Transgenic rice plants with a synthetic 2transgene were introduced with fungal vectors. However, the integration of the transgene needed to be investigated. A number of vectors, including the Rolls-Royce (RR) vectors, were used.

The first field testing of the Bt rice was conducted in China in 1998. This resulted in the approval of the transgenic rice Bt rice Huahui No. 1 and Bt Shanyou 63 with possible widespread planting in 2022.

**References**

1. Numerous scientific initiatives and strategies were developed to determine efficacy against the pathogen. Several genes were identified for resistance against lepidopteran pests.


3. Transgenic rice plants with a synthetic 4transgene were introduced with fungal vectors. However, the integration of the transgene needed to be investigated. A number of vectors, including the Rolls-Royce (RR) vectors, were used.

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**Pocket Ks**

Pocket Ks is a database of Pocket Knowledge, packaged information on crop biotechnology products and related issues available at your fingertips. They are produced by the Global Knowledge Center on Crop Biotechnology (http://www.isaaa.org/kr). For more information on Crop Biotechnology see the following:

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Abiotic Stress Resistance

Rice is a water-loving plant that uses 30% of the freshwater used for crops worldwide – two to three times more water than other food crops19. With the imminent water shortage and increased salinity brought by global warming, strategies to develop rice to combat these abiotic stresses were conducted using stress-related genes and transcription factors identified in the model plant Arabidopsis. This include the expression of the HRD gene in rice that increased the leaf biomass and bundle sheath cells that would probably contribute to enhanced photosynthesis assimilation, water use efficiency and drought resistance20, and the expression of CBF3/DREB1A and ABF3 in rice increased its salinity and drought tolerance 21. Moreover, bacterial genes for trehalose accumulation also increased tolerance to drought, salt, and cold in transgenic rice22.

Biospharming in Rice

Rice can be used as a vehicle to produce pharmaceuticals including vaccines. One of these is the development of a rice-based oral vaccine containing the vaccine antigen cholera toxin B subunit (CTB) which accumulates in the protein bodies of the starch endosperm cells. These are taken up by mucosal cells of the gastrointestinal tracts for the induction of antigen-specific mucosal immune responses with neutralizing activity26. In addition, the rice-based CTB vaccine remained stable and maintained immunogenicity at room temperature for more than 1.5 years, and was protected from pepsin digestion in vitro. Other mucosal cell vaccines can be produced in rice to target diseases of the respiratory and gastrointestinal tracts and can be administrated economically in the developing countries where need is often the greatest.

Extended use of antibiotics is documented to contribute to the development of antibiotic resistance in commensal bacteria in poultry, pigs, cattle, and humans necessitating the search for alternative strategies. Antibacterial molecules such as lactoferrin and lysozyme were considered and expressed in rice grains through biotechnology. Experimental feeding of broiler chickens fed with rice containing lactoferrin and lysozyme showed that they improve the feed efficiency, histological indices of intestinal health, and increased bacteriostatic activity. This strategy can also be used in maintaining intestinal health and in the prevention of diarrhea in other young animals including human infants27.

Nutritional Improvement

Rice is a good source of carbohydrate, proteins, fiber, lipid and fats, minerals (potassium, phosphorous, magnesium, calcium, sodium, copper and iodine) and vitamins (thiamine, riboflavin, niacin, vitamin B6 and folic acid)28. In poor countries which have less access to meat and fish, rice is predominantly eaten, thus, important minerals and vitamins are lacking in the diet. This leads to a widespread occurrence of vitamin A and E, iron and zinc deficiency which afflict susceptible children, pregnant and lactating women. Food supplementation and fortification programs conducted were found to be relatively expensive, noncompliance is high, and requires infrastructure for delivery and targeting. A novel approach is biofortification which uses biotechnological tools to incorporate genes for increased amounts of these essential food nutrients. Biotech rice with provitamin A (Golden Rice) has been developed24,25 and is being used to transfer beta carotene loci into high-yielding local commercial cultivars through marker-assisted back cross breeding in the Philippines, Bangladesh and India. Progress in molecular marker-aided breeding projects the release of golden rice varieties by 2012. Biotech rice with increased ferritin content was found to replenish the hemoglobin and liver iron concentrations in rat experiments suggesting that biotechnological approaches to manipulating ferritin expression of seed iron may contribute to a sustainable solution to global problems of iron deficiency28.

Rice is devoid of essential amino acids such as threonine, tryptophan, lysine, and methionine. Strategies to improve the lysine content of rice showed that inhibition of lysine degradation through the RNAi approach increased free lysine level, and affected the concentrations of the amino acids related to lysine metabolic pathway, such as threonine and aspartic acid27. As plant proteins are the primary sources of all dietary proteins consumed by human and animals and are inexpensive to produce in comparison with meat, improving their quality will make a significant contribution to future needs.

Biochemically, rice has been shown to be an excellent source of carbohydrate, proteins, fiber, lipid and fats, minerals (potassium, phosphorous, magnesium, calcium, sodium, copper and iodine) and vitamins (thiamine, riboflavin, niacin, vitamin B6 and folic acid). It is a rich source of carbohydrates, proteins, fiber, and lipids. It is also a good source of minerals like potassium, phosphorus, magnesium, calcium, sodium, copper and iodine. It is a good source of vitamins such as thiamine, riboflavin, niacin, vitamin B6 and folic acid.

Biotech Rice and the Future

Biotech rice has been developed to address concerns that focus on the profitability of rice farming such as pest and disease resistance and abiotic stress tolerance; value-adding rice through nutritional improvement; using it as a vehicle to produce pharmaceutical products; and as an instrument to provide environmental protection and reduce global warming.

In addition, basic studies to increase rice yield are underway including the incorporation of genes in the C4 pathway, a more efficient converter of light energy and carbon dioxide into food assimilates28. Moreover, basic research on apomictic rice or the production of cloned seed has been started and promising results are being generated31. This will considerably reduce the cost of production of hybrid rice, an important breeding strategy in rice production.