GENETIC ENGINEERING: MODERN TOOL FOR CROP IMPROVEMENT

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ABSTRACT

Genetic engineering also known as genetic modification or genetic manipulation is the use of genetic knowledge to artificially manipulate genes or alter the genetic material of an organism. It involves - recombinant DNA techniques in which pieces of genes from an organism are inserted into the genetic material of another organism producing recombinant beings; -the nucleus transplantation technology, popularly known as "cloning", and -the technology of DNA amplification, or PCR (polymerase chain reaction), that allows millions replications of chosen fragments of a DNA molecule . Even though these technologies are still young and have not been understood by many, they have contributed immensely to the development of many new plant forms and had ensured food security in many parts of the world especially in developing countries. However, a number of real and perceived risks to the environment and human health still exist. Despite the fears and risk associated with these technologies (especially regarding crop improvement) the advantages still overwhelm the side effects, thus it remains inevitable in solving the problem of food security for the ever growing human population and the degrading environment. This review predominantly considers the roles of genetic engineering as a tool for crop improvement.

Key words: Genetic Engineering, Recombinant DNA, Crop Improvement.

INTRODUCTION

Genetic engineering (also known as genetic modification) is the alteration of genetic material that would not occur naturally. It can be used as a tool to improve the quality of foods. Through genetic modification, foods can be produced in large quantities by increasing its resistance to pests and adverse weather conditions (Kamil & Yakup, 2011). It involves recombinant DNA techniques in which pieces of genes from an organism are inserted into the genetic material of another organism producing recombinant beings; the nucleus transplantation technology, popularly known as "cloning", and the technology of DNA amplification, or PCR (polymerase chain reaction), that allows millions replications of chosen fragments of a DNA molecule. The review predominantly considers the roles of genetic engineering as a tool for crop development

The breeding of new plants by recombinant DNA technology is both economically and nutritionally important and expected to increase foods' nutritional quality, shelf life, yield, pest and disease resistance, tolerance to environmental stress or, as in case of fruit tree breeding, shortening of the juvenile phase for the acceleration of the breeding process (Weiss *et al.*,2006; Bakshi, 2003). Plants, such as maize, soybean and canola have been made resistant to insects and/or more tolerant to herbicides. In Europe, however, these traits are not perceived as beneficial to the consumers in terms of reduced prices or increased product quality, but rather as benefits for the companies that own the technology and the farmers that grow these crops (Weiss *et al.*, 2006; Bakshi, 2003; Heckmann *et al.*, 2006; Moseley, 2001).

Since the mid-1990s, genetic modification is a rapidly growing and controversial method that can boost agricultural productivity, but the technology is not fully understood by the consumers (Bennett *et al.*, 2005). For example, the transfer of genetic material from *Bacillus thuringiensis* (Bt) into corn produces a variety that contain Bt-toxin, selectively poisonous to insect pests (Mehendale, 2004; Heckmann *et al.*, 2006).

Creation of Transgenic plants

Genes are inserted into plant cell by several techniques. A commonly used method (Plasmid method) takes the advantage of a natural process that causes crown gall disease, which is characterized by bulbous, irregular growths-tumors. The disease is caused by the bacterium *Rhizobium radiobacter* (formerly known as *Agrobacterium tumefaciens*, recently reclassified on the basis of genome analysis). This bacterium contains a large, circular plasmid called Ti (tumor inducing) plasmid. The interaction between the bacterium and a plant cell it infects stimulates the excision of a segment of the Ti plasmid called TDNA (for transforming DNA), which then integrates into plant cell's genome. Genes on the TDNA are then expressed; the products stimulate the transformed cell to grow and divide and therefore to produce tumour. The tumors provide essential nutrients for the bacterium. The Ti plasmid is used as a vector for making transgenic plants, in much the same way as bacterial plasmids are used as vectors to introduce genes into bacteria (Peter *et al.*, 2008). Other methods are vector and biolistic

