Transgenic Plants

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https://miteshshrestha.wordpress.com/wp-content/uploads/2018/03/flavr-savr-tomato-golden-rice-bt-cotton.pdf

Transgenic plants

- Transgenic plants are plants that have been genetically modified to possess a new trait that is not naturally present in them.
- A transgenic plant contains a gene or genes that have been artificially inserted.
- The inserted gene sequence is known as the transgene, it may come from an unrelated plant or from a completely different species.
- The purpose of inserting a combination of genes in a plant, is to make it as useful and productive as possible.
- This process provides advantages like improving shelf life, higher yield, improved quality, pest resistance, tolerant to heat, cold and drought resistance, against a variety of biotic and abiotic stresses.
- Transgenic plants can also be produced in such a way that they express foreign proteins with industrial and pharmaceutical value.
- The production of transgenic plants involves two major process.
  - The first step is the introduction of new genetic material into plant cells, a process known as transformation.
  - The second step uses tissue culture techniques for proliferation and to regenerate the transformed cells into a transgenic plants.

Introduction of new genetic material into plant cells

- Most genetically modified plants are generated by the biolistic method (Particle gun method) or by *Agrobacterium tumefaciens* mediated transformation method.
- The “Gene Gun” method, also known as the “Micro-Projectile Bombardment” or “Biolistic” method is most commonly used in the species like corn and rice.
- In this method, DNA is bound to the tiny particles of Gold or Tungsten, which is subsequently shot into plant tissue or single plant cells, under high pressure using gun.
- The accelerated particles are penetrating both into the cell wall and membranes.
- The DNA separates from the coated metal and it integrates into the plant genome inside the nucleus.
- This method has been applied successfully for many crops, especially monocots, like wheat or maize, for which transformation using *Agrobacterium tumefaciens* has been less successful.
- This technique is clean and safe. The only disadvantage of this process is that serious damage can be happened to the cellular tissue.

...Introduction of new genetic material into plant cells

- *Agrobacterium tumefaciens* is a rod shaded, gram-negative bacteria found in soil and it is the natural causative agent for crown gall disease.
- The bacteria enters the plant through cuts or wounds present in its root or stem.
- The bacteria then inserts its DNA and stimulates the plant to grow swollen galls.
- *Agrobacterium tumefaciens* is capable of interkingdom DNA transfer, thus making it a potential vector in the production of transgenic plants.

Examples of Transgenic Plants:

- **Flavr Savr Tomato:** It was the commercially grown **first transgenic plant.** This crop aimed to make tomatoes more resistant to rotting by introducing an antisense gene that interferes with Beta polygalacturonase. It would allow the farmers to regulate the ripening of the tomatoes at will by introducing ethylene externally. Ethylene is an essential plant hormone responsible for fruit ripening. This crop could not succeed in the market, as even though it had a positive effect on the shelf life of the tomatoes, it was still unable to affect the fruit's firmness.
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Golden Rice

- Project Started in 1982 by Ingo Potrykus- Professor emeritus of the Institute for Plant Sciences
- Peter Beyer-Professor of Centre for Applied Biosciences, Uni. Of Freiburg, Germany
- Funded by the Rockefeller Foundation, the Swiss Federal Institute of Technology, and Syngenta, a crop protection company.
- Golden Rice Humanitarian Board-responsible for the global development, introduction and free distribution of Golden Rice to target countries.

- Golden rice is a variety of *Oryza sativa* rice produced through genetic engineering to biosynthesize betacarotene, a precursor of vitamin A, in the edible parts of rice.
- Biofortification - The creation of plants that make or accumulate micronutrients, research was conducted with the goal of producing a fortified food to be grown and consumed in areas with a shortage of dietary vitamin A, which is estimated to kill 670,000 children under 5 each year.
- Golden rice differs from its parental strain by the addition of three beta-carotene biosynthesis gene.

- Orange/golden colour due to synthesis of proVitamin A in the kernels.
- Golden rice was designed to produce beta-carotene, a precursor of vitamin A, in the edible part of rice, the endosperm.
- The rice plant can naturally produce beta-carotene in its leaves, where it is involved in photosynthesis.
- However, the plant does not normally produce the pigment in the endosperm, where photosynthesis does not occur.
- Golden rice was created by transforming rice with two beta-carotene biosynthesis genes:
  - 1.psy (phytoene synthase) from daffodil (Narcissus pseudonarcissus)
  - 2.crtI from the soil bacterium Erwinia uredovora
- The psy and crtI genes were transformed into the rice nuclear genome and placed under the control of an endosperm-specific promoter, so they are only expressed in the endosperm.

