BIOTECHNOLOGY IN RURAL AREA

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Summary

Biotechnology denotes gene engineering in a narrow sense and all technologies using biological engineering or methods in a broad sense. In the view of international organizations, biotechnology comprises any technology using biological materials. All biological and ecological technologies belong to biotechnology since humans, plants, animals, and microorganisms are all biological materials.

Biotechnology in rural areas means that biotechnology has been extended or is being applied in rural areas and includes traditional/ conventional biological technology as well as gene engineering technology.

1. Introduction

Biotechnology can be defined as the biological study of living organisms, the relationships between living organisms and the environment, and the interrelationships between living organisms and utilizing living organisms through engineering to increase industrial and agricultural production, improve economic or agronomic characteristics, and protect the environment (see *Biotechnology*). As commonly understood in China, biotechnology denotes biological engineering - that is to say, the study of plants, animals and microorganisms either aquatic or terrestrial on the cellular and molecular level for improvement of the quality of life. Agricultural (biological) engineering mainly denotes improving the yield and quality of main plant crops, their pest and disease resistance capabilities and the yield and anti-adverse condition traits of animals. Biotechnology helps agriculture to become a most promising and prospective industry for application (see also - *Agricultural Biotechnology*).

Biotechnology has undergone a development from relatively low technology to high technology and from biological control and/or biological utilization to gene engineering. The gene sources depend on the biological study of living organisms and the relationship between living organisms. At the beginning, a new technology may be a high technology, but it could become a low technology as time lapses. There is some high knowledge in so-called low technology while there is some knowledge in high technology, which is easy to learn and to master. So it cannot be said that only high technology is biotechnology whereas low technology is not. Therefore, biotechnology denotes gene engineering in a narrow sense and all technologies by using biological methods in a broad sense. In the view of international organizations, ‘biotechnology comprises any technology using biological material’. All the biological and ecological technologies belong to biotechnology since humans, plants, animals, and microorganisms are all biological materials. Biotechnology in rural areas means the biotechnology that has been extended or is being applied in rural areas, which includes traditional/conventional biological technologies as well as gene engineering technology.

2. Advanced Biotechnological Achievements Applied in Rural Areas

2.1. Gene Engineering

Gene engineering technology (see also - *Methods in gene engineering*) developed in the 1970s, initiating a period of very rapid development. In the 1980s, gene engineering realized a preliminary industrialization in medical and pharmaceutical industries. In the 1990s, research and application of this new area of biotechnology not only expanded industrialization, but also entered into the domains of agriculture, environment protection, oceanography, biological manufacture, bio-treatment, and energy research. It has been forecast that biotechnology industries, like information industries will become one of the pillars of world economic development in the 21st century (see also - *Bioinformatics*)

In 1998 there were eight countries in the world where the area of transgenic plants (see also - *Transgenic Plants*) under cultivation reached 2,780 ha, a 15 times increase in the area since 1996 (not including data in China). These eight countries included five developed countries [U.S.A., Canada, Australia, Spain, and France] and three developing countries [Argentina, Mexico and South Africa]. Among the eight countries, Spain, France and South Africa cultivated transgenic plants for the first time. The area of transgenic plants under cultivation in Mexico, Spain, France, South Africa and China were all under 100,000 ha.

2.2. Transgenic Cotton

Transgenic Bt (*Bacillus thuringiensis*) cotton developed by the Biological Engineering Center of the Chinese Academy of Agricultural Sciences has been planted in nine main cotton-producing districts. The area under cultivation reached more than 10,000 ha in 1999. This enabled an 80 percent reduction in the use of agricultural chemicals against the bollworm *Helicouerpa armigera*, and a labor saving of 150 man-days per ha, a total saving of $200 per ha. Although the seed price of Bt-cotton was 3-5 times that of common cotton, it has been welcomed by farmers. On the basis of pest resistance gene (GFM Cry IA Bt), the Chinese scientists Guo Sandui and his coworkers have recently modified the CpTI (Cowpea Trypsin Inhibitor) gene to express the Bt + CpTI gene. They further introduced this gene by using a pollen tube transfer technique (anther culture) into main cotton strains in different cotton producing districts and gained several dozen double transgenic strains of cotton such as SGK 321 (receptor Sheyuan 321) in China. The area under cultivation of transgenic Bt + CpTI cotton reached 400 ha and will soon be extended to 10,000 ha.

