the ground, making them difficult to grow and harvest on a large scale for food use without any further domestication processes to improve the relevant traits.

Conventional breeding has long been used to domesticate wild plants. It usually makes use of crossing of closely related individuals to produce plants with desirable properties. However, it often takes a long time involving the cultivation and selection of generations of plants for those with the desirable traits as it is unknown where the changes in the genome have occurred. Recently, rapid domestication of wild plants has been achieved in a single generation through genome editing, which involved the introduction of mutations directly at several genes associated with the desirable traits for domestication at the same time.

For example, the application of genome editing to rapidly domesticate wild plants has been demonstrated in wild tomato species which are resistant to bacterial spot disease and/or salt tolerant. Tomato is one of the important crops commonly cultivated so its genome has been well studied. Based on this knowledge, genes related to plant architecture, flower and fruit production, and vitamin C synthesis were identified in the related wild tomato species and mutations were directly introduced at these genes simultaneously through genome editing. The resulting tomato plants had various desirable traits for domestication, e.g. having more compact plant architecture and mostly synchronised fruit ripening, earlier flowering, increased vitamin C levels and enlarged fruit size (see Figure). This allowed high-density growth and easier and earlier harvesting of the tomato plants, and increased the quality of the tomatoes produced. Last but not least, the domesticated tomato still retained the characteristic of the original wild tomato being resistant to bacterial spot disease and/or salt tolerant, hence facilitating the plants to adapt to changes in the environment.

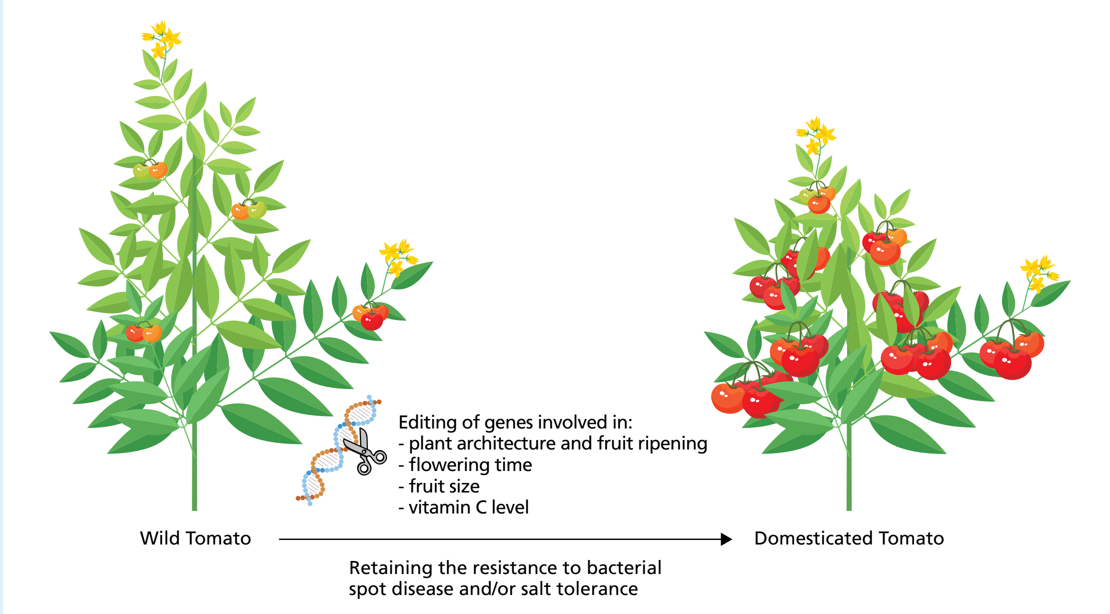

Figure: Domestication of wild tomato through genome editing. The domesticated tomato showed more compact growth with almost synchronised fruit ripening, flowered earlier, and had increased vitamin C levels and enlarged fruit size, while retaining the characteristic of the wild tomato being resistant to bacterial spot disease and/or salt tolerant.

Groundcherry, another wild plant in the same family as tomato, has also been successfully improved for domestication through genome editing. Groundcherry is genetically related to tomato and the knowledge of the genome of tomato can be applied to identify genes of similar functions in groundcherry related to the desirable traits for domestication. Genes which control plant architecture, flower production and fruit size were identified in groundcherry and they were mutated simultaneously through genome editing. The resulting groundcherry plants showed more compact growth, and produced more flowers, higher concentrations of fruits along each shoot and enlarged fruits, hence facilitating the cultivation, harvesting and also enhancing the customer quality of the groundcherries.

With the understanding of the traits related to domestication in other crops, e.g. maize, wheat and sorghum, genome editing can potentially be applied for rapid domestication of the wild varieties of these plants and also their genetically related plants which have not yet been domesticated, providing new varieties of food.

More new varieties of food are yet to come

New breeding techniques, such as gene silencing and genome editing, can be applied to modify the gene expression or genetic make-up of plants precisely and rapidly, introducing desirable traits to them so that they can be introduced as new varieties of food. With the wider application of these new breeding techniques, many other plants which have not yet entered into our food basket will one day be available in the food market.

For more information on GM food, please visit our website

http://www.cfs.gov.hk/english/programme/programme_gmf/programme_gmf.html

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