- The exogenous lyc gene has a transit peptide sequence attached so it is targeted to the plastid, where geranylgeranyl diphosphate formation occurs.
- The bacterial crtI gene was an important inclusion to complete the pathway, since it can catalyze multiple steps in the synthesis of carotenoids up to lycopene, while these steps require more than one enzyme in plants.
- The end product of the engineered pathway is lycopene, but if the plant accumulated lycopene, the rice would be red.
- Recent analysis has shown the plant's endogenous enzymes process the lycopene to beta-carotene in the endosperm, giving the rice the distinctive yellow color for which it is named.

Golden Rice

Comparison of Rice (left), Golden rice1 (middle) and Golden rice 2 (right). Source: Paine et al., 2005

Differences between Golden rice 1 and 2: More efficient phy gene introduced.
35 µg of carotinoids per gram of dry Golden rice 2 instead of 1.6 µg of carotinoids per gram of dry Golden rice 1.

Golden Rice: Fool's gold or golden opportunity?

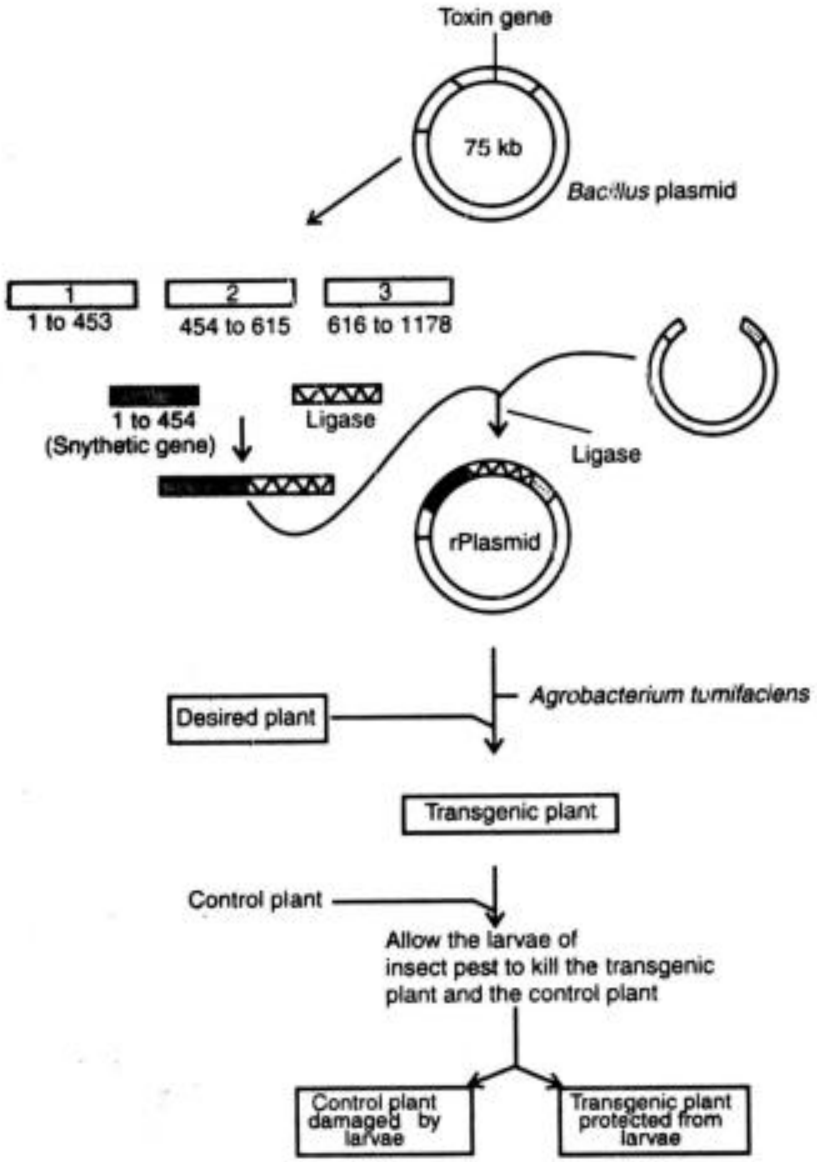
- Health
  - May cause allergies or fail to perform desired effect
  - Supply does not provide a substantial quantity as the recommended daily intake
- Environment
  - Loss of Biodiversity. May become a gregarious weed and endanger the existence of natural rice plants
  - Genetic contamination of natural, global staple foods
- Culture
  - Some people prefer to cultivate and eat only white rice based on traditional values and spiritual beliefs

*Currently, there is no cultivation or commercialization of Golden Rice in India.