Monsanto transgenic Bt cotton [NuCOTTON33B] from the Delta and Pine Land Company was planted in Anhui Province with an area of 1000 mu (66 ha) in 1998 and 40,000 mu (2,666 ha) in 1999. The highest output was 395.7 kg mu^{-1} (5,935.5 kg ha^{-1}), and averaged 218 kg mu^{-1} (3,270 kg ha^{-1}). The output of Monsanto pest-resistance cotton might reach 320-325 kg mu^{-1} (4,800~4,875 kg ha^{-1}) in Hebei Province in 1999. The area under cultivation of transgenic Bt cotton was 8,000 ha in Argentina, 80,000 ha in Australia, 52,000 ha in China, 40,000 ha in Mexico and 12,000 ha in South Africa, according to the ICAC Recorder 1999 (see also - *Crop protection through pest resistance genes*).

Recent research shows that BT cotton is effective in controlling the primary pest of cotton. However, laboratory experiments and field research shows that there are adverse environmental impacts associated with the cultivation of BT cotton including:

- associated adverse impacts on parasitic natural enemies of cotton bollworm (primary pest)
- BT cotton is not effective in controlling many secondary pests, leading to a relative increase in secondary pest with respect to the bollworm, although some pests replace the bollworm as the primary pest and damage cotton growth.
- The diversity indices of the insect community are all lower than those in conventional cotton fields.
- Cotton bollworm can develop resistance to BT cotton

2.3. Transgenic Rice

Scientists at Zhejiang University have adopted the co-transferring technique through pollen tube to create a new transgenic rice strain that is resistant to both snout moth's larva and herbicide. Snout moth's larva is the main pest to damage rice in Asia and the annual loss reaches 10% on average. This new strain will not only increase production by preventing losses to snout moth's larva, but will also reduce the costs and dangers associated with applying chemicals to control snout moth's larva in rice fields. But transgenic rice is still not commercialized in China.

2.4. Transgenic Rape-Seed

Recently it has been reported that American scientists have bred transgenic rape- seed, which can be used to produce polyhydroxbutyrate, which is the base material of readily-degradable bio plastics (see also - *Bioplastic and biopolymer production*). This could be an important step in controlling white pollution throughout the world.

2.5. Transgenic Fish

The first scientist doing basic research on transgenic fish was Tong Dizhou in China. He studied nucleus transplanting in 1964, transgenic fish in 1973, 1975 and 1976, and he studied hybridization of common carp nucleus and crucian carp cytoplasm in 1979 and got 35 hybrid of common carp nucleus and crucian carp cytoplasm and one hybrid of crucian carp nucleus and common carp cytoplasm. In common carp genetic engineering, Zhu Zuoyan was the first to rebuild the 'whole fish' growth hormone gene by using a Beta-actin promoter gene and the growth hormone gene code sequence of grass carp, and he developed a rapid growth transgenic common carp by gene transfer technology. This transgenic fish can grow to 2,600 g in 120 days, which was four times the control, but unfortunately it does not have stable genetic traits. In the transgenic fish model study, the integration behavior of the exogenous gene into the receptor gene group is very complicated. On the aspect of time, the integration of exogenous gene among cells is not synchronous, and on the aspect of space, the integration loci appear randomly and they could be integrated to different loci or multi-loci of chromosome. So the fish has not yet been released.

2.6. Transgenic Animal and Bio-Pharmaceuticals

The achievement of the transgenic bull Taotao carrying human serum albumin gene developed by the Shanghai Medical Genetics Research Institute was recognized as the first of the top ten basic research projects of China and one of the top ten news on science and technology progress in 1999 in Shanghai.

