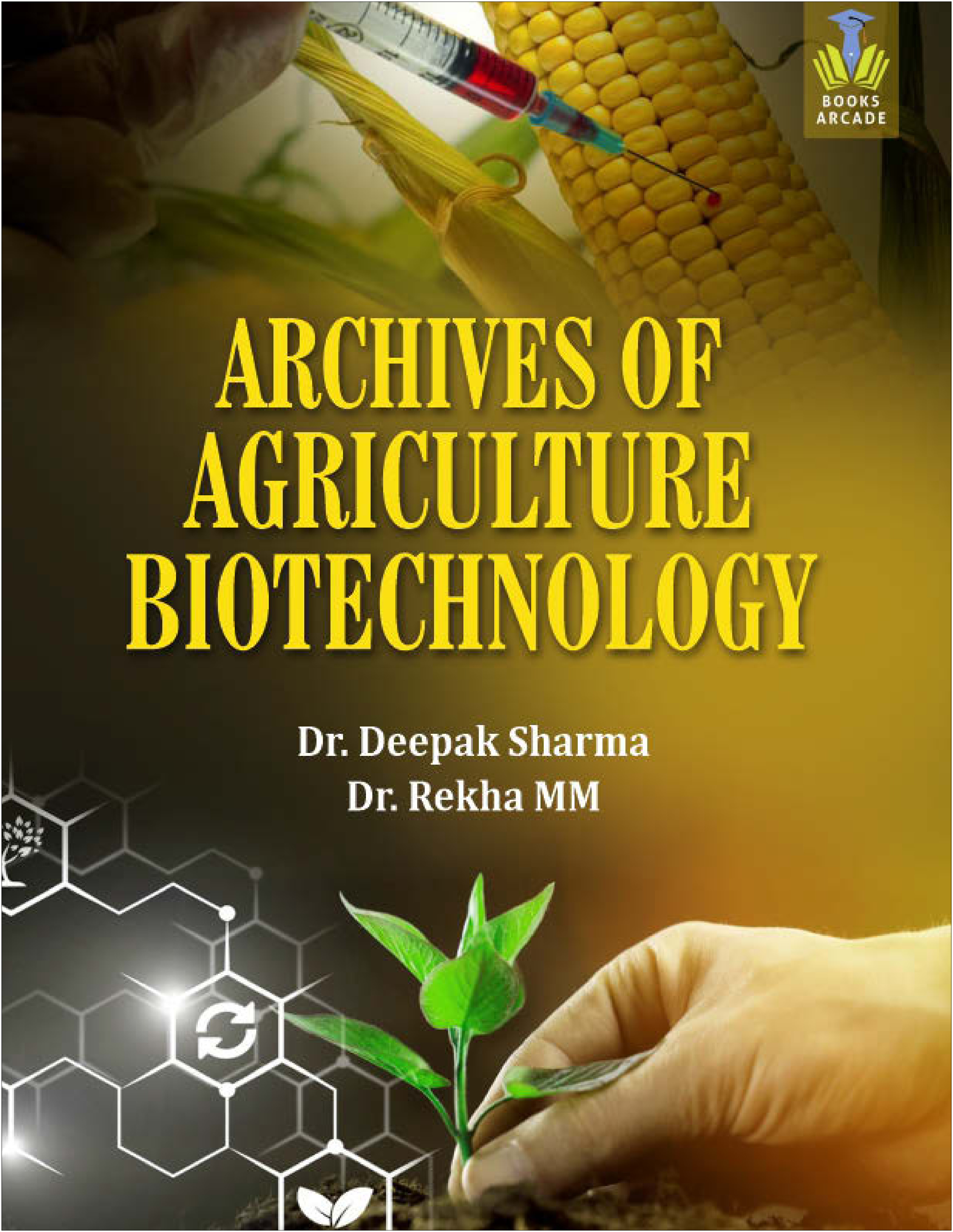

ARCHIVES OF AGRICULTURE BIOTECHNOLOGY

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CHAPTER 1

BASIC CONCEPTS OF AGRICULTURE BIOTECHNOLOGY

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There are several methods for choosing and introducing desired traits4 in plants, animals, and microbes used to produce food and feed. These include traditional breeding methods (CBT), well-known genetic modification methods (ETGM), and an increasing number of what are often referred to as innovative breeding methods (NBT). All approaches continue to be utilised in tandem to varying degrees, and the NBT may be employed in addition to CBT and ETGM. The genome sequencing and annotation of several species' genomes, as well as current developments in molecular biology and biotechnology, serve as the foundation for the NBT. The implementation of these NBT is controversial, much as ETGM and certain CBT.

The purpose of this Note is to provide the reader with information regarding the nature, traits, similarities and differences between NBT, CBT, and ETGM. In the context of their direct agricultural use in plants, animals, and microbes for the production of food and feed, it covers the most significant instances of CBT, ETGM, and NBT such examples are however by definition non-exhaustive. The Note also briefly describes the use of NBT in agriculture for synthetic biology and gene drive. These groups of approaches and the meanings of certain terminology are based on the "scoping paper" in Annex 1, although for the sake of illustration: Simple selection, sexual crossings, mutation breeding, etc. are examples of CBT, the generation of transgenic organisms is referred to as ETGM, and a broad variety of approaches, such as genome editing using, for example, CRISPR-Cas systems, epigenetic modification, etc. are examples of NBT.

A branch of agricultural science called agricultural biotechnology focuses on modifying living things including plants, animals, and microorganisms using scientific tools and methods. These include immunizations, genetic engineering, molecular diagnostics, and tissue culture. One area of agricultural biotechnology that has recently seen considerable expansion is crop biotechnology. Desirable traits are transferred from one kind of crop to another. Taste, bloom colour, growth rate, size of the harvested goods, disease and insect resistance are all desirable properties of these transgenic crops[1], [2].

Historical Background

Farmers have employed selective breeding to alter animals and plants for tens of thousands of years to achieve desired traits. During the 20th century, the growth of agricultural biotechnology was aided by a variety of traits, such as increased yield, drought tolerance, insect resistance, and herbicide resistance. The first food product made by biotechnology was on market in 1990, but by 2003, 7 million farmers were cultivating biotech plants. More than 85% of the population in developing countries were this farmer.

Plant Modification Methods

Traditional Farming

Traditional crossbreeding has been used for years to improve crop quality and output. Crossbreeding creates a new and distinct variant with the desired traits of the parents by marrying two sexually compatible species. For instance, the Honeycrisp apple's unique texture or taste is due to the crossbreeding of its parents. Using conventional techniques, pollen from one plant is applied to the female part of another, resulting in a hybrid with the genetic make-up of both parent plants. The plants that plant breeders choose have the traits they wish to pass on and they continue to breed those species. Remember that crossbreeding only works between individuals of the same or closely related species.

Polyploidy may be developed to vary the number of chromosomes present in the crop, which can affect the crop's fertility or size. Most creatures have two sets of chromosomes, or are diploid. The number of chromosomes may change, either naturally or by the use of chemicals, which can affect fertility or crop size. A 4-set chromosome watermelon is crossed with a 2-set chromosome watermelon to create a sterile watermelon with three sets of chromosomes. Every creature's DNA is subject to random mutations. To give diversity in harvests, scientists may randomly introduce mutations into plants. In mutagenesis, radioactivity is employed to create random mutations in the hopes of identifying the desired phenotype. Scientists may utilize radioactivity or chemical modifiers like ethyl methanesulfonate to create random mutations in DNA. Atomic gardens create mutant crops. Within a certain radius, radiation from a spherical garden with an enhanced radioactive core in the centre causes mutations in the around plants. Ruby red grapefruits were produced by the radiation-induced mutagenesis method.

Rotational Fusion

Protoplast fusion is the term for the joining of cells or cell components to transfer characteristics across species. For instance, the trait of male sterility is transferred from radishes to red cabbages by protoplast fusion. Because of this male sterility, plant breeders may produce hybrid crops.RNA interference (RNAi), which silences genes, reduces or disables a cell's RNA-to-protein pathway. This kind of genetic modification disrupts messenger RNA, which limits the production of proteins, thereby silencing a gene.

Transgenic

By inserting a DNA fragment into the DNA of another organism, the process of transgenic allows for the introduction of new genes into the DNA of the original organism. The genetic composition of an organism may be altered to generate a new variety with desired traits. The DNA must be prepared and stored in a test tube before being inserted into the new organism. New genetic information may be introduced using gene guns and biologics. An example of a transgenic plant that has been modified with a gene that gives resistance to the papaya ringspot virus is the rainbow papaya.

Editing a Genome

Genome editing involves employing an enzyme system to directly modify the DNA inside a cell. Herbicide-resistant canola is being produced via genome editing to assist farmers in controlling weeds.Genome editing, also known as gene editing, refers to a range of scientific techniques that enable the modification of an organism's DNA. At specific sites in the genome, these technologies enable the addition, removal, or modification of genetic material. Many methods for genome editing have been developed. CRISPR-Cas9, which stands for clustered regularly interspaced short palindromic repeats or CRISPR-associated protein 9, is a well-known example. Because it is quicker, less expensive, more precise, and more effective than existing genome editing techniques, the CRISPR-Cas9 system has sparked a lot of interest in the scientific community.

Despite the achievements thus far, there are still numerous obstacles to overcome before genome editing can fully fulfil its promise. The creation of novel technologies that can introduce genomic changes in the absence of DNA breaks comes first. One such possibility is the use of targeted recombinases, which may be designed to identify certain DNA sequences and even incorporate therapeutic elements into the human genome. Recent studies have shown that an engineered Cas9 nickase complex may enable single-base editing without DNA breaks, however, it is still unclear how successful this technique is in therapeutically relevant contexts. Self-inactivating vectors have the potential to increase the specificity of genome editing by tying genomic modifications brought on by targeted nucleases to their self-degradation. This is especially true given that the frequency of off-target modifications can be directly proportional to the amount of time that cells are exposed to a nuclease.

Additionally, immortalised cell lines have helped scientists learn a lot about genome engineering. Progenitor or stem cell populations, both of which may vary significantly from transformed cell lines in terms of their epigenome or the three-dimensional arrangement of their genomic DNA, are extremely attractive for genetic manipulation in the context of regenerative medicine. These variations may significantly affect how well genome-editing technologies may change a particular sequence or control gene expression. The promise of these technologies in stem/progenitor cells must be fully realised in these genetic backgrounds even if the intersection of genome engineering and regenerative medicine is still in its infancy. For the next wave of developments in synthetic biology and gene therapy, genome editing tools won't genuinely be able to modify cell destiny and behaviour until then.A naturally occurring genome editing mechanism that bacteria deploy as an immunological response is the basis for CRISPR-Cas9. Bacteria that are virus-infected seize tiny bits of the viruses' DNA and splice it into their DNA in a specific way to form sections known as CRISPR arrays. The bacteria can "remember" the viruses thanks to the CRISPR arrays (or closely related ones). In the event of a subsequent virus assault, the bacteria create RNA segments from CRISPR arrays that can detect and bind to certain sections of the viral DNA. The virus is subsequently rendered inoperable by the bacteria's employment of Cas9 or a related enzyme to split the DNA.

This immune system's protection was modified by researchers to modify DNA. Similar to the RNA segments bacteria make from the CRISPR array, they produce a tiny bit of RNA with a short guide sequence that connects (binds) to a particular target region in a cell's DNA. Additionally, this guide RNA binds to the Cas9 enzyme. Similar to how the Cas9 enzyme works in bacteria, when the guide RNA is delivered into cells, it detects the desired DNA sequence and causes the DNA to be cut at the desired spot. Other enzymes, such Cpf1, may also be employed, albeit Cas9 is the one that is most often used. Once the DNA has been damaged, scientists may add or remove genetic material or replace the DNA by replacing an existing segment with a unique DNA sequence using the cell's DNA repair mechanism.

The prevention and treatment of human illnesses is a major area of focus for genome editing. Genome editing is now employed in research facilities to study illnesses in cells and animal models. Researchers are currently figuring out if this method is secure and efficient for usage in humans. A broad range of illnesses, including single-gene diseases like cystic fibrosis, haemophilia, and sickle cell disease, is being investigated in research and clinical trials. Additionally, it shows promise in the management and avoidance of more complicated illnesses including cancer, heart disease, mental illness, or HIV infection.

When human genomes are edited using tools like CRISPR-Cas9, there are ethical questions that are raised. The majority of genome editing's modifications are only made to somatic cells, which are cells other than egg and sperm cells (germline cells). Only certain tissues are affected by these alterations, and they are not handed down from one generation to the next. However, alterations made to the genes of an embryo, sperm, or egg cells may be passed on to the next generations. Genome editing of germ cells and developing embryos raises a variety of ethical issues, such as whether it would be acceptable to utilise this technology to improve typical human qualities. Germline cell and embryo genome editing are now prohibited in the United States and many other nations due to ethical and safety concerns.

Plant modification methods

Conventional farming

For generations, traditional crossbreeding has been utilised to increase crop quality and yield. By mating two sexually compatible species, crossbreeding produces a new and unique variation with the desired characteristics of the parents. For instance, the honeycrisp apple's distinctive texture and taste result from its parents' crossbreeding. Traditional methods include applying pollen from one plant to the female portion of another, creating a hybrid that has the genetic makeup of both parent plants. Plant breeders choose the plants that have the features they want to pass on and keep breeding those species. Keep in mind that crossbreeding is only effective between members of the same or closely related species.

Mutagenesis

In the DNA of every creature, mutations may happen at random. Scientists may haphazardly introduce mutations into plants to provide variation in harvests. Radioactivity is used in mutagenesis to cause random mutations in the hopes of discovering the desired phenotype. Radioactivity or modifying chemicals like ethyl methanesulfonate may be used by scientists to introduce random mutations into DNA. Crops are mutated in atomic gardens. A circular garden with an elevated radioactive core in the middle emits radiation into the surrounding plants, causing mutations within a specific radius. Ruby red grapefruits were created through a procedure called radiation-induced mutagenesis.

Increased Nutritional Value

Agricultural biotechnology has been used to improve the nutritional content of numerous crops to meet the demands of a rising population. Genetically modified crops may have more vitamins. For instance, three genes in golden rice allow plants to produce chemicals that the human body uses to make vitamin A. The nutritional value of this rice has been improved to assist prevent vitamin A deficiency, the leading global cause of blindness. The Banana Project has made comparable efforts to improve banana nutrition to solve Uganda's vitamin shortage. The banana, a staple food and a significant source of starch in Africa, has helped to discover a solution to the lack of micronutrients by being genetically altered to include vitamin A and iron. Additionally, crops may be genetically altered to create varieties that are less toxic or allergy-free.

Since eight to ten thousand years ago, when agriculture first emerged, farmers have been modifying the genetic makeup of the crops they cultivate. The best-looking plants and seeds were chosen by early farmers, who then stored them for planting the next year. Compared to their wild cousins, domesticated plant species have undergone significant changes as a result of selection for traits including quicker growth, bigger yields, pest and disease resistance, larger seeds, and tastier fruits. When man discovered that agricultural plants could be intentionally married or cross-pollinated to enhance the traits of the plant, plant breeding was born. In the offspring, advantageous traits from many parent plants may be blended.

Plant breeders had a better understanding of how to choose superior plants and breed them to produce new and improved kinds of various crops as the science of plant breeding advanced in the 20th century. The productivity and quality of the plants we raise for food, feed, and fibre have significantly risen as a result. For hundreds of years, cultivating new crops has been done via conventional plant breeding. However, because of the rising population, the depletion of agricultural resources like land and water, and the apparent plateauing of the yield curve of the main crops, traditional plant breeding is no longer able to meet the demand on a worldwide scale. Therefore, it is important to develop and use innovative crop enhancement technology.

The Note also contrasts these NBT, where appropriate, with ETGM and CBT based on a variety of factors, such as the product's detectability and identification, the speed and cost of achieving the desired result, and the maturity of the technique that is, whether still in development in the laboratory or ready for use in agricultural contexts, for example, field trials for plants. Safety-related issues are also briefly covered. A scientific and technological comparison of the different methods is made. As a result, words are utilised following their scientific meaning as opposed to their legal meaning. But as was said before, the categorization of approaches is based in part on legal and regulatory definitions that were contained in the "scoping report". The HLG has preferentially cited published reviews of the literature, scientific reports, and existing published opinions from reputable scientific or science-based organisations in the following Tissue Culture and Micropropagation in addition to its general policy to consider as evidence-only information that is in the public domain at the time of publication of scientific advice and in light of a large amount of information available.

To satisfy the requirements of a growing population, agricultural biotechnology has been employed to enhance the nutritional value of several crops. Crops made via genetic engineering may have more vitamins. Golden rice, as an example, has three genes that enable plants to create substances that are transformed into vitamin A in the human body. This rice has been nutritionally enhanced to help fight vitamin A deficiency, the main cause of blindness worldwide. Similar efforts have been made by the Banana 21 initiative to boost banana nutrition to address Uganda's vitamin deficiency. Banana 21 has contributed to the development of a remedy to micronutrient shortages by genetically engineering bananas to include vitamin A and iron. Bananas are a staple meal and a key source of carbohydrates in Africa. Additionally, crops may be modified via genetic engineering to develop kinds that are less poisonous or free of allergies.

Plants typically generate new life by sexual reproduction; to do this, they produce blooms and seeds. Pollen from the stamens male portion of the same plant's flower or a different plant fertilises the egg cells in the flowers cross. DNA is the genetic material that is present in each of these sexual cells. In sexual reproduction, DNA from both parents is combined to produce children who are either genetically identical to their parents as in self-pollinated crops or different from them in unexpected ways, resulting in distinct species in cross-pollinated crops. On the other hand, some plants and trees take several years before they blossom and produce seeds, which makes improving plants challenging. To help breeders with this endeavour, plant scientists have created the science and art of tissue culture. The growing of plant cells, tissues, or organs on a specifically designed nutritional medium is known as tissue culture. A single cell may be used to regrow an entire plant under the appropriate circumstances. Over 30 years have passed since the invention of plant tissue culture. Depending on the plant explant employed, there are many forms of tissue culture. Another culture is a tissue culture technique used to create better types quickly. An anther's pollen is composed of haploid DNA, which spontaneously doubles into diploid DNA during culture. Colchicine therapy is essential to cause doubling in certain species, however. The manifestation of recessive features that were repressed, hidden, or overlooked during ordinary plant breeding will now be possible because of genome doubling.

Immature pollen inside the anthers divides when they are put in a specific media, creating a mass of dividing cells known as a callus. To develop shoots and roots, healthy calli plural of callus are selected and implanted in a different media regeneration. Plantlets that are stable are allowed to develop and flourish in the greenhouse. The required plants may subsequently be chosen by plant breeders from the regenerated plants. A new culture of F1 plants that are offspring of a certain breeding goal would permit a wide variety of regenerants. This is because the genetic makeup of the pollen will be more diverse than that of inbreds, giving breeders a greater selection of features to choose from. With the use of this method, doubled haploid lines of rice, wheat, sorghum, barley, and other field crops have been successfully developed. Since 1995, rice varieties created by another culture (AC) have been made available by the Philippine National Seed Industry Council.

In 1995, IRRI developed and commercialised PSBRc50 (Bicol), the first AC-derived, salt-tolerant cultivar. Two rainfed types and eight salt-tolerant kinds of rice were created by the Philippine Rice Research Institute. Micropropagation is a tissue culture technique created for the quick generation of many uniform seedlings and the manufacture of disease-free, high-quality planting material. Young cells that are actively dividing (meristem) are put in a particular medium and given plant hormones to develop a large number of sister plantlets that are identical to each other. A large number of uniform plantlets are created quickly from clean materials because the meristem divides more quickly than viruses that spread illness. It is now feasible to offer clean and homogeneous planting materials by micropropagation for a variety of crops, including field crops like eggplant, jojoba, pineapple, and tomato, root crops like cassava, yam, and sweet potato, and several decorative plants like orchids and anthuriums.

In comparison to traditional propagules, micro-propagated plants were shown to establish more rapidly, develop more aggressively and taller, have a shorter and more consistent production cycle and generate larger yields. To prevent the early embryo from being aborted and to encourage its germination, immature plant embryos are cultured in a specific medium as part of the embryo rescue process.When breeding parental lines with divergent or incompatible genomes, such as when transferring significant features from wild relatives into cultivated crops, this method is often done. Wide crosses between the Asian Oryza sativa and the African rice Oryza glaberrima resulted in the production of a new rice plant type for West Africa (NERICA - New Rice for Africa). To stabilise the breeding lines, embryo rescue is used during both the original breeding and the subsequent back-crossing procedure that is followed by another culture. The new plant's combined sativa parent plant yield characteristics with glaberrima parent plant characteristics for local adaptation.

Advantages of Agriculture Biotechnology

Agriculture biotechnology is a vast and quickly developing field that continues to transform our understanding of the basic ecological processes that support life by locating and exploiting biomolecules and their applications to develop clean technologies. For controlling the environment, this technology is crucial. Agriculture has a wide range of applications, including the use of certain bacteria to increase soil nutrient absorption, as well as in the control of pollution and the treatment of wastewater.

Technology is concentrated on enhancing production processes with minimal waste generation, waste recycling, the development of bioresources, the manipulation of microbes according to waste, the remediation of contaminated habitats, the breakdown of chemicals, heavy metal removal, pesticides, and the remediation of ground and surface water. Rapid industrialization, rising population, or resource exploitation all contribute to environmental deterioration, which in turn causes health risks such as ozone depletion, acid rain, or global warming.

Economic Features Insect Resistance

Insect resistance is one quality that is greatly desired. This characteristic permits a larger production while enhancing a crop's insect resistance. Crops that have been genetically modified to produce the insecticidal proteins first identified in (Bacillus thuringiensis). A bacteria called *Bacillus thuringiensis* creates harmless proteins that repel insects. Numerous crops have received isolated genes that provide this insect resistance. Bt maize and cotton are already widely available, and research is being done on Bt in connection to soybeans, sunflowers, cowpeas, tomatoes, sugar cane, tobacco, walnuts, and rice.

Tolerance to Herbicides

For thousands of years, weeds have been a problem for farmers since they compete with crops for soil nutrients, water, or sunshine, and can be fatal. Herbicide tolerance is a remedy provided by biotechnology.

Herbicide-resistant crops have the chance to thrive since weeds are killed by chemical herbicides that are sprayed directly on plants.

Resistance to Disease

Frequently, diseases transmitted by insects affect crops (like aphids). Until recently, the only way to limit the spread of illness among agricultural plants was to entirely remove the damaged crop. Through the use of genetic engineering to create viral resistance, the discipline of agricultural biotechnology provides a remedy. Cassava, maize, or sweet potatoes are now being developed as GE disease-resistant crops.

Tolerance for Temperature

Additionally, agricultural biotechnology could provide plants in high-temperature environments with a solution. Genes that assist control of cold and heat tolerance can be altered to increase production and reduce crop mortality. For instance, tobacco plants have been genetically altered using genes originally identified in Carica papaya to be more adaptable to hot and cold temperatures. Other characteristics include salt tolerance, nitrogen usage efficiency, and water use efficiency.

Typical GMO Crops

In the United States, there are currently very few genetically modified crops that may be bought and eaten. Soybeans, canola, corn, sugar beets, papaya, alfalfa, cotton, squash, apples, or potatoes have all received USDA approval. As non-browning apples, GMO apples (arctic apples) minimize food waste, enhance flavour, and do away with the need for anti-browning treatments. In 2011, 10 million hectares of Bt cotton were planted for the first time in India, which led to a 50% decrease in the need for insecticides. More than 15 million hectares of Bt cotton were planted by Indian and Chinese farmers in 2014.

Government Regulations or Safety Evaluations

Three major US government organizations oversee agricultural biotechnology regulation: the Food and Drug Administration (FDA), the Environmental Protection Agency (EPA), and the Department of Agriculture (USDA) (FDA). The FDA assesses the safety of a specific crop before it is put on the market, the EPA regulates pesticide regulation, and the USDA must authorize the release of any new GMOs.

A field creature must undergo around 13 years of development and research and costs $130 million. In the US, the regulatory procedure might take up to 8 years. In addition to the FDA's efforts, scientific studies are being done to examine the safety of ingesting GMOs, which have become a contentious issue around the globe. One of these studies concluded that Bt rice had no negative effects on digestion or the induction of horizontal gene transfer.

Environmental Science's Value

The environment is vital to everyone since it belongs to all living things. Environmental problems including ozone depletion, global warming, decreasing forests, energy resources, and biodiversity loss affect everyone.Analysis of the procedures in water, land, air, soil, or creatures that cause pollution or environmental degradation is the focus of environmental studies. It aids in setting a norm for a secure, hygienic, and stable natural ecology.It also addresses significant concerns including access to clean and safe drinking water, sanitary living conditions, clean air to breathe, fertile land, wholesome food, or development.Environmental management, Environmental engineering, or sustainable environmental legislation are emerging as aspects of environmental management and protection.

Molecular Breeding and Marker-Assisted Selection

New crop variety development is a multi-step process that, depending on the crop, might take 10 to 25 years. The time it takes to get them to market has now significantly decreased because ofthe uses of agricultural biotechnology. New crop types currently take 7 to 10 years to create. Marker-assisted selection is one of the technologies that help scientists choose plant features more quickly and easily (MAS). The genetic material, or deoxyribonucleic acid, of plants contains codes for their many characteristics and physical characteristics (DNA). One chromosome (a strand of genetic material) from each parent makes up the DNA, which is found in pairs. The exact sections of each chromosome that make up the genes are what regulate the traits of the plant. The genome of a plant is made up of all of its genes. Some characteristics, like flower colour, may only be regulated by one gene.

However, many genes may have an impact on other, more complicated traits like a crop yield or starch content. Plant breeders have traditionally chosen plants based on the phenotype traits that can be seen or measured on a plant. However, this process may be challenging, drawn out, impacted by the environment, and expensive not only for the economy as a whole as farmers experience crop losses, but also for the development itself. Plant breeders currently utilise molecular marker-assisted selection as a fast cut. Scientists utilise so-called molecular markers, which are little sequences or strings of nucleic acid that make up a section of DNA, to assist identify certain genes.

The markers are situated close to the target gene's DNA sequence. As new generations of plants are created, the markers and genes tend to remain together since they are situated near to one another on the same chromosome. We refer to this as genetic linkage. This connection enables researchers to foretell whether a plant will have the desired gene. If scientists can locate the gene's marker, it implies that the gene is indeed present.

A map of the markers and genes on certain chromosomes may be made by scientists when they understand where each marker appears on a chromosome and how near it is to a particular gene. The location of markers and genes, as well as their separation from other recognised genes, are shown on this genetic linkage map. With plant breeding, scientists can create comprehensive maps in only one generation. In the past, researchers created relatively basic genomic maps using traditional methods. Long ago, it was discovered that when plant generations were crossed, certain features often co-occurred in the offspring (genetic linkage). However, it required several crossings to produce even a very basic genetic map since researchers could only focus on a few features in each effort at cross-breeding.

Researchers may examine a small portion of tissue from a freshly sprouted seedling using very comprehensive genetic mapping and an improved understanding of the molecular structure of a plant's DNA. They may check for the existence of the particular feature right away, without having to wait for the seedling to develop into a full-grown plant.

When the tissue is examined using molecular methods, researchers can determine if the seedling has the required gene. If it doesn't, they may move on right away and focus their investigation on a different seedling, gradually limiting their work to plants that have the particular attribute. When the gene and the markers for a particular feature are known, molecular marker-assisted breeding, an agricultural biotechnology technique, is now a common stage in breeding most crops.

This method is being utilised to effectively introduce crucial genes into a variety of crops, such as rice, which has submergence tolerance and bacterial blight resistance as well as higher beta carotene content than cassava, banana, or other crops. The genetic makeup of a line or variety may also be ascertained using molecular markers. To scan the plant's genetic makeup using molecular techniques, random primers are utilised. The data is loaded into a computer algorithm that examines how closely connected each line is to the others. The lines' genetic variety is taken into account when choosing parents for hybrid seed technologies that are much unrelated to one another. Additionally, the information will provide specifics on the line's ancestry, potential features, and the distinctive identification of the plant, all of which are helpful for germplasm collection databases.

Genetically Modified (GM) Crops

The area of agricultural biotechnology has advanced quickly over the last 30 years as a result of our growing knowledge of DNA as the chemical double-helix code from which genes are created. One of the recombinant DNA-based agricultural biotechnology methods used today is genetic engineering.

The act of changing an organism's genetic composition through "recombinant DNA technology" is referred to as genetic engineering, which is often used interchangeably with phrases like gene technology, genetic alteration, or gene manipulation. This entails the removal, insertion, and modification of DNA fragments that contain one or more desirable genes using laboratory equipment and specialised enzymes. Genetic engineering differs from conventional plant breeding in that it allows for the manipulation of specific genes as well as the transfer of genes across species that would not typically interbreed. With traditional plant breeding, there is little to no assurance that any specific gene combination will be obtained among the millions of crosses produced.

Because the genes of both parents are combined and rearranged more or less randomly in the child, undesirable genes might be passed alongside beneficial genes, or while one desirable gene is obtained, another is lost. These issues restrict the advancements plant breeders may make, consuming time and resources in the process. Contrarily, genetic engineering enables the direct transfer of one or a small number of genes, across species that are either closely related or unrelated. Inserting DNA from other species is not a need for all genetic engineering methods. Additionally, plants may be altered by deleting or turning off certain genes and genetic regulators (promoters).

The term "biotech" or "biotechnology" broadly refers to a variety of techniques for altering living things for human benefit. These techniques include domesticating animals and plants and making "improvements" to them via breeding programmes that make use of artificial selection and hybridization. In general, biotechnology encompasses a broad range of developments and uses for the creation of beneficial living products and services. A branch of agricultural science known as agricultural biotechnology employs techniques from cell and molecular biology to improve the genetic makeup and agronomic management of crop plants. A kind of biotechnology used in agricultural activities is known as green biotechnology. Compared to conventional industrial agriculture, green biotechnology is anticipated to deliver a more ecologically friendly alternative. Engineering a plant that can produce pesticides without having to apply them externally, like Bt maize, is one example of this. It is often seen as the continuation of the green revolution and a platform for eradicating global hunger via the use of technology that makes it possible to cultivate plants that can withstand both biotic and abiotic stress. To decrease the usage of synthetic pesticides and/or increase the efficiency and effectiveness of pest management, several crops have been genetically modified to be resistant to certain plant diseases and insect pests. These crop production alternatives may lower production costs while assisting nations in meeting rising food needs.

The application of biotechnology in agriculture has helped producers, consumers, and farmers. While protecting crops from disease, biotechnology has helped to make pest control or weed management safer and easier. For instance, the usage of persistent, toxic pesticides that may harm groundwater and the environment has been significantly reduced thanks to genetically engineered insect-resistant cotton.

Herbicide-tolerant soybeans, cotton, and corn allow for the use of low-risk herbicides that degrade more quickly in soil and are safe for both people and animals to consume. Herbicide-tolerant plants are well suited to no-till or low-till farming techniques, which assist prevent soil erosion. Crop protection against harmful diseases has been achieved via the application of agricultural biotechnology.

For example, the papaya ringspot virus threatened to ruin the Hawaiian papaya industry until disease-resistant papaya was produced via genetic engineering. The American papaya industry was rescued by this. Research on potatoes, squash, tomatoes and other crops continues similarly to offer resistance to viral illnesses that are otherwise extremely difficult to manage. Biotech crops may make farming more lucrative by boosting the quality of crops and, in certain circumstances, improving yields. Some of these crops might make farming easier and increase farmer safety. This enables farmers to focus more of their time on other lucrative pursuits and less time on maintaining their crops. Increased amounts of beta-carotene in rice, for example, may help alleviate vitamin A deficiency and improve the oil composition of canola, soybean, and maize in biotech crops.

Genetic engineering used in agricultural production

When all other methods have failed and the trait to be introduced is absent from the crop's germplasm, it is extremely difficult to improve the trait using conventional breeding techniques, and it will take a very long time to introduce and/or improve the trait using conventional breeding techniques, genetic engineering techniques are only used. A variety of methods and components from traditional breeding techniques, bioinformatics, biochemistry, molecular genetics, molecular biology, and genetic engineering are used and integrated into the multidisciplinary and coordinated process of modern plant breeding. Creation of transgenic plants although genetic engineering uses a wide variety of intricate procedures, its fundamental ideas are rather straightforward.

However, it is crucial to understand the physiological and biochemical processes of action, the control of gene expression, and the safety of the gene and gene product being used, as shown in figure 1.1. A set of six processes must be completed to carry out genetic engineering.

Step 1: Extraction of nucleic acids (DNA/RNA)

Genetic engineering begins with the extraction of nucleic acids, such as DNA or ribonucleic acid (RNA). Therefore, it is critical that these components can be isolated from the cell using trustworthy techniques. Any isolation technique begins with the disruption of the target organism's cell, which might be a bacterial, viral, or plant cell, to get the nucleic acid. The extracted nucleic acid may be precipitated to create pellets of DNA/RNA that resemble threads after a series of chemical and biological procedures.

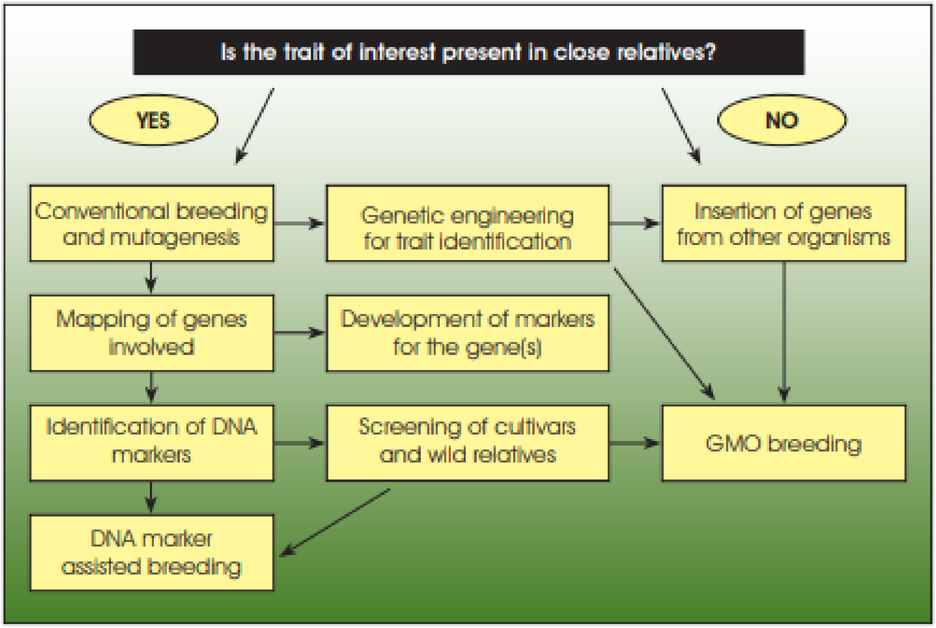

Figure 1.1: combining traditional and contemporary biotechnological techniques for crop breeding.

Step 2. Gene cloning

Gene cloning is the next stage. Any cloning experiment consists of essentially four steps: the creation of DNA fragments, attaching to a vector, propagation in a host cell, and choice of the necessary sequence. In DNA extraction, the whole organism's DNA is taken out. To enable cloning into bacterial vectors, this genomic DNA is subjected to specialised enzymes known as restriction enzymes, which break it down into smaller pieces with specified ends. The vector will then have several distinct genomic insertions in copies. Thousands of copies of these vectors are created after being converted into bacterial cells. The vector containing the appropriate sequence is found, chosen, isolated, and clones are created using knowledge of certain molecular marker sequences and the intended phenotype. Once again, restriction enzymes are used to check for full and accurate cloning of the target gene insert.

Step 3: Packaging and Gene Design

After the target gene has been cloned, it has to be connected to DNA segments that will regulate how it is expressed within the plant cell. These bits of DNA will activate the promoter and deactivate the terminatorof the inserted gene's expression. Replace an existing promoter with a new one, include a selectable marker gene and reporter gene, and add gene enhancer fragments, introns, and organelle-localizing sequences, among other techniques for creating and packaging genes.

Promoters

Promoters enable diverse gene expression. As an example, certain promoters enable the inserted genes to be expressed continuously and in all parts of the plant (constitutive), while others only permit expression at specific phases of plant development, in specific plant tissues, or response to environmental cues. The promoter also regulates how much of the gene product will be expressed. Some promoters are ineffective, while others are effective. The ability to regulate gene expression is advantageous for creating GM plants.

Step 4: Choose-your-own-marker genes

To make it easier to recognise the gene of interest after it has entered the plant tissues, selectable marker genes are often connected to it. This makes it possible to choose just those cells that have effectively absorbed the desired gene, saving both money and time. To identify cells that carry the inserted gene, genetic engineers exploited flag genes for herbicide and antibiotic resistance. The presence of the inserted gene is shown in cells that endure the growth medium's addition of marking agents. Genes coding for resistance to non-medically essential medicines is chosen, even though a rise in antibiotic resistance in people and animals is unlikely to occur utilising antibiotic resistance markers. Additionally, many kinds of marker genes that are connected to plant metabolisms, such as phosphomannose isomerase, xylose isomerase, and others, have been produced.

Reporter Genes

To make it easier to identify transformed cells and to evaluate the proper expression of the inserted gene, reporter genes are cloned into the vector near the gene of interest. The green fluorescent protein (gfp), enables transformed cells to glow under a green light, the luciferase gene, enables cells to glow in the dark, and the beta glucuronidase gene (gusA gene), which acts on a specific substrate producing a blue product, are examples of reporter genes that have been used.

Enhancers

To boost gene expression, various genetic sequences may be cloned either before the promoter sequences enhancers or inside the genetic sequence itself introns, or non-coding regions. Putting promoter enhancers for the cauliflower mosaic virus in front of the plant promoter is one example. The target gene is packed with the reporter, promoter, and marker gene before being injected into a bacterium to enable the production of multiple copies of the gene package. Particle bombardment may be used to convert plant cells utilising the extracted DNA from the bacterial clones. However, if the *Agrobacterium tumefaciens* bacteria are to be used for the plant transformation, the whole gene package must be cloned between the left and right border sequences of a binary vector plasmid. This will enable the Agrobacterium to be processed such that the plant genome will only include the transfer DNA (T-DNA).