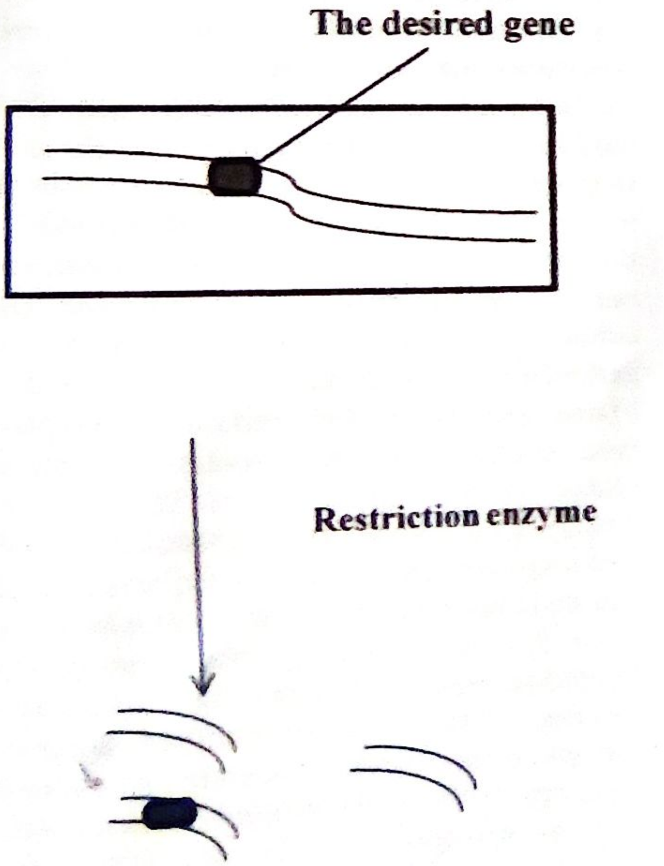


Fig 1. **Isolation and cutting of the genomic DNA Using restriction enzyme**

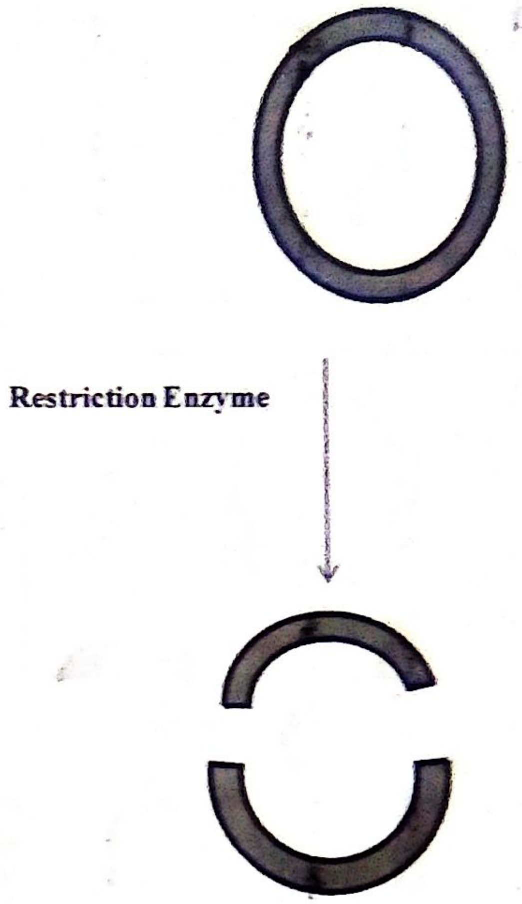


Fig 2. **Isolation and cutting of circular Bacterial Plasmid Using the Same Restriction Enzyme**