A transgenic animal (see also - *Transgenic animals*) is different from a cloned animal. At first Chinese Academician Zeng Yitao succeeded in distinguishing female embryo from male embryo in order to diagnose human genetic diseases in 1984-1985. A couple of veterinarians from Beijing Agriculture College asked them "You could distinguish the sex of an embryo before the birth, can you distinguish the sex of a cow embryo?" If possible, it is of great economic value. People would like to get cows if they need to get milk whereas they would like to get a bull if they need to get quality beef. In 1990 scientists discovered the human sex determining factor, i.e. testis determining factor (SRY gene). With great efforts Zen and his team separated the SRY gene from the DNA of a bull sperm and determined its sequence. Then they were able to distinguish a cow embryo from a bull embryo through finding the SRY gene. Afterwards, this technique was also developed for goats. Transgenic animal means the animal receiving exogenous gene, i.e. a gene with economic value or a medicinal protein gene human's need, integrated into chromosome and expressed in some part of the animal. However, the integration rate is often low about 3-5 percent, of which the expression rate is only 50 percent.

In general, there are three main problems that should be solved on this transgenic technique.

1. Exogenous gene injected into embryo will not be integrated after the embryo is transplanted.
2. Even if it is integrated, it can not be expressed. That means it has no functioning.
3. Even if the embryo is alive after injection of the exogenous gene, the pregnant rate is very low after transplanted into the receiving animal.

That is why the success rate is very low. Transgenic animals often produce tremendous economic benefits (see also - *Economics of agro-biotechnology*), but transgenic animal research needs a large farm with 300-500 cows or sheep in rural areas as well as basic research in cities. The Institute succeeded to breed a transgenic goat carrying plasma thromboplastin antecedent (PTA) factor IX gene, and a transgenic bull Taotao carrying human serum albumin gene. Human plasma thromboplastin antecedent (PTA) factor IX, anti-hemophilic factor can be used to cure hemophilia while human serum albumin can cure burn, malnutrition, and chronic digestive diseases. The annual requirement of human serum albumin is about 440 tons in the world and now all comes from human blood plasma. Professor Huang Shuzheng improved the transgenic techniques by adopting external fertilization instead of internal fertilization. They got an egg cell from the ovary of a cow and incubated the egg to maturity for external fertilization. During the incubation they closely watched the development of the fertilized egg so as to find the optimal time to practice microscopic injection of the exogenous gene into the male gamete, which forms in a very short time before fusion with the female gamete. The survival rate of the fertilized egg can reach 95 percent. In order to confirm the integration, they did molecular bio-assay on four or five cells from 64 cells to confirm integration before transplanting. As far as gene expression is concerned, they raised expression to a higher level through making a gene carrier on mice through promoter and intensifier.

Moreover, they had to solve the location of expression to express gene in the mammary gland of a goat, not on its whole body in the case of human blood coagulant factor IX gene. If expressed in its whole body, it will affect the normal growth and physical metabolism. And they also changed operational transplanting to non-operational transplanting through the vagina of the receiving cow. According to the publication, lactic protein and exogenous protein can be separated through the combination of chromatography and filtering system. The purity of exogenous protein can reach 99.999 percent. Human gene transferred into an animal body is exogenous and transgenic protein as well will do no harm to the human body in clinical tests, but it needs more tests for verification.

3. Conventional Biotechnology as Practiced in Rural Areas

3.1. Rice Heterosis Exploitation

What is the ternary hybridization method of rice seed selection and breeding? (See also - *Conventional Plant Breeding for Yield Improvement and Pest Resistance*). It is a type of plant cell engineering. In simplified terms, there are three lines: A line, the male sterility strain, B line, the maintaining strain, and R line, the restoring strain. The ternary method means using the pollen of B line to pollinate A line, so as to make its progeny to maintain its male sterility, and then, to use the pollen of R line to pollinate those plants. The hybrid plants that result from this process recover their male reproductiveness, and their seeds can be used in production fields. All of these seeds carry the excellent traits of parents and show strong heterosis.

After nine years of experiments through seed selection and breeding, Yuan Longpin, the father of hybrid rice in the world finally crossed hybrid rice Nanyou No.2 Oryza indica in 1973. The demonstration area under cultivation reached 373 ha in 1975, and expanded rapidly to 138,666 ha in 1976. The rice output was 1,500 kg ha^{-1} higher compared to the conventional rice, an increase of 20 percent.