Step 5: Bombardment with particles

The desired gene may be mechanically introduced by particle bombardment. Using the gene gun or particle gun, the desired genetic sequence is cloned onto a plant DNA vector and injected into the plant. The bullet in the gene gun is made of tiny tungsten or gold particles, much as in a regular pistol. These particles are coated with the DNA solution and fired at the plant cells in a vacuum-sealed container using the force of the helium gas. Within 12 hours of the DNA and tungsten/gold particles entering the cell, the inserted DNA has merged with the plant DNA within the nucleus. The vacuole holds the tungsten/gold particles until they are eventually excreted. In vitro cultivation of transformed cells results in the induction of tiny plant regeneration that expresses the inserted genemediated by *Agrobacterium tumefaciens* transformation.

DNA "sharing" between living things is a well-known natural occurrence. Genes have been passing from one creature to another for countless years. For instance, the soil bacteria *Agrobacterium tumefaciens*, dubbed "nature's genetic engineer," can genetically modify plants. Many different broad-leaved plants, including apple, pear, cherry, peaches, almonds, raspberry, and roses, are affected by crown gall disease. The huge tumour-like swellings (galls) that normally develop at the plant's crown, just above soil level, give the disease its name. In essence, the bacteria transmits a portion of its DNA to the plant, and this DNA fuses with the plant's genome to produce tumours and the corresponding modifications to the metabolism of the plant. This biological process has been used by molecular biologists to enhance crops. The genes that generate galls are deleted, and genes that code for good qualities are added in their stead. Instead of producing galls, the bacteria will cause plant cells to make cells that have the desired gene. These cells, when cultivated in a certain medium, will grow back into plants and exhibit the desired feature.

Genetic modification techniques Biolistics or Gene Gun and *Agrobacterium tumefaciens*-mediated transformation methods. Alfonso Any transformation procedure's primary objective is to introduce the desired gene into the cell's nucleus while preserving the cell's capacity for survival. The plant is considered to have transformed if the newly inserted gene is functional and the gene product is produced. The plant is regarded as transgenic after the inserted gene is stable, passed down through generations, and expressed. The fifth step is finding inserted genes. To check the integrity of the transgene-introduced gene in the plant cell, molecular detection techniques have been developed.

A simple test to detect if the gene is present in the regenerated transgenic cells or plants is the polymerase chain reaction or PCR. It employs a pair of forward and backward primers (DNA fragments), whose nucleotide sequences are based on the sequence of the inserted gene. The single-stranded genomic DNA is incubated with primers and single nucleotides, and numerous cycles of DNA amplification are carried out in a PCR machine. When DNA fragments identical in size to the inserted gene are present and amplified, analysis of the PCR results on an agarose gel will reveal if the plants have indeed transformed. The integrity of the inserted gene is determined by Southern blot analysis, including whether the gene is whole and not fragmented, in the right orientation, and with one copy number. The probe that binds to the single-stranded genomic DNA of the transgenic plant that is embedded in nitrocellulose paper is the DNA coding sequence. Autoradiography will show if the plant is transgenic. For the transgene to express best, just one copy is needed. The presence and proper transcription of the inserted DNA's transcript or messenger RNA (mRNA) in the transgenic plant is assessed using a Northern blot analysis. The transgenic plants' messenger RNA is purified and then processed to bind to the nitrocellulose membrane. Through autoradiography, labelled DNA may be seen binding to the mRNA. An analytical method used to determine if transgenic plants generate the particular protein product of the inserted gene is known as protein immunoblotting or Western blot analysis. From the transgenic plants, protein samples are isolated, denatured, and then transported to a nitrocellulose membrane. The target protein-specific antibodies are then used to probe or detect the protein.

Step 6: Backcross breeding

Elite or commercial varieties that already have the required agronomic qualities but lack the crucial trait of the transgene are often the subjects of genetic transformation. Therefore, if the experiment is a success and the genetically modified plant demonstrates stability over multiple generations in addition to passing and satisfying the conditions for varietal registration, it will be simple to promote it for commercialization. While certain plant kinds are accessible to genetic modification but are neither adapted nor significant in the target nation, some plant transformations may have been carried out on them. Sterility issues might potentially exist in the transgenic plant. In these situations, normal plant breeding is carried out, using the elite lines or commercial varieties as the recurrent parents and the transgenic plant as the pollen supply in the breeding procedure. Backcross breeding makes it possible for the child to combine the desired qualities of the recurrent parent and the transgenic line. The amount of time required to grow transgenic plants depends on the gene, the kind of crop, the resources available, and regulatory permission. Before a novel transgenic plant or hybrid is ready for commercial distribution, it may take anywhere between 6 and 15 years. Using genetic engineering, commercially available crops have been enhanced.

Since 1996 till the present, there has been a steady rise in the area of the world planted to transgenic, GM, or biotech crops. The area has grown, the advantages of using transgenic crops, farmer stories of growing them, and potential future applications of the technology. Alfalfa, bean, Argentine canola, carnation, chicory, cotton, eggplant, papaya, petunia, flax, maize, creeping bentgrass, melon, plum, poplar, potato, rice, Polish canola, squash, rose, soybean, sugar beet, sweet pepper, sugarcane, tobacco, tomato, and wheat are some of the 27 transgenic crops that have been commercially planted thus far. Multiple features, or "stacked traits," may be integrated into a plant by genetic engineering. Currently, these crops including soybeans, cotton, and corn are tolerant to both insects and herbicides. Commercially accessible transgenic crops with combination features include cotton and maize that are insect and herbicide resistant. The crop becomes more resilient to withstand the pest/disease and tolerates more herbicides by stacking various genes for one attribute.

Utilizing the refuge is another tactic to increase the sustainability of the technology. Developers of technology have researched efficient refuge systems for certain change events. These are thoroughly explained to farmers to ensure effective application, and they are periodically checked for any resistant weeds or insects.

Commercial GM crops have improved crop output to this point, but a variety of goods that will have a more immediate impact on food quality, a clean environment, pharmaceutical manufacturing, and animal feeds are also in the works. These include, for instance, rice with higher levels of iron and beta carotene (a vital micronutrient that the body converts to vitamin A); long-lasting bananas that ripen earlier and can therefore be harvested earlier; maize with improved feed value; delayed-ripening papaya; papaya ringspot virus-resistant papaya; tomatoes with high levels of flavonols, which are potent antioxidants; drought-tolerant maize and wheat; maize with improved pho; and maize Farmers are used to using a variety of cultivars and planting techniques to produce agricultural goods that satisfy market demands. They are used to growing a variety of crops, including spicy and sweet peppers, high and low erucic acid rapeseed, and they nevertheless meet the purity requirements set out by certified seed specifications.

Strategies for coexistence must be developed to enable nearby farmers to operate their operations profitably. This might include communicating their intentions to one another and adapting them to suit the requirements of the other. Certain farming techniques that reduce drift of synthetic pesticides, such as spatial separation of fields, staggered planting dates, planting varieties with different maturity dates, and planting varieties that are not sexually compatible, can also limit the flow of GE genes when GE crops are grown close to organic farming operations. To help coexistence efforts, further crop-specific techniques have been developed. In addition to being able to mix with conventional or organic crops via gene flow, crops must also be kept separate throughout harvest, transportation, and processing. In certain instances, techniques for preventing this mixing have been put into practice.

In the last several decades, conventional farming has contributed to tremendous improvements in food production of between 70 and 90%. The use of significant amounts of fossil fuels, unsustainable rates of water use and topsoil loss, and contributions to environmental degradation, air pollution, soil erosion, reduced biodiversity, pest resistance, pollution of lakes and streams, as well as excessive use of surface and groundwater, were all unfortunate side effects. Numerous agricultural approaches, including integrated pest management (IPM), biological control, organic farming, and the use of genetically engineered (GE) plants, in combination with a few traditional farming techniques, may help achieve agricultural sustainability.

IPM may include biological control, and neither IPM nor biological control expressly disallows the use of GE organisms. The use of synthetic pesticides and GE organisms are prohibited in organic farming, which instead depends on techniques like cultural and biological pest management, which may also include IPM and biological control. By enhancing and displacing certain traditional methods, the use of GE organisms may also support sustainable behaviours. For instance, plants may be developed that utilise more water and fertilizer efficiently, remove toxins from the soil, promote the use of no-till or low-till farming techniques, and boost yields without requiring more acreage, especially in poor nations. The finest techniques must be used in agriculture if genuine sustainability is to be achieved.

Unintended consequences of traditional plant breeding methods two haploid parental genomes are combined in offspring when the sexual crossing is used to impart a desired characteristic from a donor plant into a recipient plant. Since children acquire around 50% of each parent's DNA complement, first-generation kids who receive the desired characteristic from one parent will also inherit extra undesirable qualities from both parents. These alleles can have unexpected consequences including pleiotropic effects and effects on the expression of other genes. Further breeding may result in following generations showing a proportionately higher number of undesirable features because of the phenomena of meiotic recombination in which homologous chromosomes "cross over" and permit the rearranging of alleles during the creation of gametes. Backcrossing may be used to separate the desired characteristic from undesirable ones to regulate this. Backcrossing, however, does not completely eradicate all undesirable characteristics, particularly those whose encoding genes are situated near the gene(s) expressing the desired feature. About 7 x 10-9 base substitutions per site, each generation, are involved in spontaneous mutations. As a result, a genome the size of Arabidopsis thaliana experiences one nucleotide substitution each generation.

This implies that sexual crossover might potentially have unwanted consequences build up. Depending on the strength and quantity of the mutagenic agent, induced mutagenesis may raise this mutation rate by a factor of around 500. All mutations that happen in addition to those that bestow the intended feature are referred to as "off-target" mutations. The likelihood that random mutations in some genes will also affect the expression of other genes is quite high. These random mutations may only be found via WGS, with the caveat that not all mutations may be found in the genome sequence acquired is insufficient, for example because of the structural characteristics of the genome. However, the chosen plants will often still have a significant amount of unreported mutations, especially if they do not result in undesirable phenotypic features.

For genetically modified potatoes to be commercially successful, producers and consumers must favour features that minimise production's negative environmental effects. For instance, since amylose-free potato varieties like AmfloraTM generate starch that doesn't need chemical pretreatment, they are advantageous to industry and help protect the environment. The most efficient gene targeting for each attribute needs more study. For instance, investigating multiple target genes to reduce the amount of acrylamide found that knocking down Vlnv was the best course of action. However, as various studies have shown, it is uncertain which approach is most effective for eradicating Colorado potato beetle infestations. Agriculture will be more sustainable if pesticides and fungicides are used less. Future work should focus on creating potatoes with long-lasting resistance to pathogens and pests. To combat the Colorado potato beetle, for instance, raising the number of glycoalkaloids in the leaf looks to be beneficial, but P. infestans defence may need for pyramiding or editing of R genes.

Since it enables a variety of modifications to be done with high accuracy, we believe that the CRISPR gene editing method will continue to be the most popular technology. Base and prime editing in potatoes have a lot of possibilities. Specific procedures should, however, be created if necessary since they are unique technologies. Tools with fewer regulatory barriers should be given priority since they do not leave any traces of external DNA. In this respect, it is necessary to look at the qualities that RNAi-based gene editing has altered. Additionally, it will remain essential to examine the germplasm of closely related wild species to find features in gene pools that are available for introgression into potato cultivars.

Finally, advantages and general acceptability must be balanced while creating enhanced kinds. For this, extensive and transparent scientific dissemination about GMOs and the methods utilized is required, with an emphasis on scientific proof of their safety. In several nations, GMOs have been consistently rejected, with a notable fall in acceptability over the last ten years. A step in the right direction toward the increased accessibility of crops that have increased agricultural sustainability and may help feed the world's needy is the deregulation of gene-edited plants in the United States.

CHAPTER 2

CONVENTIONAL BREEDING TECHNIQUES IN FARM ANIMALS

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Natural pairings to contemporary breeding initiatives for thousands of years, humans have kept animals close by and enjoyed their products while also breeding domesticated animals. Humans have perpetuated those populations they have judged beneficial for their purposes using the technological possibilities that have existed in each historical period. Simple selection, which mainly affected phenotypic features, led to the creation of a large number of phenotypically distinct breeds with desirable qualities within a very short period. Cattle are an excellent example, for which there are now more than 800 breeds globally. Artificial insemination (AI) is the most often used biotechnological process in modern, scientifically based animal breeding tactics, which have been around for almost 60 years. Embryo transfer (ET) technology was introduced to animal breeding in the latter part of the 1980s, allowing for the first time greater exploitation of the genetic potential of female animals. Sexing and other biotechnologies connected to embryos, such as in vitro generation of embryos, were created and quickly incorporated into breeding programmes that already existed. These population genetics-based breeding techniques, along with AI and ET technologies, significantly improved domestic animals' capacity to produce large quantities of high-quality animal proteins, such as meat, milk, and eggs. Recent advances in molecular genetics have been combined with reproductive biotechnologies to significantly expand the selection of excellent breeding animals. The largest agricultural animals, such as cattle, pigs, fowl, sheep, poultry, and bees, have had their genomes sequenced and annotated. This has made it possible to create better breeding strategies, which were first based on marker-aided selection (MAS) and other more advanced methods.

More than 90% of all sexually mature female dairy cattle in nations with sophisticated breeding programmes use AI to effectively spread the genetic potential of valuable sires (the male father of an animal) across a herd. In pigs, where >50% of sexually mature sows are currently globally fertilised by AI, the use of AI is likewise rapidly growing. In tiny ruminants, AI is less common. The technology of embryo transfer (ET) since only a tiny percentage of the pool of female gametes (also known as eggs or oocytes) may mature into mature oocytes at birth, ET allows for the restricted but effective exploitation of the genetic potential of female animals. In 2015, over 660,000 in vivo collected bovine embryos were transferred globally, of which 50% were utilised after freezing and thawing; furthermore, about 550,000 of the transplanted embryos were produced in vitro (in vitro maturation, fertilisation and culture of embryos). Cattle may be used for non-surgical embryo harvest and transfer procedures, which makes field use easier. ETtechnology can only be used in pigs and other small ruminants via surgical or endoscopic procedures, which restricts its use to very particular uses. Embryo transfer, as opposed to artificial intelligence, is often applied to the most valued (top 1%) females in a particular breeding population.

Ovum Pick Up (OPU), also known as ultrasound-assisted follicular aspiration, has become a popular alternative to traditional bovine embryo recovery techniques that rely on the donor animals' superovulation. Regardless of the donor's reproductive state, OPU may be used. One key benefit of this approach is the large number of viable oocytes that can be extracted from a single animal in a very short amount of time. OPU is 3.5 to 5 times more effective than superovulation followed by uterine flushing for producing embryos on an annual basis. OPU is used on horses in addition to cattle. Usually, collected oocytes are put through an in vitro embryo production system (IVP), which includes in vitro maturation (IVM) to produce fertile oocytes, in vitro fertilisation (IVF), and finally, in vitro culture (IVC). Current IVP techniques allow for pregnancy rates that are comparable to those after the transfer of in vivo-generated embryos. IVP offers a wide range of applications, such as multiplying embryos from valuable females at almost any point of the reproductive state, producing calves at a low cost, for instance in beef production systems, or harvesting oocytes from pre-pubertal donors. Thus, an effective IVP system followed by OPU has become a potent tool in contemporary cow breeding to produce better rates of genetic improvement. OPU and IVP are extensively used around the world, but especially in South America.

Gametes and embryos may be kept in suspended animation at very low temperatures for an extended period of time thanks to cryopreservation. Generally speaking, vitrification (fast freezing) and traditional, gradual freezing are the two procedures used in cryopreservation protocols. A common practise in breeding programmes is the preservation of oocytes, sperm, and embryos from a broad range of domestic animal species, such as cattle, sheep, and goats, horses, and to a lesser degree, pigs. Current freezing techniques, when used appropriately, are compatible with almost no losses after thawing and permit the global dissemination of animal genetic resources. Additionally, the creation of germplasm banks has greatly aided in the effort to save rare and endangered species from extinction. Contamination is one of the main issues with cryopreservation. Health authorities are concerned about the possibility of oocyte, sperm, and embryo pathogen infection during in vitro fertilisation (IVF), artificial insemination (AI), and/or embryo transfer (ET). To stop the spread of infections, strong sanitary precautions must be taken.

In mammalian reproduction, the chromosomal configuration of the sperm, which may either contain an X- or Y-chromosome and fertilise the egg carrying one X-chromosome, determines whether the growing embryo has an XY (male) or XX (female) configuration. X- and Y-chromosome carrying sperm in cattle species vary from one other in terms of relative DNA content by 3% to 5%. It is possible to efficiently segregate populations of X- and Y-sperm in animals by taking advantage of the differences in DNA contents between X- and Y-bearing sperm. It is being utilised more often in the production of animals; according to current data, 6–10% of embryos are transferred after fertilisation using sex-sorted semen (Perry, 2016). By preventing the castration of male pigs and cattle, and by minimising the occurrence of difficult deliveries in cattle, the reliable regulation of the sex ratio promotes quicker genetic advancement and greater output while also improving animal comfort. Commercially accessible sexing technology for cattle breeding has the potential to develop into a key instrument for the adoption of more effective breeding and production strategies. To enable the commercial use of sex-sorted semen for additional livestock species, further study is required. Small biopsies of 10–12 cells taken from preimplantation embryos, especially at the blastocyst stage, may also be used to accurately establish the sex. A Y-chromosome-specific region of DNA is increased in male embryos, enabling clear differentiation between male and female embryos. Within a few hours of the transfer, embryo sexing may be completed, enabling the birth of calves with a specific sex. It is now feasible to genotype embryos in the setting of MAS and other similar procedures using the same methodology.

A laboratory procedure called somatic cloning, also known as somatic cell nuclear transfer or SCNT, is used to produce new creatures that are essentially genetically similar to existing animals. In animals, cloning entails swapping out an egg's genetic material with that of a somatic cell from an embryo or adult. The egg then grows into a whole creature that has the same genetic makeup as the donor organism.

Over the last several years, somatic cloning protocols for cattle species have seen tremendous improvement, enabling field applications. A high percentage of embryonic death is one of the persisting downsides of SCNT (EFSA Panel on Genetically Modified Organisms, 2012b), although the occurrence of large offspring, which was originally seen in ruminants following cloning, does not seem to be a significant issue any more. The 1996 birth of "Dolly," the first mammal to be cloned from an adult donor cell, sparked a flurry of research projects to advance cloning technology and comprehend the underlying mechanism of the transferred somatic cell nucleus's epigenetic reprogramming by as-yet-unidentified factors in the recipient ooplasm.

While maintaining the DNA structure, epigenetic reprogramming involves changes at the level of DNA histone proteins and is linked with considerable alterations in the expression profile of the transplanted somatic donor cell, resulting in the development of a pluripotent cell. Epigenetic reprogramming of the transplanted somatic cell nucleus from its differentiated condition into the totipotent state of the early embryo is the most important element. This entails erasing the donor cell's gene expression programme and establishing a carefully coordinated sequence for the expression of an estimated 10,000–12,000 genes that control embryonic and foetal development. In at least 24 species of mammals, SCNT has proven effective. Cloned offspring (such as cattle and pigs) seem healthy and grow properly, and they are not different from age-matched controls. SCNT is already used for producing high-performing racehorses, maintaining genetic resources, and multiplying precious breeding animals.

CBT's unintended consequences on animals

One mutation occurs per 1011 base pairs per cell cycle in farm animal preimplantation embryos, which has a low mutation rate. There isn't enough thorough research on the prevalence of postnatal mutations in agricultural animals. In CBT, pleiotropic effects happen seldom but may be helpful for breeding purposes.

Using traditional breeding methods to produce and enhance microbial strains

Microbes have been utilised by humans to make food for ages. Common examples of foods that rely on microbial components and activity include wine, bread, and cheese. Microorganisms are becoming increasingly important in the creation of food. They may create enzymes or other metabolites required in food production and processing, and they play both main and secondary roles in food fermentation and in avoiding food spoiling. Lactic acid bacteria (LAB) and yeasts, particularly *Saccharomyces cerevisiae*, are the most often utilised species. The microorganisms that create intricate microbial communities (microbiomes) closely linked to animal and plant species are also those that are important for the production of food and feed (hosts). For instance, it is widely recognised that the microbiomes of both plant and animals' guts are crucial for the host's ability to absorb nutrients, fend against biotic (pathogens) and abiotic stress, and support metabolic functions.

Nowadays, the lactic acid bacteria (LAB) family is employed as probiotics, which are believed to provide health advantages when eaten. By use of binary fission, which splits a single bacterial cell into two identical daughter cells, bacteria may reproduce (clones). They have a single circular DNA molecule that makes up their genome, but they may also contain smaller circular DNA molecules called plasmids that encode extra activities. Errors in DNA copying cause variety to emerge during binary fission. As eukaryotes with a cell nucleus that contains the majority of the DNA and mitochondria that hold the remaining little portion, yeasts are single-cell fungi. Yeasts have a tiny circular genome in their mitochondria and several linear chromosomes in their nuclear genome.

Like other eukaryotes, yeast reproduces by the process of mitosis, in which the daughter cells' two nuclei are shared by the daughter cell's duplicated chromosomes, along with a complement of mitochondria. This results in daughter cells that are genetically identical (clones). Both haploid and diploid yeasts may exist. To create a diploid, which may then go through meiosis to create haploid spores, haploids of the opposing "mating type" must fuse. Meiosis-based sexual reproduction creates diversity within populations. A range of diverse natural mechanisms that allow for the exchange of DNA, or "horizontal gene transfer," between bacteria are the source of genetic diversity within bacterial populations. DNA is transmitted from one bacterial cell to another naturally via the process of conjugation, which requires cell-to-cell contact.

When a virus transduces a cell, it introduces foreign DNA that is then integrated into the genetic material of the host. When DNA fragments are transferred across closely related bacteria, a horizontal gene transfer method called transduction is one example. Natural genetic transformation, which is the active absorption of extracellular DNA of any origin by microbial cells and the heritable assimilation of its genetic material, is another type of horizontal gene transfer. Bacteria and other microbes, including archaea from all trophic and taxonomic categories, including industrially significant bacteria like Bacillus species used for enzyme manufacturing and lactic acid bacteria with food uses, have been shown to undergo natural metamorphosis.

Not all bacteria have the ability to natively absorb foreign DNA. The cell membrane's permeability to DNA may be increased by stress, such as heat or electric shock, which can produce this capacity. If the uptaken DNA can function as an independently reproducing element such as a plasmid or has been integrated into the host genome, it may be passed on to the daughter cells. The best definition of biotechnology is the use of scientific methods to enhance and modify the value of plants, animals, and microbes. Biotechnology has been a part of several industries throughout the years, including medical, agriculture, genetic engineering, etc. You will learn about the use of biotechnology in agriculture and its importance in this article.

Application of Biotechnology and Its Significant Role in Agriculture

A collection of scientific methods that may enhance plants, microorganisms, and animals based on DNA and its ideas might be referred to as agricultural biotechnology. It might be argued that using biotechnology in agriculture is preferred over using agrochemicals. The latter is thought to be the culprit for environmental harm and is also fairly impractical for farmers. The rare instances where biotechnology has been used in agriculture are highlighted by the following:

- ***Genetic modification and rDNA technology:*** This approach involves the purposeful lab modification of one or more genes. Recombinant DNA (rDNA) technology is used to do this, changing an organism's genetic makeup in the process.
- ***Culture of tissue:*** Tissue culture is the process of preserving and promoting the growth of small pieces of plant or animal tissue in a sterile setting. It is necessary to separate this tissue initially.
- ***Embryo recovery:*** It is a kind of plant in-vitro cultivation method. Here, a developing embryo is raised in a regulated environment to increase its chance of survival. This might aid in preserving seed species that are in danger of becoming extinct. This might include regional grains with cultural importance, heritage seeds, etc.
- ***Hybridization of somatic cells*****:** It is a procedure wherein the cellular genome is changed by the joining of two protoplasts.
- ***Markers for molecular genes:*** Moleculargene markers in genetic engineering are distinct DNA segments connected to specific locations throughout the genome.
- ***Molecule-based diagnosis:*** A group of methods known as molecular diagnostics are used to examine biological markers found in the genome and proteome. Finding out how their cells express their genes as proteins are made easier by it.
- ***Vaccine:*** It is a mixture that is injected into the body of the host to trigger the desired immunological response. It aids in the prevention of several illnesses, including polio. To combat COVID, it is presently produced in large quantities.
- ***Micropropagation:*** It is the aseptic and controlled clonal multiplication of plants in a closed vessel. Find out why Bacillus thuringiensis's toxin is not dangerous in this knowledge test.
- ***Agriculture and Biotechnology:*** Agriculture uses biotechnology in a variety of ways. The following are some of the most common advantages of biotechnology in agriculture:
- ***Enhanced Crop Production:*** Biotechnology significantly increases agricultural output by improving disease management and enhancing resistance to drought and floods. This not only satisfies the rising food demand but also lowers losses for farmers.
- ***Improved Crop Protection:*** Biotechnology approaches provide practical, affordable answers to pest control issues. Farmers have developed a protein that efficiently combats insect problems from crops including cotton, maize, and potato.
- ***Increasing Nutrient Content:*** Additionally, it has made it possible for farmers to grow foods with better flavour, texture, and nutritional value. For instance, the development of technology has made it possible to grow potatoes with carbohydrates as well as beans with more amino acids and soybeans with high protein content.
- ***Better Taste and Fresher Produce:*** By boosting the activity of enzymes found in plants, it also contributes to enhancing the flavour and taste of crops. Additionally, it aids in extending the freshness of the produce.
- ***Tolerance to Chemicals:*** Herbicides are used by the majority of farmers to prevent weed development, which often causes soil erosion. But since genetically modified crops are resistant to many different chemicals, including herbicides, soil erosion is considerably reduced.

- ***Disease Resistant:*** In addition to the fact that pesticide usage often threatens the quality of the soil and the crop, viral diseases carried by insects are frequently challenging to control. However, genetically engineered plants are less prone to virus contamination and help farmers control crop loss. Although using biotechnology in agriculture has many advantages, it is not without drawbacks. To elaborate, there are certain worries about social, environmental, and health concerns.

Among the numerous concerns surrounding the use of biotechnology in agriculture is resistance to antibiotics, pesticides, superweed development, and biodiversity loss. One might, however, hold out hope that with the development of technology, scientists will discover workable methods to properly address the worries and related hazards. Understanding the many facets and how new technology may transform the face of agriculture can be made easier by learning about the function of biotechnology in agriculture.

The Influence of Biology

Biotechnology's technologies provide both a difficulty and a huge opportunity. They don't alter agriculture's objective, which is to effectively provide the food, fibre, lumber, and chemical feedstocks that society needs. Instead, they provide fresh methods for modifying the DNA of animals, plants, and microbes. Building on a foundation of knowledge obtained from conventional research in biology, genetics, physiology, and biochemistry, biotechnology techniques supplement rather than replace the conventional approaches used to increase agricultural output.

Agriculture now has a fascinating new frontier thanks to biotechnology. The new methods that biotechnology offers are reasonably quick, very specialised, and resource-effective. The widespread applicability of a common set of techniques such as gene identification and cloning, for instance—is very advantageous. With the more accurate current procedures, we may not only improve on earlier, conventional methods but also explore new ones. We may look for solutions to inquiries that we would have never considered making only a few years ago. Biotechnology's potential is already a reality. We have started to translate concepts into usable applications in recent years. For instance, researchers have discovered how to genetically modify certain crops to make them more resistant to particular pesticides. Pseudorabies, enteric colibacillosis (scours), and foot-and-mouth disease are only a few of the viral and bacterial illnesses for which vaccines have been designed and developed using biotechnology.

However, we have just begun to scratch the surface of the possible advantages. There is still much to learn, and progress will need a major investment of time, skill, and money. The main applications of biotechnology in agriculture are reviewed in this chapter. It focuses particularly on genetic engineering's advancements and possible applications in plant and animal agriculture as well as bioprocessing. These sections examine conventional methods, go through biotechnology-based instances of advancement, and list future potential.

Gene Transfer for Agriculture Improvement

Humans have profited from the natural process of genetic exchange that results in biological characteristic diversity throughout the history of agriculture. This fact serves as the foundation for all efforts to enhance agricultural species, whether those efforts include conventional breeding or molecular biology methods. In both instances, humans engineer a natural process to create different species of creatures that exhibit desirable qualities, such as disease-resistant plants or food animals with a better ratio of lean to fat tissue.

Traditional breeding and molecular biological techniques of gene transfer vary greatly in terms of speed, accuracy, dependability, and scope but not in terms of aims or procedures. Tens of thousands of genes are jumbled when conventional breeders cross two sexually reproducing plants or animals. Through the union of sperm and eggs, each parent gives their kid half of their genome, or the full set of genes that make up an organism. However, the makeup of this half differs in each parental sex cell, and therefore in each cross. Before the "correct" random recombination of genes produces offspring with the desired mix of features, several crossings are required.

Some of these issues are resolved by molecular biology techniques since they enable the manipulation of one gene at a time. Scientists may directly introduce individual genes for certain features into a genome that has already been constructed, as opposed to relying on the recombination of huge numbers of genes. Additionally, they may regulate how these genes are expressed in novel species of animals or plants. In other words, molecular gene transfer may increase accuracy and speed up the development of novel kinds by concentrating particularly on a desired characteristic. Additionally, it may be used to exchange genes across species that are incapable of mating.

Many biotechnology applications depend on gene transfer methods. The capacity to isolate a specific gene—one that encodes a desirable feature in an organism—study its function and regulation, change the gene, and then reintroduce it into its native host or another organism—is the core of genetic engineering. These methods are tools, not final products. They may be used to control growth and development, regulate disease resistance, decipher the nature and function of genes, and alter cell and organism communication.

The Discovery of Important Genes

Finding the necessary gene(s) among the tens of thousands that make up the genome is the initial step in the genetic engineering of an organism. The researcher may be looking for genes to promote disease resistance or to raise tolerance to certain environmental stresses. Similar to attempting to locate a reference in a book without an index, this may be a challenging endeavour.

Restriction enzymes, which can split complex, double-stranded DNA polymers into manageable fragments, facilitate this effort. A restriction enzyme snips the DNA strands when it locates a certain sequence in the DNA. Genomic DNA of an organism may be lengthened to match one or more genes by applying a variety of restriction enzymes. These smaller pieces may be sorted, followed by cloning, to provide a large amount of genetic material for more research. To find a specific gene, one may search a gene library, a collection of DNA segments from a single genotype. Even if the precise gene responsible is still unclear, patterns may be studied to connect a certain sequence—a marker—to a specific attribute or illness.

Gene cloning also employs restriction enzymes. The same restriction enzyme that was used to isolate a desired gene is used to split apart a plasmid, a tiny circular of DNA that resides apart from an organism's main chromosomal complement. The isolated gene fragment is integrated into the plasmid ring when the cut plasmid and the isolated gene are combined with an enzyme that rejoins the cut ends of DNA molecules. The cloned gene is reproduced together with the repaired plasmid. By doing this, a large number of copies of the cloned gene are created inside the host cell, which is often a bacterium. The cloned gene may be extracted in many copies by using the same restriction enzyme to cut it out after replication. The growth of biotechnology has been greatly aided by the capacity to extract and clone certain genes. For a study on the structure, operation, and expression of genes, cloned genes are a must. Furthermore, until enough gene copies were accessible, certain gene features could not be transmitted to other creatures. Cloned genes are also employed in agriculture and health as diagnostic test probes to identify certain disorders.

The technology of Gene Transfer

Vectors are a tool used by molecular biologists to transfer genes from one creature to another. Vectors may mediate the entrance, upkeep, and expression of foreign genes in cells. They are the "carriers" utilised to transfer genes to a new host. Viral plasmids, transposable DNA elements, and mobile DNA segments are all examples of vectors used to transmit genes. Genes may also be inserted using laboratory techniques including chemical reactions, electrical pulses, and physical procedures like microneedle insertion. Animals, plants, and bacteria can all use these technologies since the underlying principles are the same, with some possible changes. The Appendix, "Gene Transfer Methods Applicable to Agricultural Organisms," provides a detailed description of the fundamental gene transfer techniques.

To introduce desired genes into animals, plants, and microorganisms, vectors built on viruses, plasmids, and transposable elements have been developed. The Ti plasmid from the soil bacteria *Agrobacterium tumefaciens* is a typical example for plants since it naturally transfers a section of DNA into plant cells, causing the recipient cells to develop into tumours. This plasmid has been modified by scientists by removing its tumour-causing characteristics to produce a flexible vector that can introduce foreign genes into a variety of plants.

Similar to this, Drosophila melanogaster's transposable P-element is a successful vector for transferring genes into this fruit fly. This or comparable transportable components should show their ability to adjust to agriculturally significant insects. Animal viruses including simian virus 40 (SV40), adeno, papilloma, herpes, vaccinia, and the retroviruses are presently being developed as vectors for gene transfer into animal cells and embryos. These viruses were all first explored because of their significance in illness. Similar applications of plant viruses that may transmit genes include geminiviruses, brome mosaic virus, and cauliflower mosaic virus.

Techniques for Cell Culture and Regeneration

For gene transfer into plants to advance, it is critical to have the capacity to regenerate plants from single cells. Since animals cannot regenerate asexually, a foreign gene must be inserted into the sperm, egg, or zygote to spread throughout the whole animal. Techniques involving cell culture are crucial for plant regeneration. They are also essential for manipulating microbes and for basic research on both plant and animal cells.

Some crops often use vegetative propagation to create genetic clones from stem cuttings or other developing plant elements. For instance, vegetative propagation is used to develop plants like potatoes, sugarcane, bananas, and other horticultural species. There are methods for growing and regenerating whole plants from tissues, isolated plant cells, or even protoplasts—plant cells that have had their cell walls destroyed by enzymes—in culture. For several agricultural species, including alfalfa, carrots, oilseed rape, soybeans, tobacco, tomatoes, and turnips, this collection of methods is comprehensive. Other crops, such as important food species like many grains and legumes, have progressed more slowly.

Techniques for cell cultivation have become more crucial as biotechnology has advanced. The capacity to alter individual cells as receivers of isolated genes is necessary for genetic engineering. Utilizing cell culture methods, researchers may enhance their capacity for gene transfer and the analysis of the outcomes by maintaining and growing cells outside of the body. Additionally, cell culture enables researchers to create several copies (clones) of the modified kinds, which is simpler, more effective, and more practical, particularly for growing large numbers of stock plants. Regenerating "somaclonal variants," plants with changed genetic features that may be helpful as new or better crops, is a third use of cell culture. Cell culture methods are crucial for boosting agriculture's production and adaptability.

There are some significant restrictions, however. Chromosomal anomalies develop throughout time in cultures. These alterations, which are connected to the somaclonal variation phenomena and may be advantageous to agriculture, are often unwanted. Thus, researchers must discover ways to stop chromosomal alterations in cell cultures. Second, the regeneration capacity of long-lasting cultures is lost. Understanding why various species have varying capacities to regenerate from cell cultures into plants and how elements like the genetic or physiological origin of the cells and the culture conditions impact development will be crucial as biotechnology develops. The majority of plant cells seem to be totipotent, meaning they are in a state of reversible differentiation that would allow them to regenerate into a whole plant given the right circumstances. The study of plant growth and its genetic regulation still has many open questions, including what these ideal circumstances are.

Technologies for Monoclonal Antibodies

On improvements in cell culture techniques, monoclonal antibody technology has emerged. The immune system's protein building blocks known as antibodies are present in mammalian blood. They possess a special aptitude for recognising certain chemicals and weeding them out. A protein called an antibody is produced by specialised cells called B lymphocytes to fight an antigen when it enters the body. Think of a lock and key to get an idea of how antibodies function: Only the particular antigen lock "fits" with the antibody key. The antigen is now marked for eradication. Each of the specialised B lymphocyte cells can only identify one antigen and can only create one kind of antibody.

Antibodies serve a variety of purposes in science in addition to their natural function of defending organisms via the immune response. Drugs, bacterial and viral products, hormones, and even other antibodies may all be found in the blood, as well as their levels of existence. Antigen injection into laboratory animals to stimulate an immune response is the traditional way of making antibodies. After that, the animal's antiserum (blood serum carrying antibodies) is taken. However, the quantity of antiserum that can be collected in this manner is limited and comprises a wide variety of antibodies. The production of antibodies can now be done more effectively, precisely, and profitably thanks to modern biotechnology. Scientists discovered that the resultant hybrid cells, known as hybridomas, generated a lot of homogenous antibodies after combining two kinds of cells, antibody-producing B lymphocytes and almost immortal cancer cells from mice. Because each hybridoma may develop forever in cell culture, it can make an essentially limitless number of particular "monoclonal" antibodies. Researchers may make and choose hybridomas that generate a culture of certain, desired monoclonal antibodies by immunising mice with particular antigens.

Thus, a method of producing pure lines of antibodies that may be utilised to recognise complicated proteins and macromolecules has been developed using biotechnology. Monoclonal antibodies are effective molecular analysis tools, and their applications in the detection of minute quantities of pathogens like bacteria and viruses are fast-growing. Hybridoma technique has the potential for immunopurification of chemicals, imaging, and treatment in addition to several diagnostic applications. A potent method for separating big, complex molecules from a mixture of either unrelated or closely related compounds is immunopurification. Monoclonal antibodies may have readily observable tags added to them for imaging purposes to offer pictures of internal organs and pinpoint cancers that the antibody will particularly bind to. Finally, novel treatment approaches have been created that inactivate certain immune cell types, and tumour cells, or stop the spread of specific bacteria.

Although many of these applications are still in the experimental phases, monoclonal antibodies are already being used commercially in agriculture. For instance, therapeutic monoclonal antibodies are now available for the treatment of calf and pig enteric colibacillosis, which results in newborn diarrhoea (scours). This strategy supports genetically modified vaccinations and is often more effective than traditional immunisations. To help veterinarians choose the best therapeutic monoclonal antibody to use on an infected herd, diagnostic kits based on monoclonal antibodies have been developed. These kits can determine whether animals that are scouring are infected with a specific strain of the Escherichia coli bacterium that causes scours.

