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The Future Of Agricultural Biotechnology: A Step Forward

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Introduction: Scientists have been improving plants by changing their genetic makeup since the late 1800s. Typically, this has been accomplished through crossbreeding and hybridization, in which two related plants are cross-fertilized and the resulting offspring have characteristics of both parent plants. In the breeding process, however, many undesirable traits often can appear in addition to the desirable ones. Some of those undesirable traits can be eliminated through additional breeding, which is time consuming. Breeders can then further select and reproduce the offspring that have the desired traits. Many of the foods that are already common in our diet are obtained from plant varieties that were developed using conventional genetic techniques of breeding and selection. Today, by inserting one or more genes into a plant, scientists are able to produce a plant with new, advantageous characteristics. The new gene splicing techniques are being used to achieve many of the same goals and improvements that plant breeders historically have sought through conventional methods. They give scientists the ability to isolate genes and introduce new traits into foods without simultaneously introducing undesirable traits. This is an important improvement over traditional breeding. Because of the increased precision offered by the bioengineered methods, the risk of introducing detrimental traits is actually likely to be reduced.

Gene and genome analysis:

Detailed studies have been conducted on plant genome and physical and genetic maps are available for several plants. As an example of studies on genome the rice genome is discussed here. Rice has a much smaller genome (430 Mbp per haploid genome) than many other crops that belong to the Poaceae family. Due to the genome colinearity, high similarity in gene order and gene content, among the Poaceae family, the importance of rice genetics has been emphasized, and comparative analyses among rice, wheat, and maize have been intensively studied. As a result, rice becomes the model crop for the molecular genetic approach. This crop is available for many applications, including the construction of a high dense map, expressed sequence tag (EST) and full genomic sequence database, bacterial and yeast artificial chromosome (BAC and YAC) libraries, quantitative traits loci (QTL) mapping for yield and morphology, functional genomics by knockout mutagenesis using T-DNA insertion, map-based cloning, and genetically modified rice using transformation techniques. (see review Cho et al. 2007 cited in Kumar and Sopory 2007). State-of-the-art Genome Profiling (GP) : The traditional approach for species identification is exclusively based on phenotypic traits such as morphological, anatomical, chemical properties and others, which are often affected by environmental factors and thus are difficult to analyze and unreliable. Interspecies homogeneity, intraspecies variability and the existence of undescribed species often lead to phenotypic misidentification. Moreover, species, which are phenotypically far less prominent, cannot be always identified in this way. To overcome these problems, genotypebased (nucleic acid-based) techniques'have been employed as an alternative or complementary approach and have continuously been developed including RFLP,AFLP, RAPD, 16S rRNA or 16S-23S internal transcribed spacer (ITS) sequence analysis and others. These methods provide a possible way to identify species directly based on their genomic sequences but none of them have been shown to identify species in general, mainly because of the insufficiency in the amount of information which they can provide.

In this stream, the whole genome sequencing is surely the most definitive solution for species identification though simply too redundant for such purposes and impossible in practice to analyze all the constituents of a heavily dense population. On the other hand, the information obtained from the comparison of a single gene is often not sufficient to place a species at the appropriate position on the phylogenetic tree. In order to deal with above issues, previously Nishigaki and co-workers have described a realistic solution conforming to the notion of the amount of information sufficient for species identification and demonstrated this by inventing a novel method called Genome Profiling (GP), which is a temperature-gradient gel electrophoresis (TGGE) analysis of random-PCR products. Next, the complexity of the generated data, genome profiles, can be simplified by extracting feature points in GP, i.e., species identification dots (spiddos) which can be used for further processing of measuring the similarity of two species by calculating Pattern Similarity Score (PaSS). Further, the technical advances by constructing internet-based GP databases (named On-web GP), and developing a highly reproducible and miniaturized system (micro-TGGE) have moved this technology towards being a universal, general and global tool for species identification (see review Biyani 2007 cited in Kumar and Sopory 2007).

