New Genetic Inventions in Agriculture

Dr Renuka Karunagoda

Genetics is the area in biology, where studying of heredity is involved. Genes are components of cells which are responsible for all the characters of living organisms. A gene is a length of DNA, which codes for a particular protein. DNA occurs in pairs of strands intertwined with each other and connected by chemicals called bases. Two strands of DNA and the bases between the strands compose a specific gene. A major breakthrough in genetics took place when scientists developed the process of genetic engineering where they transfered genes from one organism to another between distinctly related organisms. It is possible to remove genes which are responsible for certain characters and introduce them into another organism, so that the given character is introduced into the recipient organism (Fig. 1). This technology, which is known as 'Recombinant DNA Technology' is used to alter the characters of microorganisms, plants or animals. Plants which have been genetically modified are known as 'transgenic plants'. Production of transgenic plants with new characters is an area of new science, known as 'plant biotechnology', with many potential applications in agriculture to increase agricultural production.

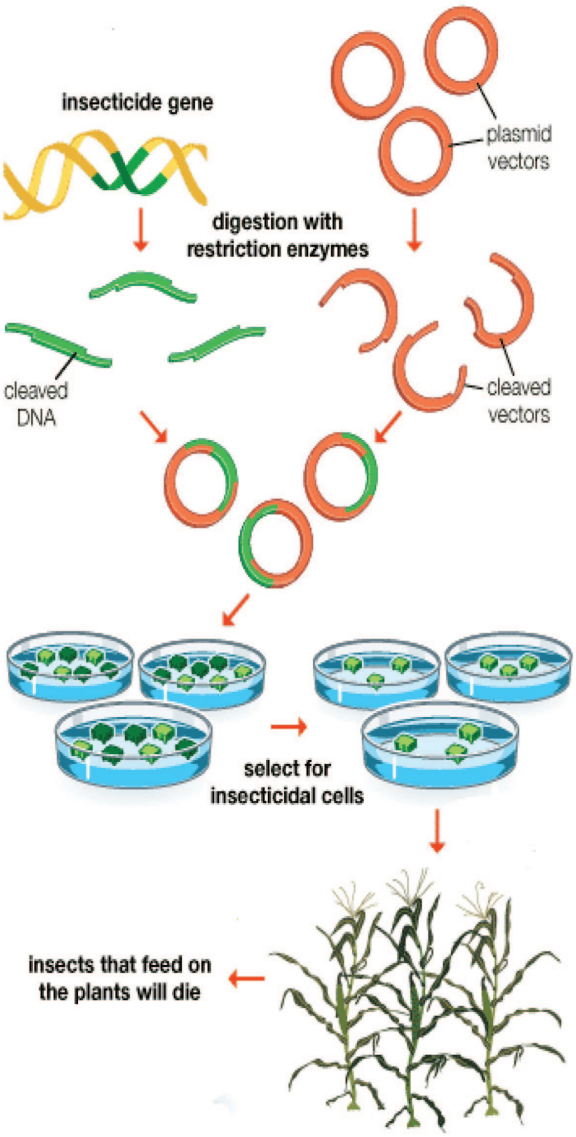

Figure 1 Procedure for the production of transgenic plants with insecticidal properties

Agriculture constitutes a major sector of the global economy. The applications of biotechnology in agriculture have a highly potential market, and therefore, various groups are working towards development of transgenic plants with greater productivity, resistance to pests and diseases, improved nutritional quality and better tolerance to environmental stresses. There has been a rapid expansion in the commercial cultivation of genetically modified crops, rising from the first plantings in 1995 to 44.5 million hectares worldwide in 2000. Most genetically modified crops are cultivated in the USA (68%), Argentina (23%) and Canada (7%). Of the

total 44.5 million hectares planted worldwide in 2000, 58% was soybean, 23% corn, 12% cotton and 6% oil seed rape. Other GM crops include potato, squash and papaya.