In its most basic form, genetic engineering is adding, modifying, or removing genetic material from a host organism to confer new traits on it. Much as breeding did throughout many thousands of years of human history, this technology is anticipated to greatly help agriculture. Researchers are now able to influence an organism's genetic makeup while getting beyond the challenges and constraints of sexual gene exchange thanks to the creation and use of novel approaches. Analysis of genetic data and gene transfer are becoming faster thanks to genetic engineering. The specificity and precision of analytical research techniques are substantially improved by the development of genetic engineering and monoclonal antibody technology, two additional significant technological advancements.

Additionally, these new technologies are opening up new research fields and enabling the use of very precise molecular analysis. The strength and speed of biological research findings are greatly accelerated by the use of biotechnology instruments in conjunction with conventional biological and chemical methods.

Innovative Methods for Crop Production

While the quantity of area under cultivation has decreased somewhat over the previous 50 years, agricultural productivity has more than quadrupled in the US. Numerous factors have contributed to this remarkable agricultural success, including an abundance of fertile land and water, a hospitable climate, a tradition of creative farming, and several developments in agricultural science and technology that have enabled more intensive use of yield-enhancing inputs like fertilizer and pesticides. However, unless alternative strategies are explored, it may be more difficult to replicate the productivity improvements brought about by farm automation, enhanced plant varieties, and the introduction of agricultural chemicals in the future.

The efficiency of agricultural production may be increased by the use of biotechnology, which would cut costs and improve food quality. To create crop types that produce more and are healthier, to increase their resilience to disease and unfavourable environmental circumstances, or to lessen their need forfertilizers and other costly agricultural chemicals, scientists may use the techniques of biotechnology. The examples of how genetic engineering may be utilised to improve agricultural output are highlighted in the following paragraphs.

Genetically Modified Plants

The ability to genetically modify plants, that is, change their fundamental genetic makeup, to give them new traits that increase crop production efficiency, maybe the most direct application of biotechnology to agricultural agriculture. Producing more and better harvests for less money is the traditional aim of agricultural farming. However, by enabling scientists to test successive plant generations for a particular characteristic or to transfer a trait more rapidly and accurately, biotechnology's tools may expedite the process. With the use of these technologies, breeders and genetic engineers may choose from a greater range of characteristics. Although effective, the procedure is not easy. Normally, scientists need to be able to identify the gene of interest, insert it into a plant cell, cause the altered cell to develop into a whole plant, and then check to see that the gene is being expressed as intended. For example, if researchers were to introduce a gene encoding a plant storage protein with a higher ratio of necessary amino acids for human or animal nutrition, the protein would need to be produced in alfalfa leaves and stems, potato tubers, and maize or soybean seeds. In other words, different organs in various crops would need to be targeted by the production of such a gene.

Utilizing the New Technologies

There have previously been successful attempts to genetically modify plants for agricultural purposes. It is possible to manage weeds more effectively by transferring characteristics that promote herbicide resistance. Plant storage proteins, lipids, and starches may soon have their composition changed to improve their value. One plant gene encoding the sulfur-rich protein present in the Brazil nut, Berthalletia excelsa, has been identified, cloned, and transferred. Methionine and cysteine, two nutritionally significant sulfur-containing amino acids, are present in high concentrations in this protein. These are the very nutrients that are lacking in legumes like soybeans. If the gene encoding the sulfur-rich protein were introduced into soybeans, it may improve the legume's status as a global supply of protein.

Scientists were able to create a fake segment of DNA coding for a piece of this protein by purifying the Brazil nut protein and figuring out the order and type of amino acids in the protein. This DNA "probe" was used to locate and extract the Brazil nut's native gene. Tobacco and tomato plants were selected because they are simpler to work with than soybeans, and researchers subsequently put the gene into them. The gene has also been introduced by researchers into yeast cells. According to preliminary findings, genetically modified yeast does indeed create a protein high in sulphur.

Improved oil crops are the subject of similar research. In 1984, oil crops grown in the US were valued at $11.8 billion. Oils and waxes from plants are used in feed, food, and industrial items like paints and polymers, depending on their chemical makeup. The length of the fatty acid chains that make up the oil and their level of saturation determine the chemical characteristics and therefore the applications of plant oils. Due to the extensive study of many of the enzymes governing the biochemical processes that affect molecular chain length and degree of saturation, it is now feasible to genetically modify the kind of oil a crop produces. Although certain crops' oil content has been changed by conventional breeding techniques, genetic engineering offers a wider variety of potential solutions.

To increase agricultural output, scientists have made another significant advancement by creating plants that are for the first time resistant to potent pesticides. One such is the widespread, efficient, and ecologically safe pesticide glyphosate. However, glyphosate destroys weeds and crops alike without discrimination. It must thus typically be applied before crop plant germination. However, scientists plan to increase the range of the herbicide's usage by genetically modifying crops to be resistant to glyphosate. A glyphosate-resistant gene has been successfully introduced into cotton, poplar trees, soybeans, tobacco, and tomatoes by scientists. The Salmonella typhimurium bacteria provided the gene. This result was dependent on substantial preceding fundamental research on metabolic processes in bacteria and plants, as well as advanced gene cloning and transfer procedures, similar to other technological successes. Crops resistant to glyphosate should soon undergo field trials and be on sale. If farmers utilised glyphosate instead of the present pesticides, they may save up to $100 per acre on weed control expenditures, with corresponding decreases in labour, equipment, and environmental impact. This prediction comes from an analysis of tomato producers' costs in California. Additionally, this development would provide farmers with greater flexibility, productivity, quality, and weed management options.

Considering the Future

It is intriguing to consider new options when such encouraging instances have already been accomplished. Could scientists, for instance, create agricultural plants with their capacity to manage weeds using naturally existing substances that impede plant development, such as the substance released by crabgrass to keep other grasses from encroaching on its territory? By studying these allelopaths, scientists may be able to engineer or breed plants that would provide farmers with new biological tools to fight weeds in addition to mechanical cultivation and other cultural tools, as well as chemical herbicides. Scientists have long known that some plants produce chemicals that affect the growth of other plants. The potential utility of biological weed control research is enormous, but the task is highly difficult, and rapid advancements are not anticipated. Understanding how particular plants create allelopathic compounds while also defending themselves from these toxins is one of the complex issues that have to be resolved. Opportunities to control plant growth and development may also arise from observations of nature coupled with plant engineering skills. A very small number of plant hormones or growth-regulating compounds have been shown to have an impact on a variety of growth and developmental processes, including fruit ripening, blooming, and dormancy.

A variety of inhibitors and analogues of these regulatory chemicals have previously been developed by agricultural chemists, and they have easily found commercial uses. For instance, they are used to promote and coordinate flowering and fruit production in pineapple fields, to prevent fruit from ripening too quickly and falling off trees and vines before it is ready, and to stop elongation growth to produce more compact and aesthetically pleasing potted plants like chrysanthemums and poinsettias.It has been challenging to research the synthesis and mechanism of action of natural growth regulators since they are only active in extremely modest concentrations. However, new methods and genetic probes to find the genes in charge of their products are now available, providing researchers with new instruments to examine these compounds. We'll probably find more techniques to govern and manage plant growth and development as our knowledge expands. For instance, maybe scientists may develop better techniques to regulate fruit ripening so that ripening can be postponed until the fruit is on its way to market. To boost plant productivity, researchers may find techniques to stimulate blooming, fruiting, seed production, or other growth patterns.

The Genetic Engineering of Plant-Related Microorganisms

Many of the ways that environmental microorganisms influence plant development is still not well understood. They might have either positive or negative impacts. Some microbes, for instance, shield plants against bacterial or fungal infestations. Others defend plants against environmental challenges such as acidity, salt, or high hazardous metal concentrations. Others go after weeds that threaten crops. The symbiotic link between nitrogen-fixing bacteria of the genus Rhizobium and members of the legume family, such as soybeans, is the most well-known interaction between microorganisms and plants.

The genes regulating these relationships, whether in the microorganism or the plant, can be modified to increase the capabilities of beneficial microorganisms or reduce the negative effects of harmful microorganisms as our understanding of the interactions between microorganisms and crops advances. But for microbes to be properly engineered, scientists must comprehend the molecular processes by which they communicate with their plant hosts. There is still much to learn about the involved plant and microbial genes, their regulation, and the complex interactions between microbes and their hosts.

Utilizing the New Technologies

Microorganisms were the subject of the first genetic engineering discoveries because they are simpler living forms than higher plants and animals and are thus simpler to work within the laboratory. The techniques used in medical research with bacteria and viruses are increasingly being used for microorganisms important to agriculture. Genetically modified bacteria intended to stop frost damage is one instance that has advanced to the stage of field testing. Pseudomonas syringae is a bacterium species with several members that often lives on the surface of plant cells and is typically unharmful. But some of these bacteria have a protein that starts ice crystal production when it's below freezing. Plant cells may be ruptured by the developing ice crystals. Plants may survive cooler temperatures without suffering if the bacteria are absent. Now, scientists have developed a strain of P. syringae called "ice-minus" by deleting the gene responsible for producing the protein.

The ice-minus strain has been sprayed on plants during lab experiments to replace the natural strain and provide the crop with some degree of frost protection. Despite the genetically modified, ice-less Pseudomonas's existence for several years, field tests required to evaluate its commercial application have been halted by public unease, which has resulted in legal actions and uncertainty regarding the kinds of safeguards required to regulate such environmental testing. Utilizing DNA probes to find plant viruses and viroids is another useful use. Detection enables quick screening to get rid of contaminated stock and stop the spread of illnesses.

Scientists discovered almost 60 years ago that a moderate strain of the tobacco mosaic virus (TMV) might shield tobacco plants from the negative effects of a later-inoculated, severe strain of the virus. On a small scale, this phenomenon known as cross-protection has been used to defend greenhouse tomatoes and a few orchard crops. The traditional cross-protection strategy, however, may have issues since the harmless, protective virus might spread to other crops or change into a more virulent form. TMV genome fragments were recently planted in tomato and tobacco plants by scientists. The issues with traditional cross-protection are avoided since these "transgenic" plants only carry a part of the genetic material required for TMV replication. The TMV virus didn't seem to affect certain transgenic plants at all. According to tests, the viral resistance brought about by recombinant DNA technology may be passed on via seed as a straightforward Mendelian characteristic and can thus be passed on by normal breeding methods.

Because the genetic and biochemical relationships between microbes, plants, and the environment are poorly understood, many instances of prospective alterations advantageous to agriculture are yet hypothetical. Genetic engineering to enhance nitrogen fixation, a field that has great potential, is proving especially difficult. Although plants cannot directly absorb and utilise the nitrogen gas that makes up more than 75% of the atmosphere, all living creatures require it. Nitrogen gas must first be "fixed," or changed into molecules that include nitrogen, either via industrial processes or by certain bacteria and blue-green algae that exist in the soil. The genus Rhizobium, which is associated with plants in the legume family including soybeans, beans, peas, peanuts, alfalfa, and clover, contains the most well-known bacteria that are capable of fixing nitrogen. The goal of genetic engineers is to enhance nitrogen fixation in these plants and expand the ability of other plants. By minimising the demand for energy (petrochemical) inputs required in the synthesis of nitrogen fertilizers, this breakthrough might significantly contribute to cutting production costs.

Numerous approaches are being investigated by researchers to enhance nitrogen fixation. The most straightforward strategy could be to enhance the symbiotic connection already present in nature by genetically engineering Rhizobium to fix nitrogen for their native host legumes more effectively. The development of Rhizobium, which can infect and fix nitrogen for other plants, particularly cereal crops, would be a second strategy. Alternately, it could be able to give other microbes that currently coexist with a particular crop the capacity to fix nitrogen. Trying to develop plants so they can fix nitrogen on their own is another strategy.

Due to substantial fundamental studies on the genetics and biochemistry of nitrogen-fixing, these methods have made some progress. Nod genes, which are found in bacteria, be involved in nodulation. Leguminous plants get infected by bacteria, which causes the nod genes to become active. Nodules then develop where the bacteria are present, and nitrogen fixation starts. Currently, scientists are attempting to identify the chemical cues that trigger the bacteria and induce the plant to produce nodules. The genes of bacteria, which do nitrogen fixation, have received much research. The control of the expression of these many genes is becoming better understood by scientists, but their interactions are very complicated. One of the many unresolved issues is that in the field, indigenous strains compete with laboratory-modified rhizobial inoculants.

Genetic Modification to Protect Crops

Using genetic engineering to increase agricultural productivity also entails safeguarding crops from pests. Agriculture may be negatively impacted by weeds, nematodes, viruses, bacteria, fungus, insects, and other organisms. However, in a natural environment, organisms often perform a variety of tasks. For instance, insects may be pests because they can spread illness and ruin stored goods and crops. They may also be helpful by recycling organic waste, consuming other pests, and pollinating plants. The majority of chemical pesticides, herbicides, and other insecticides that have historically been used as the main means of pest management are not selective enough to exclusively impact dangerous species. Techniques for dealing with pesky pests and beneficial species will be developed as biotechnology advances.

Utilizing the New Technologies

The development of biological pest management techniques is one area where genetic engineering technology will be very helpful. Some plants entice insects while others repel them. Some plants create substances that resemble the hormones of insects and prevent the reproduction of insects that feed on the plant. As a result, there is a chance to discover the genes in charge of the qualities and pass them on to new plants. Already, modest amounts of insect hormones are utilised in pest control. For instance, pheromones are utilised as attractants in traps to measure the density of insect populations. Alaromones may also be used to keep insects away from things that are being preserved. Because hormones often have complicated structural makeup, producing them may need the coordinated expression of many genes. The biosynthesis routes of these substances must thus be thoroughly studied at the fundamental level before they may be produced in microbial, cell culture, or plant systems. Genetic engineers may eventually be able to modify crops so they create their insect repellents as their expertise grows.

There is currently some sophisticated use of hormones for biological pest control. Synthetic chemical substances known as juvenile hormone analogues resemble a hormone that naturally regulates insect growth. An insect exposed to the juvenile hormone analogue stays in an immature stage and dies rather than developing and reproducing. An organisation that created such a drug registered it with the EPA and is now selling a fly, mosquito, flea, and cockroach version of it. This is an excellent illustration of how understanding insect physiology or chemistry may result in useful applications.

A genetically modified bacteria are used in another investigation that might be significant for the management of insects. The organism, a kind of Pseudomonas fluorescens corn-root colonising bacterium, has undergone genetic modification to create an endotoxin that is a strong pesticide for several pests, including black cutworm. The gene needed to make the toxin was taken from Bacillus thuringiensis, a different bacteria that has been sold as a biological pesticide for more than 20 years. The recombinant bacteria may be sprayed into the fields or freeze-dried and applied directly to seeds before sowing. According to tests, the nonrecombinant parental P. fluorescens strain barely survives in the wild for 8–14 weeks before it disappears and doesn't seem to have any lasting consequences. The business creating the recombinant strain wants to use it as a prototype for items that may be sold in the coming years, even though it only affects a tiny variety of insects. The transfer of the poison gene into plants themselves, which makes them self-protective against certain insects, most notably the tobacco hornworm, has been the subject of successful research at another business. A similar method is being used to look for genes that govern toxins or resistance to worms.

CHAPTER 3

FACTORS AFFECTING THE SUPPLY OF AGRICULTURAL BIOTECHNOLOGY

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In a given sector, new technologies do not merely arise. Despite the possibility of serendipity, most discoveries are the product of expenditures on research and development (R&D). A commercial company or governmental organisation will decide whether to invest after weighing the costs and rewards of doing so. The predicted profitability, or net advantages, must outweigh the alternatives when deciding whether to engage in R&D. However, investing involves risk since there is no assurance that the money spent on research will lead to a successful invention. To put it another way, there is no "production function" for new technologies that can be used to estimate how many innovations will result from a certain amount of expenditure. Modern R&D is often sequential, and not every component has to be done by the same company. Basic research is carried out to learn things that are generally relevant to various fields of technology or study. General or "foundations" research is another name for basic research. The goal of applied research is to create a product that can be sold.

Testing, tweaking, and perfecting are all steps in the development process that prepare the technology for use in the marketplace. Development costs make up the majority of private companies' R&D expenditures. Basic research receives more public funding than either applied research or development. Innovative technologies are produced by both governmental and commercial R&D. Through mechanisms such as direct public funding of research, regulatory policies, intellectual property rights legislation, education policies, financial and tax policies, and other policies covering the environment and industry, public policies have an impact on the profitability of private R&D investment. Private funding for biotech research and development To boost earnings, private entities fund agricultural biotechnology research. Typically, businesses do this by investing in R&D to generate new technologies that will lower manufacturing costs and/or new goods that will expand their market share or open up new markets.

The likelihood that the study will produce the intended outcome is never definite. The appropriability of technology, public support of fundamental and applied research, technical potential, and anticipated demand for the product created by R&D are some of the variables that may affect private investments in R&D. Technology refers to all information developed via research and development activities. Investment in R&D is driven by a company's ability to profit from the inventions that arise from such efforts. The term "appropriability" describes a company's capacity to "own" an idea and bar others from making unrestricted use of it. There would be no private sector motivation to perform R&D if other firms had instant access to the new technology and were not obligated to pay the research company.

If a corporation did not anticipate recovering its investment expenditures and making a profit on its discoveries, it would not get funding for a biotechnology research project. In general, the bigger the projected reward and the stronger the motivation to create a new technology, the higher the appropriability associated with it. Companies can use a variety of strategies to increase the degree of appropriability, including trade secrecy, lead time, and intellectual property rights like patents and copyrights. Lead time is the process of developing technology before competitors and profiting from the time it takes them to copy it. The extent to which a company is allowed to exploit these mechanisms relies on a variety of elements, including the technology's unique properties, the intellectual property rights that are accessible, governmental rules, and the industry's market structure. To account for the fast scientific advancements resulting from biotechnology research, the legal framework for determining appropriability is continuously being established.

In other words, public support of fundamental and applied research will likewise have an impact on the predicted profitability of private R&D. Basic research is sometimes a lengthy endeavour, and it is unknown if the study will provide a "useful" output. Private companies generally do applied research, which often has current or upcoming commercial applications. However, applied research would be more costly and less effective without the gains in understanding brought forth by fundamental research. Furthermore, the outcomes of fundamental research are often not applicable. Private revenues from fundamental research would be limited (or nonexistent), therefore private enterprises would not be expected to spend much in basic research. Basic research often does not result in a commercial product right away. Basic research supported by public funds may expand a sector's technical opportunities.

Increased technological possibilities may, in turn, encourage businesses to increase their R&D spending. The term "technological opportunity" describes the possibility for the creation of new technologies in a field as a result of developments in fundamental scientific understanding or adjacent domains. The possibilities for doing applied research on technological advances are increased by fundamental scientific research. Basic research in disciplines like molecular biology led to some new technological advancements in the domains of agriculture and health. For instance, the creation of "expressed sequence tags" which are used to locate a specific gene is the outcome of the fusion of molecular and computational approaches. This advancement enables researchers to define the protein of the gene and create products more swiftly. Basic research has increased the number of possible new items that can be created inexpensively.

The cost of R&D inputs falling may potentially increase technological opportunity. For instance, as compared to conventional plant breeding procedures, the use of genetic engineering and tissue culture techniques may speed up the production of novel plant types while also minimising the associated expenses. By using biotechnology techniques, the development period for many agricultural plants may be slashed by only a few years. However, for trees, the time it takes to generate new types may be cut in half, from 20 to 30 years, by using tissue culture to screen and assess features. Applied research is also funded by the public sector, but to a smaller extent than by the private sector. Publicly funded applied research is mostly used to create technologies that have the potential to have significant societal benefits but are unlikely to be created by the commercial sector. Two examples of societal requirements for which the government takes on a significant research duty are public health and the military.

Applied research in fields that may compete with activities already taking place in the commercial sector has often been avoided by public research organisations. However, it is difficult to create clear divisions across sectors. There are several businesses in the private sector engaged in biotechnology research, each with its objectives and tactics. A wide range of educational, research and related institutions make up the public sector. The lines between the proper duties for public and private sector research are becoming even more blurred as a result of recent developments in university-industry-government connections.

Agriculture Production and Technology Demand

To create crop and animal commodities, agricultural producers mix farm-supplied inputs like land and labour with bought inputs like seeds, fertilizers, insecticides, gasoline, and equipment. By allowing farmers to utilise inputs more effectively, new technology may increase agricultural production. A better market value may be achieved by producing new or higher-quality commodities using innovative technologies. The market's demand for agricultural commodities is ultimately a result of the need for inputs given by farms or businesses and for the technologies needed to turn those inputs into commodities. Often, different inputs may be used in place of one another to achieve a certain degree of output. The degree of input substitution is growing as a result of new technologies. Farmers look for a set of inputs and technologies that can provide a certain level of production at the lowest cost to maximise earnings.

Farmers will be encouraged to replace less costly inputs with more expensive ones if the relative costs of the various inputs vary. Similarly to this, the relative prices of agricultural inputs have an impact on producer demand for certain kinds of technology. When wages grow, one example of how relative input costs affect input substitution in manufacturing is the replacement of labour by mechanical power. The substitution of artificial inputs like insecticides and fertilizers for natural resources like the land is a less evident example. Farmers have been motivated to employ chemical inputs more intensively as a result of the lowering cost of chemical inputs compared to the value of lan. Similar to how the introduction of the internal combustion engine significantly expanded the possibility of replacing equipment with labour, the discovery of more fertilizer-responsive crop types boosted the capacity of chemical fertilizers to replace land. The development of biotechnology expands the options for replacing chemical and natural resource inputs with biological inputs.

Using pest-resistant cultivars to decrease the need for conventional pesticides and cultivating drought-tolerant types that require less irrigation are two examples of how biotechnology may replace traditional inputs. When input substitution takes place in reaction to changes in relative input prices and the adoption of new technologies, yields may be impacted since inputs are often not exact replacements for one another. Furthermore, agroecological characteristics like soil type, water availability, and temperature may have an impact on how much new technology may broaden the spectrum of agricultural resource substitution. Only those areas where new technology performs at least as well as current technology will get its adoption. If new technologies are more suited to one location than others, they may alter regional comparative advantages in manufacturing. The acceptance and dispersion of technology will determine its usefulness to society. While diffusion describes the pace and scope of technology acceptance over time, adoption refers to the choices made by individual producers over whether or not to utilise a certain technology. The adoption trend among farmers may vary within a given area. In farms with various endowments of resources like land and capital, including human capital, the cost of implementing new technologies may vary.

Adoption of Technology and Human Capital

The talents and aptitudes possessed by the decision-maker are referred to as "human capital." These skills may be acquired or inborn. Profitability will vary amongst producers whose farms have identical natural resource endowments, such as soil type, due to variances in human capital. As a result, not all manufacturers will experience an equal effect from the introduction of new technology. Early adopters learn how to effectively use and manage new technologies in their agricultural systems throughout the adaptation phase that occurs when farmers first get access to them. Producers who are good managers, risk-takers, well-educated, financially stable, and who have strong relationships with farm input suppliers and agricultural extension agents are more likely to be early adopters of new technology.

They also tend to have a history of successful adoption of new technologies. Farmers in Taiwan who are also innovators are crucial to the process of bringing cutting-edge technology from research facilities to farms. Other producers often profit from their work since they assist in screening and adapting new technologies and agricultural techniques to local environments. Technologies that are proven to be successful spread quickly to other farms in places where they are well suited after a period of trial and adaption by early adopters. New technology may be adopted by certain manufacturers extremely slowly or never at all if it is unprofitable or too challenging to utilise. Some farmers may also be reluctant to accept new technology due to other reasons that are not immediately connected to profitability, such as social issues, moral principles, and religious convictions. Given the increasing complexity of new agricultural technology, farmers who seek to use them may face rising administrative and human capital requirements in the future.

The prompt adoption and effective use of new technologies will rely in part on a farmer's familiarity with new analytical techniques and the availability of affordable information. To be implemented successfully, several future biotechnologies are likely to need investments in information technology, such as computers and expert systems (OTA, 1992). Farmers may embrace biotechnology-derived agricultural inputs more slowly if they are unfamiliar with the proper techniques. Applications of biotechnology in agriculture that don't significantly alter current production techniques are probably more likely to be accepted than those that need for learning new skills. Farmers may accept and handle new technologies with the help of both the public and private sectors.

Public spending on education contributes to the development of human capital. Additionally, farmers may get technical information and guidance regarding innovative agricultural methods and resource management from the USDA Extension Service and Soil Conservation Service. Farmers may learn a lot about new technologies through private sector sources including farm implement dealers, seed and chemical industry representatives, and farm management consultants. Public and private sources of information often work best together. Farmers often depend on agricultural extension agents and other farmers as impartial sources of information on the efficacy of new technology, whereas agribusiness salespeople aggressively advocate new production inputs. Public extension services also provide farmers with knowledge of socially beneficial technology and approaches, such as those for conserving natural resources that the commercial sector would not normally promote.

Effects of Agricultural Biotechnology on the Economy

Any new agricultural technology that is introduced will have an impact on markets, producers, and consumers. The factors that influence consumer demand for new technologies were covered in earlier parts of this paper. This section looks at the many factors that affect how agricultural biotechnology is developed, used, and disseminated economically. Whether biotechnologies have a positive or negative impact on production costs, product quality, or both on the market for agricultural goods will determine their economic impact. Technologies that cut manufacturing costs are expected to result in reduced food prices. Demand for agricultural goods may rise as a result of technologies that improve product quality. The structure of the agricultural industry may change as a result of the advent of biotechnology. Any new technological advancement may accelerate the trend toward fewer, bigger farms.

When resources can be employed more effectively to create goods with relatively inelastic demand, excess capacity arises. Farm efficiency improvements might result in surplus capacity and resources exiting the agricultural industry. Through economies of scale, new technologies may also be advantageous to huge farms. Greater vertical integration between farmers and processors and increased concentration among input suppliers are other structural problems that agriculture is now confronting. These changes are the result of several technical and economic factors, and advancements in biotechnology can only be partially blamed for them. The use of novel biotechnologies has effects on both food safety and environmental quality. Some methods used in agricultural production may result in the depletion of natural resources and the degradation of the environment.

The use of limited petroleum resources for the production of fertilizer, soil erosion brought on by tillage techniques, water depletion, the impact on biodiversity and ecological balance, and the effects of chemical fertilizers and pesticides on water quality are just a few of these environmental effects. Due to the unacceptably high quantities of pesticide residues, they may leave on food, several of these agricultural production and processing methods may also have an impact on food safety. Agricultural biotechnologies may sometimes harm the environment or raise food safety issues, but they can also improve it or improve food safety. The adoption of biotechnology has a variety of implications, including those on the markets for goods and inputs, farm organisation, environmental quality, and food safety. The adoption of several agricultural biotechnologies' economic impacts is reviewed in a review of empirical research. The analysis serves as an illustration of some of the issues covered in an ex-ante economic evaluation of new agricultural technology.

Relevance to Product Markets

Technological Change: Quality-Improving vs. Cost-Reducing

There are two main categories of technical change: quality-improving and cost-reducing. Increased yields or lower input prices are two ways that cost-cutting technical development lowers a producer's unit production costs. Technological advancements that increase the quality lead to improvements in the properties of the food product. Varied technical developments will have different effects on the state of the market. The distribution and scale of societal costs and benefits change as a consequence of changes in market pricing and quantity. Therefore, the sort of technology farmers embrace will influence how the economic effects of agricultural biotechnology are assessed. By enabling a producer to produce a certain quantity of a crop at a reduced cost, cost-reducing technology might boost profitability. There is sometimes a distinction made between new technologies that increase quantity while decreasing costs; quantity-increasing technologies may increase yields while decreasing costs, so market prices would not change because the farmer would keep the cost savings in the form of higher profit margins. This reasoning ignores the possibility that farmers who are already producing the item will devote additional resources to it. Additionally, other farmers who aren't producing the crop right now could start. These changes would lead to an increase in overall production and downward pressure on market pricing, similar to what happens when a technology with a higher quantity is implemented.

Biotechnology is the use of scientific methods to change and enhance microbes, plants, and animals to increase their value. The branch of biotechnology that involves applications in agriculture is known as agricultural biotechnology. Agricultural biotechnology has been used for a very long time as a means of selecting and developing organisms that are crucial to agriculture. The creation of disease-resistant wheat varieties via cross-breeding several wheat types until the necessary disease resistance was established in a new variety is an example of conventional agricultural biotechnology. In the 1970s, developments in molecular biology gave researchers the tools they needed to edit DNA, the chemical building elements that define the properties of living things. Genetic engineering is the name given to this technique.

Additionally, it enables DNA exchange between species that are more distantly related than was previously conceivable using conventional breeding methods. As of right now, this technology has developed to the point where researchers may remove one or more particular genes from almost any creature, including bacteria, viruses, plants, or mammals. Transgenic or genetically engineered organisms are organisms that have undergone genetic engineering-based transformations. These features of modern biotechnology are described by a variety of additional words that are often used. Even though purposeful crossings of one type or breed with another result in children that are genetically changed relative to the parents, the term "genetically modified organism" or "GMO" is often used to refer to genetic alteration. Similar terms have been used to describe foods made from transgenic plants, including "GMO foods," "GMPs," and "biotech foods."

Foods created through genetic engineering are often referred to as "frankenfoods," while some term them "biotechnology-enhanced meals." The production of genetically altered organisms and their usage as food and feed are controversial for the reasons covered later in this article. What distinguishes genetic engineering from conventional biotechnology? Traditional breeding involves somewhat arbitrary cross-making. Although the breeder selects the parents to cross, the outcomes are genetically unpredictable. DNA from the parents randomly recombines, resulting in the bundling of good qualities like insect resistance with negative ones like low yield or poor quality. Traditional breeding practices need a lot of time and effort. Separating unwanted features from good ones requires a lot of work, which isn't always economically feasible. For instance, to breed out undesired traits caused by random genome mixing, plants must be backcrossed repeatedly over many growing seasons.

Segments of DNA that code for genes for a particular trait may be chosen and individually recombined in the new creature using current genetic engineering methods. It is possible to choose and transfer the gene after the genetic coding for the desired characteristic has been found. Similarly to this, undesirable features' genes may be silenced. This technology makes it possible to modify a preferred variety more quickly than using conventional breeding methods. Any stage of development, such as in young seedlings in a greenhouse tray, may be used to test for the presence of the target gene influencing the characteristic. Compared to conventional breeding methods, modern biotechnology's accuracy and adaptability allow for faster advances in food quality and output.

Increased crop productivity

By giving crops traits like greater drought tolerance and disease resistance, biotechnology has helped to boost agricultural yield. Researchers may now choose disease-resistance genes from other animals and introduce them into significant crops. For instance, by transferring one of the virus' genes to papaya to confer resistance in the plants, researchers from the University of Hawaii and Cornell University created two types of papaya resistant to papaya ringspot virus. In arid climes, where crops must utilise water as effectively as possible, there are more instances. Many crop types may be made more drought-tolerant by introducing genes from naturally drought-resistant plants.

Better crop protection

Crop protection technologies are used by farmers because they provide affordable solutions to pest issues that, if unchecked, would significantly reduce output. As previously indicated, genetic engineering has been used to effectively modify crops like maize, cotton, and potatoes to produce a protein that kills certain insects when they feed on the plants. The protein comes from the *Bacillus thuringiensis* soil bacteria, which has been utilised for many years as the main component of various "natural" pesticides. In certain instances, an efficient transgenic crop protection technique may manage pests more effectively and affordably than current ones. For instance, when Bt is incorporated into a maize crop, the whole crop rather than just the area to which Bt pesticide has been applied is resistant to certain pests. In these situations, yields rise as a result of the new technology's improved control. In other instances, new technology is adopted because it costs less and provides equal control to existing technology. In certain instances, new technology is not accepted because it cannot compete with state-of-the-art technology for one reason or another. For instance, organic farmers may not approve of transgenic Bt crops even when they use Bt as a pesticide to manage insect pests in their crops.

Modifications to food processing

Chymosin, an enzyme created by genetically modified bacteria, was the first food product originating from genetic engineering technology to earn regulatory clearance in 1990. It currently makes about 60% of all cheese produced and takes the role of calf rennet in the cheese-making process. Increased purity, a steady supply, a cost reduction of 50%, and excellent cheese output efficiency are a few of its advantages.

An enhanced nutritional value

New alternatives for enhancing the nutritive content, taste, and texture of food are now possible because of genetic engineering. Soybeans with more protein, potatoes with more readily accessible carbohydrates and increased amino acid content, beans with more important amino acids, and rice with the capacity to create beta-carotene, a precursor to vitamin A, might all be examples of transgenic crops now under study.

Improved taste

By increasing the activity of plant enzymes that convert aroma precursors into flavouring chemicals, the taste may be changed. Trials in the fields are now being conducted on flavoured transgenic peppers and melons.

Fresher food

Improved keeping qualities brought about by genetic engineering may facilitate the transportation of fresh produce, provide customers with access to nutrient-dense whole foods, and stop rotting, damage, and nutrient loss. Vine-ripened transgenic tomatoes with delayed softening may still be delivered without developing bruising. Similar alterations to broccoli, celery, carrots, melons, and raspberries are being researched. Using substances whose fatty acid profiles have been altered has also increased the shelf life of certain processed meals, such as peanuts.

Environmental advantages

When genetic engineering reduces our reliance on pesticides, we have fewer pesticide residues on food, less pesticide leaking into groundwater, and less exposure to harmful goods for agricultural workers.

The transgenic type currently accounts for half of the cotton crop in the United States and has made the global usage of insecticides drop by 15% as a result of its resistance to three primary pests. Additionally, the U.S. Food and Drug Administration (FDA) states that "increased adoption of herbicide-tolerant soybeans was linked with minor yield improvements and fluctuating profitability but large reductions in herbicide usage" (our italics).

Advantages for emerging nations

Technologies based on genetic engineering may assist to improve the state of health in underdeveloped nations. Researchers from the Institute for Plant Sciences at the Swiss Federal Institute of Technology inserted genes from daffodils and bacteria into rice plants to create "golden rice," which has enough beta-carotene to satisfy the needs of developing nations with rice-based diets for all of their vitamin

A needs. In places of extreme poverty where vitamin supplements are expensive and difficult to get and where vitamin A deficiency causes childhood blindness, this crop has the potential to greatly increase vitamin intake.

Concerns relating to health bacterial resistance

A characteristic of interest that has been inserted into plant cells may be found and tracked using genes for antibiotic resistance. This method guarantees the success of a gene transfer during genetic alteration. The use of these markers has sparked worries about the emergence of novel bacterial strains that are resistant to antibiotics. Some critics of the use of genetic engineering technologies have legitimate medical concerns about the emergence of illnesses that are difficult to cure with generic antibiotics. The danger of transmission between bacteria or between humans and the bacteria that live naturally in our gastrointestinal systems is far greater than the risk of transfer from plants to bacteria. However, the FDA has encouraged food makers to abstain from employing marker genes that encode resistance to clinically significant antibiotics to be safe.

Ecological and environmental concerns

Some opponents of genetic engineering techniques hold the opinion that transgenic crops may cross-pollinate with related weeds, perhaps creating "superweeds" that are harder to manage. One issue is the possibility of glyphosate resistance spreading from related weeds to crops that have developed resistance to the herbicide. Resistance to one herbicide does not always entail that a plant is resistant to other herbicides, therefore impacted weeds might still be managed with other chemicals. The likelihood of this occurring, albeit very remote, is not implausible. Some individuals are concerned that genetic engineering may increase a plant's capacity to "escape" into the wild and cause ecological imbalances or catastrophes. The majority of agricultural plants are unlikely to survive in the wild as weeds because of the severe constraints in their growth and seed dispersion characteristics that prohibit them from surviving for an extended period without continual agronomic care.

"Nontarget" species effects

According to some environmentalists, transgenic crops may have unintended and undesired impacts after they are released into the environment. Although transgenic crops are thoroughly evaluated before being on sale, not all possible effects can be anticipated. For instance, Bt corn generates a highly particular insecticide that is exclusively meant to kill bugs that consume the maize. However, Cornell University researchers discovered in 1999 that the Bt corn's pollen was capable of causing the deadly Monarch butterfly's larvae to die. In the lab, half of the larvae perished when fed milkweed that had been sprinkled with Bt corn pollen by Monarch caterpillars. However, further field experiments revealed that it is very unusual for Monarch butterfly caterpillars to come into touch with Bt maize pollen that has landed on milkweed leaves—or to consume enough of it to damage them.

Resistance to insecticides

Whether insect pests may evolve a resistance to the crop-protection characteristics of transgenic crops is another issue connected to the possible environmental effects of agricultural biotechnology. There is concern that the widespread use of Bt crops would lead to a quick rise in insect populations' resistance. Even thoughBt crops have been widely planted, no Bt tolerance in the targeted insect pests has yet been discovered, even though insects have an impressive ability to adapt to selection pressures.

Biodiversity loss

Farmers and other environmentalists are highly worried about the decline of biodiversity in our environment. Similar worries were expressed in the last century with the increased use of conventionally grown crops, which prompted considerable efforts to gather and preserve seeds of as many different types of all-important crops. Plant breeders in the USA and other countries preserve and make use of these "heritage" collections. Agricultural biotechnologists also want to ensure that we maintain the pool of genetic diversity of crop plants that will be required in the future, and modern biotechnology has significantly increased our understanding of how genes express themselves and highlighted the importance of preserving genetic material. While transgenic crops aid in ensuring a steady supply of staple foods, specialist crop types and locally produced vegetables seem to be seeing growth in the U.S. market rather than a decline.

Therefore, it seems doubtful that using genetically modified crops would have a detrimental effect on biodiversity.Responsible researchers, farmers, food producers, and decision-makers understand that using transgenic organisms must be carefully studied to guarantee that there are no environmental or health concerns, or at least none worse than those posed by using conventional crops and farming techniques. Through the creation of crops with increased nutritional value, pest and disease resistance, and lower production costs, modern biotechnology provides novel scientific applications that may benefit society. If handled correctly and responsibly, genetic engineering, a kind of biotechnology, has the potential to bring about significant advantages. The principles of biotechnology and genetic engineering, the procedures used to create transgenic species, the kinds of genetic material employed, and the advantages and hazards of the new technology should all be fairly presented to society.