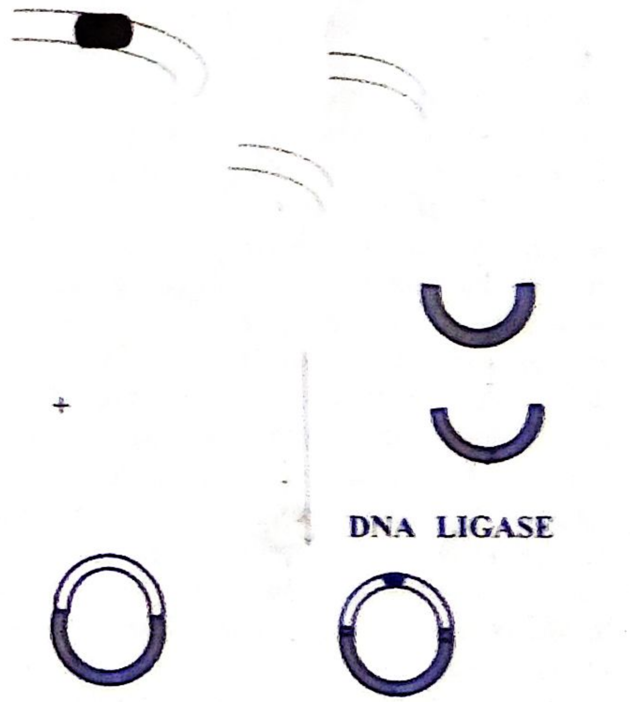
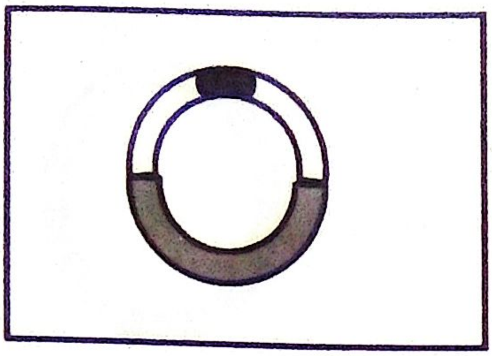
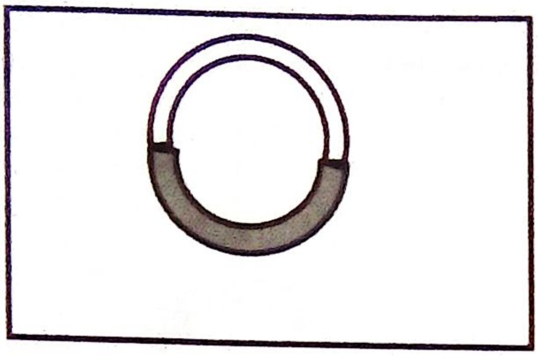


Fig 3. Insertion of the Genomic DNA Fragment into the Plasmid to make a Recombinant plasmid.





Advantages of Genetic Engineering over the Traditional Breeding Methods

Because transgenic organisms offer an alternative to traditional methods of animal and plant breeding, they offer an exciting new way forward in agriculture. Improving crops or domestic animals by traditional methods is a slow process which relies on a lot of chances because of crossing over in meiosis and random segregation of chromosomes during sexual reproduction. Some key aims in plant and animal breeding which might be the subject of transgenic are: increased yield, improve quality of food from the point of view of health or digestibility (e.g. oil, fat and protein), resistance to pests and diseases, increasing tolerance of, or resistance to environmental stress such as drought, cold etc. (Taylor *et al.*, 2005).

Traditional methods of producing genetic modifications only work if the organisms that carry the desired traits can cross-breed. Genetic engineering takes these gene-swapping manipulations to an entirely new level (Cecie *et al.*, 2008). Although traditional plant breeding has been around for ages, the development of recombinant DNA techniques has offered a wide range of valuable gene and methods of inserting them into the plant genomes. Two major advances in molecular biology have resulted in new plant breeding technology (Conner *et al.*,1999).It is the second method of breeding that has come into the most light recently and offers the opportunity to develop a wide variety of new crop cultivars. Transgenic plants are usually made up of a genetic marker(antibiotic or herbicide resistance) and a well-characterized gene which express some economically important or valuable trait (Snow and Pedro, 1997).There are four main advantages of genetically engineering plants over traditional methods. First, the source of the DNA is not limited to related wild plants. It may come from other plant species, animal, microorganisms, or even lab synthesized genes. Next, transfer of new genes is more direct and does not require many generations of breeding to recover the new cultivar. Also, while traditional methods of gene transfer may result in the transfer of closely linked or unwanted genes, genetic methods allow for a more discrete transfer of a single valuable gene. Lastly, new gene constructs can be made, using molecular biology techniques, which could not be found in wild plants used for traditional breeding (Snow & Pedro, 1997). The other methods include vector and biolistic methods.