Biological Engineering:

Biotechnological engineering or biological engineering is a branch of engineering that focuses on biotechnologies and biological science. It includes different disciplines such as biochemical engineering, biomedical engineering, bio-process engineering, biosystem engineering and so on. Because of the novelty of the field, bioengineer is still not clearly defined. However, in general it is an integrated approach of fundamental biological sciences and traditional engineering principles. Biotechnologists are often employed to scale up bio processes from the laboratory scale to the manufacturing scale. Moreover, as with most engineers, they often deal with management, economic and legal issues. Since patents and regulation (e.g., U.S. Food and Drug Administration regulation in the U.S.) are very important issues for biotech enterprises, bioengineers are often required to have knowledge related to these issues.

The increasing number of biotech enterprises is likely to create a need for bioengineers in the years to come. Many universities throughout the world are now providing programs in bioengineering and biotechnology (as independent programs or specialty programs within more established engineering fields).

Bioremediation and biodegradation:

Biotechnology is being used to engineer and adapt organisms especially microorganisms in an effort to find sustainable ways to clean up contaminated environments. The elimination of a wide range of pollutants and wastes from the environment is an absolute requirement to promote a sustainable development of our society with low environmental impact. Biological processes play a major role in the removal of contaminants and biotechnology is taking advantage of the astonishing catabolic versatility of microorganisms to degrade/convert such compounds. New methodological breakthroughs in sequencing, genomics, proteomics, bioinformatics and imaging are producing vast amounts of information. In the field of Environmental Microbiology, genome-based global studies open a new era providing unprecedented in silico views of metabolic and regulatory networks, as well as clues to the evolution of degradationpathways and to the molecular adaptation strategies to changing environmental conditions. Functional genomic and metagenomic approaches are increasing our understanding of the relative importance of different pathways and regulatory networks to carbon flux in particular environments and for particular compounds and they will certainly accelerate the development of bioremediation technologies and biotransformation processes.

Marine environments are especially vulnerable since oil spills of coastal regions and the open sea are poorly containable and mitigation is difficult. In addition to pollution through human activities, millions of tons of petroleum enter the marine environment every year from natural seepages. Despite its toxicity, a considerable fraction of petroleum oil entering marine systems is eliminated by the hydrocarbon-degrading activities of microbial communities, in particular by a remarkable recently discovered group of specialists, the so-called hydrocarbonoclastic bacteria (HCCB).

Biotechnology regulations:

The National Institutes of Health (NIH) was the first federal agency to assume regulatory responsibility in the United States. The Recombinant DNA Advisory Committee of the NIH published guidelines for working with recombinant DNA and recombinant organisms in the laboratory. Nowadays, the agencies that are responsible for the biotechnology regulation are: US Department of Agriculture (USDA) that regulates plant pests and medical preparation from living organisms, Environmental Protection Agency (EPA) that regulates pesticides and herbicides, and the Food and Drug Administration (FDA) which ensures that the food and drug products are safe and effective.

Agricultural Biotechnology:

For thousands of years, humans have manipulated nature to grow the best crops and livestock. By matching together various strains of crops or animals, we've guided the developmental path of countless organisms. If you were to step back in time thousands of years, the crops you'd see would look very different - in some cases, they'd be unrecognizable!

Agricultural biotechnology is a set of tools and disciplines meant to modify organisms for a particular purpose. That purpose can include anything from coaxing greater yields from food crops to building in a natural resistance to certain diseases. Though there are multiple ways to accomplish this goal, the method that tends to get the most attention from the public is genetic modification.

Genes are the basic units of hereditary information. A gene is a segment of deoxyribonucleic acid (DNA) that expresses a particular trait or contributes to a specific function. Genes determine everything from the color of your eyes to whether or not you are allergic to certain substances.

As we learn more about which genes affect different aspects of an organism, we can take steps to manipulate that feature or function. One way to do this is to take genetic information from one organism and introduce it into another -- even if that organism belongs to a completely different species. For example, if you found out that a particular bacterium had a resistance to a certain herbicide, you might want to lift those genes so that you could introduce them into crops. Then you could use herbicides to wipe out pest plants such as weeds while the crops remain safe.