CHAPTER 4

AGRICULTURAL MICROBIOLOGY

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Microorganisms from a variety of categories, such as bacteria, fungus, actinomycetes, and protozoa, are connected with plants. Since it aids in understanding the significance of pertinent microbial strains to agricultural applications to reduce agricultural loss, and boost soil fertility, and harvest, agricultural microbiology has been intensively investigated over the past 10 years. Plants and related microbes have a symbiotic connection where both are mutually beneficial. Additionally, certain areas of agricultural microbiology aid in the detection and averting the development of plant illnesses that may be brought on by plant pathogens. Understanding the particular plant needs, which include soil texture, soil nutrients, water content, and related microbes, is made easier by agricultural microbiology.

According to research in agricultural microbiology, many microorganisms may be utilised for various tasks, all of which eventually result in decreasing plant and plant product loss and boosting fertility and yield. In addition to lowering manufacturing costs, this research investigates potential locations for growing plants in labs using methods like plant tissue culture. Bacteria make up the majority of the microorganisms in the soil and plants. To aid in activities like nitrogen fixation and mineral delivery, these bacteria are present in a symbiotic relationship with the plants. Actinomycetes are the second most dominant group after bacteria. Actinomycetes are also investigated in agricultural microbiology since they generate many classes of antibiotics and contribute to the soil's increased fertility. The majority of fungi that colonise well-aerated, cultivated, or acidic soils work with plants to increase the harvest by supplying essential minerals and vitamins. Agricultural microbiology enables the investigation of cutting-edge methods that may be applied to agricultural activities to make them more dependable and safe.

The study of bacteria that are connected to plants is known as agricultural microbiology. It tries to deal with issues in farming methods often brought on by a lack of biodiversity in microbial communities. To improve aspects like soil nutrients, plant-pathogen resistance, crop robustness, fertilizer absorption efficiency, and other things, it is helpful to have a good grasp of microbial strains that are important to agricultural applications. In the long run, the many symbiotic interactions between plants and bacteria may be taken advantage of to increase food production, which is important to feed the growing human population, as well as to develop safer agricultural methods for the goal of avoiding ecological impact.Agricultural microbiology is a subfield of microbiology that studies illnesses of plants and animals as well as bacteria that are connected with plants. It also covers the microbiology of soil fertility, including the microbial breakdown of organic materials and the alteration of soil nutrients.

Mechanisms for promoting plant growth

Various symbionts infect in different ways on the microscopic surface of a root. Once attached, certain bacteria release genes that transform chemicals from the soil and atmosphere into compounds beneficial to plants, such as those containing nitrogen and phosphorus. Others, such as mycorrhizal fungi, create enormous networks of hyphae that serve as extra root surface areas to mine the soil for nutrients.

They also provide the host roots with some pathogen protection. At the plant-fungi interface, fungi exchange plant carbohydrates produced during photosynthesis for molecules like ammonium, nitrate, inorganic phosphate, amino acids, and organic chemicals like urea. The cells that have shed from plant roots are a significant source of carbon for rhizosphere-dwelling microbes. By raising the quantities of labile carbon and nitrogen in the soil, these symbiotic partnerships not only boost the bioavailability of essential nutrients to plants but also raise soil fertility. For this reason, crop rotation is used, particularly when dealing with legumes and their Rhizobia symbionts.

Microbes in the soil

The significance of soil microbes plays a part in the process of nutrient transformation; decompose refractory elements of plant and animal tissue; and participate in microbial competition.

Biofertilizers using microorganisms

Due to their capacity to boost output and soil fertility by improving crop immunity and growth, biofertilizers are seen as a potential, sustainable alternatives to hazardous chemical fertilizers. These biofertilizers populate the rhizosphere or inside of the plant root when used on soil, plants, or seeds. These bacteria may assist in solubilizing and breaking down important environmental nutrients that would otherwise be inaccessible or challenging for the crop to integrate into biomass after the microbial community is formed.

Nitrogen

Nitrogen, which is often regarded as a limiting nutrient in agricultural systems, is a crucial component required for the production of biomass. Although nitrogen is plentiful in the atmosphere, plants cannot directly absorb it; thus, biological nitrogen fixers are needed to convert atmospheric nitrogen into a form that can be taken up by plants. Diazotrophs, or bacteria that fix nitrogen, fall into one of three categories: free-living, symbiotic, or associative symbiotic.

Examples of free-living diazotrophs include Azotobacter, Anabaena, and Clostridium (ex. Azospirillum). These organisms can convert atmospheric nitrogen into forms that are bioavailable to plants and may be included in biomass.

Leguminous plants and Rhizobium have a significant symbiotic relationship that aids in nitrogen fixation. Rhizobium has been shown to deliver up to 300 kg of nitrogen per hectare per year to a variety of leguminous plants, and their use in crops has been demonstrated to boost crop height, seed germination, and nitrogen content in the plant. The use of nitrogen-fixing bacteria in agriculture may lessen the need for artificial nitrogen fertilizers produced via the Haber-Bosch process.

Phosphorus

Through the solubilization or mobilisation of phosphorus by bacteria or fungi, phosphorus may be made accessible to plants. Phosphorus is the least mobile nutrient in the environment under most soil conditions, hence it has to be solubilized to be absorbed by plants. The process by which organic acids are released into the environment to decrease the pH and breakdown phosphate bonds, leaving the phosphate solubilized, is known as phosphate solubilization. Bacillus subtilis and Bacillus circulans are two examples of phosphate-solubilizing bacteria (PBS), which account for up to 50% of all microbial phosphate solubilization.

Along with the solubilized phosphate, PBS may also provide trace minerals like iron and zinc that promote plant development even more. This process is also carried out by fungi, such as *Aspergillus awamori* and *Penicillium spp.*, however, their involvement accounts for less than 1% of total activity.

Aspergillus niger inoculation significantly increased fruit size and yield in comparison to non-inoculated crops, according to a 2019 study. When the crop was co-inoculated with Azobacter, a nitrogen-fixing bacterium, and *Aspergillus niger*, the crop's performance was superior to that of crops that were not inoculated at all. Phosphorus mobilisation, which is accomplished by mycorrhiza (for example, arbuscular mycorrhiza), is the process of moving phosphorus from the soil to the root. Arbuscular mycorrhiza penetrate the roots and increase their surface area, which aids in the mobilisation of phosphate into the plant. Microorganisms that mobilise and solubilize phosphate may contribute up to 30 to 50 kg P2O5 per hectare, which has the potential to boost crop output by 10 to 20%.

Agriculture microbiology is a field of microbiology that is researched because of its many applications in agriculture, horticulture, animal sciences, fisheries, and forestry. The bulk of plant illnesses is caused by a large variety of pathogens, which are dangerous microbes. These microbial pathogens may infect plants via the roots and leaves and are often found in large quantities in the soil, air, and water. Understanding the fundamentals of microbiology is necessary to understand the origins, modes of transmission, prevalence, and control of illnesses. This area of study is known as plant pathology or phytopathology.

Animal Pathology

The study of microbes that infect plants and cause illness is known as plant pathology. It also requires knowledge of how hosts and environmental variables interact with the infectious bacteria. Plant pathogens are microbes that afflict plants with illness.

Antagonism

In contrast to plant diseases, certain natural soil microorganisms consume (or are hostile to) these pathogens and may shield agricultural plants from infection. Antagonism is the term used to describe this specific behaviour of microorganisms. A relationship between two organisms in which one gains at the expense of the other is known as antagonism. Predation, when a predator eats its victim, and parasitism are two examples. When it comes to planting pathogens, antagonism often entails competition between two bacteria for food, nutrients, and the synthesis of inhibitory substances including antibiotics, extracellular enzymes, secondary metabolites, and antimicrobial metabolites.

Bio-pesticides

Some soil microbes create substances that boost the plant's defence systems and increase its resistance to diseases. These microorganisms are collectively referred to as biopesticides in the commercial world. Biopesticides are substances made from live organisms that are used to control insect pests by having unique biological fatal effects. Biopesticides are natural and derived from living organisms as opposed to more generalised manufactured chemical pesticides. It usually refers to items made using biocontrol agents or compounds including their genes or metabolites produced from naturally occurring materials such as bacteria or other microorganisms, animals, or plants and used to control pests.

Natural farming

Our understanding of health and environmental problems has caused us to reevaluate and scrutinise conventional or chemical-intensive agricultural techniques more closely. Modern farming aims to use healthy agricultural methods and preserve the long-term ecological harmony of the soil ecosystem. Under the guise of organic farming, the use of microbial inoculants in agriculture (as biofertilizers, phytostimulators, and biopesticides) provides an alluring environmentally acceptable alternative to chemical pesticides and mineral fertilizers.

Genetic Modification

The ability to transfer genes from one creature to another has been made possible by recent developments in molecular biology. In this manner, plants have effectively adapted specific genes from specific bacteria that can kill certain insects but not damage people. In the host plant, the transferred genes are expressed as proteins.

Since the insects are poisoned by this protein when they eat on the plant, the insects perish. Similar to animals, bacterial gene transfer has made it feasible for plants to develop both qualitatively and quantitatively. The comparatively simple bacterial gene modification has greatly advanced biochemical and genetic studies. These features of gene transformation are now the topic of much research and study.

Technology in Food and Fermentation

Despite being an ancient discipline, fermentation technology is now becoming a viable tool for advancing the food industry. The manufacture of beer and wine by yeast, bread, the conversion of milk into dairy products by lactic acid bacteria, as well as the production of vinegar by acetic acid bacteria are some of the promising instances where microorganisms have been widely exploited to help food businesses.

Microbiology of Soil

Since the soil provides a favourable habitat for a wide variety of microorganisms, such as bacteria, fungus, algae, viruses, and protozoa, these creatures are often found in large concentrations in the soil. Approximately one to ten million microorganisms are present in every gramme of soil, according to estimates.

The most frequent microorganisms are bacteria and fungus. Conditions are continually changing as a result of interactions between all of these microorganisms, with one another, the environment, and the soil. Soil microbiology is a unique field of agricultural microbiology that studies how these many components interact to produce variations in soil types in a specific location. All of these microbes must be active for the soil to function, and their activity determines the soil's quality, texture, structure, and other characteristics.

The Value of New Technologies in Crop Agriculture

Production agriculture has always emphasised the use of technology. Between 1948 and 2017, aggregate agricultural U.S. farm production in the United States quadrupled thanks to the use of technology and better management techniques, with hardly any increase in aggregate input. The usage of technology in production agriculture is anticipated to increase during the next ten years for the reasons that follow. The technology kinds that are presently being used or that are most likely to be used shortly are covered in this article. The vital role of information and precision agricultural technology, potential benefits of precision agriculture, automation and robotics, and skill shortages related to the adoption of new technologies will all be covered in upcoming articles.

Crop Agriculture Changes

Global crop production is going through a significant technical change. Based on site-specific information about environmental, biological, and economic factors that affect physical output, profitability, and soil and water quality, production management is shifting toward increased micro-management of production activities by individual field or location within a field. The quantity of knowledge accessible on what influences plant growth and well-being will significantly increase with increased usage of monitoring equipment. Innovations in communication technology, data analytics, and sensors for use in monitoring and control systems will enable this. Additionally, we'll soon have a better grasp of the interactions between many environmental and development elements.

The best input combinations for the field or within a field will be determined using this knowledge, which will subsequently be implemented into management systems. Global positioning systems (GPS), yield monitors, and variable rate application technologies are all used in precision farming to more accurately apply agricultural inputs to improve growth, minimise costs, and prevent environmental damage. Precision farming, which integrates biotechnology, nutritional science, monitoring, measuring, and information technology, as well as process control technology, may be referred to as "biological manufacturing" when it comes to growing crops. The data and information that can be continually recorded and used to manage the system and act in real-time to regulate and improve the plant development process is the crucial linchpin among various "technology buckets" for effective execution.

Production agriculture is now transforming an industry that grows crops to one that biologically produces raw materials with certain qualities and features for food and industrial-use goods. The following discussion will centre on three different categories of technology: process control technology, monitoring, measuring, and nutritional technology.

Nutritional technology and biotechnology

The goal of biotechnology and nutritional technology is to control how plants grow, develop their traits, and deteriorate. A stronger scientific foundation influences not only plant growth but also attribute development and is enabling more effective process manipulation and control. Additionally, biotechnology is improving our ability to use genetic modification to regulate and alter plant development, including attribute composition such as the composition of amino acids or starch. To control or modify the growth environment (temperature, humidity and moisture, pest and disease infestation, etc.), nutritional and biotechnology concepts are combined with mechanical and other technologies. This brings the process control approach and thinking that is a part of the assembly line used in mechanical manufacturing closer to reality in biological manufacturing.

Technology for monitoring, measuring, and data collection

This technique focuses on tracking the improvement or decline of traits throughout the plant growth process and measuring the effects of both controlled and uncontrollable elements on that growth process. This technology is used in agricultural production and includes yield monitors, GPS, GIS, satellite or aerial photography and images, weather monitoring and measurement systems, and plant and soil sensing systems. In-plant sensors that can identify disease features and growth rates may become accessible in the future. These systems will be connected to growth models to find methods to boost plant growth performance as well as to accounting systems for physical and financial performance to track overall success. New monitoring and measuring technology, including near-infrared (NIR) and electromagnetic scanning, is now being developed to assess a wide spectrum of parameters of the plant development process. Computer technology is easily accessible to manipulate enormous volumes of information.

Control Technology for Processes

When the actual performance of a process deviates from prospective performance, process control technology intervenes with the appropriate changes or controls to narrow the gap. Such technology is being used in greenhouse production to control temperature, humidity, sunshine, and other elements of the plant-growing environment. Modern irrigation systems connected to weather stations, plant and soil sensors, and irrigation systems automatically switch irrigation systems between on and off to ensure that moisture levels are sufficient for optimal development. Irrigation systems are an example of this technology in field agricultural production. Row shut-off technology and variable rate fertilizer and chemical application are two examples of modern process control technology used in rain-fed crop production. Another example is the use of modern precision planter technology, which uses soil sensors to automatically modify seed location, depth, and soil covering.

Technology for anytime intervention process control and real-time monitoring and measurement have the potential to provide considerable advantages. Instead of anticipating a potential issue and proactively dispensing control inputs that may be wholly unnecessary (and thus expensive) and possibly even harmful to the growth environment if that issue does not occur, anytime intervention technology enables one to detect a problem when it occurs and in real-time solve that problem. Any-time intervention technology, for instance, enables the detection of corn borers and the treatment of those borers once they reach an economic threshold, as opposed to spending money and using resources in anticipation of a corn borer infestation that may occur but is unnecessary if the infestation does not reach an economic threshold during the growing season. Using a similar strategy, weeds might be managed. When using drop-down nozzle attachments for high clearance equipment and real-time sensor technologies, similar techniques to fertility control may permit lower levels of pre-season fertilizer treatments by enabling additional applications throughout the growing season. If such technology is created, using biotechnology to manage certain insects or using more fertilizer than required to ensure the highest yield may become less necessary.

It would be unrealistic to expect these process control and sensing technologies and methods to be as effective in reducing variability and systematizing the production processes of manufactured goods like automobiles, computers, or even chemical and industrial goods as they have been in industrial manufacturing. It would also be unrealistic to ignore the potential of these technologies to increase efficiency, decrease costs, improve quality, reduce environmental impacts, and generally more systematically produce biologically based attributes for food, feed, fuel, and fibre raw materials. These technologies have the potential to reduce variability and gain more control over biological growth processes. Using monitoring and measuring, biological and nutritional modification, and process control technologies to consistently produce food and goods for industrial application is, in essence, what the ideas behind biological manufacturing are all about.

Financial Significance

The two most important rabi oilseed crops in India are rapeseed and mustard. They have an important position, coming in second to groundnut in terms of output and area while also providing the majority of the people in the states of Uttar Pradesh, Punjab, Rajasthan, Madhya Pradesh, Bihar, Orissa, West Bengal, and Assam with the necessary amounts of fat. India ranks #1 in the globe and provides the lion's share of the world's rapeseed and mustard output. About 42% of rapeseed and 38–40% of mustard seeds are oil-rich. When making pickles and flavouring curries and vegetables, the seed and oil are utilised as condiments. In Northern India, oil is used for frying and heating food for human consumption. Additionally, it is used to make medications and oils for hair. It is used with mineral oils for lubrication while producing soap. Rapeseed oil is a component in the production of greases. The oil cake is utilised as manure and livestock feed. As glucosinolates hurt protein, the mustard cake is not acceptable for human consumption. Green feed for cattle may be found in green stems and leaves. Young plants' leaves are consumed as green vegetables because they provide adequate sulphur and minerals for the diet. Mustard oil is used to soften leather in the tanning business.

Soil conditions

Except for taramira, which is grown on lighter soils, rape and mustard generally flourish best on medium to heavy loam soils. However, heavy soils that are vulnerable to waterlogging should be avoided since the crop cannot handle such circumstances. While saline and alkaline soils are typically unsuitable for the crop, despite their high resilience to such circumstances, they often result in considerable moisture stress and poor crop development.

Over the last 50 years, the agricultural business has seen a tremendous transformation. Farm equipment has become larger, faster, and more productive because of technological advancements, allowing for the more effective cultivation of larger areas. Additionally substantially enhanced, seed, irrigation, and fertilizers have helped farmers boost harvests. Currently, agriculture is in the early stages of a new revolution, one that is driven by connection and data. Emerging technologies like artificial intelligence, analytics, networked sensors, and others might boost yields even more, enhance the effectiveness of water and other inputs, and foster sustainability and resilience in both agricultural production and livestock rearing.

The future of connectivity

But none of this is feasible without a reliable connection infrastructure. According to our analysis, agriculture may provide $500 billion in added value to the global gross domestic product by 2030 if connectivity is properly deployed in the sector. This would result in an increase of 7 to 9% above the predicted total and significantly lessen the burden now placed on farmers.

While the demand for food is increasing, the supply side is constrained by the availability of land and agricultural inputs. By 2050, the world's population is expected to reach 9.7 billion people, necessitating a 70 percent rise in the number of calories that are accessible for consumption, even as the price of the ingredients used to produce those calories is going up. The water supply won't be able to fulfil the world's water demands by 2030, and growing energy, labour, and nutrient expenses are already putting pressure on business margins. A quarter of the world's arable land is deteriorated and requires extensive repair before it can support large-scale agriculture once again. 4 Additionally, there are growing social and environmental pressures, including the call for more moral and sustainable farming practises, such as higher standards for farm animal welfare and lower chemical and water use. Environmental pressures include climate change and the economic impact of catastrophic weather events.

Agriculture must embrace a digital revolution made possible by connectivity to combat these factors that are threatening to further destabilise the sector. However, compared to many other sectors worldwide, agriculture is still less digitalized. The majority of earlier advancements were mechanical, such as more potent and effective equipment, and genetic, such as more productive seeds and fertilizers. Digital technologies that are far more advanced are now required to achieve the next productivity boost. While more sophisticated ones are being developed, several currently exist to assist farmers in using resources more responsibly and effectively. With the help of these new technologies, decision-making may be improved, enabling better risk and variability management to maximise yields and boost economics. When used in animal husbandry, they may improve livestock well-being, addressing the rising concerns over animal welfare.

While the demand for food is increasing, the supply side is constrained by the availability of land and agricultural inputs. But the sector faces two major challenges. The creation of connection infrastructure is crucial since certain places lack it. Farms have been hesitant to use digital technologies in areas where connection infrastructure already exists since their effectiveness has not been properly established.

Other difficulties facing agriculture in five areas efficiency, resilience, digitalization, agility, and sustainability have been made worse by the COVID-19 situation. Farmers now have an even greater need to control expenses as a result of squeezed margins brought on by lower sales volumes. The necessity of having more local suppliers has been underlined by congested global supply networks, which may boost the resilience of smaller farms. The worldwide pandemic has worsened the situation for farms whose workers have limited mobility due to a large dependence on physical labour.

A demand for more local, sustainable sourcing is also expected to be driven by the huge environmental advantages of lower travel and consumption during the crisis, necessitating changes to companies' long-standing procedures. In summary, the crisis has highlighted the need for more automation and digitalization, while abrupt changes in demand and sales channels have highlighted the need for flexible adaptability.

Current agricultural linkage

Many farmers have started using data regarding critical elements including soil, crops, animals, and weather in recent years. However, very few people, if any, have had access to cutting-edge digital technologies that may aid in transforming this data into worthwhile, actionable insights. In less developed areas, practically all agricultural labour is done by hand and requires little to no modern technology.

Even in the United States, a forerunner in connectivity, only about 25% of farms currently use any connected tools or devices to access data, and that tech isn't exactly cutting edge, running on 2G or 3G networks that telcos plan to decommission or on very low-band IoT networks that are difficult and expensive to set up. In any instance, such networks are only capable of supporting a small number of devices and are unable to handle real-time data transmission, which is necessary to realise the full potential of more complicated and advanced use cases.

Nevertheless, many simpler use cases, including sophisticated agricultural and livestock monitoring, may be enabled by existing IoT technology operating on 3G and 4G cellular networks. However, in the past, the economic case for using IoT in farming did not hold up due to the high cost of hardware. Costs for hardware and devices are already falling quickly, and some suppliers are now offering solutions at a price that, in our opinion, will pay for itself within the first year of investment. The requirement to produce more food is increasing daily at an exponential rate. Around 5 billion hectares of land are used for agriculture worldwide, or 38% of all land. Although the producing area hasn't changed, the rising demand must be satisfied; this necessitates a shift in agricultural practices and considerable technological advancements to maximise the use of existing resources. Learn about the technical developments that have occurred over these years of agriculture.

Crops are now grown for both home and commercial uses. They include food, feed, fibre, oil, decorative, and industrial crops. Crops account for 1.1 billion tonnes of the world's total production, followed by wheat and rice, which produce 760 and 756 million tonnes, respectively. The top four agricultural producers in the world are China, India, the United States, and Brazil. Crop production, which encompasses the management of all inputs needed to sustain and develop crops, includes the production of food and fibre. Among these include soil preparation, seeding, watering, weeding, applying manure, insecticides, and fertilizers, as well as harvesting and storing. To produce the greatest yields, these characteristics are optimised in crop production.

Sustainable farming

Agriculture that satisfies social demands while protecting and enhancing the available natural resources for current and future requirements are referred to as sustainable agriculture. Both farming and managing cattle are involved.By 2050, there will be more people than there will be food and resources due to current trends in population increase and food consumption. The bulk of the resources needed by the agroecosystem on Earth originates from natural sources. Therefore, using sustainable agricultural practises contributes to the management of Earth's resources so that they may be improved and used to their full potential. The impacts of water shortage, land degradation, water pollution, and resource depletion all leave a substantial environmental imprint. By applying a range of techniques to safeguard plants, soil nutrients, energy, water, and other resources, sustainable crop management has created a pathway to addressing the problem with natural resources.

Benefits of sustainable agriculture include resource efficiency, biodiversity improvement, environmental preservation, less pollution, cost and waste reduction, and increased quality. Technologies for producing crops resistant to climate change.Agriculture is changing thanks to Industry 4.0. The newest techniques and technology are being used in agriculture to increase agricultural productivity and efficiency. The sustainability of crop yield is increasing, as shown in figure 4.1.

Digital technology makes it easier to monitor sustainable practises, utilise resources more efficiently, cut greenhouse gas emissions, and create a circular economy. Innovation and teamwork are fostered by digital technology. The next generation of climate change solutions is being made possible by AI, IoT, and blockchain. All the stakeholders in the value chain are brought together on a single platform by the unified data-sharing platforms, which aids in achieving alignment on shared objectives.

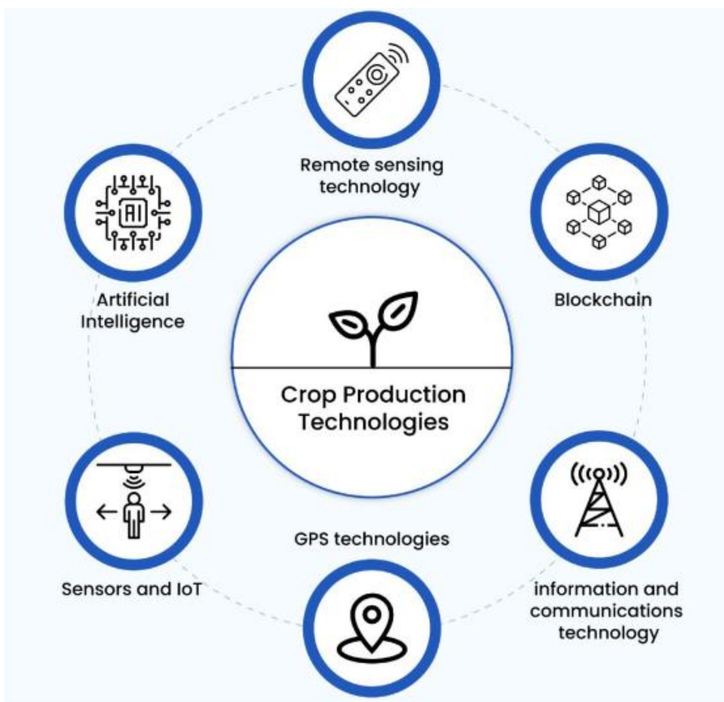

Figure 4.1: Illustrate the crop production technology.

Remote sensing technology

Without ever touching them, essential steps may be taken by using satellite photographs to take pictures of and inspect a farm or ranch. It establishes the physical features of a region by calculating the separation between its reflected and emitted radiation.

The electromagnetic spectrum is the collection of waves that make up solar light. Depending on the traits and quality of the plant, this light may reflect, absorb, or transmit as it strikes green plants. Remote sensing eliminates these interactions between plants and the sun. These statistics are specific to plant species and are based on ranges of both healthy and damaged crops.

- To detect issues like overgrazing, weed infestation, bug damage, etc. even before they are visibly noticed, a top view of the area is projected. This method only applies to the afflicted land, however.
- It serves as a guide for choosing inputs like fertilizers, pesticides, water, and resources by identifying crop health, nutrient deficit, wind damage, plant population, and water inputs.

Blockchain innovation

Blockchain is a ledger-based record-keeping system in which data is input, replicated, and shared throughout the network using decentralised, immutable, open-source, and transparent computer systems.From the seed source to the producers and farther along the supply chain, every stage of agricultural production is tracked using blockchain technology. If anything goes wrong, it will be simpler to monitor and trace thanks to this. Processes such as the acquisition of seeds, planting, inputs, fertilizers, and harvest are connected in a way that allows one to track them back to their original location.

ICT-based communication systems

Devices that facilitate the flow of information from one location to another are referred to as information and communication technology (ICT). It makes use of a wide range of technology, including satellites, smart devices, the internet, sensors, and phones, to convey data that is used to process and control agricultural operations.

The implications of IOT, Big Data, Cloud Computing, sensors, drones, etc. in recent years have helped gather crucial information and share it in real-time, assisting farm managers to monitor crops, adapt to changes in the environment, deciding on resource inputs, etc. This has increased crop production efficiency and optimised the use of available resources.

- Facilitates the rapid sharing of knowledge, which leads to better judgements.
- Farmers' response times may be sped up with the use of real-time data on crop health, weather, soil fertility, production, trends, etc.

Contemporary positioning techniques

Geographical information systems (GIS) and Global Navigation Satellite Systems (GNSS) are recent developments in addition to the older Global Positioning System (GPS). These systems, which are of a military calibre, are utilised in agriculture to map out the precise position of the field as well as information on the soil, crops, animals, and other factors. Additionally, it transmits data in real-time and records every movement.

Utilizing this programme will boost agricultural output and save resources. As a result, every aspect of farming is looked through and improved to get the finest results. Real-time data on seed planting, fertilizer application, and resource inputs helps to prevent overlap and area skipping. Plans the path for automated equipment while also gathering information on the condition of the soil and crops. It is possible to monitor labour, livestock, and yield. A simple yet efficient device that sends information from the field to the farmer. Sensors are devices that are installed in the fields and, when activated, perform a pre-automated task.

Sensors may communicate a variety of information, including pH levels, nutrients, latitude and longitude, weather conditions, soil quality, moisture content, and meteorological data. Additionally, sensors may plan water delivery, fertilizer inputs, reminders, etc. with the use of IoT. Drones are used in both manufacturing and monitoring nowadays. It is simpler to monitor crops, map farms, and identify weeds, pests, and changes in soil and crops because of the aerial height it offers.

AI-based Data Analytics for Agriculture

Most agricultural choices are data-based, and artificial intelligence (AI) offers such essential real-time data to not only automate the farming process but also to optimise production and quality while minimising the use of resources. Activities related to soil management, such as health, moisture content, defects, nutrients, etc., are identified for diagnosis. Uses automated equipment across a huge amount of land to produce goods more quickly and precisely. Based on the kind of plant, plant condition, necessary nutrients, etc., farm inputs are intelligently designed. Predictions and insights on when to plant, the state of the weather, pricing changes, etc.

Future of agricultural management

Using technology in agriculture is undoubtedly a good thing. In addition to boosting crop production, it has enhanced several aspects of farming, including management, planning, financing, and budgeting. Government support for different discoveries and technological improvements has also been given in the form of investments, subsidies, and regulations. Blockchain technology underpins the Farm management solutions offered by TraceX. The pre- and post-harvest management modules guarantee a good crop yield at a reasonable price. Healthy crop yields are guaranteed by monitoring sustainable practises in the first mile and upholding quality requirements. A strong supply chain is created through process management and improved workflows, guaranteeing greater operational effectiveness and increased profitability.

The world's food supply may run out by the year 2050, according to the latest projections. Food waste is still prevalent and has an impact on both the environment and food security. Technology has reduced the negative effects on the environment by increasing productivity, reducing waste, utilising fewer resources, and increasing profitability. To demonstrate their advantages to the agriculture industry, technological innovations work hand in hand with regenerative and sustainable farming methods.

The food sector has advanced significantly; decades of knowledge and the application of different ways and approaches have led us to the point where we produce equipment and machinery that can support farmers' opinions and advance farms. When technology and agricultural principles are in line, a wide gateway opens up for utilisation that is now being explored. Every day, new developments are made to enhance the agricultural process and meet this ever-expanding need. As a result, using this route will allow you to reach the peak of crop output.

Crop Production Technologies for Conservation and Sustainable Use: A wealth of research on significant and novel production systems for the effective, sustainable cultivation of vital crops is presented in Physiological and Molecular Advances. The majority of the important crops that are used to produce food, sugar, and commercial fibre are covered in this book. The study present molecular and physiological research and innovations for improving yield, quality, and safety with a focus on sustainability and conservation issues in crop production. This is done while also taking into account rising demand, dwindling water and land resources, and the agricultural effects of climate change on crop production. Wheat, sugarcane, eggplant, jute, mungbean, cotton, Solanum including potatoes and tomatoes, peppers, okra, fruits like apples and pears, and more are among the main crops covered. This includes recent advances and research on fertilizer production methods, biosystematics or molecular biology of different crops, and enhancing climate change resistance, including drought tolerance, salt stressors, and more.

One of the core subfields of agriculture is crop production. Producing crops provides the foundation for feeding the people and supplying feed to the animal business. Additionally, agricultural products are utilised as plant-based raw materials in several sectors, including those that produce food, textiles, pharmaceuticals, fuel, and others. Agriculture's component known as crop production comprises activities like field cultivation, vegetable and fruit producing, among others. This sector provides the essential nourishment. Raw materials are obtained for the food and consumer products sectors. The livestock business, in turn, makes use of leftovers from the food industry, including straw, silage, and trash. Despite the challenging production circumstances brought on by high costs for inputs, the unattractiveness of rural locations, and the challenges in getting financing, agricultural firms have a significant output potential. Amid challenging circumstances, domestic agricultural firms are compelled to use innovations to increase the effectiveness of the production organisation.

Practice demonstrates that despite greater pricing, consumers still choose local agricultural firms' goods since they are more expensive than those offered by international producers. This is mostly explained by the fact that domestic manufacturers create goods that are ecologically friendly and utilise the least amount of preservatives possible during manufacturing. Because of these factors, there is a need for agricultural goods. Additionally, there is a rising demand for farm agriculture products, which are goods made under natural circumstances. In today's sociopolitical and economic climate, which is changing quickly, the economy must ensure not only its survival but also the increase of the output. Without fostering the application of science, technology, and innovations, it is thus difficult to shift to sustainable economic development and further enhance the organisation of food production. An in-depth analysis of the real processes of producing the product, as well as its nature, direction, and dynamics, is required for an individual's choice of the appropriate implementations.

The study we conducted enabled us to identify the following key strategic goals for enhancing the agricultural management system in the Russian Federation: it is critical to intensify the development and support of innovative activities aimed at the technological modernization of agricultural production, and it is necessary to develop relevant areas of the Russian state's agrarian policy, focused on ensuring food independence in the face of new geopolitical challenges. Some of the aforementioned strategic goals are now being addressed, but a complete solution is required for the efficient management of crop production in particular and the growth of the agricultural sector of the economy as a whole.

Modern Technology for Pest Management: An animal or plant that poses a threat to people or human interests, such as those in agriculture, forestry, or livestock, is considered a pest. In the production of crops, there are weeds, insects and plant infections such fungus, bacteria, and viruses that are harmful and even cause crop failure. As the environment changes, there are also behavioural changes that are troublesome. Maintaining biodiversity necessitates limiting pest populations below the point at which economic stress can no longer be tolerated. Nano-pesticides: Although pesticides and fertilizers are often employed to increase agricultural yields, fewer than 0.1% of the pesticides used in the field reach their intended targets. Due to the financial costs and growing environmental and human health issues, such indiscriminate use of chemical pesticides is harmful. The use of nanotechnology to develop innovative formulations has recently shown significant promise for reducing the indiscriminate use of pesticides and offering ecologically cleaner alternatives.

Targeted and regulated release mechanisms are used in smart nano-based insecticides to effectively deliver appropriate quantities of active components in response to biotic and/or abiotic stimuli that function as triggers. Recent years have seen a rise in interest in controlled release systems from scientists and businesses worldwide. These systems are used in a variety of industries, including agriculture, food, engineering, cosmetics, and medical. Sustainable agriculture is an all-encompassing strategy that aims to meet human requirements for food and other products while preserving environmental quality and avoiding the depletion of natural resources. The primary goals of establishing sustainable agriculture are to lessen the strain on the environment and ecosystems, minimise using chemicals like fertilizers, pesticides, and herbicides, and conserve natural resources and human health.

In particular in emerging nations, agricultural biotechnology is essential for competitiveness and sustainable economic development. Additionally, biotechnology has a unique role in boosting food security, which might be a benefit for small farmers in developing nations that want to practise sustainable agriculture. By lowering the use of pesticides in agriculture, biotechnology has improved our society's and maybe the world's environmental conditions while also spurring economic expansion. Even though these instances are seen as significant advancements, sustainable agricultural growth is still a work in progress. The structure of political ideologies and research organisations must be significantly altered to generate goods that fit ecological and socioeconomic standards. Authorities must reevaluate the connections between farmers, industry, consumers, and universities to bring about these changes.

Crops that have been genetically modified (GM) are utilised more often to increase plant quality and stress tolerance. Many nations have embraced transgenic crops that are insect- and herbicide-resistant as a food security precaution. Since the introduction of genetically engineered crops, output has increased 100 times. Today, GM crops are being used to produce fuel. Additionally, researchers are improving the capacity of plants and crops to store dangerous and harmful substances to restore soil and water resources. The destiny of GM crops, however, depends on finding a balance between cultivating them for hunger control, nutritional fulfilment, insect resistance, crop effectiveness, and their secondary consequences beyond their goal purposes, including multitrophic effects on non-target species.

Modern Harvesting Technology:

Farm workers are increasingly leaving the agricultural industry, which causes a labour shortage and increased salaries that make the practise unprofitable in terms of both time and money. Before the shift in time and environment, there was sufficient labour available, but it is now impossible to satisfy demands without engaging in agriculture, which is the main cause of labour shortage. Crops should be harvested quickly and with little waste to maximise the yield from a given field. Technology is being used to decrease the reliance on labour and save time via timely harvesting. Reaper, combine harvester, tea leaf plucker, harvester for peanuts and sugarcane, among other contemporary technology for agricultural harvesting, effectively and inexpensively cut the crops.

Farmers face a variety of challenges, including managing climate change, soil erosion, and biodiversity loss, as well as meeting the rising demand for more food of higher quality and adjusting to consumers' changing tastes and expectations. In some regions, however, poor economic conditions and fragmented land limit farm mechanisation. However, as times change, so should the methods use to mitigate climate change and the emigration of people from the agricultural sector? The use of sustainable resources for climate change mitigation is made easier by new methods in crop production. Removing superfluous procedures from crop production and placing an emphasis on preserving biodiversity and protecting the environment from pollution are two examples.

Many aspects of agriculture are impacted by technology, including seed technologies, herbicides, and fertilizers. Pest resistance and higher agricultural yields are products of biotechnology and genetic engineering. Tilling, harvesting, and physical work have all become more efficient as a result of mechanisation. Improvements in transportation and irrigation systems, less waste from processing machines, and other factors are all obvious. Robotics, precise farming, blockchain technology, artificial intelligence, and other modern technologies are highlighted.

Several technical developments have transformed agriculture:

Increased production as a result of agricultural mechanizationparticularly in tropical areas, manual labour and hand tools employed in agriculture have energy and production constraints. Due to accessibility, cost, and maintenance concerns, smallholder farmers' resistance to agricultural automation is often counterproductive. Combine harvesters are being used more often to eliminate human work and accelerate procedures. Indian agriculture is characterised by limited landholdings, making collaboration necessary to use contemporary machinery. Future acceptance of mechanised services will increase as a result of hand-holding farmers to increase their capacity, making new machinery accessible, particularly to small farms, and addressing cost difficulties via regulation. Agricultural mechanisation can reduce post-harvest losses and boost harvest gains, which might have a direct and indirect impact on yields.

The application of artificial intelligence in agriculture has made it possible to anticipate the climate and weather (AI). Data collection is made possible by current technology and AI-based solutions, which also support precision farming and well-informed decision-making.

Drones, remote sensors, and satellites continuously collect data on the weather in and around fields, giving farmers crucial knowledge on temperature, rainfall, soil, humidity, and other factors. However, in a nation like India, where subpar farming, dispersed landholdings, and other factors pose obstacles, AI adoption is gradual. But there is no denying that AI-based technology may increase production exponentially while bringing accuracy to large-scale farming. Agriculture refers to a broad range of procedures, including conventional breeding techniques, genetic engineering, and the creation of microorganisms for agriculture. Resilient crops are produced via the application of biotechnology. Generally speaking, genetic engineering brings improvements to animals and crops by identifying and manipulating genes to boost crop resistance to pests. High-yielding varieties are also created via the application of genetic engineering.