Outcomes of Genetic Engineering in crop improvement

Transgenic plants are plants have their DNA modified using genetic engineering techniques. In most cases the aim is to introduce a new trait to the plant which does not occur naturally in this species. Examples include resistance to certain pests, disease or environmental conditions (Bock, 2010).The first trial of genetically engineered plants occurred in France and USA in 1986, when tobacco plants were engineered to be resistant to herbicides (James, 1996).

Transgenic plants have genes inserted into them that are derived from another species. The inserted gene can come from species within the same kingdom (plant to plant) or between kingdoms (bacteria to plant).In many cases the inserted DNA has to be modified slightly in order to correctly and efficiently express in the host organism. Transgenic plants are used to express proteins like the cry toxins from *Bacillus thuringiensis*, herbicide resistant genes and antigens (Walmsley & Arntzen, 2000). Farmers benefit from increased yields (4 billion pounds) and profitability ($1.2 billion saved in production costs).GM crops promotes the adoption of reduced tillage, which save energy and soil quality (Thomas *et al*., 2006) .A deficiency in vitamin A results in blindness. It is estimated that 124million children worldwide are vitamin A-deficient; and in Southeast Asia, 250,000 children go blind each year because of this deficiency. Through genetic engineering, scientists in Switzerland have designed a variety of rice that produces seed with endosperm rich in beta-carotene. Beta-carotene is the precursor for vitamin A. The new rice has enough beta-carotene to colour the seeds, leading to its name "golden rice" (Thomas *et al*. 2006).

One strategy used by plants to survive and even thrive in saline soils is to transport salt into their cells' vacuoles, where it does not interfere with cellular processes. A specific protein, called a Na+/H+ antiporter, serves as the channel between cytoplasm and vacuole. Researchers have inserted into a tomato plant a gene that synthesizes high level of this channel. The plant grows, flowers, and bear fruits when irrigated with 200mM NaCl, a concentration 50 times the normal limit for tomato. The salt accumulates in the vacuoles of the leaves, but not the fruit; therefore, the fruits are edible, and harvesting the leaves can help clear a field of salt (Thomas *et al*. 2006).

Fears of Genetic Engineering

Genetic engineering is a form of biotechnology that has a promising future for mankind however, a lot of fears and risks associated with it. According to Lusk *et al*., (2006 biotechnology has the potential to lower food prices and environmental impact of agriculture but a number of real and perceived risks to the environment and human health still exist. Consumer acceptance of GM foods remains a critical factor that will determine the future of biotechnology.

Despite the enormous importance of the subject, reliable information about consumer awareness and perceptions of GM foods is rather scarce (Hossain *et al*., 2003).There are unconfirmed concerns about the transfer of genes from one species to another, or about antibiotic resistance from GM crops to animals. The debate over genetic modification remains intense. Claims that GM is "tampering with nature" or "playing God" are prevalent in some societies or sectors. Future large-scale growing of GM crops may have implications for biodiversity, the balance of nature, wildlife and the environment (Dean and Shepherd, 2007; Bakshi, 2003).It has been argued that GM crops cause increased antibiotic resistance, presence of toxins, fungi, or toxic metals and increased cancer risks in humans, and that it degrades the nutritional food value, produces new allergens and other potential risks (Bakshi,2003; Gizzarelli *et al*.,2006; Warner,2002; Heckmann *et al*.,2006; Dean & Shepherd, 2007). DNA breakdown during digestion eliminates the possibility that intact genes capable of encoding foreign proteins will be transferred to gut flora (Plahuta & Raspor, 2007).

Production of GM foods raises broad socio-cultural and ethical issues at the national and international levels. Law making in this field has to take into account multiple- and sometimes conflicting policy objectives, including policies to (1) protect the natural environment and biological diversity; (2) safeguard diverse cultural and religious traditions;(3) optimize GM production of quality foods;(4) ensure socially equitable distribution of benefits, and (5) hold governments and businesses accountable for food safety and adequate information to consumers (Sand, 2006).

Conclusion

Though this technology has both real and perceived risks its contributions to crop improvement has made it inevitable for plant breeders for quick development of new plant forms in order to meet up with the ever growing human population and degrading environment.

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