The double-line method of exploiting heterosis between sub-species succeeded in 1995. The rice hybrid produced by the double line method is 5-10 percent more productive than rice produced by the ternary line method. The area under double-line hybrid cultivation in China reached 2 million ha at the end of 1999. The purchase order for double line hybrid seed from Southeast Asia reached 10 million tons.

In recent years the area of hybrid cultivation exceeded 13.3 million ha, or about 50% of the total rice fields in China and the hybrid rice now accounts for 60% of the total rice yields. From 1976 to 1998, the cumulative area under cultivation reached 220 million ha, resulting in production increase of 300 million tons of rice, enough to feed 800 million people for a year.

In launching the International Year of Rice 2004, Jacques Diouf, director-general of the United Nations Food and Agriculture Organization, said rice "is the staple food for over half of the world's population ‘but warned’ its production is facing serious constraints."

The concept of hybrid rice, or "super rice" was first set forth by the International Rice Research Institute (IRRI) based in the Philippines. Since IRRI proposed hybrid rice with the per hectare yield of 12 tons to be reaped by 2000, various rice producing nations the world over have been vying with each other in announcing their respective super rice research plans. China has been the most successful with its super rice research scheme. "On pilot farms, super rice yields 10.5 tons per hectare and is well on the way of producing 13.5 tons per hectare by 2010,"

Recently Yuan has bred a new type of super hybrid rice and has achieved a record production of 1,138 kg/mu (17 t/ha) in a demonstration field in Yongsheng County, Yunnan Province. This super hybrid may be extended to large scale planting early in the new millennium. It is a conservative estimate that the area under cultivation of super hybrid will be 13.3 million ha each year with a production increase of 2,250 kg per ha. The newly increased production could feed 80 million people. Thus, China can secure food security for 1.2 billion people in the new millenium and make a great contribution to the world.

Chinese agronomists have cultivated new species of "super rice," the Super Rice II YOU 28, with average per hectare yield reaching a record high of 18,449.55 kilograms.

After four years of trial crops, a variety named "State Rice No.6" was developed with an average yield 12.07 tons per hectare in east China's Zhejiang Province, with a record yield of 12.37 tons per hectare.

3.2. Induced Breeding of Fish

As early as 1921 the first attempts to induce breeding and hatching on grass carp were made in the Pearl River Delta in China. Induced breeding of four cultivated fishes in pond culture succeeded at the end of 1950s. It was the second turning point of fish farming history in China, because it obviated the need to collect fry and fingerlings from the great rivers, and it greatly promoted the development of aquaculture in China. This biotechnology was an advanced technology at that time in the world.

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Biographical Sketch

Li Kangmin has Chinese nationality. He was born on December 3, 1934 at Wuxi, Jiangsu Province China. Occupation: Freshwater Fisheries Research Center, Chinese Academy of Fisheries Sciences Senior Researcher; China National Rice Research Institute, visiting researcher; Zero Emissions Research Initiative Resources Personnel (1997-1999) and a member of the Planning Committee of the Internet Conference of IBS in 2000.

He graduated from CMC Engineering College in the early 1950s, postgraduated from Luoyang Foreign Language Institute and engaged in GSH of the PLA. He transferred to the Ministry of Agriculture in 1983. Deputy Director of Asian Pacific Regional Research and Training Center for Integrated Fish Farming NACA/FAO in charge of International Training Course of Integrated Fish Farming for three and half years. He is engaged in IFS Deep Water Rice Fish Research, IRRI Deep Water Rice Screening, Eutrophication Control of Lake Taihu, IDRC extracting phycocyanin from blue-green algae Microcystis aeruginosa and Surface Aquaponics early or later.

Li Kangmin has been involved in rice/fish farming research since 1986, when he published his first paper on the subject. In 1988 he published in the International Journal of Aquaculture. He published several papers later on, on the same topic i.e. rice fields as fish nurseries and grow-out systems in China.

In 1998 he and Li Peizhen published a paper on Rice Aquaculture System in China on the Internet Conference, which explained how rice/fish farming system was developing into rice aquaculture system in China, and pointed out the reasons why sustainable development of rice/fish culture is possible in China while it is declining elsewhere in the world.