For farmers and final consumers, the use of biotechnology in agriculture has had several positive effects. Given the changing environment and rising population, there is little question that SAFE biotechnology will play a significant role in the future of agriculture even if certain contentious ways have caused opposition to the use of biotechnology.

- **Agriculture Sensors:** Indian communications technology has advanced quickly, opening the door to smart farming. To help farmers monitor and optimise crops given the environmental conditions and constraints, sensors are increasingly being employed in agriculture. These wirelessly connected sensors are used for a variety of tasks, including pinpointing precise locations, measuring airflow, identifying nutrients, and analysing soil composition and moisture content. Farmers use sensors to apply fertilizer more effectively while using fewer chemicals and less effort. They enable farmers to produce more with fewer natural resources.
- **Increasing agricultural outputs and using supply chain management:** Big Data The use of data for decision-making and problem-solving is being expanded via its collection, compilation, and subsequent processing. The advantages of using big data in smart farming are expected to spread across the whole supply chain and the markets. Agriculture is expanding and is influenced by a wide range of factors.

As a consequence, complicated data is being gathered and used more often, which requires effective interpretation and management. Data may come from marketplaces, supplier networks, social media, or sensor/machine data collected in the field.

Big data is transforming agriculture, which has an impact on agricultural production, supply chain management, yield forecast, etc. Livestock monitoring is essential for large-scale livestock management and may aid in the prevention of disease outbreaks. Body sensors and chips assess essential data and signs that might identify disease early and stop herd infection. In a similar vein, ultrasounds are a helpful tool for determining meat quality. This aids in maintaining and raising the meat's quality.

In contemporary agriculture, innovation is more crucial than ever. The sector as a whole is confronted with formidable obstacles, including growing supply prices, workforce scarcity, and shifting customer desires for transparency and sustainability. Agriculture firms are becoming more and more aware that these problems need answers. Agriculture technology has witnessed a tremendous increase in investment over the last ten years, with $6.7 billion spent over the past five years and $1.9 billion in just the previous year. The most significant technological advancements in this field have been in fields like indoor vertical farming, automation and robotics, livestock technology, contemporary greenhouse techniques, precision agriculture and artificial intelligence, blockchain, and animal technology.

Indoor vertical farming may boost crop yields, circumvent land-use restrictions, and even lessen the environmental effect of farming by reducing supply-chain travel distance. Growing food in a controlled, enclosed environment as it is piled one on top of the other is known as indoor vertical farming. In comparison to conventional farming techniques, employing growing shelves that are installed vertically greatly minimises the quantity of area required to cultivate plants. Because it can flourish in a small area, this sort of growth is often linked to urban farming. In certain configurations, vertical farms are unusual because no soil is needed for plant growth. Most are either hydroponic vegetables are grown in a bowl of nutrient-rich water) or aeroponic water and nutrients are routinely sprayed on the plant roots. The usage of artificial grow lights is employed in place of natural sunshineup to 70% less water is used by vertical farms than by conventional farms. The benefits of indoor vertical farming are clear, ranging from enhancing agricultural productivity with lower labour costs to promoting sustainable urban expansion. Vertical farming increases food production with consistent harvests by accurately regulating year-round factors including light, humidity, and water. Since vertical farms use up to 70% less water than conventional farms do, energy saving is maximised. By deploying robots to manage logistics, planting, and harvesting, farms may overcome the difficulty of the present manpower shortage in the agricultural sector.

Automation of the crop or animal production cycle on farms increases efficiency and is sometimes referred to as "smart farming." A growing number of businesses are focusing on robotics innovation to create robots that can automatically irrigate plants, sow seeds, and operate tractors and harvesters. Even though these technologies are still relatively new, more conventional agricultural businesses are incorporating farm automation into their operations.

Modern agriculture has undergone a dramatic transformation because of new technological developments in fields like robots, drones, and computer vision software. The main objective of agricultural automation technology is to take care of simple, routine operations. Drones, autonomous tractors, sowing, and weeding are some of the primary technologies that are most often used by farms. Major concerns including a growing global population, a lack of agricultural labour, and changing consumer demands are addressed through farm automation technologies. By addressing challenges like customer preferences, labour shortages, and the environmental impact of farming, automating conventional agricultural operations has enormous advantages.

Although it is undoubtedly the most important, the traditional cattle business is a sector that is often disregarded and underserved. Our daily needs for sustainable, natural resources are met by livestock. Traditional definitions of livestock management include managing the operations of agribusinesses that are directly tied to animals, such as dairy and cattle ranches, poultry farms, and dairy farms. Managers of livestock must oversee employees, maintain correct financial records, and guarantee that animals are fed and cared for properly. But current developments have shown that technology is fundamentally altering the cattle management industry. The sector has seen significant advancements in the last 8–10 years that have made monitoring and maintaining cattle considerably simpler and data-driven. This technology may be found in a variety of areas, including nutrition, genetics, digital technology, and others.

The productive potential, welfare, or management of animals and livestock may all be improved or enhanced by the use of livestock technology. The productive potential, welfare, or management of animals and livestock may all be improved or enhanced by the use of livestock technology. The idea of the "connected cow" emerged as a consequence of the increasing use of sensors in dairy herds to track health and boost output. By placing individual wearable sensors on cattle, it is possible to monitor daily activity and health-related problems while also presenting the whole herd with data-driven insights. Additionally, all of this created data is being transformed into insightful knowledge that can be used immediately by producers to take time management choices.

The science of examining an animal's whole gene landscape and how its genes interact to affect the animal's growth and development is known as animal genomics. The genetic risk of a herd may be understood by livestock producers through genomics, which also helps them predict the future profitability of their cattle. Cattle genomics enables farmers to maximise the profitability and yields of livestock herds by being strategic with animal selection and breeding choices.

The existing cattle sector may greatly benefit from sensor and data technology. By identifying unwell animals and intelligently identifying areas for improvement, it may increase cattle output and welfare. We can access a wide range of objective data thanks to computer vision, which will be condensed into valuable, practical insights. Better, more effective, and quicker judgements are made as a result of data-driven decision-making, which will increase the production of animal herds.

The greenhouse sector has been evolving over the last several decades from modestly sized buildings used solely for research and aesthetics (i.e., botanic gardens) to much larger buildings that directly compete with land-based traditional food production. Currently, the total worldwide greenhouse business generates about $350 billion in vegetable output each year, with less than 1% of that production coming from the United States. The industry is now experiencing a flowering, unlike any other period in its history, in large part because of the enormous recent advances in developing technology. Today, there are more and more large-scale, well-financed, and urban-focused greenhouses sprouting.

The market has undergone significant growth as well as definite trends in recent years. Modern greenhouses are getting more and more technologically advanced, incorporating automated control systems and LED lighting to precisely customise the growth environment. To meet the rising demand for local food year-round, successful greenhouse businesses are expanding dramatically and situating their growing operations close to metropolitan centres. The greenhouse business is also investing more money to complete these tasks, using venture capital and other sources to develop the infrastructure required to compete in the present market.

Agriculture is changing, and technology is now a necessary component of any commercial farm. With the use of new precision agriculture firms, farmers will be able to optimise yields by managing every aspect of crop production, including moisture levels, insect stress, soil conditions, and microclimates. Precision agriculture helps farmers enhance productivity and control expenses by offering more precise methods for planting and producing crops. Companies that specialise in precision agriculture have great potential to expand. According to a recent study by Grand View Research, Inc., the market for precision agriculture would grow to $43.4 billion by 2025. Farmers in the younger generation are drawn to quicker, more adaptable companies that methodically optimise agricultural output.

CHAPTER 5

PLANT PATHOLOGY OF AGRI CROPS

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The study of fungus, bacteria, viruses, nematodes and other microorganisms that cause plant diseases is the focus of the agricultural science field known as plant pathology. Plant diseases and disorders cause suffering in plants, either causing death or reducing their capacity for survival and reproduction. Plant disease refers to any anomalous situation that affects a plant's appearance or functionality. Pathology is a phrase derived from the Greek terms pathos and logos, which indicate sorrow and reason, respectively. Pathology, therefore, is the "science of misery." Thus, the field of biology known as plant pathology, sometimes known as phytopathology, is concerned with the study of sick plants. It combines the science of discovering and comprehending the nature of the disease with the art of identifying and managing the illness. The significance of plant disease Plant diseases must be studied carefully since they may harm both plants and their yield.

The numerous losses might happen on the farm, in storage, or at any point between planting and harvesting. Direct financial loss and material loss are directly attributable to the disorders. Untold millions of people still experience pain due to plant diseases, which are projected to result in a 14% yearly yield loss worldwide and a 220 billion US dollar economic loss. Fossil data suggests that 250 million years ago, many illnesses plagued plants. Numerous significant occurrences in the earth's history that have affected humanity have been linked to Plant sickness. A 30–50% crop loss is thought to be the result of illnesses. Compared to their wild ancestors, cultivated plants are often more sensitive to disease.

Temperature, relative humidity, soil moisture, soil pH, soil type, and soil fertility are significant environmental elements that may influence the development of plant diseases. There is an ideal temperature for each pathogen to flourish. Destructive water mould fungus include species of Aphanomyces, Pythium, and Phytophthora thrive when soil moisture levels are high. High humidity encourages the growth of the vast majority of bacterial and fungal-based leaf and fruit diseases. A few diseases, including club root (Plasmodiophora brassicae) of crucifers and common scab of potatoes, are significantly influenced by soil pH, a measure of acidity or alkalinity. The development of various infectious illnesses is also influenced by changing the quantities of specific nutrients. The majority of control strategies target the pathogen's inoculums and include exclusion and avoidance, eradication, protection, host resistance and selection, and therapeutic tenets.

The study of creatures infectious organisms and environmental variables (physiological factors) that lead to illness in plants, the processes by which disease arises, and the interactions between these causative agents and the plant is known as plant pathology (phytopathology) effects on plant growth, yield and quality. In addition, the study of pathogen identification, disease aetiology, disease cycles, economic impact, epidemiology of plant diseases, resistance to plant diseases, the effects of plant diseases on people and animals, pathosystem genetics, and management of plant diseases are all included in the field of plant pathology. It also integrates information from several other scientific disciplines, including biochemistry, mycology, microbiology, virology, and bioinformatics. Since man needs to cultivate enough food and fibre to support civilization, plant pathology is directly important.

The activities of the cells are disrupted, altered, or inhibited, the cells malfunction or die, and the plant becomes diseased when the ability of the cells of a plant or plant part to carry out one or more of the essential functions is interfered with by either a pathogenic organism or a harmful environmental factor. The condition is first limited to one or a few cells and is unnoticeable. However, the response quickly spreads, and the damaged plant sections experience changes that are obvious to the human eye. These outward changes are signs of illness. The level of illness in a plant is determined by the visible or other observable negative changes that the plant undergoes as a result of an organism infecting it or as a result of an unfavourable environmental circumstance. The series of invisible and visible reactions of plant cells and tissues to a pathogenic organism or environmental factor, which result in unfavourable changes in the form, function, or integrity of the plant, can then be described as a disease in plants. Partial impairment or death of plant parts or the entire plant can result from these reactions. Pathogens are responsible for plant illnesses. Consequently, a pathogen is always linked to a disease. In other words, illness is a symptom brought on by a pathogen that may invade, persist, and spread.

Diagnosis of plant diseases

In addition to a thorough understanding of the symptoms and signs of the host plant, the diagnosis of plant diseases necessitates taking into account a variety of biotic and abiotic elements that may be involved in the disease's pathogenesis. Each circumstance may be influenced by a variety of factors, such as the host's health, the cultural history of the region, the weather, the soil, and other site-specific details. It is crucial to have a solid grasp of the "typical host," and experience is priceless. The intricacy of the disease's aetiology, or root cause, often dictates how challenging a diagnosis will be. Numerous illnesses that are caused primarily by a single organism have distinctive and recognisable symptoms and indications. More complicated diseases may include symptoms that point to several probable causes and be difficult to correctly identify.

Environmental variables and infections' negative effects on the host

The transmissible biotic agents known as pathogens, or pathogenic microorganisms, usually cause disease in plants by interfering with the metabolism of plant cells through the release of enzymes, toxins, growth regulators, and other chemicals, as well as by consuming nutrients from the host cells for their use. Some infections may also cause illness by developing and proliferating within the xylem or phloem vessels of plants, obstructing the upward or downward circulation of carbohydrates or water via these tissues, respectively. When abiotic variables, such as temperature, moisture, mineral nutrients, and pollutants, occur at amounts beyond or below a limit that the plants can tolerate, this causes illness in the plants.

Infection of the xylem vessels, as occurs in vascular wilts and some cankers, prevents water and minerals from being transported to the plant's crown; infection of the foliage, as occurs in leaf spots, blights, rusts, mildews, mosaics, and other diseases, prevents photosynthesis; infection of phloem cells in the veins of leaves and the bark of stems and leaves; and infection of the roots may cause the roots While most illnesses to cause infected cells to weaken or die, certain diseases, such as crown gall, cause infected cells to proliferate considerably more quickly (hyperplasia) or swell much more than normal cells (hypertrophy), which results in aberrant amorphous overgrowths (tumours) or malformed organs.

Plant Disease Management

The term "control" refers to the whole process, while "management" refers to the ongoing process of reducing the negative effects of a disease. Permanent "control" of a disease is uncommon. To make informed management choices, it is essential to have a thorough grasp of all areas of crop production, economics, the environment, culture, genetics, and epidemiology. The significance of plant diseases causes significant agricultural losses around the globe. From the moment the seeds are sown in the field until they are harvested and stored, loss may happen. The Irish Famine brought on by late potato blight, the Bengal Famine brought on by rice brown spot, and coffee rust, among other epidemics, are significant historical examples of plant disease outbreaks. The economies of the nations affected had been impacted by such diseases.

Infectious bacteria and noninfectious elements commonly referred to as " biotic illnesses" or "abiotic disorders," may both harm plants. Abiotic illnesses are brought on by nonliving elements like overwatering or unfavourable planting circumstances, or by inappropriate cultural practises including drought stress, sunscald, frost damage, wind damage, chemical damage, or nutrient inadequacy. Unlike biotic issues, biotic problems often impact several species or plants of different ages; damage is generally rather uniform, doesn't spread, and is frequently not progressive. Pests are not connected to biotic issues. They are often brought on by a single event and are associated with either physical, environmental, or cultural behaviours. The plant may overcome the issue and establish new, normal-appearing leaves after the relevant cause has subsided and is no longer impacting it.

Deficits in nutrients

Lack of nutrients results in smaller leaves and smaller shoots, as well as leaf chlorosis, necrosis, and dieback of plant components. However, because various other plant issues might manifest similarly, nutritional deficiencies cannot be accurately identified based just on symptoms. Nutrient shortages may cause broad symptoms, but in most cases, soil or leaf samples are required to identify the issue. Plant tissue analysis is the most effective way to identify nutritional deficits in plants. Plant tissue analysis, as opposed to soil nutrient analysis, enables one to pinpoint plant nutrient absorption as opposed to plant nutrient availability. Nutrient deficiencies are sometimes confused with viral infections since they don't have any outward symptoms. The distribution of symptoms on the plant is one of the greatest indicators of nutritional problems.

Symptoms manifest on the lower (older) leaves of the plant because mobile nutrients are easily moved inside the plant to the growth sites. In contrast, with nutritional deficits, immobile nutrients cause symptoms to appear on the plant's meristem. Deficits in nitrogen may also be caused by root diseases like nematodes that cause root-knots (Meloidogyne spp.). Higher sensitivity to some leaf infections, such as Alternaria solani, may occur from nitrogen deficiency, while increased susceptibility to other pathogens, such as Botrytis cinerea or Rhizoctonia solani, can come from excessive plant nitrogen levels. However, phosphorus shortage may cause stunting, poor development, and leaf colourations like blue/green or purple on the stems and undersides of the leaves. The earliest signs of an iron deficit are seen in the newly formed yellow-green leaves, which are often striped in appearance.

While interveinal chlorosis, leaf curling and browning, and necrosis (tissue death) on the leaf edges are signs of a K deficit. K-deficient plants may be more vulnerable to some illnesses and frost damage. On fruits, blossom end rot is a typical sign of a Ca shortage, while additional signs include leaf marginal chlorosis, localised tissue necrosis, and plant stunting. Blossom end rot and other Ca deficiency-related fruit illnesses, such as the bitter apple pit, may often result in subsequent fungal colonisation. Additionally, Ca is a part of host defence proteins against pathogen poisons like oxalic acid, which is used by certain fungi like Sclerotium rolfsii to infect host cells. A lack of magnesium causes tissues to become chlorotic and necrotic and take on an orange, red, or brownish hue.

On several plant species, yellowing of the leaf edge is also typical. As Mg is quickly translocated throughout the plant, early leaf senescence may also happen, especially on older leaves. Mg shortage may also result from the excessive application of K and/or Ca, which compete for cation exchange sites in the soil. Maintaining an appropriate Ca:Mg ratio in agricultural soils is critical because excessive Mg application might result in Ca shortage. Epsom salt may be applied granulated or foliar to agricultural plants to treat magnesium shortage. In many industrial systems, toxicities from micronutrients are prevalent. Chlorosis or necrosis on leaf edges or tips isa common sign, although leaf spotting, flecking, and other symptoms might also appear. Extremely low or high soil pH levels cause nutrient poisoning. In greenhouse floriculture, toxicities from micronutrients are especially prevalent. As an example, Fe and Mn toxicity often happen in greenhouse crops when the pH of the growth medium is low. When irrigation water or soil has large micronutrient concentrations, excessive micronutrients may also develop phytotoxicity caused by herbicides, pesticides, and fungicides.

Some herbicides may produce root swelling or stunting, which might be mistaken for nematode damage. Other herbicides produce blotches or patches that mimic foliar disease and are necrotic or chlorotic. Some herbicides may create vein banding, distorted hues, or mottled colours that resemble viral diseases. For instance, grape, cotton, tomatoes, and many other plants exhibit deformation as a result of the phenoxy herbicide 2-4D, a synthetic auxin, which may be mistaken for a viral illness. Diuron may sometimes also induce grapevine vein discolouration that may be mistaken for a viral infection or a dietary issue. The effects of insecticides and fungicides might sometimes result in visible plant damage. Pesticide treatments often cause greater harm to flower petals than leaves.

The leaves are more vulnerable to damage from pesticide treatments the younger and more fragile they are. The harm that chemicals do might be made worse by warm temperatures. Pesticides with systemic effects may have a more significant impact. Some active components may hurt the photosynthetic system or other physiological processes, which may cause leaf stunting, interveinal chlorosis, overall leaf chlorosis, and leaf curling.

The waxy surface layer that shields the leaf from desiccation may be negatively affected by emulsifiable concentrate (EC) formulations, soaps, and oils. Applications with these products may cause leaf spotting, necrosis, and the loss of a leaf's glossy lustre. Pesticides sprayed on the soil might result in stunted plant development, seedling mortality, or poor germination.

Genetic and Physiological Disorders

Physiological conditions

Extremes in the environment, such as light, temperature, water, or wind, may lead to a variety of diseases. Sunburn is damage to the leaves and other herbaceous plant components brought on by an excess of heat, light, and moisture. The foliage starts to turn yellow or brown and eventually dies, starting in the spaces between the veins. Damage to bark brought on by too much light or heat is known as sunscald. Broken bark gets sunken and fractured. High temperatures and poor soil moisture may cause blistering on the leaf edges, early leaf loss, and in extreme situations, complete plant death in plants. Physiological changes may sometimes cause aberrant growth patterns or colour. For instance, geranium (*Pelargonium spp.*) freshly developing leaves may get "bleached" or white when exposed to temperatures exceeding 95°F (35°C). Shoots, buds, and blooms damaged by frost curl, become brown or black and eventually die.

Hailstones harm twigs, leaves, and in extreme circumstances, even the bark. Sensitive plants may experience withering of their foliage and blossoms as well as the formation of black water spots on their leaves, which may ultimately become light brown or bleached and cause the plant to die. The severity of low-temperature damage might vary based on the season and the kind of plant. Shoots that are just beginning to grow are more delicate than mature plant components. After spring bud break, shoots may get seriously wounded or even destroyed if frigid conditions are experienced. Cold temperatures (over 32°F; 0°C) may harm developing plant components, sometimes causing necrosis and a purple tint of the leaf.

Subfreezing temperatures may also harm a plant's woody sections. Bark may split, leaving the underlying wood vulnerable to infections or insects. The vulnerability to infection by pathogens like *Agrobacterium tumefaciens*, which produces crown gall on many ornamentals, is dramatically increased when bark cracks as a result of freezing damage.

In addition, freezing rain and cold temperatures may cause ice to build up on the limbs of woody plants, which can shatter severely. Plants may be subjected to harmful quantities of ethylene gas in enclosed spaces like greenhouses and nursery storage rooms.

Ethylene gas at toxic levels may hasten the abscission of floral buds, petals, and foliage. Wilted blooms, chlorosis, twisted growth or downward bending of stems and leaves, and small or narrow leaves are further indications.

Nursery plants may suffer harm when exposed to atmospheric pollutants such as ozone, carbon monoxide, nitrous oxide, and sulphur dioxide in open spaces. The majority of the time, the signs include sluggish growth and discoloured, decaying, or prematurely falling foliage. Plants near sources of contaminated air, such as those near roads or businesses, or in areas where the weather and geography concentrate the pollutants sometimes suffer damage.

Plants that consistently get too much water to have undeveloped shoots and seem stunted. Cankers on stems that bleed may happen in extreme circumstances. At the root crown, adventitious roots may develop. The bark might crack, and the wood can get wet and get discoloured. On the underside of leaves on plants growing in wet soils, edoema or corky, blister-like swelling might appear. Whenever it's dark or overcast, edoema may become worse. Due to sulphur gas generation in the anaerobic soil, a stench of rotten eggs may be detectable in locations where waterlogged soils are common for extended periods.

Genetic Conditions

Sometimes plants or plant branches display a unique and abrupt shift in hue, resulting in distinct variegation marks. For instance, a plant with fully green leaves may suddenly grow a branch with margins of its leaves that are striped, blotched, or deficient in green pigment. Such a newshoot is a chimaera. It is created when a particular area of the developing tip experiences a genetic mutation, resulting in a segment with genetically distinct cells. The configuration and expression of the genetically diverse cells at the shoot tip determine the apparent outcome of the genetic change. This may result in sometimes odd variegation forms or occasionally highly attractive shapes. Viruses may sometimes be the cause of variegation. In contrast to chimaeras, which often generate patterned shapes like stripes or a total lack of pigment, viruses typically induce non-uniform chlorosis, such as mosaics. Some viroids may also bleach the pigments in leaves, however, these symptoms often occur across the whole plant and are not exclusive to a particular stem. However, these nutritional problems may also lead to variegation.

Nearly half of the Indian population depends on agriculture and related industries for their livelihood, which also substantially contributes to the socioeconomic structure of the nation. India is already self-sufficient in food because of historic increases in agricultural productivity. However, in light of the multilateral issues of a growing population, climate change and its related biotic and abiotic stress factors, declining arable land, and depleting natural resources, sustainable development in agricultural output and productivity has emerged as a key concern. Due to complicated problems with hidden hunger, adequate food supply is no longer a reason for complacency, placing a greater focus on nutritional security.

Despite these difficulties, India has a significant advantage due to its rich biodiversity and a large pool of people resources. Plant biotechnology has proved crucial in increasing crop yield to increase food, feed, and fibre security as well as in lowering agriculture's environmental impact. Quantum advancements in molecular biology, like genomics, proteomics, and genome engineering/editing, provide tremendous economic, environmental, and societal prospects for driving forward present and future agricultural research. The Department's Agriculture Biotechnology Program aims to transform agricultural research via the adoption of technical advancements, the bolstering of research infrastructure, and the development of human resources in cutting-edge research.

The program's goals include knowledge creation, the development of technologies and products for increased production, nutritional fortification and higher quality standards, the ability to withstand biotic and abiotic stress, input usage efficiency, climatic resilience, and biosafety. The programme funds research on horticultural crops as well as commercially significant crops including rice, wheat, cotton, millets, oilseeds, and pulses. The department has sponsored R&D initiatives in fundamental and translational research, national networks, centres of excellence, international collaborations, as well as public-private partnerships, via its concentrated efforts throughout the years. The programme has changed paradigm throughout time in response to the changing demands of farmers, consumers, and export markets to provide solutions in the form of new varieties, technologies, and products, capacity building, infrastructure development, and knowledge generation. Research projects backed by QTL/gene discovery, marker-trait association studies, marker-assisted selection (MAS), and molecular breeding have produced enhanced crop varieties with superior yield metrics, climatic resilience, and input usage efficiency.

Demand for resources and necessities like food, housing, clothes, etc. has increased as a result of a population's significant growth. The overuse of land for food production is a consequence of the growing population. As a result, farming has only been practised in a tiny region. We must exert a lot of effort to satisfy the expectations with the resources we have. The face of this ailment has altered as a result of agricultural biotechnology. Biotechnology is the use of technology in any biological system or living system to generate or enhance goods for a variety of uses. Agriculture is one of the many industries where it is commonly used. Various strategies have been put forward by researchers to increase food production. Agriculture based on genetically modified crops is a choice, along with agrochemical-based agriculture or organic agriculture.

The green revolution attempted to increase food production, but it was unable to keep up with the rising demand. Later, the notion of a programme to develop agricultural varieties was advanced. The use of agrochemicals by farmers, however, seems to be impractical. Additionally, the environmental problems associated with them decreased their usage.

Biotechnologically Modified Plants

The most recent development in agriculture is genetically modified crops (GMO). These crops are the consequence of changes made to the genetic structure of the crops. The crops benefit from this change in a variety of ways, including:

1. Harvest-related losses are lower.
2. Crops may be altered to provide more nutrients valuable to human well-being.
3. These crops have been developed to be very effective, producing a high yield while using fewer minerals.
4. The reduction in the usage of pesticides and insecticides, causes environmental degradation.
5. Higher tolerance for environmental challenges including natural disasters, very hot or cold temperatures, and a shortage of minerals and water.

The case of Bt Cotton is one of the most prevalent instances. Bt stands for Bacillus thuringiensis, a microorganism that, when injected into plants, helps them fight pests like maize borer and bollworm. Thus, genetically engineered crops aid in streamlining the whole agricultural process. The use of biotechnology in agriculture has produced a wide range of GMO, such as plants that are resistant to pests and diseases.

People began gathering their food from the area's abundant natural biological variety some 10,000 years ago, and they later tamed both plants and animals. People started choosing better plant materials for propagation and animals for breeding throughout the domestication process, at first unintentionally but eventually to create better food crops and livestock. Farmers have enhanced plants for agricultural use over thousands of years by selecting beneficial features in crops. Crop varieties (also called cultivars, from "cultivated varieties") with shorter growing seasons, greater resistance to diseases and pests, larger seeds and fruits, nutritional value, shelf life, and better adaptation to a variety of ecological conditions under which crops were grown were desirable traits.

Agriculture technology has evolved throughout the ages to provide a wide range of possibilities for the production of food, feed, and fibre. In many respects, technology makes our lives simpler and more fun while reducing the time we spend on essential tasks like food production. Everyone is aware of how transportation has evolved through time to become safer and more effective. Significant modifications have also been made to agriculture, many of which have improved the productivity and security of the production of food and fibre. For instance, in 1870, 38,558,371 people were living in the USA, and 53% of them were engaged in farming; in 2000, 275,000,000 people were living in the country, and just 1.8% of them were farming. Although there are drawbacks to so few people in society working in agriculture, this serves as an example of how technological advancements have reduced the need for simple agricultural labour.

This focuses on how technological advancements and scientific discoveries have enhanced crop growth in agriculture. Most people are unaware that the ancient Egyptians used fermentation to make wine and rise bread dough, two early agricultural innovations that essentially mark the beginning of agricultural science. The introduction of maize, a native of the Americas, to the rest of the globe in 1492 was a pivotal moment in the history of agriculture. European farmers then modified the plant to thrive in their particular agroclimatic conditions. At this time in history, crops were cultivated in a variety of environments and shipped all over the globe.

Crops were first selectively bred by agriculturalists before they fully understood the principles of genetics. New insight into the subject is provided by Gregor Mendel's explanations of how qualities are passed down from parents to children. In addition to demonstrating that genes are transferred separately to children, Mendel's study also demonstrated how genes split during the development of gametes and then randomly join during fertilisation. People now can selectively breed crops and livestock because of our increased knowledge of how plants and animals inherit qualities from their parents. By enabling the creation of selective cross-breeding and providing a thorough grasp of the underlying mechanics of heredity, Gregor Mendel's discovery transformed agriculture.

Judicious cross-breeding

In conventional plant breeding, new varieties are created by either choosing plants with desired traits or by selectively breeding traits from two closely related plants. These characteristics can include, for instance, a certain pest or disease resistance or climate tolerance. One crop variety's plants transmit pollen containing the genes for a desired characteristic to another crop variety's blossoms containing other desirable qualities. A new variety of plants will eventually have the desired characteristic after careful selection of their progeny. Over the years, conventional plant breeding has created a large number of very productive new crop types. Numerous unsuccessful crossings have also been made.

Crosses are often produced in a very unrestrained way in traditional breeding. Although the breeder selects the parents to cross, the outcomes are genetically unpredictable. DNA from the parents randomly recombines, and advantageous features like insect resistance may be combined with disadvantageous ones like low yield or poor quality. To generate offspring, the parent plants must be closely linked.

Traditional breeding methods require a lot of effort and take a long time to generate new crop types that are viable. Separating unwanted features from good ones requires a lot of work, which isn't always economically feasible. As plants are eliminated along the route that does not exhibit the introduced features, many potential advantages are lost. A new crop variety is created by traditional plant breeding between 12 and 15 years on average.

Traditional Breeding Combined with Induced Mutation

Mutations are modifications to a plant's genetic structure. Natural mutations sometimes lead to the emergence of new, advantageous features. Mutagenesis is a method that plant breeders discovered in 1940 that allowed them to accelerate the occurrence of mutations. DNA, the fundamental molecular structure that makes up the genetic code of every living thing, may be altered by radiation or chemicals. The aim is to alter the DNA's base pair sequence, which contains biochemical instructions for the growth of plants. The genetic material of the resulting plants may have been altered, giving them new and desirable traits. Plant breeders must develop and assess each plant from each seed generated throughout this procedure.

Radiation mutagenesis has been used to create more than 2,500 plant types, including cultivars of rice, wheat, grapefruit, lettuce, and several fruits (FAO/IAEA, 2008). In the 1970s, induced mutation breeding was extensively used in the United States, but it is now only utilised to generate a small number of types. New tools for the production of plant varieties emerged in tandem with advances in our knowledge of genetics. Examples of these in use today include genetic engineering and genetic marker-aided breeding, which make use of molecular markers linked to certain qualities to guide breeding operations. The following is an explanation of some of the key processes that led to the present state of the art.

1. Watson and Crick discovered the DNA structure in 1953. The discovery of the structure and functioning of DNA the building block of genes was another significant breakthrough in our knowledge of genetics and how genes operate. This discovery, which is regarded as one of the most important scientific achievements in biology, was produced by two scientists, James Watson and Francis Crick, mostly by the synthesis of the work of other scientists (Pray 2008). Their study made a substantial contribution to our knowledge of genes.
2. Finding transposons, or moving genes, which are pieces of DNA that migrate from one place on a chromosome to another. Transposons are also referred to as "jumping genes," or mobile genes. Interestingly, transposons can be used to change living things' DNA. Transposons were shown to have an intriguing impact by Barbara McLintock in 1950. She was able to demonstrate how transposons' effects on DNA altered the colour of maize kernels.
3. Tissue culture and plant regeneration: The invention of micropropagation methods, often known as tissue culture, was a key technological advancement that was crucial for plant breeding (Thorpe 2007). By removing tiny pieces of tissue from plants that are of interest, stimulating the development of the tissue on medium, and eventually forming a new plant, tissue culture enables researchers to clone plant material. The whole genetic makeup of the donor plant is present in this new plant. As a result, exact duplicates of a desired plant might be created fast and without the need for seeds or pollinators.
4. Embryo rescue: When closely related plant species are hybridised or crossed, the embryos that are created as a result of fertilisation often end up being aborted. With the advent of embryo rescue technology, crop breeders were now able to cross kinds that were far apart from one another, preserve the resultant embryos, and then grow those embryos into whole plants using tissue culture.
5. Protoplast fusion: Cells that have lost their cell walls are known as protoplasts. The removal of the cell wall may be accomplished mechanically or by the activity of enzymes. They are left with little more than the cell's membrane. There are several

approaches to modifying protoplasts that may be used to plant breeding. This involves creating hybrid cells (via cell fusion) and introducing new genes into plant cells using protoplasts so that they may be cultivated using tissue culture methods (Thorpe 2007).

6. Genetic manipulation: Building on the aforementioned findings, developments in molecular biology throughout the 1980s gave researchers the ability to intentionally transfer DNA across creatures, whether they were closely related or not. This opened the door for crop breeding advancements that may be highly advantageous, but it also generated a lot of debate.

Genetically Modified Organisms

All living creatures have the same fundamental DNA structure. The arrangement of DNA base pairs in an organism determines its many traits. Researchers may now insert one or more particular genes into the genome of another creature using biotechnology. This includes genes from bacteria, viruses, plants, and almost any other kind of organism. Recombinant DNA technology is what it is (Watson et al. 1992). Synthetic insulin was the first commercially successful recombinant DNA technology-based gene transfer product, released in 1978. Insulin for human use was previously solely made from the pancreatic glands of pigs and cattle. The first enzyme derived from a genetically engineered source yeast to be authorised for use in food was chymosin (also known as Rennin) in 1988. Previously, cow stomach linings were used to acquire this enzyme for the manufacturing of cheese.

In agricultural biotechnology, the genome of the plant is directly modified. Once the gene responsible for a desired feature has been located, it may be chosen, extracted, and then directly inserted into the genome of another plant. Transgenic plants are those that contain genes from other species. Any stage of development, such as in young seedlings in a greenhouse tray, may be used to test for the presence of the target gene, which controls the characteristic. Thus, a breeder may choose the plants that best exhibit the desired feature after swiftly evaluating the plants that are created. It typically takes ten years for genetic engineering to produce new crop types.

As recombinant DNA technology's uses grew over time, the first small-scale field experiments of genetically modified plant types were planted in the United States and Canada in 1990. These were followed by the first commercial release of genetically modified crops in 1992. Since then, farmers have adopted genetically modified plants more often each year. Although the advantages of genetically modified crop types are well known, there has been significant resistance to this technology from the viewpoints of the environment, ethics, and those worried about corporate control over crop varieties.

Crop Breeding Through Genetic Engineering and Traditional Breeding in Comparison

Genetically modified organisms (GMOs) are a term occasionally used to describe crops created via genetic engineering. It's common to practise abusing the terms "genetic modification" and "so-called genetically modified organisms" (GMOs). All forms of conventional and organic agriculture alter plant DNA to give them desired characteristics. Traditional breeding methods affect a plant's genetics indirectly by choosing plants with certain qualities, while genetic engineering directly alters the DNA to change the traits. Traditional breeding involves somewhat arbitrary cross-making. Although the breeder selects the parents to cross, the outcomes are genetically unpredictable.

As opposed to this, genetic engineering enables highly focused gene transfer, rapid and effective gene monitoring in new varieties, and eventually enhanced efficiency in the creation of agricultural varieties with novel and desired features. There are several techniques available to boost and enhance agricultural productivity. These technologies include techniques for creating new types, such as biotechnology and conventional breeding. With growing interest in organic agriculture, a strategy that rejects the use of genetically modified crops, traditional agricultural methods are now witnessing a little revival. Future research on the potential role of genetic engineering in the development of sustainable agriculture appears promising.

Concerns regarding potential hazards are present throughout the development of every new technology, and agricultural biotechnology is no exception. Before being approved for commercial usage, every crop created by genetic engineering is put through a rigorous safety testing process. Only those of these novel types that have passed risk analyses and are safe for human consumption are made available. Some worries are caused by persons who don't properly comprehend the reporting of danger. Many people believe that any danger is too great. When releasing new technology, some people want to follow the cautious principle, however, this is not a realistic understanding of what risk assessments tell us (See information presented by Land Grant Universities of the USA). There are no types of crops produced via the use of genetic engineering that poses dangers to consumers, according to extensive risk assessment and safety testing. This is not to mean that newly developed kinds shouldn't be thoroughly scrutinized for safety; rather, each situation should be evaluated on its own merits.

CHAPTER 6

Economic Development Supporting the Bio-economy

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By 2030, there will be a large increase in the global population, most of which will occur in emerging and impoverished nations. Although affluent nations' birth rates have significantly declined below replacement levels, they have been able to keep their population numbers stable because of ongoing immigration. Affluent and educated immigrants have been the main targets of developed nations' immigration policies, which has helped to maintain the wealth and high quality of life enjoyed by these nations. The many cultures of the immigrants have woven together to produce a multicultural mosaic that shapes the customs and values of these communities. Developed nations are well-educated and acutely aware of their interconnectedness with one another and the Earth, and they seek luxury goods "with all the bells and whistles."

The younger generation, which was more "connected" and aware of global concerns on a "moment by moment" basis, fostered this feeling of global stewardship and obligation to reduce mankind's environmental impact. Through the lens of "real-time" TV and the internet, young people saw the natural disasters linked to global warmingssuch as starving polar bears, homes and industries destroyed along flooded coastlines, and thousands of deaths from extreme storms like tsunamis and global poverty such as the mass exodus of refugees, starvation, and disease and felt a sense of responsibility and a desire to right the wrongs of previous generations. Given the fast-paced metropolitan lifestyles, some consumer markets demanded luxury goods and services to maximise their own time, while the majority insisted on environmentally friendly items and a stewardship attitude from the businesses they supported.

Developing nations like China, India, and Indonesia, as well as important South American nations including Brazil and Mexico, have seen steady population growth and rapid economic expansion. These towns have the resources to construct efficient infrastructure, technological know-how, and the ability to draw in outside investment while being equally affected by the consequences of climate change (such as drought and unpredictable weather. As a consequence, multinational companies (MNCs) play a significant role in both manufacturing and commerce in these nations. These nations' high standards of living have boosted material consumption and the desire for high-end goods like vehicles, high-tech entertainment, computers, and cell phones as well as more costly consumables like meat and oils. While this was going on, sub-Saharan Africa's poor nations continued to suffer from extreme poverty and protracted droughts that destroyed their already failing agricultural sectors.