Recombinant DNA technology is used in plant biotechnology where it can contribute to increase crop production via two areas. Firstly, plant biotechnology can be used to add new lands for agricultural production. New plant varieties can be produced with more tolerance to drought and poor soil conditions, such as, saline or acidic soils. In this way, it is possible to expand the existing lands which have been unable to be cultivated so far. Secondly, biotechnology can be used to reduce crop losses, either caused by pests and diseases or transportation or storage problems. Pests, diseases and weeds not only reduce the crop yields, but also increase the cost of production, and therefore reduce the profitability of agriculture.

Development of crop varieties resistant to herbicides

Herbicides are used in agriculture to control weeds that compete with crop plants for space, water, nutrients and sunlight. It is important to control weeds to increase the productivity of crops. There is no single herbicide designed for broad-spectrum weed control to control all types of weeds. Some herbicides are effective in controlling weedy grasses, but not effective against broad-leaf weed species. The development of crop varieties tolerant to herbicides has been a major focus for biotechnology companies and today there are varieties of various crop species with resistance to herbicides that kill all types of plants except the crop variety. The U.S. company Monsanto developed the first transgenic crop varieties resistant to the herbicide called 'Roundup' which contains the chemical glyphosate that kills both broad-leaf weeds and weedy grasses. These varieties are known as Roundup Ready as they are resistant to the herbicide Roundup. In 1996, Roundup Ready soybean variety (Fig. 2) was made commercially available followed by Roundup Ready corn in 1998. Roundup Ready varieties allow farmers for more efficient and economic weed control with application of only one herbicide by reducing the number of herbicide applications needed and amount of chemicals applied to the land. Other than soybean and corn, herbicide resistance was introduced to sugar beet, canola (oil seed rape) and cotton.

Development of crop varieties with enhanced nutrition

A transgenic rice variety, named 'Golden Rice' has been developed in 2000, which has elevated levels of β-carotene, a precursor to vitamin A (Fig. 3). This rice variety can help to fight blindness resulting from a deficiency of vitamin A, a critical problem in developing countries. Within this rice plant, the biochemical

Figure 2 Herbicide tolerant Roundup Ready Soybean

Figure 3 Golden rice with enhanced levels of β-carotene

pathway for β-carotene was introduced by inserting relevant genes from daffodil and a fungus. The grains of this genetically modified rice are similar to those of other varieties, but the core of the grain is pale yellow, instead of white, due to β-carotene. Golden rice can be considered a particular advantage to poor people in underdeveloped countries, particularly in areas of Asia, where most of the population live on rice throughout the day.

Development of crop varieties resistant to insects

Insect resistance is achieved by incorporating a gene from the bacterium *Bacillus thuringiensis* into the food plant. *Bacillus thuringiensis* produces a protein that is toxic to the larvae of the Lepidopteran insects. When the caterpillars eat plant leaves on which the bacterial spores have been deposited, the bacteria grows in the digestive tract and a protein-like crystal (Bt-toxin) is produced, which kills the insect. The Bt-toxin gene has been transferred to varieties of corn, cotton, tobacco, potato and other species to control caterpillars (Fig. 4). Bt crop varieties synthesize the Bt toxin in their own tissue, and therefore after eating the plant matter, the caterpillars die within 2 days. This has dramatically reduced the amount of insecticides needed to control the insect in crops. If Bt-toxin is ingested by mammals, it rapidly degrades in the digestive tract, making it one of the safest chemicals to man and the environment.

Development of crop varieties with longer shelf life

The first transgenic crop commercialized was a tomato variety named 'Flavr Savr' which was released to the market in 1994 (Fig. 5). This was the first genetically modified food available to consumers. This tomato variety has a long shelf life and is genetically modified to produces less of the substance that causes tomatoes to rot, so it remains firm and fresh for a long time. This is important in harvesting because tomatoes can be allowed to ripen in the sun before picking, resulting in a better tasting tomato. Further, they can tolerate a lengthier transport time, which reduces postharvest losses.

Figure 4 Genetically modified corn with Bt-toxin gene

Figure 5 Genetically modified Flavr Savr tomato with longer shelf life

Dr Renuka Karunagoda
Department of Agricultural Biology
University of Peradeniya