While some people might think that changing organisms at such a fundamental level is unnatural, the truth is that we've been using a much cruder method of shaping organisms for centuries. When farmers crossbreed plants, they are engaging in a primitive form of this methodology. But with crossbreeding, all the genes of one type of organism are introduced to all the genes of the second organism. It's not precise, and it can take generations of plants before farmers arrive at the desired result.

Benefits of Agricultural Biotechnology:

The applications of agricultural biotechnology are nearly limitless. Your own diet may include many products that are the result of agricultural biotechnology projects. Produce, milk and other foodstuffs may be in your store courtesy of agricultural biotechnology.

Through genetic manipulation, scientists can create crops that produce more than their unmodified counterparts. It's also possible to introduce genes so that a crop has more nutritional value. The Golden Rice Project is a good example scientists have used genetic engineering to produce rice rich in vitamin A. While rice already has genes that would produce vitamin A in wild species, these genes are turned off during the growth process. The genes inserted into golden rice keep the vitamin A production genes turned on.

Another useful application of agricultural biotechnology is to give plants the ability to grow in a wider range of environments.

Some plants do well only in certain climates or soil conditions. By introducing genes from other organisms, scientists can alter these plants so that they'll grow in climates that normally would be too harsh for them. Land previously unsuited for crops can be reclaimed for food production.

A third application involves making plants more resistant to disease, pests and chemicals. Genes can give plants a defense against threats that could normally wipe out an entire generation of crops. Genetic manipulation can lead to plants that are toxic to pests but still safe for human consumption. Alternatively, scientists can develop genes that will make crops resistant to pesticides and herbicides so that farmers can treat their crops with chemicals.

Genetic manipulation doesn't stop there. By introducing new genes -- or turning off existing genes -- scientists can change everything from the appearance of food to its taste. But while genetic engineering and modification has many benefits, the practice isn't free of criticism. Some scientists, agriculturalists and activists are worried about what genetic modification could produce in the long term.

Criticisms of Agricultural Biotechnology:

Any time a process involves manipulating living organisms for a specific purpose, criticism is sure to follow. Some may feel that any sort of genetic manipulation is wrong. Scientists working on agricultural biotechnology point out that we've been genetically modifying organisms for generations - we're just much more precise now.

But there are other, more specific criticisms that aren't as easy for scientists to dismiss. One is that genetic modification often requires scientists to take genes from one organism and insert them into a completely unrelated organism. This wouldn't necessarily happen otherwise, and so the counterargument that we've been doing this for centuries doesn't really apply.

Another objection is that we aren't really sure what the long-term effect on the environment will be. What happens if genes from modified crops find their way into the wild species? It's difficult to assess exactly what impact modified crops might have on indigenous species of plants. It could be possible that other species of plants could develop similar traits to modified crops. If weeds develop resistance to herbicides, we're back to square one on that front.

Some fear that by introducing genetic material into crops, scientists may also create new allergens. In the United States, the Food and Drug Administration places strict regulations on genetically modified food that include extensive allergenic tests. It may even be possible to remove the allergenic components in existing foods to make them safe for people who otherwise would have to avoid that type of food.

Pest-resistant crops might lead to a few problems. Farmers might use more chemicals to treat crops genetically engineered to resist poisons. These chemicals could build up toxins in the soil or seep into groundwater. Genetically modified crops with toxic proteins designed to ward off pests could also affect other species. On the other hand, farmers wouldn't need to use as much pesticide when growing crops with a built-in pest repellent. Some studies suggest that by decreasing the reliance on pesticides, some species may actually benefit from a switch to genetically modified crops.

There's also a fear among some agriculturalists that biotechnology could lead to a decrease in biodiversity. If we find a particular crop to be profitable and easy to grow, farmers may abandon other varieties in favor of the modified crop. Decreasing diversity could lead to dangerous consequences. Entire populations of crops could die out if hit by disease. Diversity can also help keep soil healthy and prevent toxins from building up over time.