Unprecedented levels of hunger and disease particularly an increase in AIDS in Western and Southern Africa occurred. Youth were educated and motivated to make up for the failed endeavours of older generations through effective public education campaigns, greater media attention, and quick reportage on highly visited websites. This younger generation was the main force behind coordinated attempts to persuade governments to take action since they were both sensitive to the human footprint and other social reasons. Governments in OECD nations have reaffirmed their commitment to targets for foreign assistance and debt forgiveness for Africa in response to mounting public pressure. To help African nations in their efforts to rebuild, developed nations upped the amount of food assistance they provide to the continent and started exporting massive amounts of biotech health and diagnostics, new agricultural, and animal technology.

Population Growth and Climate Change Driving the Development of Technology Both the average global temperature and the frequency of severe weather events have risen more than expected by the year 2030. In the face of the more unpredictable weather, several traditionally productive agricultural centres such as Australia, Brazil, the United States, and nations in southern Europe have failed to sustain production. These environmental challenges have prompted private businesses to make significant investments in new technology to stay up with markets, along with the soaring worldwide demand for higher-value agricultural commodities. The ability to boost production under drought circumstances and to provide value-added features such as improved nutrition, taste, and ease of preparation desired by customers in agricultural commodities and animal variations has been made possible through biotechnology.

Climate change-related temperature increases have created ideal circumstances for disease and pest infestations. Protection against viruses found in wheat, rice, and potatoes was made possible by molecular biology innovations like viral coat protein technology. Due to ongoing investment in DNA databanks and sharing among trading partners, a significant portion of the major and minor crops used in agriculture had known DNA profiles. As a result, some minor crops also benefited from virus reduction technologies through the adoption of new technologies with straightforward and affordable practices. Furthermore, gene sequence transfers contributed to the conferral of resistance to fungal diseases and plant nematode infestations, both of which have become more frequent in the most widely grown crops worldwide (soybeans, maize, rice, potatoes). Despite growing pest and disease concerns, the agricultural industry was able to preserve stability in agricultural output because of developments in molecular biology and genetics.

The biotech and seed development industries invested in new technologies that made available high-yield food crops adapted to grow in the changing climate, and dedicated energy crops similar to Jatropha, Miscanthus, and Switchgrasses that were not suitable for eating yet grew on marginal lands. As a result, the early concerns from 2005 to 2015 regarding the limited availability of biomass and societal tension over crops for food versus fuel diminished. The efficiency of "whole-use" crops grew due to the emergence of more efficient processing methods and refineries that used less energy and produced more products while using less land. The forestry sector expanded its efforts in biotechnology to create trees kinds that can withstand drought and rising temperatures. Additionally, the industry created cultivars with salt tolerance, drought tolerance, and pest and disease resistance to fight the effects of a warmer environment and stressed trees.

Tree varieties grown on company plantations in southern regions (in South America) were intended for the global pulp and paper industry, whereas varieties grown on plantations in northern regions (like Canada and Russia) with prosperous forestry industries were intended for high-value structural timber and composite wood products. To clean up the surrounding coastal waters, certain places around the coasts of China, eastern India, and the Gulf of Mexico have pushed ahead with the acquisition of generic brands of genetically modified (GM) marine plants. Adapted marine plants were used to revitalise maritime regions that had become "dead zones" due to industrial pollution or agricultural run-off. Argentina and Brazil's coasts, as well as those bordering the Adriatic and Baltic Seas, would have profited from this technique, but because of widespread public apprehension over the spread of such plants into nearby coastal waters, regional governments prohibited their usage. Wealthy customers have been increasing their demand for so-called "green" items made from renewable resources such as crops and the adoption of sustainable production techniques by industry, driven by the palpable evidence of climate change and severe waste disposal difficulties. These renewable goods will be widely accepted by the market by 2030 because biotechnology has made it possible to create and sell them at competitive prices.

Distinctive Markets Call on Businesses to Deliver Unique Food Products By 2030, developed nations and wealthy consumers especially in China and India would seek meals with value-added characteristics including improved nutritional quality, and flavours, while being low in calories and requiring little preparation time. The food sector has profited from the uses of nanotechnology that were created for cosmetics and pharmaceuticals because they improve the flavours and textures of food. The growing middle classes in developing nations are demanding a wider variety of goods, such as meats and oils, and have more spending power. The adoption of genetically modified crops to secure the availability of feed for animals was motivated in part by the demand for meat. Additionally, to ensure the supply, the growing demand for oils put pressure on agricultural yields and biotechnology.

The importance of health to developed nations and wealthy markets in China and India

The average life expectancy has continued to rise globally as a result of improved health management strategies, which have greatly contributed to extending and improving the quality of life. Biotech-derived medications and diagnostics, improvements in food quality and preservation, and the availability of foods fortified with value-added nutrients while still being low in calories are examples of scientific advancements in health management. Up until 2015, obesity rates continued to climb in developed nations (especially the United Kingdom and the United States), which were characterised by ageing, primarily urban, sedentary populations. In response, these nations made significant investments in healthy urban planning (such as financial incentives for builders to include small markets and parks inside subdivisions to promote walking and exercise), as well as health-related solutions in their meals (e.g. nutritional attributes and bioactive ingredients to stimulate optimal health and counter health challenges).

Genetic and molecular developments led to the first generation of health-related solutions in food, which included bioactive components to fight common diseases like antioxidants to fight cancer, vitamin B and niacin to fight heart disease, and polyphenols and fatty acids to fight cardiovascular conditions. To fight obesity and weight gain, functional food items such as foods enhanced with enzymes to metabolise carbohydrates in the stomach before absorption and coenzymes to increase metabolism were produced. Meals were created to cater to various demographics based on their life stages or genetic make-up as a result of "nutrigenomics" research, which resulted in the second generation of health-related solutions in foods. For instance, meals containing vitamin B and folates were created for kids and teenagers to help quick growth and development.

These items were aggressively advertised and labelled as being fortified with nutrients for this age range. Through an improved understanding of science and its role in improving their quality of life, the younger generation first showed support for the use of biotechnology to modify crops and animals for food reasons. The research was made accessible showing that biotechnology, and specifically genetic alteration, had no long-term negative impacts. As foods with immediate health advantages were more readily accessible and were sold as the result of cutting-edge research, support from older generations expanded. It should be emphasised that the once-vibrant organics niche market still exists today, but with considerably less vigour. The unfavourable reception of GM food when it was initially launched in 1996 led to the development of the organics sector. Market demand prompted investment in non-GM food biotechnologies including Marker Assisted Selective Mutagenesis These technologies, which were developed at the dawn of the new century, have yielded only modest improvements and continue to lag behind more precise ones like GM and nanotechnology.

Several technologies are improving to provide solutions for low-cost food security and traceability. There was a financial incentive for the industry to develop precise technology to separate and identify these seeds due to the rising use of GM seeds that were marketed at a premium to express agronomic and consumer desired features. In addition, when factories were developed to generate non-food items like industrial chemicals or pharmaceuticals, the industry expanded its expenditures in security and traceability systems to guarantee that these items were kept out of the food and feed supply. To make food safety and traceability systems generally accessible and inexpensive, public and private investment was made in the development of several technologies including molecular and genetic diagnostics, nanotechnology, and information technology.

In the agri-food sector and agriculture, for instance, quick-reaction biosensors to detect nanoparticles of poisons, infections, or undesired industrial pollutants were widely accessible between 2020 and 2025. Rapid genetic diagnostics to identify certain crop kinds also become widely accessible and inexpensive. In addition to the developments in agricultural biotechnology that have improved food safety, several already used methods have been improved upon, their costs have decreased, and they are now broadly accessible. For instance, cutting-edge tracking systems were created as a result of the traceability systems created around the turn of the century in response to the Bovine Spongiform Encephalopathy (BSE) problem in the United Kingdom. Each animal was fitted with a microchip and a scanner to track its activities and health from birth to the present. To stay up with commercial partners, developed and some emerging nations adopted these applications as they evolved and their prices decreased. Some World Trade Organization (WTO) accords made it easier to use security and traceability measures more often such as those requiring export countries to make fullrecords of all livestock available for importing countries.

Markets for biotech fish and livestock

At the turn of the century, biotechnology was extensively applied in industrialised nations via marker-assisted breeding projects to modify livestock kinds with consumer-preferred traits like soft flesh or higher fatty acid content. In the years leading up to 2015, medical biotechnology made strides that made accurate diagnostics for cattle health and therapies for common illnesses accessible. These technologies steadily decreased in cost and were widely recognised and employed in OECD nations. Animal cloning research made some progress between 2010 and

2015 but North American and New Zealand regulatory bodies continued to deem such cattle safe for consumption. However, fierce public resistance made sure that animal cloning remained a rare practise in OECD nations. Different civilizations in Asia, including China and Japan, advanced animal cloning as a calculated effort to feed their soaring populations.

The first nations to employ transgenic animals to manufacture medications in their milk were Argentina and New Zealand. They benefited greatly economically and prestigiously from this technological innovation as early adopters. Specialized agriculture is still thriving in Australia and New Zealand, two of the major industrialised nations that provide the developing and underdeveloped nations that the United Nations has classified as in need of assistance with much-needed vaccinations and medications (UN). 2020 saw the OECD countries agree to pay suppliers and provide these nations with affordable pharmaceuticals as part of assistance. Strong public pressure, NGOs, and foundation support made this effort possible such as the Bill & Melinda Gates Foundation. The extensive investment in and use of biotechnology in aquaculture was another chance that the Asia-Pacific nations grasped. Fish, shrimp, and molluscs which are already a staple of the Asian-Pacific diet have been bred to increase size, reproduction, health, and consumer preferences for flavour and texture. Consumers in North America and certain areas of the Eastern European Union are often ready to ignore "the technique of production" to profit from the low cost and excellent quality produce, even if cloning plays a major part in their breeding programmes.

Non-Food Products

Tools for biofuels, bioproducts, or biorefineries are provided by biotechnology. Several variables contributed to the development of industrial biotech between 2005 and 2015, which had a direct influence on agriculture. The necessity for non-petroleum-based goods is indicated by the combination of climate change and decreasing global petroleum reserves. This provided a chance for agriculture to diversify. Agriculture has been vigorously marketed by farmers, agricultural lobby groups, and other interested parties as a solution to society's problems including the environment and energy supply. To maximise the plant chemistry for the extraction of biofuels, valuable compounds, and biomolecules, there was a worldwide boom in investment in the production of crops with improved quality features.

Additionally, research into new and more effective ways to utilise plant and animal waste has expanded (e.g. for energy production). Low-nutrient grasses were used to create specialised energy crops with increased starch or fatty acid content, changed lignin and protein composition, and employed as industrial feedstocks for the extraction of high and low-value co-products. The development of processing facilities to extract the necessary goods went hand in hand with the growth of crops to generate non-food items. The development of biorefineries first in the United States, and then in nations of the European Union allowed for the effective "total utilisation" of agricultural inputs. These advanced processing facilities can change which products were extracted in response to market signals, much like petrochemical refineries (e.g. price of energy).

The products that are extracted include compounds needed to create sustainable materials (bioplastics), high-value oleochemicals, biolubricants, and biofuels that are sought after by the chemical and industrial sectors. Even if certain sectors of the biofuels sector faced ongoing issues with economic viability, subsidies from industrialised nations ensured that biofuels would remain a viable option for diversification into "greener" lands. Cellulosic ethanol was one of the second-generation biofuels that the industry was researching in 2015. The industry struggled to find the inputs near enough to refineries, even though waste from biorefineries and forests were perfect inputs for this generation of biofuels to limit transportation costs. For fast-growing plantations of specialised trees positioned close to processing factories, the industry invested in biotechnology.

To fight pest infestations brought on by rising global temperatures, trees have improved features for producing biofuel and being pest resistant. As the infrastructure for plants generating biofuels and biomaterials such as processing facilities, transportation, agronomic knowledge, and biotech expertise became firmly established (2015), diversification possibilities emerged to create plant-based components for a range of varied industries. Plants have been genetically altered to produce materials that can be used as semiconductors, plant-based metals and inks for computer hard drives, and crystals for magnetoelectronics.

Parallel to the processing facilities that extracted dependable goods with high degrees of chemical purity, these genetically modified plants were created. A second possibility for agricultural sector diversification was the creation of plants modified to generate human cells for the health sector, in addition to plants adapted to create components for the electronics industry. Research is being done to improve the capacity of the plant to generate more complicated bodily tissues including intestines, arteries, and muscle tissue. GM plants were developed to create basic human tissues like collagen, cartilage, and neurologia. Although the growth of these plants is highly compensated, most of it takes place in greenhouses, thus the agricultural sector is only little involved producers as employees in rural settings.

The industry is driven by customer demand and input cost

There has been a conflict between the materialistic desiring all the "bells and whistles" and the altruistic desiring global stewardship and to lessen humanity's environmental imprint ends of the consumer spectrum in rich consumer markets. Numerous customer demand profiles and a significant market distinction were produced as a consequence of this dynamic push and pull. No company model survived in the face of the intense competition for customers without always inventing to better serve them.

Consumer demand pushed businesses to invest in technology to stay competitive and look for mergers and acquisitions to use one industry's knowledge for the benefit of another. For instance, chemical oligopolies acquired biotech and seed development companies, fuel oligopolies diversified and invested in agronomy and botany, and automobile MNCs acquired smaller biotechnology companies, all of which led to the creation of new value chains and industry niches.

Green goods

Rich customers also encouraged businesses to employ sustainable practices and make "green" goods. Initially, the industry changed little by little while fiercely selling them. The media-savvy society of the 2020s, on the other hand, chose choices based on the real "green" value of items and the track record of the businesses selling them, not on flashy marketing efforts. This put pressure on businesses to use biotechnology as a tool to produce the substitute goods that customers wanted, such "green" energy, plastics, chemicals, and fibres. Environmentally friendly industrial goods and procedures were often economical. Companies looked for alternatives, for instance, to growing input prices associated with rare or depleted resources, such as petroleum, electricity, and water. Industries that had been dependent on petroleum diversified by making investments in substitutes, such as GM crops and processing facilities enhanced by biotechnology, to create "green" substitutes, such as biofuels and molecules to create biodegradable goods.

Water

Consumers have always been concerned about the availability and quality of the water supply, but from 2015 to 2030, when there were severe droughts that affected agriculture and water shortages that affected new building complexes, this concern became much more apparent. Because of the increased cost of water due to this uncertainty, there has been a large increase in global R&D spendingssuch as water conservation and desalination technologies, and alternative technologies that did not require water. During this time, bioremediation methods, irrigation technology, and water conservation technologies all saw significant advancements, which benefited commercial practices for a range of businesses as well as individual access to potable water.

As a result of improved technologies such as water reuse systems, low friction machinery, and alternative technologies, industries that rely on natural resources such as mining, forestry, minerals, and biofineries no longer need as much water for processing. This lowers input costs and enables these industries to meet consumer demand for sustainable practises.

Due to domestic legislation that set stringent water conservation rules, agriculture firms operating in nations that had undergone extended drought such as Australia, China, India, and the United States invested in water conservation technology. The industry invested in technologies ranging from anti-leakage technology, desalination near coastal areas, slow drip watering powered by solar power, to erecting geographic barriers to decrease wind and evaporation, in addition to GM crops adapted for drought and soil altered by nanotechnology to decrease water evaporation.

MNCs expanded into new technological fields and relocated their operations to developing nations with a lack of water conservation rules. Such emerging countries were ready to give up their national riches in exchange for quick financial gain. Concerned NGOs made an aggressive effort to identify and disclose the names of MNCs that engaged in this dishonest behaviour. They encountered a lot of indifference among rich nations, which was primarily fostered by the rates of economic development in these emerging countries, and they found it difficult to keep track of all such commercial agreements.

Carbon trading

Early sustainability experts suggested many schemes, one of which was a carbon trading market that would call for global adoption of carbon limitations. Despite the fact that the Kyoto Protocol's proposed carbon limitations were not widely accepted, it was effective in igniting the debate. Important expenditures were made into the cost-benefit assessments of carbon reductions, carbon limitations sequestration markets, how carbon markets may function, and the effects of carbon increases on climate patterns. This study promoted a practical approach to the very delicate subject. Both rich and developing nations started to acknowledge that increasing carbon emissions were harming the planet's climate in the face of overwhelming evidence. International steps to address the issue were established as a result of growing public pressure, including the launch of a worldwide carbon trading system. Although they were slow to adapt, China and the United States soon understood that once carbon markets were established, they might provide considerable potential for innovation.

The carbon cap and trade market, enforced by OECD nations and implemented by the majority of major emitters, forced industry, which emits carbon into the atmosphere, to invest in carbon-free alternatives. The present agreement on carbon limitations was approved in 2025 as a result of popular pressure on states to take action. The latest accord set attainable goals with creative market-based solutions, building on the "lessons learned" from the disastrous Kyoto Accord. The agreement created a worldwide framework for carbon trading with absolute restrictions on the amount of carbon that each nation was allowed to discharge. Based on existing greenhouse gas (GHG) emissions, certain nations received carbon limitations, which were then allocated to industry. The ratification of the agreement took ten years because of several difficulties, such as the expense of regulatory enforcement, precise monitoring, auditing, and individual emissions restrictions.

Developed nations that profit from the bio economy

Overall, many countries have profited directly from the discoveries made possible by contemporary biotechnology, and extra advantages have extended to nations that were not involved in the revolution. Increased technical know-how, improved transportation infrastructure, and adaptable/supportive business environments (financial incentives, laws) for innovation and new sectors all helped the countries directly engaged in biotech. By 2030, other nations began to reap the advantages of biotech inventors' work as effective and tested technologies were adopted wherever practicable.

Widespread use of biotechnologies helped to eradicate misconceptions about the field and brought biotech into the mainstream. The economy has seen the biggest growth in emerging economies like China and India, although wealthier nations (notably Japan and the United States) have continued to be hubs for research and industry investment. These emerging economies were able to take advantage of the first-mover benefits linked to early discovery and adoption because of their high technical skills and adaptable regulatory frameworks. Although they battled a lacklustre infrastructure and intellectual resource exploitation (such as offshoring), their economies are now on par with those of wealthy nations.

International trade

The discussions and debates over trade liberalisation persisted from 2005 to 2030. Only little improvements were accomplished, however, as economic superpowers competed with one another to advance trade while defending their national interests. Even though it has been slightly slowed down by ongoing disputes, the WTO nevertheless serves as a venue for trade since most nations advance bilateral and multilateral agreements with other like-minded nations. Biotech improvements in food safety inside the WTO regulatory accords permitted the Sanitary and Phytosanitary Measures and Technical Barriers to Trade Agreements to remain and function well. Early in the century, contamination incidents had significantly increased, mostly because developing nations without the necessary regulatory framework, including China and Indonesia, included them. But efficient food safety technology enhanced monitoring and tracing, and more sanitised food processing facilities resulted in a significant decline in the incidence of contaminated food occurrences.

Introduction to Disruptive Change

By 2030, several things had happened that influenced both global agriculture and the agendas of the world's governments. Terrorist assaults against the United States, including one on American oil refineries, and a zoonotic illness that originated in China and eventually spread worldwide were two incidents that had severe effects. These events led to a change in global government objectives away from reducing hunger and preserving the environment and toward increasing domestic security, notably in the areas of food, water, health, and energy. The growth of an economy centred on domestic security needs has overtaken the economy of renewable feedstocks, which profited from environmental goals under the "steady progress on agricultural biotechnology" scenario. Although many technologies were pushed to assist past environmental concerns, many of them were now being developed for security purposes, thus for many of them, this was merely a shift in the justification for adoption. When it comes to agriculture, biotechnologies and other supporting technologies such as nanotechnology, biosensing, and molecular and genetic diagnostics developed in support of security goals have only modestly improved agricultural practises and output.

A World of Enhanced Defense and Security (2001-2016)

In the post-September 11 world (from 2001 to 2016), there was a strong push for increased security and defence policies, especially in the United Kingdom, the United States, and allied nations. These countries spent billions of dollars on defence, military operations, and numerous security initiatives. They were aware of the potential effects of militarily focused government budgeting on the overall economy and other domestic initiatives, even as their citizens were reminded of the terrorist attacks that had inspired the expensive defence and security spending, such as those that occurred on September 11th or the July 7th London subway bombings. These nations have strict domestic security laws that were designed to safeguard their citizens.

However, increased border and airport security drew complaints from travellers who were inconvenienced and stressed the economy. A growing number of people believe that laws enacted to give government officials more authority might violate civil liberties and provide the groundwork for a police state. This tension between security and privacy was covered by local and international media, and an increasingly connected global public could watch it online and on easily accessible satellite TV.

Globally, economies have had modest economic growth, with China and India and the developing world, in particular, seeing growth. There was more money available to purchase goods like meats and oils, raising the quality of life in developing countries and those who were not affected by the global conflicts. The prosperity of wealthy nations has been progressively hampered by financial restrictions brought on by rising military spending.

However, there was still a rising class of wealthy individuals competing for the luxuries to which they had become used in both established and emerging nations (e.g. PDAs, remote controls, computers, satellite phones, and cars). The gap between customers who chose high-end and innovative products and those who believed restraint should be utilised to allocate resources toward enhancing domestic security has grown. These markets encouraged significant investment in information and communications technology, making it possible to do business while seated in the next room. Thus, as MNCs continued to establish R&D labs, manufacturing plants, and call centres, buoyed by low-cost inputs, growing research competency, and government-induced incentives, technology advanced in urban areas of nations like Brazil, China, and India where strong government investments in technological expertise have paid off.

China in particular became a centre for international industrial investment, while Canada, Russia, and Ukraine saw significant investment in their natural resources industries such as forestry and mining. Due to decreasing input costs and increasing use of high-yield genetically modified organisms, food production rose in South American nations like Argentina and Brazil (GMOs). To avoid the security dangers connected with food imports, however, the majority of other nations nevertheless supported home production.

Though government funding for biofuels was patchy and was often diverted to military, security, and defence activities, citizens who were concerned with their country's defence, security, or self-reliance backed them as a secure option for energy. The technology for renewable fuels had not advanced above the first generation stage, and the long-promised cellulosic ethanol technology was still failing. Oil prices remained mostly unchanged, and studies continued to reveal that renewable options were more costly than their current non-green equivalents, giving the industry little motivation to advance this technology. Consumers who prioritised personal security or showed a lack of interest in security problems in favour of growing consumerism were typical of the worldwide consumer profiles at this time. After the events of 2017, the profiles that were obvious in 2016 changed.

Broad effects on environmental and global stewardship

Due to the emphasis on defence and security, insufficient attention and funding were given to environmental sustainability and global stewardship. While governments in rich nations made meagre, disorganised attempts to address each separate crisis, impoverished countries continued to experience starvation and illness. Widespread hunger and illness persisted unabated and, in some instances, worsened as a result of their insufficient reactions, which failed to address the underlying causes. Governments in affluent nations set extremely modest domestic environmental sustainability targets that were intended to be achieved with little government investment. Renewable biomaterials (such as biodegradable oils, polymers, and industrial inputs) got less attention since the general public and consumer markets were preoccupied with important security problems and had less money to spend on frills. Sustainable environmental practises and goods continued to be very rare, and they continued to be the exclusive focus of disinterested environmentalists. This required farmers to assume their historical function as producers of food.

Production and research were cut down by specially produced energy crops and other agbiotech innovations created for environmental reasons. Farmers had to look for extra ways to increase the value of their products, putting as much emphasis as they could on advantages like organic farming and sustainable agricultural methods to generate more revenue. As a consequence of climate change, such as harsh weather patterns and the melting of the ice caps at both poles, environmentalists continued to report that carbon levels in the atmosphere were constantly rising. Despite overwhelming evidence of pollution and climate disruption brought on by industrialization, no international agreement could be reached. Due to the extreme heat and an increase in fires, tourism has started to decline in certain southern European nations including France, Greece, Italy, and Spain. These nations suffered (given the already weak circumstances in the global economy) and cried out for international action on environmental sustainability since tourism accounted for a significant amount of their GDP. Low-lying countries with floods affected their inhabitants and hampered trade in such regions including The Netherlands and portions of the United Kingdom. Sustainable technology advanced in different locations to address local or regional issues while global governments abandoned coordinated efforts toward an environmental agenda. For instance, China and Japan created technology to satisfy the demand for clean water and alternative energy sources. They created "cascading usage" processing facilities that burn waste in a way that uses and eliminates waste at every level of energy consumption. These facilities were built in densely populated metropolitan areas and provide power for the domestic industry instead of coal and gasoline, in addition to serving as waste disposal facilities. Another example is the development of an ocean thermal conversion process via the work of Nobel Prize-winning Indian scientists, which has continued to get funding in light of the importance of energy and water security. Several nations with deep ocean access presently employ this technique (India, Japan, the United Kingdom, and the United States).

These cutting-edge processing facilities are situated in deep ocean waters and provide desalinated water for human use as well as power for industries located along industrialised coastal zones. Large low-pressure tanks are used to store warm ocean water. As the water boils, expanding steam drives a turbine that generates energy. The steam supplies a supply of fresh water that is subsequently transferred for human use after being cooled by exposure to the chilly deep-sea waters. The creation of GM trees as a remedy for soil erosion by scientists from northern latitudes like Canada, Russia, and the Scandinavian nations is another example of sustainable technology development. Early public unease about the possibility of the trees spreading into natural stands led to restricted usage of the swiftly growing, deeply rooted GM trees that were developed and trademarked back in 2010.

However, the severity of floods in low-lying places especially in India, Japan, Malaysia, and the UK put pressure on the populations in these areas to adopt GM trees as a way to reduce erosion and restore the land. The creation of water purification and conservation technologies is a last illustration of how technical advancements have enabled household independence. Australia, China, India, and Eastern Europe, technologically sophisticated countries with water shortages and internal security goals, received investment (the United States). Countries like Australia, China, and India were investing in dam projects, desalination, and water recycling and conservation technologies due to increased temperature rises, droughts, and an expansion in industrial sectors needing water as inputs.

Implications on agricultural biotechnology in general

The use of new technology to further national security objectives or address particular regional problems has little spillover effects on agricultural processing and production methods. Several nations (including Australia, Canada, the United States, and Eastern Europe) that were experiencing drought benefited from the development of water purification and conservation technology for residential water security and industrial growth. Another area where cutting-edge energy-security technologies, like incineration, influenced the development of food safety technology was the sanitization of food commodities of bacteria or newly imported diseases. These instruments had become more affordable, were now available to food shops, and were often needed by laws. In wealthy nations (Australia, the United Kingdom, Canada, and the United States), advances in nanotechnology and information technology for defence were being used for food security and traceability.

While GM agricultural technology has made gradual progress to preserve output in hotter climates and during droughts, it was not being employed for quality food qualities such as enhanced taste, nutrition, or fast prep time. Similar to how biotech aquatics and animals in Asia have sputtered ahead to increase productivity but not to deliver the extras. Consumers had to make individual decisions in their everyday lives while governments, multilateral organisations, and companies concentrated on national and international efforts. Customers wanted food that was secure, familiar, and, if at all possible, produced locally. Consumers preferred familiar meals over novel ones that were high in nutrients, delicious, and had few calories. As more people connected organically with reliable and ethical producers, the trend for organic foods grew.

Markets in advanced and security-conscious countries searched for "local food" labels that indicated the distance that a food product had travelled on its box. The distance that food travelled from the time it was produced until it reached the customer was shown as food miles. Although it was first created to evaluate the environmental effect of food, it is currently used to evaluate its security, with the assumption that every unit of travel increases the likelihood that it would be tampered with. Consumers were ready to give up certain items they had become used to prevent drastic price hikes on food, and they ate more easily accessible foods in the season as a result. Governments and MNCs in developed nations played a vital influence in the development of food safety and traceability technology in this dynamic sector. The majority of the technology was borrowed from the military, IT, nanotech, and molecular biology divisions of enormous monolithic corporations that were devoted to advancing security and defence objectives. Ag-biotech SMEs had all but vanished as a result of the decline in government financing, venture capital, and continuous investment.

This was a major R&D shift since it significantly diminished the role that SMEs had previously played as R&D innovators. As fundamental and early-stage research has decreased, scientists realised that this would have a significant long-term influence on innovation and technological development. The establishment of bilateral agreements by Western countries did not include emerging countries like China, India, and Indonesia because they did not consider the significant expenses of adopting traceability to be worth the potential advantages. These nations' large rural populations and reliance on subsistence farming make it challenging to implement advancements in food safety and traceability. Furthermore, since they were not aligned with the countries that had been the target of terrorism, these governments were less concerned with internal security.

There was also a greater demand for traceability for nations that established or renewed bilateral agreements to guarantee safe commerce, especially between friends. Nanotechnology and biosensing, two technologies that were already getting funding for defence and health security applications, also got funding to pursue applications for food security and traceability. For instance, nanotechnology and biosensing technologies have combined to create biosensors that can detect nanoparticles of a disease or contaminant in shipments of crops or animals. Additionally, sensors that could recognise crops or animals' DNA in an instant were used to spot inconsistencies in DNA kinds and warn when shipments of crops or livestock had several DNA types (i.e. unwanted adventitious presence).

Instead of paperwork, shipments would include a microchip with extensive information about them, their origin, and their ultimate destination. Other technologies for ensuring food safety that entered the market include cutting-edge pasteurisation methods that could guarantee no pathogens while maintaining the food's quality attributes, cutting-edge packaging that could recognise bacterial nanoparticles and thus indicate a food's shelf life or when contamination had occurred, and high-pressure washing that could instantly remove contaminants while maintaining food quality. Even though there were many advancements in the "farm to fork" chain, only a few of them reached the farmers in developing nations. Even in industrialised nations, the majority of advances occurred above the level of the farmer, leaving livestock producers in poorer nations especially prone to illness and pollution.

Even though the infected areas were quarantined, with millions of poultry being killed and hospitalization/quarantine zones established for affected humans, this outbreak showed how vulnerable developing countries were without the necessary safety precautions to support their rapid economic development. The WHO, the Food and Agriculture Organization (FAO), the World Organization for Animal Health, and NGOs continued to emphasise the need for holistic growth that aligns health and safety with development even if some of these nations were recognised as efficiently managing the problem. While the IMF and World Bank employed funding that had been promised to counterbalance the budgetary issues these nations were facing, the WHO also stressed the need for health and safety risk mitigation techniques to cope with potential extra consequences of the "Southeast Asian flu." The problem was best managed by regional organisations like ASEAN, which acted as a powerful middleman to balance the interests of individual nations with those of the region and the global community. When the immediate effects of the flu pandemic receded, there was a worldwide shift in which more people demanded more personal health and safety as well as a clearer understanding of the social and economic justifications for improving animal welfare. All nations, especially industrialised nations, started to anticipate better detection, investigation, and containment capabilities from their trade partners as the importance of human and animal health and safety rose.

Implications of the pandemic on agricultural biotechnology

The revamping of the regulatory monitoring of food commodities was one of the earliest political shifts in Southeast Asia. Using the regulatory frameworks of industrialised countries as a template, ASEAN, the UN, and the WTO collaborated to establish their standards, rules, and a system for licencing and monitoring. To go "back to business," China, Thailand, and Vietnam were able to make the infrastructural adjustments required to support these new frameworks. A strategic decision to reorganise agricultural sectors was made in conjunction with this regulatory revision. While farmers with commercial operations in less isolated areas benefited from opportunities through widespread agri-business MNC expansion and to a lesser extent their local co-op or jobs on government farms, poor isolated farmers kept their produce for domestic purposes and received information on proper animal husbandry.

To support this new regulatory system, technology and tools were required. Genomic research and development were conducted to create hardy animal and crop types that would be more resistant to emerging illnesses. In addition to poultry, R&D increased in pigs, goats, and cattle, as well as rice, wheat, potatoes, peanuts, and oilseeds. To be better prepared for future illnesses and genetic issues, it was vital to do research in the maintenance of accurate biological records of both ancient and new types. As evidence of their dedication, extensive gene banks were created and shared with trade partners. China, Thailand, and Vietnam used interactive biotech games, powerful biotech branding campaigns, virtual and in-person tours of cooperative farms and government agricultural centres, and other means of communication to portray an "openness" with trade partners. As more information on crop and, to a lesser degree, animal health was gathered, trade partners were informed of the advancements being achieved in South East Asia.

Both rich and developing countries profited from this experience in their initiatives for food security and safety. As South East Asia drew scientists and engineers with those crucial specialities, they incorporated developments that had been developed in the United Kingdom and the United States as part of their focused agenda toward defence and security. As South East Asia's research agendas were less constrictive than those in Europe and North America, which were now more focused on their S&T spending, highly inventive academics were drawn to the region. The creation of newer versions of those technologies that were accessible and manufactured on a wide scale was influenced by developments in nano, molecular, and biosensing technology developed years earlier in the United Kingdom and the United States. The technology included skin tag scanners that quickly recognised the livestock kinds, biosensors that could detect nanoparticles of infection and illness and microchips with accompanying scanners that could offer a whole history of the particular animal.

Policies for broad livestock vaccination were in place to stop the spread of recognised illnesses in the future. ASEAN and the UN worked with firms located in France, Germany, and New Zealand to get licences for patented biotechnologies to aid in the large-scale production of vaccines generated in cattle milk to provide the number of vaccinations required. Then, to immunise cattle herds and human populations in South East Asia and to send them back to the contributing nations like France, Germany, and New Zealand for domestic use, these vaccines were manufactured in enormous numbers on government farms in China, Thailand, and Vietnam.

Advances in genetic and molecular engineering for the production of vaccines in animal milk led to a diversification into other active biologics (such as nutrients, medications, and enzymes) generated in livestock milk. Through this breakthrough, these nations were able to recoup a portion of the money they had spent on regulatory technology and infrastructure. Many industrialised and developing nations benefited from widely accessible, affordable pharmaceuticals and functional foods since predictable and regular dosages were now available. As philanthropic or humanitarian efforts joined with readily accessible, affordable pharmaceuticals, this turned out to be a turning point in assistance to Africa and underdeveloped countries. Countries in need received some functional food items and desperately needed medications thanks to the coordinated efforts of developed nations and the UN.

CHAPTER 7

AGRICULTURE BIOTECHNOLOGY FOODS WITH HEALTH-RELATED BENEFITS

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Plant biotechnology has mostly only influenced crops that are very valuable economically in the developed world thus far. Soybean, corn/maize, cotton, canola/rapeseed, and potato were the five main transgenic crops in 1998, in decreasing order of acreage. Over 50% of the land was taken up by transgenic soybeans alone; other significant crops included wheat, sunflower, and rice. Herbicide resistance (71%) and insect resistance (28%) were the most prevalent transgenic characteristics. Crops that are crucial to poor nations have received less attention since the majority of multinational seed and biotechnology corporations depend on revenues. As a result, efforts to genetically and biotechnologically improve these "neglected" food species are limited to regional and specialised research at particular crop centres within those nations, as well as targeted partnerships with national agricultural research institutions in the developed world. Fortunately, the ability to produce general approaches for crop enhancement is one of the main benefits of plant biotechnology. These techniques may then be improved and used with a variety of crops.

Agricultural biotechnology's objectives

With a few exceptions, they are substantially the same as those of traditional plant breeding. The objectives may roughly be divided into two categories: Improving crop performance in the field (so-called input traits). Creating new goods with more value (output traits). The majority of commercially produced transgenic crops to date have input features, but it is projected that many more crops with output traits will be released on the market during the next several years. We'll talk about input qualities in this section and output traits in the one after that. Resistance to pests and diseases Pests and disease may cause significant crop losses, especially in underdeveloped nations. Reduced crop loss and decreased or eliminated the use of agrochemical pesticides are both possible benefits of genetic transformation using genes that confer resistance to pathogens and pests. Virus protection. Up to 80% of different crops are often destroyed by several plant viruses. Crops may be genetically modified to include virus DNA fragments that naturally protect them against viral infections. Future plant generations get this "immunity" from their parents.

Iterations of this technique have now been used to develop transgenic plants that are resistant to more than 20 distinct plant species and 30 different viral infections. A novel Hawaiian papaya that has genetic resistance to the destructive papaya ring spot virus is one such. This virus-resistant papaya was created by Cornell University, the University of Hawaii, and the Pharmacia-Upjohn Company and is currently cultivated globally. Resistance against insect pests. The "Bt" technique is the most used method for boosting plant resistance to insect pests. Plants are genetically modified to produce a protein that is poisonous to numerous insect pests and is naturally found in the soil bacteria Bacillus thuringiensis. The plants may withstand insect assault and go on to manufacture the poison on their own. There are many distinct Bt toxin varieties with marginally different mechanisms of action and species-specificity. Commercial production of Bt insect-resistant maize, cotton, and potatoes has already begun, and shortly sunflower, soybean, canola, wheat, and tomatoes are anticipated. Tobacco, walnut, sugar cane, and rice are some of the other crops being studied.

Adaptability to other illnesses

The hunt for disease-resistance genes in several plant species is now under progress, and transgenic solutions to different kinds of plant pest and diseases are being considered. Banana, among other plants, has had genes that create antifungal proteins introduced into them to protect against the destructive Sigatoka disease brought on by the fungus Mycosphaerella fijiensis. resistance to herbicide Although it may seem odd, creating transgenic plants that are herbicide resistant was the driving force behind 70% of all transgenic crops planted globally in 1998. The alteration allows for the adoption of easier weed control methods that farmers find appealing. Herbicide-resistance genes may be introduced into plants and are found naturally in bacteria. Crops that are resistant to herbicides enable farmers to use chemical herbicides on their fields without hurting the crop, a quality that might encourage conservation tillage.

One such herbicide, RoundupTM, is broad-spectrum, has minimal animal toxicity, and degrades quickly in the environment. There are currently commercially produced soybean, cotton, maize, canola, and rice types that are resistant to herbicides. Wheat and sugar beet with herbicide resistance is short to be expected. Numerous more crops are still being studied. Environmental stress tolerance Development of crops more tolerant to: is a key objective of agricultural biotechnology environmental extremes including heat, cold, and water stress. Unfavourable soil characteristics include excessive salinity, acidity, and alkalinity, as well as other forms of toxicity (aluminium, heavy metals). The objective is to boost crop yields in these conditions, lowering the risks to food security in areas where farmers must contend with harsh weather conditions or problematic soils enhanced post-harvest survival.

