Over the last 50 years, the field of genetic engineering has developed rapidly due to the advent of DNA technology. This technology has been employed to exchange the genes of one species with those of another species.

Genetic engineering and genetic modification refer to the transfer of genes between organisms. Genetic engineering accomplishes this transfer of genes between species. Genetic modification, however, involves the transfer of genes between closely or distantly related organisms. Genetic modification is used to change the same or very closely related species, while genetic engineering can be used to transfer a gene of interest from one species to another. Genetic engineering is used to change the genetic material of an organism to achieve a specific goal. Genetic modification involves the transfer of a gene to an organism to achieve a specific result.

Table 1. Conventional Breeding vs. Genetic Engineering

<table>
<thead>
<tr>
<th>Conventional Breeding</th>
<th>Genetic Engineering</th>
</tr>
</thead>
<tbody>
<tr>
<td>Allows transfer of one gene of interest</td>
<td>Allows transfer of one gene of interest</td>
</tr>
<tr>
<td>No guarantee of obtaining any particular gene combination</td>
<td>Guarantees obtaining a single gene of interest</td>
</tr>
<tr>
<td>Limited to exchanges between the same or very closely related species</td>
<td>Allows the transfer of genes from different species</td>
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</table>
| Results are produced by the Global Knowledge Center and GM Crops | Pocket Ks are Pockets of Knowledge, packaged information on crop biotechnology products and related issues available at your fingertips.

References

Nature's own genetic engineer

The "sharing" of DNA among living forms is well documented as a natural phenomenon. For thousands of years, genes have moved from one organism to another. For example, Agrobacterium tumefaciens, a soil bacterium known as ‘nature’s own genetic engineer’, has the natural ability to genetically engineer plants. It causes crown gall disease in a wide range of broad-leaved plants, such as apple, pear, peach, cherry, almond, raspberry, and roses. The disease gains its name from the large tumor-like swellings (galls) that typically occur at the crown of the plant, just above soil level. Basically, the bacterium transfers part of its DNA to the plant, and this DNA integrates into the plant's genome, causing the production of tumors and associated changes in plant metabolism.

Application of genetic engineering in crop production

Genetic engineering techniques are used only when all other techniques have been exhausted, i.e. when the trait to be introduced is not present in the germplasm of the crop; the trait is very difficult to improve by conventional breeding methods; and when it will take a very long time to introduce and/or improve such trait in the crop by conventional breeding methods (see Figure 2). Crops developed through genetic engineering are commonly known as transgenic crops or genetically modified (GM) crops.

Modern plant breeding is a multi-disciplinary and coordinated process where a large number of tools and elements of conventional breeding techniques, bioinformatics, molecular genetics, molecular biology, and genetic engineering are utilized and integrated.

Development of transgenic crops

Although there are many diverse and complex techniques involved in genetic engineering, its basic principles are reasonably simple. There are five major steps in the development of a genetically engineered crop. But for every step, it is very important to know the biochemical and physiological mechanisms of action, regulation of gene expression, and safety of the gene and the gene product to be utilized. Even before a genetically engineered crop is made available for commercial use, it has to pass through rigorous safety and risk assessment procedures.

The first step is the extraction of DNA from the organism known to have the trait of interest. The second step is gene cloning, which will isolate the gene of interest from the entire extracted DNA, followed by mass-production of the cloned gene in a host cell. Once it is cloned, the gene of interest is designed and packaged so that it can be controlled and properly expressed once inside the host plant. The modified gene will then be mass-produced in a host cell in order to make thousands of copies. When the gene package is ready, it can then be introduced into the cells of the plant being modified through a process called transformation. The most common methods used to introduce the gene package into plant cells include biolistic transformation (using a gene gun) or Agrobacterium-mediated transformation. Once the inserted gene is stable, inherited, and expressed in subsequent generations, then the plant is considered a transgenic. Backcross breeding is the final step in the genetic engineering process, where the transgenic crop is crossed with a variety that possesses important agronomic traits, and selected in order to obtain high quality plants that express the inserted gene in a desired manner.

The length of time in developing transgenic plant depends upon the gene, crop species, available resources, and regulatory approval. It may take 6-15 years before a new transgenic hybrid is ready for commercial release.

Commercially available crops improved through genetic engineering

Transgenic crops have been planted in different countries for twenty years, starting from 1996 to 2015. About 179.7 million hectares was planted in 2015 to transgenic crops with high market value, such as herbicide tolerant soybean, maize, cotton, and canola; insect resistant maize, cotton, potato, and rice; and virus resistant squash and papaya. With genetic engineering, more than one trait can be incorporated or stacked into a plant. Transgenic crops with combined traits are also available commercially. These include herbicide tolerant and insect resistant maize, soybean and cotton.

New and future initiatives in crop genetic engineering

To date, commercial GM crops have delivered benefits in crop production, but there are also a number of products in the pipeline which will make more direct contributions to food quality, environmental benefits, pharmaceutical production, and non-food crops. Examples of these products include: rice with higher levels of iron and beta-carotene (an important micronutrient which is converted to vitamin A in the body); long life banana that ripens faster on the tree and can therefore be harvested earlier; tomatoes with high levels of flavonols, which are powerful antioxidants; arsenic-tolerant plants; edible vaccines from fruit and vegetables; and low lignin trees for paper making.