BT Cotton

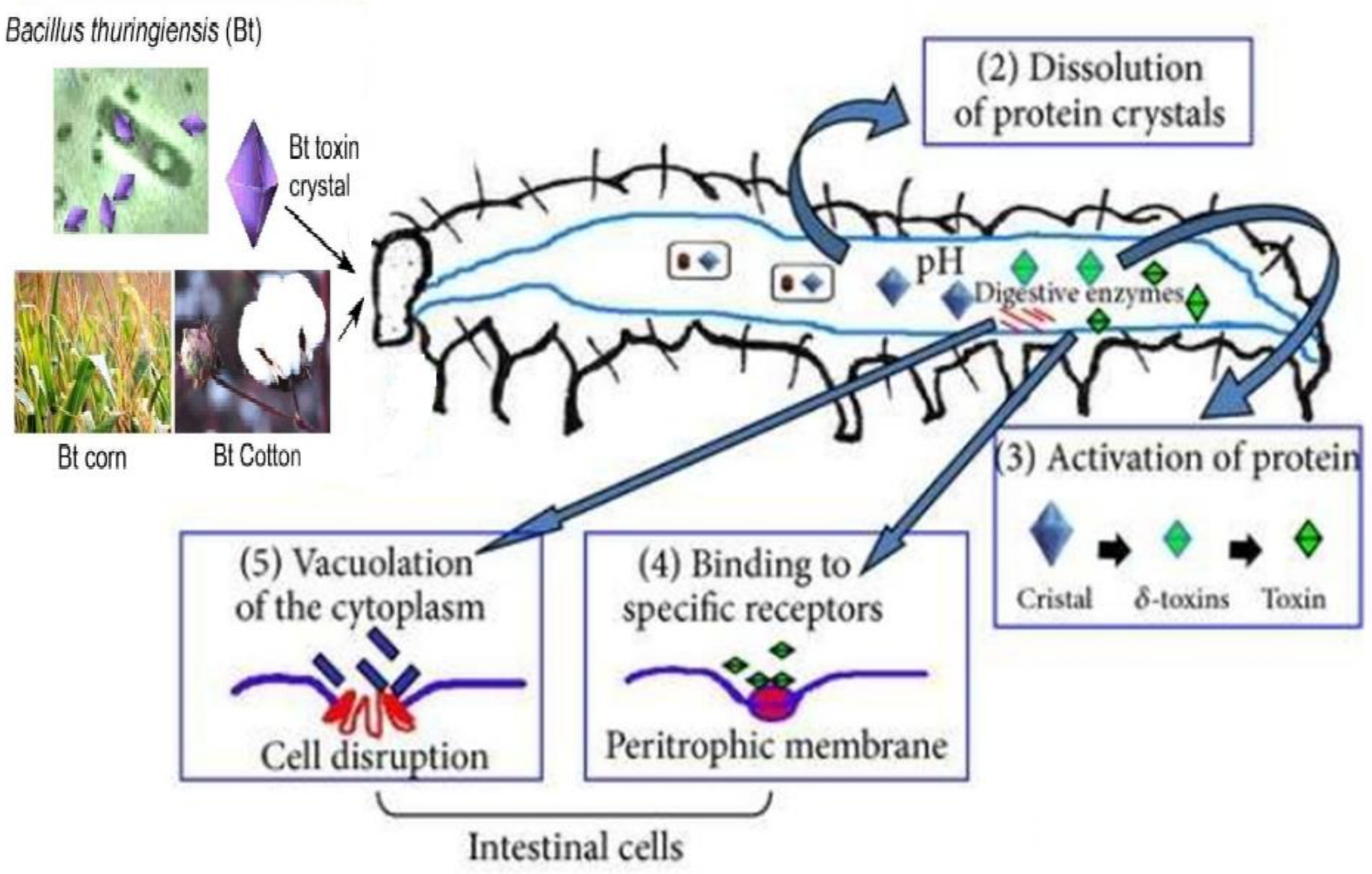
- Cotton, also known as **White Gold,** is an important **cash crop** in India and plays an important role in the Indian economy.
- Genetically modified to produce insecticidal toxins derived from the bacterium *Bacillus thuringiensis*.
- Toxins are crystalline proteins (Cry proteins) that target specific pests.
- **Bt cotton** was the **first GM crop**approved in India in March **2002** for commercial cultivation.