Fruits and vegetables may be genetically modified to have better flavours and post-harvest characteristics. Although these fruits are not yet produced commercially, genetic manipulation has been utilised to delay softening in various fruits (apple, raspberry, and melon), extending their shelf life during transportation and storage. Other crops including bananas, pineapples, sweet peppers, peaches, nectarines, mangoes, and strawberries may be able to use this technique as well. Some fruits and vegetables, including tomato, chicory, lettuce, and potato, are also being worked on to make them sweeter and more delectable. For instance, FLAVR SAV tomatoes, which were genetically altered to have a longer shelf life, do not get soft during shipping and can thus be kept on the vine for a longer period to develop their full flavour. Currently, Mexico is the source of these tomatoes. Enhanced nutritional value in foods Supplemental vitamin content Crops with increased vitamin content might be created by genetic alteration to enhance their nutritional value. Three genes have been inserted into genetically modified "golden rice," for instance, enabling plants to manufacture beta-carotene, a substance that the human body transforms into vitamin A.

As many as 250 million children worldwide are affected by vitamin A deficiency, the primary cause of blindness. Wholesome oils numerous oil crops are having their composition changed because of biotechnology. Numerous oil crops have undergone genetic modification, either to produce more oil or to change the sorts of oils they produce: Oils with varying levels of "saturation" have various characteristics. Genetically modified soybeans are more stable when frying without further processing, richer in oleic acid, and lower in saturated fats.

Oils that have been created to have less saturated fat include canola and soybean oils. increase in protein content Some plant proteins that lack one or more of the "essential" amino acids are currently regarded as incomplete or of little biological significance. Biotechnology is being utilised to improve these proteins. Examples include peanuts with a better protein balance, sweet potatoes with more protein overall, and maize and soybeans with protein content tailored for certain animal diets. Added starch for less absorption of fat additionally, potato types with a greater starch content than usual are being created through biotechnology. These potatoes may be used to make lower-fat potato chips and crisps since they absorb less oil during cooking. allergen-free food Certain dietary proteins may cause allergic responses. The proteins that cause severe allergies are being removed from rice, wheat, and peanuts by genetic modification.

Foods that are good for your health

Biotechnology is being utilised to create functional foods, sometimes known as "nutraceuticals," which have therapeutic capabilities in addition to being enhanced in terms of nutrition. Products marketed as having additional health benefits over and above "standard" nutrition are known as functional foods. These consist of fresh produce with increased antioxidant content vitamins C and E, betacarotene and selenium. Brassicas with higher glucosinolate levels of anti-cancer substances. plants that make innovative items Plants may create new compounds by genetic engineering, such as alternate industrial resources including starches, fuels, medicines, enzymes, antibiotics, and vaccinations. Corn and soybeans may develop into organic processing plants for substances like sucrose, lysine, and methionine. Researchers are harnessing biotechnology to create edible vaccinations in plants, which would effectively replace industrial manufacturing and be recyclable and biodegradable.

These vaccinations don't need refrigeration, sterilising tools, or needles since they are genetically inserted into food plants. This innovative technique will be particularly helpful in providing low-cost, secure, and highly effective vaccinations all around the globe. For instance, scientists are creating vaccinations against E. coli and cholera in potatoes and a vaccine against hepatitis in bananas. Oilseed crops might provide farmers with value-added industrial crops that would take the place of industrial components supplied by petrochemicals, such as valuable oils like gamma-linolenic acid.

Bioremediation

Groundwater, polluted soils, sludge, and industrial waste streams may all be cleaned up via bioremediation, also known as biological remediation. Microorganisms are being created using genetic engineering methods with novel capacities to degrade toxic substances. Fixation of nitrogen Utilizing nitrogen fixation, biotechnology is being utilised to improve the capacity of soil microorganisms to provide nutrients to plants.

The topic of biosafety is perhaps the one that generates the most debate. The term "biosafety"refers to regulatory frameworks created to guarantee the environmental, agricultural, and human health safety of technological applications. As was previously mentioned, several international accords include biosafety, including the Sanitary and Phytosanitary (SPS), Technical Barriers to Trade (TBT), and Biosafety Protocol of the Convention on Biological Diversity (commonly known as the Cartagea Protocol on Biosafety). Here, we'll start with a brief explanation of the broad concepts and terminologies used in assessing, controlling, and managing risks and perceptions of hazards.

Process for regulating biosafety

There are two essential phases in the biosafety regulating process:

Risk evaluation

This stage aims to ascertain the likelihood of certain hazards as well as the impact if those risks do come to pass. Probability and consequence are equally important. For instance, the possibility of an accident is a risk related to driving a vehicle. Statistically speaking, however, the majority of drives do not result in an accident, and the majority of automobile accidents do not seriously endanger human health. This fact is taken into consideration in the regulation of automobile production and usage; cars are not outlawed or severely limited in their use only because of danger.

Management of risk

Following the identification of risk, this stage seeks to mitigate it to lessen its likelihood of happening or its severity. Governments manage risk via production standards, seat belt rules, speed limits, traffic signals, law enforcement, etc., using the automobile as an example once again. The majority of the disagreement over biotechnology regulation centres on variations in the second step of risk management. Regulators in the US, EU, and elsewhere have noted that although there is frequently little disagreement regarding the types and probabilities of risks (risk assessment), political and socioeconomic factors are taken into consideration when deciding on risk management tactics or acceptable levels of risk.

Comparing socioeconomic hazards and science

A scientifically based standard for risk assessment and risk management was developed by the WTO SPS agreement. In certain circumstances, such as where religious or humanitarian factors are present, the SPS does permit non-scientific considerations. One of the most ardent advocates of science-based norms for laws governing human health, food safety, the environment, and agriculture is the United States. Numerous nations have fought for the regulatory process to take economic effect and cultural considerations into account. Socioeconomic factors were given top attention during the Biosafety Protocol negotiations by poorer nations. The argument against the inclusion of these more subjective standards has been that they have been and probably will continue to be misused as cover for protectionist trade policy. Norms for risk that are acceptable the standard of risk, or determining if hazards can be adequately managed to be acceptable, may be established using a variety of criteria. Although these ideas are not necessarily mutually incompatible, a lot of the current discussion around biotechnology centres on how much weight is given to each idea's Similarity in substance.

The United States follows this criterion, which is endorsed by consensus papers on the safety of biotechnology from the OECD, WHO, and FAO. According to this tenet, things made using biotechnology need to be "as safe as" those made using other methods (e.g., conventional foods or conventional farming practices). To hold biotechnology products to the same relative risk standard as other technologies and techniques, it is important to assess the kinds and degrees of risk associated with biotechnology in comparison to those of other technologies and approaches. The realisation that holding biotechnology to a higher standard can result in lost opportunities or larger advantages is embodied in this idea. For instance, prohibiting the use of pest-resistant biotechnology crops may compromise the chance to minimise the use of pesticides on certain crops, for which pesticides are now the primary alternative and come with their well-documented dangers.

The precautionary concept or method

Although this strategy is included in several international accords, there is a great deal of disagreement over how it should be used. It demands concrete evidence of safety before approving the use of new technology in its strictest sense. On the other end of the spectrum, the United States concurs that nations shouldn't be forbidden from allowing the use of new technology while adopting safety precautions, such as setting up regulatory processes when there are concerns about danger. According to this logic, the creation of biosafety laws is proof of the precautionary principle in and of itself. The argument that the absence of complete scientific knowledge should be a justification for technology bans has been strongly opposed by the United States. For instance, this served as the foundation for the disagreement between the United States and the European Union on hormone-treated cattle. Until additional study on the hazards has been done, some have used it as a call for either banning or drastically increasing the control of biotechnology. When biotechnology is held to a different standard than comparable technologies or goods, this latter strategy may run afoul of the concept of substantial equivalence.

Benefit evaluations

Both positive and negative effects of biotechnology are taken into account while analysing its effects on the environment. Positive effects may be immediate or indirect, such as reduced pesticide usage in connection with pest-resistant crops, the use of less toxic pesticides, or effects resulting from modifications to agricultural methods. The price and effects of regulations According to this notion, cost should be taken into account when making policy decisions as USAID, poor nations, and the global community debate tighter regulation of biotechnology. Is it reasonable given the risks? What effects do the various sectors of public research, governments, business, agriculture, and consumers face? To provide an example, tiny biotechnology businesses protested when the EPA decided to regulate pest-resistant biotechnology crops under federal chemical pesticide legislation. They said that the expense would make it impossible for them to compete with the large, well-funded multinational corporations, which would prevent them from bringing goods to market. The increasingly onerous biotechnology regulatory framework presents a unique difficulty for both donor organizations and research institutes in developing nations. Could the existing biosafety strategy impede poor nations' efforts to develop and exploit biotechnology? Consumer concerns and biotech food labelling Japan and the European Union have passed laws requiring the labelling of food goods made using biotechnology. Consumer worry about the safety of biotechnology goods and/or the desire to facilitate consumer choice has served as the justifications for labelling. For several reasons, the United States and several other nations oppose mandatory labelling.

For example, in the United States, labels are only necessary for health-related reasons (such as nutritional labelling or warnings about ingredients that may be allergenic or otherwise harmful to some populations; for example, see the Nutrasweet labels on diet soft drinks). Consumer safety issues should be handled without the use of regulations (such as outreach or educational programs). Labelling biotechnology foods would probably give customers the wrong impression about their safety, even if the FDA has approved them. The notion of optional labelling has received support in the United States, which favours letting the market handle customer choice rather than having the government control it. Biotech crops would need to be strictly separated from non-biotech crops to be labelled as such. Testing and certification methods for "GMOfree" claims would be implemented after tight segregation, and their viability and accompanying costs are a major topic of discussion internationally.

It's crucial to prevent the labelling controversy from rich nations like the United States, Europe, and others from directly influencing the developing world. Instead, the interests and limitations of developing nations themselves should be taken into consideration when analysing labelling concerns. There are already several instances when biotechnologically altered foods are causing problems in poor nations: Supermarkets in the EU are requiring that feed for beef livestock not include GMOs. The use of genetically modified soybean oil in Thai canned tuna has raised concerns, posing a danger to the export of Namibian cattle grown on South African maize or soybeans, some of which may be GM.

Due to worries about the segregation of GMOs, a British retail chain is said to have advised an Asian rice supplier against using the nutritionally improved "golden rice." There are notable disparities between the United States, Europe, and emerging nations in how risk is perceived, as well as in the amount of socially acceptable risk and how governments handle it. The advantages of biotechnology in underdeveloped nations are undoubtedly different. The discussion around these concerns, and the accompanying legislative frameworks, have a history of being imported straight to emerging countries by both industrialised and developing nations. We must carefully assess the implications of these dangers, advantages, and means of regulation for developing nations as we go. Failure to do so might hinder developing nations' adoption of biotechnology to solve pressing national challenges.

CHAPTER 8

DEVELOPMENT OF AGRICULTURE BIOTECHNOLOGY

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Any potential advantages must be taken into account in any risk appraisal. Following is a list of some possible environmental advantages of biotechnology: a rise in crop production without the need for more inputs Crop losses may be decreased by improving crop resilience to pests and diseases and eliminating weeds. For instance, the European corn borer decimates 7–20% of the yearly maize yield worldwide. If Bt is effective in controlling the corn borer, maize yields in Europe and the United States alone might rise by 7–10 million tonnes, providing enough food in calories for 60 million people each year. Less pesticide and herbicide are being emitted into the environment. In areas where transgenic crops are planted, American farmers have reported considerable reductions in the use of herbicides and insecticides.

In 1,000 fields of herbicide-tolerant soybeans, the reduction in herbicide use ranged from 10-40%, depending on the region and growing conditions. Growing insect-resistant GM cotton resulted in 3 million litres of insecticide saved, compared to non-GM cotton, an 80% reduction in the state of Alabama. Studies conducted in the UK have shown that non-transgenic sugar beet requires at least five applications of a variety of selective herbicides whereas herbicide-tolerant sugar beet only requires two applications of glyphosate throughout the growth season. Less of a need to utilise more uncultivated land. For instance, to produce the same amount of wheat as in 1997, roughly 600 million extra hectares of land of the same quality would have been required if Asia's average grain yields of 930 kg per hectare from 1961 had continued to be the norm.

To produce the same amount of grain as in 1992, three times as much land would have been required in China, the United States, and India. Decreased soil erosiveness Farmers must remove the weeds before sowing non-transgenic soybean seeds. But with herbicide-tolerant soybean, growers may put the seeds straight into relatively undisturbed soil, making it easier to subsequently manage the weeds. This prevents water and wind erosion and preserves soil moisture, fauna, and plants. the development of alternate, renewable energy sources (for example, biodiesel). The development of new, more ecologically friendly industrial raw materials. Examples include high-value speciality chemicals and biodegradable polymers made from plant starches.

Farming energy consumption reduction

According to the available data, GM crops that are resistant to insects and herbicides are grown with fewer pesticides. Consequently, less energy is required to generate and transport those compounds, which saves energy overall. Additionally, there may be energy savings on the farm. What environmental dangers may there be? Transfer of genes "superweeds" and "genetic pollution." The possibility that GM crops' genes may "escape" and cross-pollinate with non-GM crops or their weedy cousins is one of the worries surrounding them. For instance, weeds in natural settings could acquire a herbicide-tolerant gene, transforming them into "superweeds." These hazards should be evaluated on a case-by-case basis, taking into consideration things. The potential for cross-pollination between various species or with weedy relatives; the presence of a crop's near related in the region. Whether the specific genes would provide the new plants with any kind of "selective advantage." A gene for delayed ripening, for instance, probably wouldn't harm the ecosystem. If danger is suspected, it may be controlled in several ways, such as physical separation from other farmed fields, the use of boundary rows or "buffer zones" of non-transgenic plants, etc. In any situation, measuring gene flow may be done to determine how well these techniques work. The majority of crops are products of millennia of selective breeding and do not thrive in their natural environments.

Therefore, it is doubtful that the majority of transgenic crops, which are based on these existing crops but modified for product quality, would cause harm to the environment. Additionally, despite references to transgenic "superweeds," none have been shown to exist. Consequences for non-target animals. Transgenic crops that have been engineered to be resistant to a certain pest or disease may negatively impact innocuous or helpful organisms. For instance, there have been recent claims that Monarch butterfly toxicity may be caused by Bt maize pollen. All transgenic crops are put through extensive testing to find these non-target impacts. If these dangers are shown to be real, they could still be efficiently controlled. Laboratory studies on the Monarch butterfly are still looking at elements like the real amounts of pollen present in the fields and the time of pollen discharge during larval feeding. It's vital to keep in mind that the transgenic crops' present substitute is often considerably worse for the environment. For instance, using broad-spectrum insecticides as part of regular spraying kills all insects, whether they are good for the crop or not.

Insect repellent

Any pest management method's likelihood of developing resistance to the pest it is intended to treat increases with the frequency of usage. One current worry is that this type of pest management may become less successful due to insects developing tolerance to poisons like the Bt protein. However, the idea of managing resistance is not new to agriculture, and some methods might lessen the possibility of resistance developing in insect populations. For instance, transgenic crops are planted alongside vulnerable plant habitats (refugia) in the United States. In many places, this is either a mandated or optional activity under the law. To lessen the selection pressure on pests, researchers are also exploring novel Bt toxin varieties that might be substituted, combined, or blended in transgenic crops. There haven't been any proven instances of resistant pest populations growing in the wild as of yet.

Biodiversity loss

It has been hypothesised that the very success of transgenic crops might cause a loss of biodiversity since less successful crops would not be planted and the number of types would decrease; nevertheless, population expansion is the key factor that could contribute to biodiversity loss. More acreage being used for agricultural production has mostly satiated the demands of an expanding world population. Compared to the tremendous issues caused by habitat loss, transgenic crops are unlikely to play a substantial contributor in increasing biodiversity loss. In reality, by raising yields on already-cultivated land, transgenic crops may be able to aid in the preservation of untouched environments.

Significant emphasis is focused in the media on how little biotechnology benefits consumers. By using fewer pesticides on food, current consumers are indirectly benefited. In the next years, a variety of goods catered to customer tastes will be sold commercially, such as "heart-healthy" oils, meals loaded with vitamins, fresher and more delectable fruits and vegetables, etc. It is crucial to differentiate between the food systems in developed and developing nations and those in the US and Europe. Since they may also be "producers," increases in agricultural output in emerging nations may more directly benefit "consumers." In developing nations, more local food production may result in reduced food prices and greater food security. In emerging nations, pesticide usage is a bigger health issue.

The wealth and income distribution gaps between the north and south will widen as a result of biotechnology, as will existing disparities. Given what they have learned from previous agricultural technology, proponents are ready to admit that these are legitimate worries. There are three specific problems: The public and commercial sectors contribute to biotechnology financing in different ways. Access to biotechnology will be difficult for resource-poor farmers, as it has been with more conventional inputs like seed, fertilizer, and pesticides, which are primarily funded and developed by the private sector. It is only too likely that many developing countries, small farmers, or certain crops will be bypassed, based on market considerations.

Biotechnology may not necessarily eliminate current imbalances in resource access or pose new problems in this area. Innovations in biotechnology may compete with conventional agricultural exports from developing nations, as was the case with high-fructose corn syrup made using an enzyme developed from biotechnology and conventional sugar exports. However, biotechnology may enhance the exports of other developing nations, for instance, by reducing fruit and vegetable deterioration during transport. How concerns of fair access to and financing for biotechnology are handled will have an impact on how these problems are resolved. However, these are not the only problems with biotechnology.

One of the scientific disciplines with the greatest growth is biotechnology, which has greatly advanced several disciplines including agriculture, medical, pharmacy, industry, and environmental science. In actuality, biotechnology is the science and technique of using living things in a peaceful, humanitarian manner for the benefit of humans and the environment. Sustainable agriculture has been considered as this technology has been developed. According to biotechnologists, biotechnology is akin to a miracle that might enable us to attain agricultural sustainability. Biotechnology increases output reduces the need for chemical input and saves time and money. However, other facets of biotechnology, such as the socio-economic ones, are often disregarded.

Contrarily, conventional agriculture, regardless of the use of this technology in sustainable agriculture, thinks that these benefits are just short-term and may potentially pose major long-term damage to ecosystems. Sustainable agriculture is a comprehensive strategy that aims to meet human requirements for food and other items while preserving the environment's quality and avoiding the depletion of natural resources. The major goals of establishing sustainable agriculture include easing the burden on the environment and ecosystems, minimising the use of chemicals such as fertilizers, pesticides, and herbicides, and protecting the environment and public health. In particular in emerging nations, agricultural biotechnology is essential for competitiveness and sustainable economic development.

Additionally, biotechnology has a unique role in boosting food security, which might be a benefit for small farmers in developing nations that want to practise sustainable agriculture. By lowering the use of pesticides in agriculture, biotechnology has improved our societies and maybe the world's environmental conditions while also spurring economic expansion. Even though these instances are seen as significant advancements, sustainable agricultural growth is still a work in progress. The structure of political ideologies and research organisations must be significantly altered to generate goods that fit ecological and socioeconomic standards. Authorities must reevaluate the connections between farmers, industry, consumers, and universities to bring about these changes.

Biotechnology uses living things to create useful goods and services for society. It does this by applying scientific and technical concepts to live things. The curriculum looks at bacteria, plants, and animals concerning the discovery, comprehension, development, and enhancement of workable goods and activities.

The field incorporates concepts from a wide range of disciplines, including molecular genetics, microbiology, immunology, physics, chemistry, engineering, and mathematics. A variety of technologies are used by scientists in modern agricultural biotechnology to comprehend and alter the genetic structure of organisms for use in the production or processing of agricultural goods.

To solve issues in all facets of agricultural processing and production, biotechnology is being applied. Plant breeding falls under this category since it helps increase and stabilise yields, better food nutrition, and improve resistance to pests, diseases, and abiotic conditions like drought and cold. For crops like bananas and potatoes, biotechnology is being utilised to create low-cost, disease-free planting materials.

It is also producing new instruments for the detection and treatment of illnesses in plants and animals, as well as for the assessment and preservation of genetic resources. To increase the number of qualities that may be addressed and to speed up breeding programmes for fish, animals, and plants, biotechnology is being applied.

Greater knowledge of industrial fermentation led to the development of the discipline of zymotechnology, which is the traditional name for the study of the processes of fermentation in yeast and bacteria in the manufacture of foods and drinks such as bread, cheese, tofu, beer, etc. Techno-scientists started to separate and investigate the microorganisms engaged in the 19th century's significant industrial growth, especially in Britain and Germany. Technoscientists started to consider zymotechnology to be a component of the applied sciences in the early 20th century, much as they did with chemistry. They created organisations to gather microbes. The definition of zymotechnology was expanded to include the utilisation of biological substances such amino acids, proteins, and enzymes in industrial manufacturing, which falls within the wider definition of biological chemistry.

Development of biotechnology

To address the diverse demands of people, biotechnology is now in various phases of development. The development of new technologies throughout time, which are based on the use of greater technical breakthroughs and a better grasp of numerous life-science concepts, has increased the complexity of biotechnology. The development of biotechnology may be split into three distinct phases: ancient, classical, and contemporary.

Farming biotechnology

A variety of scientific methods are employed in agricultural biotechnology to enhance plants, animals, and microbes. Based on a knowledge of DNA, scientists have created strategies to boost agricultural output. The capacity of biotechnology to increase breeders' ability to improve crops and animals starts with the ability to pinpoint certain genes that may bestow benefits on particular crops and the ability to work with such traits very accurately. Improvements made feasible by biotechnology are not achievable via the simple conventional crossing of related species.

Biotechnology and organic farming

The use of genes conferring tolerance or resistance to biotic and abiotic stresses, increased productivity and quality, improved nitrogen fixation, increased nutrient uptake and use efficiency, improved technologies for producing biomass-derived energy, and production of high nutrient levels in nutrient-deficient staple crops are all ways that biotechnology generally contributes to sustainable agriculture. Thus, traditional and local knowledge, organic and agroecological practises, conventional breeding, the use of tissue culture and genomic methods, marker-assisted breeding, and gene splicing may all be considered to be a part of biotechnology. Genetic engineering (GE), which involves the insertion or deletion of genes through transgenic technologies to produce genetically modified (GM) organisms, is the most prevalent example of "modern biotechnology," which is defined as "the manipulation of genetic material and fusion of cells beyond normal breeding barriers" (GMOs). The most significant area of biotechnology, which encompasses several fields with close scientific ties, is genetic engineering. It is a collection of techniques that, by definition, allows for the transfer of genes or their sequence, as well as the more or less stable existence of such a thing in the host cell. Methods of genetic engineering include:

1. Recombinant DNA techniques that use vector systems;
2. Techniques for introducing hereditary material directly into an organism after the material was recombined outside of that organism; and
3. Hybridization techniques, result in the formation of new living cells with a new combination of the hereditary genetic material. By merging two or more cells in a manner that is very improbable to occur in nature, it is accomplished.

Biotechnology and microorganisms

Soil-based microbes may increase agricultural output. To promote plant development and eradicate weeds, pests, and illnesses, men exploit naturally existing organisms to create biofertilizers and bio-pesticides. Soil-dwelling microbes assist plants in absorbing more nutrients. "Nutrient recycling" is a process that involves plants and these helpful bacteria. The bacteria facilitate the plant's "absorption" of necessary energy sources. In exchange, plants provide microorganisms access to their waste byproducts for nourishment. These helpful microorganisms are used by scientists to create biofertilizers.

Bio-fertilizers

Nitrogen and phosphate are essential for plant development. Although these substances are present in the environment naturally, plants can only absorb a small amount of them. Crop quality, maturity, and ability to withstand stress are all significantly influenced by phosphorus, as is, directly or indirectly, nitrogen fixation. *Penicillium bilaii*, a fungus, aids in releasing phosphate from the soil. For the roots to utilise the phosphate in the soil, it creates an organic acid that dissolves it. The use of this organism's biofertilizer involves either inoculating seeds with the fungus or putting it straight into the ground. A microbe called Rhizobium is utilised to create biofertilizers. On the roots of the plant, this bacteria resides in nodules, which are clumps of cells. The nodules are biological factories that can transform airborne nitrogen into an organic form that plants can utilise. This technique of fertilisation was created by nature. The legume may utilise naturally produced nitrogen in place of the pricey conventional nitrogen fertilizer because of the abundance of the beneficial bacteria on its roots. Farmers may use fewer chemical fertilizers because biofertilizers enable plants to use all of the food present in the soil and air. This safeguards the ecosystem for future generations.

Bio-Pesticides

All of the soil-dwelling microorganisms are unfriendly to plants. These infections may harm the plant or bring about sickness. Biological "tools" that exploit these disease-causing bacteria to naturally manage weeds and pests were created by scientists.

Bio-Herbicides

For farmers, the issue is weeds. In addition to competing with crops for space, sunshine, nutrients, and water, they can shelter pests, block irrigation and drainage systems, reduce crop quality, and introduce weed seeds into agricultural harvests. Another method of eliminating weeds without harming the environment is by the use of bio-herbicides. The bacteria have invasive genes that may assault the weeds' defence genes and destroy them. The advantage of utilising bio-herbicides is that they may persist in the environment long enough to infect more weeds throughout the next growth season. It is less expensive than synthetic pesticides and, if used correctly, may significantly save agricultural costs. In addition, it has less of an impact on the environment than traditional herbicides and won't damage creatures that aren't the target.

Bio-insecticides

Insect pest control alternatives to synthetic pesticides might be developed with the use of biotechnology. Microbes that fight the fungus, viruses, or bacteria that cause root illnesses in the soil. It is possible to create coverings for seeds (inoculants) that contain these helpful organisms to protect the plant during the vulnerable seedling period. Bio-insecticides are less toxic to humans and animals than synthetic insecticides, do not last as long in the environment, are only effective in small doses, are highly targeted, frequently only kill one species of insect, have a very specific mode of action, are slow acting, and the timing of their application is crucial.

Food production that both meets the requirements of the current generation and does not jeopardise the ability to meet the food demands of future generations is referred to as stable or sustainable agricultural production. It is also morally right and financially sensible. Biotechnology is one of the ecological and financial components of sustainable agriculture. Constant food production is possible by using contemporary biotechnology processes and techniques, both in terms of quantity and quality. Our research and profession must stay up with contemporary agricultural developments or we will not be able to keep up and maintain our position as a global leader in food production.

CHAPTER 9

AGRICULTURAL BIOTECHNOLOGY IN CROP IMPROVEMENT

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Through the use of scientific methods for the modification of genes providing resistance to biotic, and abiotic stress and enhancing the quality of crops, agricultural biotechnology is emerging as the key sector in crop development. There have been several advancements in the area of crop improvement as a result of the transition from Mendelian genetics to molecular biotechnology. Recent biotechnology developments have tried to free crops from physiological restrictions and boost agricultural output potential. Various transgenic crops have been developed over the years and have been given the go-ahead for commercialization with the help of various agricultural biotechnology tools, including genetic engineering, somatic hybridization, tissue culture, embryo rescue, genome doubling, molecular marker-assisted selection, and omics technologies. Transgenic technology has been demonstrated to boost agricultural yields, decrease CO2 emissions, cut down on pesticide and insecticide usage, and lower food production costs. Despite the enormous potential for the biotechnological method and transgenic organisms to contribute to global food security, various worries about genetically modified crops endangering the environment and human health have emerged. This review will discuss how biotechnology is being used to enhance crops while taking environmental and health dangers into account.

Biotechnology is the use of extensive scientific procedures to modify and improve the traits of many plants, animals, and microbes that are significant to the economy. Biotechnology is a wide phrase that encompasses the use of microorganisms and other foreign genes gene of interest in the processing of food, in forestry and agriculture, in protecting the environment, in the medical field, and in other fields. The use of scientific methods for the modification and development of both crops and animals constitutes the field of agricultural biotechnology. Traditional agriculture cannot keep up with the world's growing food demand due to the growing population, thus a successful integration of biotechnology and conventional breeding is necessary to achieve an evergreen revolution and maintain agricultural production.

Mendelian genetics applications have greatly increased crop productivity during the 20th century, but if farmers are to better meet the demands placed on them over the next fifty years, biotechnology and molecular biology research should focus on removing the physiological constraints of the crops and increasing crop yield potential. Recent advancements in plant molecular biology and genomics have given us knowledge of and access to plant genomes, as well as the potential to alter them. In addition to allowing precise progress toward the production of novel and beneficial plant and animal genotypes, biotechnology offers several tools that operate in tandem with traditional breeding methods to provide access to a larger gene pool.

Without a doubt, the use of traditional techniques has significantly improved key heritable traits in crops, such as yield, disease resistance, etc. However, there are some limitations to these techniques, such as the possibility that it will take a very long time to introduce, select, and establish a trait into a cultivar or that it will be impossible to incorporate certain traits with these techniques.

By quickly introducing the desired feature without changing other characteristics of the plant, genetic engineering overcomes these constraints. Agriculture is now experiencing a biotechnological revolution that might significantly assure agricultural sustainability via improved product quality, increased disease and insect pest resistance, environmental protection, and increased agricultural output. With the development of molecular biology, scientists are now able to change DNA to create transgenic species. This technique, known as "Genetic Engineering," has several advantages as well as potential drawbacks. Genetic engineering and food generated from transgenic crops have debatable societal and regulatory repercussions. Therefore, not all transgenic crops created have been made available for commercial cultivation. The current developments in agricultural biotechnology and the main issues they raise are attempted to be covered in this overview.

The foundation of the global food supply is agriculture. Initially, agriculture was carried out manually using simple tools like the plough and harrow. People moved from rural regions to industrialised cities as a result of the Industrial Revolution (1875–1885), which permitted faster economic growth. Around this period, chemical fertilizers were used to combat illness and increase yields.

The current human population is 7.87 billion, and between 2015 and 2020, it will grow at an average annual rate of 1.1%. Global food security is seriously threatened by this population growth, which is expected to reach 9 billion by 2050. A growing number of people have settled on agricultural land as a result of global population growth. As a result, less land is being used for agriculture, which lowers production.

Therefore, boosting global agricultural output will help to meet the growing global food demand. However, less area needed to be planted for agriculture, which necessitated a major technological advance that would boost agricultural production while simultaneously ensuring its long-term sustainability. This was made possible by the biotechnology field's breakthrough. The 1866 publication of Gregor Mendel's "Experiments on Plant Hybridization" featured information on the transmission of features from one generation to the next, which signalled the advent of new methods intended to advance crop species. However, it is thought that gene modification in crops began approximately 10,000 years ago as a consequence of chance or random selection of new crop varieties.

Three major cereal crops rice, maize, and wheat saw an increase in production in 1960 as a result of the Green Revolution. Deoxyribonucleic acid's (DNA) molecular structure and its connection to heredity were two especially significant discoveries. After the genetic code was broken in the 1960s, it became much simpler to transfer genetic material. Various unique creatures are formed by the exchange of genes between different organisms, and they are sometimes referred to as "genetically modified organisms" (GMOs). Modern biotechnology has centred on genetic modification for agriculture, horticulture, environment, medical, forensic research, and many other disciplines as a result of the introduction of several GMOs. the pivotal moments in the evolution of biotechnology.

The Use of Agricultural Biotechnology to Improve Crops

Using biological organisms or a variety of technologies to enhance plants, animals, microbes, or food obtained from them is referred to as agricultural biotechnology. The following are some examples of agricultural biotechnology tools:

Transgenesis

Transgenesis, also known as genetic engineering or recombinant DNA (rDNA) technology, is the use of a variety of techniques to manipulate DNA, particularly DNA from different species, as desired. The resulting hybrid DNA is then introduced into a new organism to create novel combinations of heritable genetic material. Transgenic organisms are referred to as genetically modified organisms (GMOs). In 32 distinct crops, 530 different transgenic events have been licenced for production globally.

The most occurrences among them are accounted for by maize (240), which is followed by cotton (67), potato (50), Argentine canola (42), soybean (42), carnation (19), and so on. Herbicide-tolerant (HT) transgenic crops have been developed through the use of transgenesis. Transgenic crops with traits such as insect resistance (IR), abiotic stress tolerance (AST), disease resistance, and enhanced nutrition are also available.

Transgenic plants that are herbicide-tolerant

Glyphosate-tolerant soybean (also known as Roundup Ready soybean), which carried the EPSPS gene from the CP4 strain of *Agrobacterium tumefaciens*, was the first transgenic crop to be sold that was herbicide-tolerant. This gene is present in most commercially available glyphosate-resistant crops. For the development of glufosinate-resistant crops, pat and bar, two distinct genes from Streptomyces spp., were used. Similar to this, newly launched HT transgenic crops are specific to additional herbicides like 2, 4-D, Isoxafutole, Oxynil, and Sulfonylurea. 351 herbicide tolerance events in all have been given the go-ahead to be grown. About this, maize has had the most HT events commercialised, followed by cotton, Argentine canola, and other crops.

Transgenic Plants Resistant to Insects

Most insect-resistant transgenic crops are created using *Bacillus thuringiensis* (Bt) cry genes, which provide resistance to several insect pests (Lepidopterons, Coleopterans, and Dipterans). In addition to offering protection against insect pests, cry genes are also safe for mammals. Cotton, which had a cry gene introduced to give resistance to its lepidopteron insect pest, was the first crop to be commercially successful. Cry genes have been integrated into various crops, including potato, rice, canola, soybean, maize, chickpea, alfalfa, and tomato, after the success of transgenic cotton. For insect resistance, cotton and maize have acquired genes derived from Bacillus species (B. thuringiensis and B. cereus).

Plants, bacteria, and fungi with genes expressing protease inhibitors (PI) have all been utilised to create plants that are resistant to insects. Tobacco, rice, and cotton, respectively, have each received the cptII and potato protease inhibitor II genes to provide insect resistance. 305 insect resistance events have thus far received cultivation approval. Of them, maize has been marketed for the greatest number of insect-resistant events (208), followed by cotton, potatoes, and other crops.

Transgenic Crops Resistant to Abiotic Stress

With shifting climatic conditions, abiotic stressors have a greater influence on crops. By changing the expression of a variety of genes, certain plants can adapt to these abiotic challenges at the molecular level. This contributes to the formation of circumstances that are almost ideal for plant growth. Abiotic stress tolerance events have been marketed less often than features like disease, pest, and herbicide tolerance because of the complexity of the abiotic stress adaption trait (several genes are involved). The cultivation of 12 different abiotic stress tolerance events in maize, sugarcane, and soybean has been authorised. the use of bacterial cold shock proteins (csp) to reduce the impact of abiotic stressors on plants, such as cold in Arabidopsis, heat, cold, water shortage in rice, and water deficit in maize.

The cspA gene from E. coli and the cspB gene from the soil bacteria *B. subtilis* were integrated into maize, which not only demonstrated superior adaptability under times of water scarcity but also did not result in pleiotropic effects in maize. Recently, Verdeca's drought-tolerant transgenic soybean, marketed as Verdeca HB4 Soybean, received the Hahb-4 gene from *Helianthus annus* (Sunflower). The gene results in an isolated nucleic acid molecule that codes for the transcription factor Hahb-4, which binds to a plant region that controls transcription under dehydration. Similar to this, drought-tolerant transgenic sugarcane has been created utilising the betA gene from E. coli and *Rhizobium meliloti*. When compared to non-transgenic plants under drought circumstances in a field study, these transgenic sugarcane crops yield 10–30% more sugar and can resist drought conditions for up to 36 days.

Transgenic Plants Resistant to Disease

Pathogens (fungi, bacteria, viruses, and other microorganisms) are the source of diseases, which significantly reduce agricultural productivity. Despite the risks to the environment posed by their usage, agrochemicals are often employed to treat plant diseases, which presents the problem of the emergence of pests that are resistant to the chemicals. Transgenesis has allowed scientists to produce plants with features that make them resistant to disease. There are now 29 disease-resistance events that can be grown. Potato has had the most disease-resistant events commercialised out of all of them, followed by papaya, squash, and other fruits and vegetables. The majority of commercially available disease-resistant crops also provide viral resistance.

The first disease-resistant plant was discovered using a gene expressing the viral coat protein of the tobacco mosaic virus (TMV), which was also resistant to TMV infection. Similar to this, transgenic papaya with PRSV resistance has been created via a "pathogenderived resistance mechanism," in which papaya is bombarded with microparticles to deliver the "prsv cp" gene. By silence the sequence area of the AC1 viral gene, which prevented the production of the BGMV's viral replication protein, bean (*Phaseolus vulgaris L.*) was able to create RNAi-mediated resistance to the Bean Golden Mosaic Virus (BGMV). Using Agrobacterium-mediated gene transfer, the Rpi-vnt1.1 gene from *Solanum venturii* is inserted into the potato (*Solanum tuberosum L.*), conferring resistance to potato late blight and producing late blight resistance protein. The chitinase enzyme breaks down the two main components of the fungal cell wall (chitin and -1, 3 glucan), hence when the chitinase gene was inserted in tobacco and rice, it has been found to increase the plant's ability to resist fungi.

Improved Transgenic Crops for Nutrition Utilizing transgenesis, several effective attempts have been undertaken to enhance the nutritional value of crops. The most recent instance is the biofortified rice line GR2E (Golden Rice), which was created by introducing the genes "crt1" from *Pantoea ananatis* and "psy1" from *Zea mays*. Carotenoids may be produced by Golden Rice in the endosperm. In the Philippines, Australia, New Zealand, Canada, and the United States, GR2E was given the go-ahead for food usage. Similar to this, transgenic potato tubers were created by expressing the Amaranthus seed albumin gene AmA1, which is abundant in all required amino acids for human diet specifications as per the WHO standard, to increase the nutritional value of potatoes. Through the creation of transgenic tomatoes and the bacterial gene transfer for the phytoene-desaturase enzyme, an attempt was made to increase the pro-vitamin a concentration in tomatoes. These transgenic plants also generated three times as much carotene as typical plants. Low erucic acid concentration has been caused by antisense fae1 gene transfer to *Brassica napus* and *Brassica juncea*. Lysine synthesis in maize has risen thanks to the insertion of the "cordapA" gene from*Corynebacterium glutamicum*.