Ultimately, we must weigh the potential benefits of agricultural biotechnology against the risks. The U.S. Food and Drug Administration (FDA) has tight regulations on genetically modified crops designed to ensure scientists use safe protocols when developing new crops. If we trust in science while remaining vigilant, we may find that agricultural biotechnology could help feed the world.

Current Uses of Biotechnology in Agriculture Genetic engineering can be used to modify the genetic compositions of plants, animals, and microorganisms. The number of genes that have been isolated and are available for transfer is growing daily. Currently, the technology is used primarily to modify crops, although a number of other applications are in the wings.

Like other products, genetically engineered products undergo a period of research and development before they are ready for commercial release. Many products never emerge from the research and development pipeline. While this is true for almost any technology, genetic engineering is turning out to be more difficult and more expensive than early proponents expected. Although in the early 1980s biotechnology was touted as a miracle technology that was going to usher in a new era of agricultural abundance with minimal harm to the environment, the initial set of products has proved modest. Some of the most important commercial applications of biotechnology are discussed below.

Engineered Crops :

The most widespread application of genetic engineering in agriculture by far is in engineered crops. Thousands of such products have been field tested and over a dozen have been approved for commercial use. The traits most commonly introduced into crops are herbicide tolerance, insect tolerance, and virus tolerance.

Herbicide Tolerance:

Case Study: Soybeans

Herbicide tolerance allows crops to withstand otherwise lethal doses of herbicides, which are chemicals that kill plants. Some herbicides kill virtually all plants and cannot be used on crops. By offering crops tolerant to herbicides, chemical companies can expand the market for their products. Indeed, the major developers of herbicide-tolerant plants are companies that sell herbicides. The current set of commercially available herbicide-tolerant crops is tolerant to three herbicides based on three active ingredients: Bromoxynil, Glyphosate, and Glufosinate.

Insect Tolerance:

All of the commercially available insect-tolerant plants contain a version of the toxin Bacillus thuringiensis (Bt), which is found in nature in soil bacteria. Bt toxins are highly effective for many pest organisms, like beetles and moth larva, but not toxic to mammals and most other nontarget organisms. A major concern among farmers and environmentalists is that wide use of Bt crops will lead to the rapid development (over the course of perhaps as few as three to five years) of resistance to the toxin. If resistance develops, the Bt toxin will be useless as a pesticide. In this case, the environmental benefits of the product will be short lived.

Loss of Bt efficacy will affect those who currently use the engineered Bt crops, but also many other farmers who use Bt in its natural bacterial form, usually as a spray. These other farmers include those who grow food organically and those who use Bt as part of integrated pest management (IPM) plans. Natural Bt sprays are a valuable mode of pest control for these farmers. Organic farmers and others who rely on Bt question whether the companies who sell the Bt crops have the right to use up this resource guided only by commercial calculations. UCS considers Bt to be a public good that should be reserved for everyone.

The third major application of biotechnology to crops is virus tolerance. These crops contain a gene taken from a virus. By a process that is not well understood, plants that produce certain viral proteins are able to fend off infections by the viruses from which the proteins were taken. Two virus-tolerant crops are currently approved for commercial use, papaya and squash. The squash, which is resistant to two viruses, is currently off the market. Although it is difficult to get information on why products are not on the market, it is possible that the squash did not perform well enough in the field to capture market share.

Summary:

Many genetically engineered products have been .ruct a "hybrid" virus made up of a component of the rabies virus inserted into an unrelated "carrier" virus. The resulting virus confers immunity to rabies but poses no danger of causing the disease. Baits laced with the vaccine have been distributed in many parts of the eastern United States in attempts to combat rabies in wild raccoon populations. The vaccine has been approved by the U.S. Department of Agriculture, despite suspicions that it has been only marginally, if at all, effective. Early studies on efficacy failed to demonstrate that the product could control rabies in wild raccoon populations. Data from more recent studies are being withheld from the public as confidential business information.

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