How is it produced?



- Bt cotton has been genetically modified (GM) by inserting one or more **genes** from Bacillus thuringiensis, (a **common soil bacterium)** making them **transgenic plants.**
- The insertion of B. thuringiensis genes causes cotton plant cells to produce crystal insecticidal proteins known as **Cryproteins.**
- These insecticidal proteins are effective in killing some of the most damaging cotton **caterpillar pests**, such as **tobacco budworm and bollworm larvae.**
- **Bollgard I:** In 1996, Bollgard cotton (a trademark of Monsanto) was the first Bt cotton to be marketed in the United States. The original Bollgard cotton produces a toxin called **Cry 1Ac,** which has excellent activity against tobacco budworms and pink bollworm.
- **Bollgard II:** It was introduced in 2003, representing the next generation of Bt cotton. It contains a second gene from the Bt bacteria which encodes the production of **Cry 2Ab.**

How BT cotton works against pests?



Production of Bt Cotton

- As the share of Bt hybrids in the country's area sown under **cotton touched 95%,** average per-hectare **lint yields** more than doubled from 278 kg in 2000-01 to 566 kg in 2013-14.
  - But both production and yields started falling after 2013-14, to 343.5 lakh bales and 447 kg/hectare in 2022-23. This is due to pink bollworm larvae developing resistance to Bt proteins over time by continuously feeding on **Bt hybrids.**

Benefits of Bt Cotton in India

- **Employment:** The use of Bt cotton in India has resulted in massive increases in women's employment.
- **Increase in farmer's income:** The introduction of Bt cotton has brought impressive increases in the incomes of farmers as well as profits to **biotechnology** companies and seed companies.
- The impact of Bt cotton on Indian agriculture can be seen through the replacement of large tracts of varietal areas of north, west, and south India with Bt hybrids.
  - These hybrids are instrumental in reducing the overall quantity of insecticides, apart from showing spectacular yield levels for cotton crops.

Limitation of Bt Cotton in India

- **Non-resistant to other pests:** Bt cotton was developed for **cold-climate countries** such as the **United States,** where pests are limited, most notably the bollworm, against which the Bt toxin works, and pest loads in fields are low.
  - Apart from the **bollworm**, India has a plethora of cotton pests. Hence, pesticides will have to be used again because spraying is required to kill these other pests.
- **Incompatibility with agricultural and climatic conditions:** According to some experts, Bt cotton is unlikely to last more than a few years in India because it is fundamentally incompatible with the country's agricultural and climatic conditions.
  - Insects are likely to develop resistance quickly, leaving the variety ineffective in a matter of years.

Advantages and Importance of Transgenic Plants:

- Any genetic recombination experiment is undertaken with a clear objective and needs in mind to be addressed. Thus the advent of **transgenic plants** has been essential in rejuvenating an already stretched agricultural sector. The advantages can be listed as follows:
- Improving Production yield
- Cutting down transportation costs
- Enhancing the nutritional values of already established crops.
- Preventing crop damage by producing herbicide, insect, virus, and pest-resistant crops.
- Development of drought-resistant crops.
- The development of such **transgenic plants** will help reduce the environmental burden by reducing the use of weedicides, fungicides, and insecticides. It will be a massive benefit to the environment besides keeping up with the demand and a win-win situation for everyone.

Ethics Related to Transgenic Plants:

- Recombinant DNA technology comes with its fair share of ethical concerns and arguments. A few opinions or potential ethical problems that are raised in this debate against **transgenic plants** are:
- Potential harm to human health
- Undisclosed damage to the environment causes unpredictable results.
- The negative impact of traditional farming practices.
- Corporate dominance
- The unknown nature of the long-lasting effect of the technology.
- RDT is a potent tool, and its misinterpretation or misuse can lead to unpredictable damage in the future. Thus one must be very careful while undertaking any project or product based on **transgenic organisms**.