Culture of Tissue

Tissue culture is the sterile cultivation of cells, tissues, organs, or their constituent parts in a nutritional media. Explants are often used, which are tiny bits of plant tissue that are cultivated in an aseptic environment. Through manipulation and time extension, tissue culture creates a whole, live, developing creatures from cells, anthers, pollen grains, or other tissues. Genetically modified creatures may be created from genetically modified cells via tissue culture. Through the in-vitro cultivation of protoplasts, anthers, microspores, ovules, and embryos, tissue culture has been widely utilised to enhance the amount of suitable germplasm accessible to plant breeders and to promote genetic variety to improve agricultural plants.

It is a key piece of biotechnology equipment. For seeds like bananas that are difficult to germinate, tissue culture is utilised. Tissue culture is used to create the Grand Naine (G9) variety of bananas, which leads to the widespread multiplication of disease-free, high-yielding clones and true-to-type plants. Similar to this, brome mosaic virus and banana bunchy top virus-free plants are created when banana plants are grown from the tips of their meristems (BMV). The preservation of endangered germplasms may be accomplished via the use of in vitro cell and organ cultures. Tissue culture methods may be used to maintain a gene bank for plants that do not generate seeds sterile or produce seeds that cannot be kept for a long time recalcitrant seeds.

For widespread hybridization, embryo rescue

Because of pre- or post-fertilization incompatibility obstacles, inter-specific or inter-generic cross-produced embryos may not result in a hybrid. These obstacles may be removed by saving such embryos and growing them into whole plants, which makes it easier to introduce advantageous genes from wild cousins into cultivated species. Wide hybridization or embryo rescue are two names for this method. To impart fruit rot resistance, extensive hybridization and embryo rescue were done in capsicum.

Hybridization somatic

Somatic hybridization is a method for altering cellular genomes that involve fusing somatic cells from two distinct cultivars, species, or genera of plants. Through tissue culture, somatic hybridization through protoplast fusion aids in the regeneration of new germplasm into complete organisms. Similarly, somatic hybridization may get beyond barriers of incompatibility at inter-specific or intergeneric levels. Pomato was formed from the union of the protoplasts of tomato and potato (*Lycopersicum esculentum* and *Solanum tuberosum*, respectively) (Solanopersicon, a new genus). In addition to removing obstacles caused by sexual incompatibility, it also produces new genotypes. Somatic hybridization between Rice (*Oryza sativa*) and Mangrove grass (*Myriostachya wightiana*) produced a salt-tolerant hybrid callus culture that may be used to create salt-tolerant rice varieties. Asymmetric somatic hybridization was utilised to transfer the bacterial blight resistance trait from the wild, and somatic hybridization is also employed to transmit disease resistance genes. Using protoplast transformation followed by somatic hybridization, it is simple to transfer traits that are cytoplasmically regulated, such as male sterility and tolerance to several antibiotics and herbicides. To transmit Cytoplasm Male Sterility (CMS) in rice, hybridization has been employed.

Genetic research and selection were supported by molecular markers

Gene identification is supported by molecular marker-assisted genetic analysis, which examines DNA sequences in particular to identify genes, QTLs (quantitative trait loci), and molecular markers as well as link them to the organism. A succession of generations may be followed to detect and track the inheritance of previously discovered DNA fragments thanks to molecular marker-aided selection. Utilizing genomics, linkage maps, and molecular markers, molecular marker-assisted breeding modifies and enhances plant or animal properties based on genotypic tests. Using phenotypic and molecular marker-assisted selection, rice genotypes with desirable agronomic traits, resistance to Bacterial Blight (BB), and Basmati quality were found. These genotypes can either be used directly in the creation of commercial varieties or used as a donor of BB resistance in Basmati breeding programmes.

Similar to this, Marker-assisted selection made it possible to identify the origins of Coffee Berry Disease and Coffee Rust Resistance for use in preventative breeding for these illnesses' resistance. In breeding projects targeted towards multiple and long-lasting resistance, several genes from different Coffea species served as significant gene pyramiding sources. Using standard and conditional methods, a genetic investigation of Fusarium Head Blight Resistance in CIMMYT bread wheat line C615 was conducted. The genetic links between FHB response and associated variables were shown in this work at the QTL level. This information may be used to guide marker-assisted selection during breeding to increase FHB resistance.

A genotype called a doubled haploid (DH) is created when haploid cells double their chromosomes or genomes. Spontaneous chromosomal doubling occurs in haploid cells such as pollen, egg, or other gametophyte cells, producing doubled haploid cells that develop into doubled haploid plants. Compared to conventional breeding, it enables the generation of pure line variants or inbred parental lines more quickly.

Wheat using double haploid technology had a quicker time to market and faster genetic advances in yield and resistance, which aided in shortening the time needed for varietal development. Similar to how DH practises another culture, it provides a fantastic chance to advance breeding efforts and enhance grain quality. A quick and effective way to produce homozygous rice lines which are discovered to be more viable than other lines is to use DH plants in antherculture. Similar to this, in a 2017 research by Bakhshi, Bozorgipour, and Shahriari-Ahmadi, double haploid wheat lines were developed by crosses using maize as the male parent using the chromosome elimination approach. Additional wheat lines were chosen so they could grow and adapt to situations of heat stress.

Technologies using "Omics"

Technologies classified as "Omics" include genomics, proteomics, transcriptomics, genome sequencing, and metabolomics. Omics technologies are a subset of bioinformatics. Genomic analysis is used to identify DNA that contributes to phenotypes in animals and to comprehend the structure, operation, and evolution of genes. Proteomics assists in analysing the proteins in tissues to determine the expression of certain genes in that tissue and to determine the precise purpose of proteins encoded by particular genes. An omics-based method aids in deciphering the complete genome to give customised solutions for crop development by providing insights into plant molecular reactions. We can identify the DNA (gene) encoding for a certain trait (genomics), the RNA it codes for (transcriptomics), the proteins formed (proteomics), the metabolites produced (metabolomics), and the phenotype expressed (all using the omics approach) (phenomics). The structure and behaviour of crop genomics may be better-understood thanks to the use of omics technologies. Any gene in charge of a certain attribute may be used in many ways to improve breeding. By carefully inserting a target gene using site-directed mutagenesis, a maize line resistant to herbicides was created.Agriculture Biotechnology Issues in 2019, biotech crops were produced in 29 nations, making a substantial contribution to global food security, sustainability, climate change mitigation, and the improvement of farmers' and families' lives. There are, however, some worries about gene modification in crops being hazardous for human consumption and environmentally detrimental. The following is a quick discussion of the main issues with agricultural biotechnology:

Adverse impacts on species that are not the target

The adoption of transgenic crops for a certain purpose (disease/pest resistance) has had unforeseen consequences on species that were not the original targets. The adoption of glyphosate-resistant transgenic crops in the USA and Mexico has been linked to a decline in the population of monarch butterflies. Higher mortality has also been linked to the monarch butterfly larvae feeding on milkweed leaves dusted with genetically modified Bt maize than under normal laboratory conditions. Similar to how the widespread use of Bt cotton in China boosted the population of the Mirid insect, a small problem that subsequently became a big pest.

Biosafety Concerns

There have been worries that transgenic food safety might endanger both the environment and human health. Allergenicity, toxicity, horizontal gene transfer and feed safety are risks related to human health. When a gene is added to an organism, the number of allergens in the modified organism may rise over the range seen in its normal state or a new allergy may be created. The expressed protein of the transgene was found to be extremely allergic, hence bean crops engineered to boost the amount of cysteine and methionine content were abandoned. Therefore, testing transgenic food may be necessary to protect consumers. Similarly to this, the WHO said that transgenic food may transmit genetic material to soil microorganisms, intestinal bacteria, or human body cells largely because the DNA eaten from transgenic food is not eliminated by digestion. Although it is exceedingly unlikely, antibiotic resistance in the gut microflora may develop as a consequence of the horizontal transfer of antibiotic-resistant marker genes from transgenic food to animal and human gut bacteria. Similarly to this, growing genetically modified crops might result in "genetic erosion" if farmers only produce a select few widely used kinds. The revival of pests and the creation of superweed are the outcomes of these changes in ecology and evolution since GM crops are not a natural part of the process.

Resistance disappears

Through intense selection pressure, the cultivation of herbicide- and insecticide-tolerant crops raises the likelihood that the targeted insect population may evolve resistance. The development of new insect biotypes that are resistant to transgenic technologies is possible. In a similar vein, superweed that is resistant to pesticides may appear. Spodoptera frugiperda (Fall armyworm), a field-evolved pest, is resistant to Bt maize in both cry1F-expressing corn and cry1Ac-expressing soybeans in Brazil. Field-evolved resistance to Cry1Ac-expressing cotton in Cotton Bollworm (Helicoverpa armigera) has been documented in China.

Issues of the economy, society, and politics

Economic worries exist about GM crops since small farmers and farmers in developing nations won't be able to buy seeds for GM crops due to the high cost of seeds. There is also concern about the detrimental socioeconomic effects of fast technological development on rural or agricultural structures. The usage of GMOs in Muslim societies is seen as either halal or haram. One of the main political issues is the labelling of foods that have been genetically modified. The USA does not identify genetically modified food, but there has to be global agreement on labelling such food and its byproducts. Similar to how biotechnology rules vary between the US and EU, these variations are the result of subtle variations in customer preferences.

From the green revolution to the gene revolution, agriculture has advanced significantly. More and more updates and applications are made every day. We can meet the growing need for food by creating innovative crop types with a greater yield, better tolerance to biotic and abiotic influences, and environmental sustainability thanks to the capacity to understand and alter the genetic make-up of organisms using biotechnological methods. In addition to boosting crop output, the application of biotechnology in agriculture has benefited farmer livelihoods by lowering production costs by reducing the demand for inputs like pesticides.

Similar to this, biotechnology applications have led to the development of novel plant types with greater yields while requiring fewer inputs, broader environmental tolerance, and better rotation to save natural resources.

Despite these quick improvements, worries about the safety of GM crops for human health, the safety of food and feed, and the environment, social, economic, and political problems are continually brought up. Strong regulatory implementation mechanisms for the use of GM crops should be used, together with a thorough and transparent evaluation of the deployment of GM crops and their impacts. As an alternative, modern techniques like cisagenesis, intragenesis, and genome editing may be used to create better crops.

One technique used in tissue culture to quickly enhance the growing supply of needed plant material is micropropagation. Most plants that are propagated are resistant to disease. This is a cutting-edge method of vegetative propagation. Commercially, micropropagation from tiny explants may be utilised for asexual propagation to create a huge number of the same plants with the same genetic make-up.

Large numbers of plants can be generated quickly and kept alive in constrained areas, preserving certain endangered species and genetic resources. The finest illustration of this method is a disease-free banana. Regenerating disease-free banana plantlets from healthy tissues is a technique known as micropropagation.

It has all the advantages of being a reasonably affordable and simple technique. Avocados, pineapple, citrus, coffee, and papaya are more examples of crops grown utilising tissue culture. Agricultural biotechnology applications help sustain food production. It provides a variety of tools to improve our knowledge of and management of the genetic resources for food and agriculture. The generation of crops with improved nutritional value, insect and disease resistance, and cheap production costs are only a few of the novel uses of science that modern biotechnology demonstrates. When applied responsibly and ethically, biotechnology in the context of genetic alteration has the potential to provide significant advantages.

Crops with Genetic Modifications

Crops that have been genetically modified (GM) are agricultural plants whose DNA has been changed using genetic engineering methods. Agrobacterium may be used to physically alter plant genomes or to transfer sequences from T-DNA binary vectors. The aim is often to provide the plant with a novel trait that does not arise in the species normally. Examples of food crops include those that are resistant to certain pests, diseases, and environmental conditions, a reduction in spoilage, resistance to chemical treatments like herbicide resistance, or a crop with a higher nutritional profile. Crops utilised in bioremediation, the production of pharmaceuticals, biofuels, and other products used in industry are a few examples of non-food crops.

According to a meta-analysis published in 2014, the usage of chemical pesticides has dropped by 37%, agricultural yields have grown by 22%, and farmer profitability has increased by 68%. Abuse may lessen the ecological benefits of this reduction in pesticide usage. Crop productivity improvements and pesticide reductions are larger for insect-resistant crops as compared to herbicide-tolerant crops. The yield and profit increases are bigger in developing countries than in developed countries. Pesticide usage was reduced by 2.4 to 9 million times yearly in India alone, and the widespread adoption of Bt cotton led to a 25% reduction in farmer suicides. Bt cotton technology "has been extremely helpful overall in India," according to a 2011 examination of the relationship between its usage and farmer suicides in that country, and "Available data suggest no sign of a recurrence of farmer suicides."

There is scientific agreement that currently accessible food made from GM crops does not represent a larger danger to human health than traditional food, but that each GM product has to be examined individually before being released. However, the general population is significantly less inclined than experts to believe that GM foods are safe. The legal and legislative status of genetically modified foods varies by country, with some prohibiting or limiting them while others allow them with varying levels of restriction.

But critics of GM crops have raised issues with their effects on the environment, food safety, whether they are necessary to meet global food demands, whether they are adequately available to farmers in underdeveloped nations, and whether they should be subject to intellectual property laws. 38 nations, including 19 in Europe, explicitly forbade its cultivation due to safety issues [3], [4].

History

Modern genetics has made it possible for humans to modify plant genetics. Restriction enzymes, which allowed DNA to be cut at particular locations and allowed for the isolation of individual genes from an organism's genome, were discovered in 1970 by Hamilton Smith's team. Earlier in

1967, DNA ligases that patch up damaged DNA were found; by combining the two techniques, it was feasible to cut and paste DNA sequences or produce recombinant DNA. The 1952 discovery of plasmids led to the development of crucial tools for reproducing DNA sequences and transmitting data across cells. *Agrobacterium tumefaciens*, a bacterium that causes plant tumours, was identified in 1907, as well as the Ti plasmid, a DNA plasmid, was revealed to be the tumour-causing agent in the early 1970s. Researchers have been able to infect plants with *A. tumefaciens* and allow the bacteria to insert their desired DNA sequence into the plants' genomes by taking out the genes from the plasmid that produced the tumor and replacing them with fresh genes. Other techniques, such as microinjection and electroporation, were developed since not all plant cells were amenable to infection by *A. tumefaciens*.

Modification Types

Transgenic

Genes from other species have been put into transgenic plants. The inserted genes may originate from species within the same kingdom (plant to plant) or from species outside of the same kingdom (for example, bacteria to plant). The inserted DNA frequently has to be somewhat changed to be accurately and effectively expressed in the host organism. Proteins, including B. thuringiensis cry toxins, genes for herbicide resistance, antibodies, and vaccine antigens are expressed in transgenic plants. The European Food Safety Authority (EFSA), which oversaw the study, also discovered viral genes in transgenic plants.

Taliglucerase alfa, a medication used to treat Gaucher's disease, is made from transgenic carrots. Transgenic plants have been altered in the lab to boost photosynthesis, which is now only around 2% for most plants but has a theoretical potential of 9–10%. This might be accomplished by altering the rubisco enzyme (converting C3 plants to C4 plants), encapsulating the RUBISCO in a carboxysome, incorporating CO_2 pumps into the cell wall, or altering the shape or size of the leaves. Electric illumination may one day be replaced by bioluminescent plants that have been genetically modified to produce light [5].

Cisgenic

Utilizing genes from the same species or a closely related one, when traditional plant breeding is possible, cisgenic plants are created. Scientists and breeders contend that cisgenic alteration is beneficial for plants that are challenging to crossbreed through traditional methods (such as potatoes) and that cisgenic plants shouldn't be subject to the same regulatory scrutiny as transgenic plants.

Subgenus

By using gene knockdown or gene knockout procedures to generate genetically modified plants, the genetic makeup of a plant may be altered without using genes from other plants. The strain lacks genes for proteins that inhibit the body's natural defenses against mildew. The researchers eliminated all three copies of the genes from the hexaploid wheat genome.

Polyhouses Technology

The practice of farming has undergone dramatic change as technology advances every day. The need for off-season yields has dramatically increased, and when traditional methods were formerly deemed to be sufficient for agricultural production, they now have limited application and appeal to consumers. People came up with a common answer a polyhouse to all of these and many other issues. Traditional agricultural practices in nations like Bangladesh and India have changed because of polyhouse, which also offers new chances to increase productivity while using fewer resources [6], [7].

Used Materials

In the past, the primary construction of a polyhouse was supported by wooden frames. To give more support and greater strength, modern polyhouses employ several stronger materials, such as G.I. steel or aluminum rods. A polyhouse can withstand severe weather thanks to these materials, despite its little size. These modern polyhouses are best suited for India's arid regions like Rajasthan or Uttar Pradesh. Polythene sheets are then placed over the internal skeleton to ensure that the internal temperature and other climatic conditions may be changed and maintained without the interference of the outside world [8], [9].

A polyhouse is a form of greenhouse where crops may be grown in partially or completely regulated climate conditions by using a customized polythene sheet as a covering material. The greenhouses were traditionally built on timber frames with glass utilized as a cladding material. The development of plastic technology made it possible to use plastic material instead of glass. For tropical and subtropical climates like India, polyhouses are more appropriate.

The G.I. steel frame used to construct modern polyhouses is coated in plastic that is fastened to the frame with aluminum grippers. High-quality, 200-micron-thick white plastic film with a three-year warranty against weather and UV deterioration is used as a covering. What distinguishes a polyhouse from a greenhouse is one of the often-asked questions we receive. They will clarify this now and put an end to the misunderstanding. In essence, a polyhouse is a greenhouse. It may also be thought of as a specific kind of greenhouse [10].

The roof of the greenhouses was traditionally composed of sheets that were green in hue. Then, as technology advanced, people were given access to more dependable plastic supplies, such polythene. This new polythene was a popular choice since it worked well in greenhouses and was inexpensive. This is how this particular form of greenhouse acquired its new moniker, polyhouse.

Polyhouse Varieties

With the present development, the polyhouse industry has seen some incredible changes. Based on the kind of material utilized, the location, the yield obtained from them, and other factors, there are several distinct varieties of polyhouses. The polyhouse may be broadly classified into two categories.

They will talk about the primary two categories as this is only a simple introduction to help you understand polyhouse and create some notions about how it functions.

Polyhouse with Natural Ventilation

The most fundamental and conventional variety of polyhouse is this one. There is virtually little ability to influence climate change in this category. Your plants and harvest are mostly at the mercy of the weather outdoors. Even with a few supportive tools like a fogger, ventilation control, drip irrigation system, or pest control system, off-season crops still cannot be produced with them.

Polyhouse with Environmental Controls

They belong to the most advanced polyhouse varieties. Equipped with several highly practical extra functions, such as temperature control, humidity control, and sunshine control, among others. These polyhouses extend the growing season and allow you to grow some of the most unusual off-season types. These polyhouses are also utilized in places to grow crops that would not be possible to grow there.

Benefits of Poly House Agriculture

- Crops are shielded by polyhouses from wind, rain, radiation, precipitation, and other environmental elements.
- It develops a microclimate around the crops that promotes the highest development in terms of yield and quality.
- Polyhouse yields are much greater than open field cultivation since it also delivers higher CO_2 concentrations to boost production to its maximum level.
- In a polyhouse, you can grow plants that would be difficult to grow in that particular climate zone. Example: Strawberry cultivation on Indian plains.
- You can grow polyhouse crops in a little amount of space and yet make the most money.
- The number of manual tasks, reliance on labor, and overall labor cost are lowered with the highest level of automation.

Farming in Poly Houses Has Drawbacks

The cost of production is relatively expensive, and a sizable sum of initial capital expenditure is needed. Polyhouse cultivation is a labour-intensive form of agriculture that demands constant attention. Running a polyhouse requires technical expertise, as well as a qualified supervisor and experienced laborers to carry out everyday tasks. Organic farming has fewer opportunities than polyhouse farming since it is overly dependent on fertilizers and chemical pesticides.

CHAPTER 10

APPLICATIONS OF BIOTECHNOLOGY IN AGRICULTURE

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Gene-modified crops

GM crops are agricultural plants whose DNA has been altered via the use of genetic engineering methods. The fundamental objective is to introduce a novel characteristic that does not exist in the species normally.

Foods generated from organisms that have undergone particular DNA modifications via genetic engineering are referred to as genetically modified foods. If not misused, GM crops may provide several ecological benefits.

However, opponents have objected to GM crops per se for a variety of reasons, including economic worries brought on by the fact that such species are covered by intellectual property laws, environmental concerns, concerns about the safety of food made from GM crops, and concerns about whether GM crops are necessary to meet global food needs. Uses for GMOs include the following.

They can withstand a variety of abiotic stressors, including cold, heat, and drought.

A. They can withstand pests.
B. They aid in lowering losses after harvest.
C. Plants that have been genetically engineered are more nutritious.
D. For instance, vitamin A-enriched rice.

Soybean, maize, canola, and cottonseed oil are some of the high-demand cash crops by farmers that have received the majority of genetic food changes to far. They were created to have enhanced nutritional profiles as well as tolerance to pathogens and herbicides. Plants that have undergone genetic modification include:

In 1994, Calagen released their FlavrSavr late-ripening tomato product for commercial sale for the first time. The softening and rotting caused by fungal infections were slowed down using molecular genetic technology, extending the shelf life of GM tomatoes. The flavour of this tomato was enhanced through further genetic manipulation. Due to issues with maintenance and shipment, the FlavrSavr tomato did not succeed in remaining on the market.

Golden Rice

Agricultural biotechnology provides several dietary advantages. "Golden rice" is one example of this, since it contains beta carotene, an essential source of vitamin A for the body. The transgenic grain's colour, which is caused by three genes, two of which are from daffodils and one from a bacteria, gives rise to the term "Golden rice." To create "Golden rice," these three genes were cloned.

Genetic modification Crops that can tolerate herbicides

Genetically modified HT crops employ a gene that was obtained from the gram-positive soil bacteria *Agrobacterium tumefaciens*. The broad-spectrum herbicide glyphosate becomes tolerable to the recipient plant as a result. HT crops may lower production costs and aid in weed control. The HT crop has been created as a Roundup Ready variety (RR). In 1996, RR soy beans were made available for industrial farming. The output of RR soya beans is comparable to that of regular soya beans, while cultivation expenses are lower.

Adaptability to drought

Although traditional breeding for drought resistance still has an effect, it is time-consuming and has limitations because of the lack of readily available breeding genes. The Central Soil Salinity Research Institute in Karnal, India has developed varieties of rice, wheat, and Indian mustard that are tolerant to salt and alkaline soils as well as efforts to incorporate salt tolerance into wheat from closely related wild species. Other examples of conventional breeding programmes for drought tolerance include efforts to develop maize hybrids with increased drought tolerance. On the other hand, the creation of tolerant crops by genetic engineering entails locating the key genes underpinning stress tolerance in plants and introducing these genes into crops. Plants respond to drought in a variety of physiological ways, and it also affects how many genes operate. Numerous hundred genes that are either activated or repressed during the drought have been discovered via research on gene expression. Using gene transformation methods, the gene responsible for drought tolerance has been found, isolated, and introduced to agricultural plants. To produce transgenic plants that provide drought tolerance, genetic engineering mostly uses two methodologies, namely the targeted and shotgun approaches.

Micropropagation

One technique used in tissue culture to quickly enhance the growing supply of needed plant material is micropropagation. Most plants that are propagated are resistant to disease. This is a cutting-edge method of vegetative propagation. Commercially, micropropagation from tiny explants may be utilised for asexual propagation to create a huge number of the same plants with the same genetic make-up. Large numbers of plants can be generated quickly and kept alive in constrained areas, preserving certain endangered species and genetic resources. The finest illustration of this method is a disease-free banana. Regenerating disease-free banana plantlets from healthy tissues is a technique known as micropropagation. It has all the advantages of being a reasonably affordable and simple technique. Avocados, pineapple, citrus, coffee, and papaya are more examples of crops grown utilising tissue culture. Agricultural biotechnology applications help sustain food production. It provides a variety of tools to improve our knowledge of and management of the genetic resources for food and agriculture. The generation of crops with improved nutritional value, insect and disease resistance, and cheap production costs are only a few of the novel uses of science that modern biotechnology demonstrates. When applied responsibly and ethically, biotechnology in the context of genetic alteration has the potential to provide significant advantages.

Using genetically engineered microorganisms, fungi, plants, and animals, biotechnology primarily deals with the industrial-scale manufacture of biopharmaceuticals and biologicals. This is something you probably learned from the previous chapter. Therapeutics, diagnostics, genetically modified crops for agriculture, processed foods, bioremediation, waste management, and energy generation are just a few of the uses for biotechnology.

1. Providing the finest catalyst in the form of an enhanced organism, often a microbe or pure enzyme, is one of the three crucial biotechnology study fields. Engineering the best circumstances for a catalyst to work;
2. Purifying the protein or organic component; and
3. Using downstream processing methods.

Let's examine how biotechnology has been utilised by people to enhance their quality of life, particularly in the areas of food production and health.Although the food supply tripled as a result of the Green Revolution, there was still insufficient food to support the world's expanding population. Improved crop types have contributed to higher yields in part, but better management techniques and the use of agrochemicals have been the primary drivers (fertilizers and pesticides). Agrochemicals are often too costly for farmers in underdeveloped nations, and traditional breeding cannot boost yields with current types. Is there another route that genetics' expertise can point us in so that farmers can maximise the production from their fields? Is it possible to use pesticides and fertilizers less often so that their negative impacts on the environment are lessened? One approach is to use genetically modified crops.

Genetically Modified Organisms are any plants, bacteria, fungi, or animals whose genes have been changed (GMO). GM plants have a variety of uses.

1. Crops are now more resistant to biotic and abiotic stressors thanks to genetic manipulation (cold, drought, salt, heat).
2. Reducing the use of chemical pesticides (pest-resistant crops).
3. Aided in lowering losses after harvest.
4. Improved plant mineral use efficiency (this prevents early exhaustion of fertility of soil).
5. Improved nutrient content of food, such as golden rice, which is rice that has been vitamin "A" supplemented.

In addition to these applications, GM has been utilised to design plants specifically for supplying starches, fuels, and medications as alternatives to traditional resources to companies. You will explore in-depth uses of biotechnology in agriculture, such as the development of pest-resistant plants that might reduce the need for pesticides. A bacteria called *Bacillus thuringiensis* produces the Bt toxin (Bt for short). To give insect resistance without the use of pesticides, the Bt toxin gene was cloned from bacteria and expressed in plants; this effectively developed a bio-pesticide. Bt cotton, Bt maize, Bt rice, Bt tomatoes, Bt potatoes, etc. are a few examples.

Bt Cotton: Some *Bacillus thuringiensis* strains generate proteins that kill specific insects, including dipterans, lepidopterans, and coleopterans (beetles, armyworms, and tobacco budworms) (flies, mosquitoes). During a certain stage of their development, *B. thuringiensis* produces protein crystals. A poisonous insecticidal protein is present in these crystals. Why doesn't the Bacillus be killed by this toxin? The Bt toxin protein exists as inactive protoxins, but when an insect ingests it, the alkaline pH of the stomach causes the crystals to dissolve, turning the dormant toxin into an active form of toxin. The midgut epithelial cells' surface is where the active toxin attaches, forming holes that lead to cell swelling and lysis and ultimately result in the insect's death. From *Bacillus thuringiensis*, specific Bt toxin genes were extracted and inserted into a variety of agricultural plants, including cotton. Since the majority of Bt toxins are insect-group specific, the choice of genes depends on the crop and the targeted pest. A gene called cryIAc encodes the toxin. There are many of them; for instance, the proteins controlled by the genes cryIAc and cryIIAb and cryIAb govern the corn borer.

Plants That Resist Pests

Numerous nematodes parasitize a broad range of plants, animals, and even people. The roots of tobacco plants are infected by the nematode *Meloidegyne incognitia*, which significantly reduces production. A unique approach based on the RNA interference mechanism was used to stop this invasion (RNAi). All eukaryotic species use RNAi as a kind of cellular defence. With this technique, a particular mRNA is silenced by a complementary dsRNA molecule that binds to it and inhibits the mRNA from being translated (silencing). This complementary RNA may have originated from an infection with a virus with an RNA genome or from transposons, which are mobile genetic elements that reproduce through an intermediary RNA. Nematode-specific genes were inserted into the host plant using Agrobacterium vectors. DNA was introduced in a way that caused the host cells to create both sense and anti-sense RNA. The complementary nature of these two RNAs resulted in the formation of a double-stranded (ds) RNA, which started RNA interference and silenced a particular nematode mRNA. As a result, the parasite was unable to thrive in a transgenic host that was producing a particular interfering RNA. Consequently, the transgenic plant acquired parasite protection.

Applications of biotechnology in medicine

Recombinant DNA technical advancements have had a significant influence on healthcare by allowing the mass manufacture of therapeutic medications that are safer and more effective. Furthermore, unlike comparable products obtained from non-human origins, recombinant therapies do not cause unintended immunological reactions. Approximately 30 recombinant medicines have now received global human use approval. Twelve of them are currently being offered in India.

Insulin Made Through Genetic Engineering

By taking insulin at regular intervals, adult-onset diabetes may be controlled. If there wasn't enough human insulin, what would a diabetic patient do? You would quickly realise if you spoke about it that one would need to separate and utilise insulin from other animals. Would human body-secreted insulin be equally as effective as that from other animals, and would it not trigger an immunological reaction in humans? Now consider the possibility of a bacteria producing human insulin. All of a sudden, the procedure seems so straightforward. You can simply grow a lot of the bacteria and produce all the insulin you need.

Previously, pancreas from butchered pigs and cattle were used to make the insulin needed to treat diabetes. Even yet, some individuals who received animal-derived insulin had allergic or other sorts of responses to the alien protein. Chain A and Chain B, the two short polypeptide chains that makeup insulin, are joined by disulfide bridges. In animals, including humans, the hormone insulin is produced as a pro-hormone that has an additional stretch known as the C peptide. Prohormones, like pro-enzymes, must be processed to become fully mature and functioning hormones. This C peptide is eliminated throughout the maturation process to create mature insulin, which does not include it. Using rDNA methods, the biggest problem in producing insulin was assembling it into a mature state. In 1983, the American corporation *Eli Lilly* created two DNA sequences that represented the A and B chains of human insulin and inserted them into the plasmids of *E. coli* to manufacture the chains. Human insulin was made from the independent production of chains A and B, their extraction, and disulfide bonding.

The use of genes

Can a person have a remedial treatment if they are born with a genetic illness? This is what gene therapy tries to accomplish. A gene abnormality that has been identified in a kid or embryo may be corrected using a variety of techniques known as gene therapy. In this instance, genes are injected to cure an illness into a person's cells and tissues. A normal gene is introduced into the person or embryo to take over the non-functional gene's function and make up for it to correct a genetic abnormality. A 4-year-old child with adenosine deaminase (ADA) deficiency received the first clinical gene therapy in 1990. The immune system's ability to operate depends on this enzyme. The loss of the adenosine deaminase gene is what causes the illness. Bone marrow transplantation may treat ADA deficiency in certain children, whereas enzyme replacement treatment, in which the patient receives functioning ADA by injection, can treat it in others. However, the drawback of both of these methods is that they are only partially curative. Lymphocytes from the patient's blood are cultivated in a culture outside of the body as a first step in gene therapy. Then, these cells are given a functioning ADA cDNA (using a retroviral vector), and they are given back to the patient. However, since these cells are not immortal, the patient has to get these genetically modified lymphocytes regularly. However, a lasting treatment could be possible if the ADA-producing gene isolates from marrow cells are inserted into the cells during the early phases of embryonic development.

Genetic Analysis

You are aware of how crucial early diagnosis and knowledge of a disease's pathogenesis are to its successful treatment. Early detection is not achievable using traditional diagnostic techniques (such as serum and urine analyses). Some of the methods used for early diagnosis include recombinant DNA technology, Polymerase Chain Reaction (PCR), and Enzyme-Linked Immuno-sorbent Assay (ELISA). A pathogen's (bacteria, viruses, etc.) presence is often only suspected after the infection has caused a clinical manifestation. At this point, the body's pathogen concentration is already exceedingly high. However, by amplifying their nucleic acids using PCR, bacteria or viruses with extremely low concentrations (at a period when the disease's symptoms are not yet apparent) may be found. PCR is now often used to identify HIV in people suspected of having AIDS. Additionally, it is utilised to find gene alterations in those who may have cancer. It is an effective method to find many different genetic diseases. In a clone of cells, a single-stranded DNA or RNA that has been radioactively labelled (tagged with a probe) is allowed to hybridise with its corresponding DNA before being detected by autoradiography. Because the probe lacks complementarity with the mutant gene, the clone with the altered gene will thus not show up on the photographic film. The foundation of ELISA is the antigen-antibody interaction theory. Antigens (proteins, glycoproteins, etc.) or antibodies made against the pathogen may be used to identify the existence of a pathogen infection.

Transgenic animals are those who's DNA has been altered so they have an additional (foreign) gene and can express it. Although transgenic mice make up more than 95% of all currently existent transgenic animals, transgenic rats, rabbits, pigs, sheep, cows, and fish have also been generated. Why is it necessary to generate these animals? How does man stand to gain from such changes? Let's attempt to examine a few of the prevalent causes:

Normal development and physiology

Transgenic animals may be particularly created to enable the study of how genes are controlled and how they impact the body's development and normal functioning, for example, the study of intricate growth-related factors like insulin-like growth factors. Information regarding the biological function of the factor in the body is discovered by introducing genes from different species that modify the creation of the factor and by examining the biological repercussions that follow. To better understand how genes influence the onset of illness, several transgenic animals are created. These were created specifically to act as models for human diseases, enabling the exploration of potential novel therapies for illnesses. Many human illnesses, including cancer, cystic fibrosis, rheumatoid arthritis, and Alzheimer's, have transgenic models available today.

Biological substances

Certain human illnesses may be treated using medicines that include biological products, although producing such molecules is often costly. The insertion of the piece of DNA (or genes) that codes for a specific product, such as the human protein (-1-antitrypsin) used to cure emphysema, may result in transgenic animals that generate beneficial biological products. Similar efforts are being conducted to treat cystic fibrosis and phenylketonuria (PKU). The first transgenic cow, Rosie, produced milk enhanced with human protein in 1997. (2.4 grammes per litre). The milk was a more nutritionally complete product for human newborns than natural cow-milk since it incorporated human alpha-lactalbumin.

Vaccine efficacy

To assess the safety of vaccinations before administering them to people, transgenic mice are being created. Testing the safety of the polio vaccination on transgenic mice. They might take the place of using monkeys to evaluate the safety of vaccination batches if effective and shown to be dependable.

Testing for chemical safety

Testing for toxicity and safety is what this is. The method is the same as that used to assess medication toxicity. Genes are inserted into transgenic animals to increase their sensitivity to toxins compared to non-transgenic animals. After which, the impacts of the harmful compounds are evaluated. We can get data faster if we screen for toxicity in these animals.The public's indignation about some businesses receiving patents on goods and innovations that employ genetic resources, plants, and other biological resources that farmers and indigenous people of a particular area or country have long discovered, produced, and utilised is rising. The history of rice cultivation in Asia dates back thousands of years, making it a significant food crop. In India alone, there are said to be 200,000 different types of rice. India has one of the widest varieties of rice in the whole globe. There are 27 known types of Basmati rice farmed in India, and they are distinguished by their distinctive scent and flavour. Since it has been cultivated for so long, Basmati is mentioned in ancient writings, folklore, and poetry. A US corporation obtained patent protection for basmati rice in 1997 from the US Patent and Trademark Office. Because of this, the firm was able to offer a "new" strain of Basmati both domestically and overseas. This 'new' Basmati type was taken from farmer's varieties in India.

Semi-dwarf cultivars were crossed with Indian Basmati, and the result was marketed as a new creation or novelty. Since the patent covers functional counterparts, it implies that it may impose restrictions on other vendors of Basmati rice. Additionally, there have been other efforts to patent uses, goods, and methods based on Indian traditional herbal remedies, such as turmeric and neem. If we are not watchful and do not quickly oppose these patent applications, other nations or people may profit from our valuable heritage and we may not be able to stop them.

The exploitation of bio-resources by multinational corporations and other organisations without formal authorization from the nations and people affected or with payment instead of compensation is referred to as "biopiracy." Although the majority of industrialised countries are wealthy monetarily, they lack traditional wisdom and biodiversity.

The emerging and underdeveloped globe, in contrast, has a wealth of traditional knowledge about bio-resources. Traditional knowledge about bioresources may be leveraged to create contemporary applications and can also be used to save costs, time, and effort when they are being commercialised. The unfairness, insufficient remuneration, and unequal benefit sharing between rich and poor nations are becoming more evident. Because of this, several countries are creating legislation to stop the unauthorised use of their bioresources and traditional knowledge. The second amendment to the Indian Patents Bill, which takes into account problems like emergency clauses for patent periods and R&D initiatives, was recently approved by the Indian Parliament.

By using bacteria, plants, animals, and their metabolic systems, biotechnology has provided humans with several beneficial goods. Recombinant DNA technology has allowed for the genetic engineering of bacteria, plants, and animals to give them new capacities. Using techniques like recombinant DNA technology, it is possible to construct genetically modified organisms by transferring one or more genes from one creature to another outside of the natural process. Increased agricultural yields, lower post-harvest losses, and increased stress tolerance have all been achieved with the help of GM plants. Various GM agricultural plants increase food quality and minimise the need for chemical pesticides (pest-resistant crops). Because they allow for the mass manufacture of safer and more potent treatments, recombinant DNA technical techniques have had a significant influence on the healthcare industry. Recombinant therapies are free from the danger of infection since they are identical to human proteins and do not cause unintended immunological reactions, as was shown in the case of comparable products derived from non-human sources.

Despite being produced by bacteria, human insulin has a structure that is utterly similar to that of the natural molecule. Using transgenic animals as models for human illnesses including cancer, cystic fibrosis, rheumatoid arthritis, and Alzheimer's disease allows researchers to better understand how genes influence the onset of disease. To cure illnesses, particularly genetic ailments, gene therapy involves inserting genes into a patient's cells and tissues. It does this either by gene targeting, which entails gene amplification, or by replacing a dysfunctional mutant allele with a functioning one. To transmit healthy genes or, more recently, sections of genes, viruses that assault their hosts and insert their genetic material into the host cell as part of their replication cycle are utilised as vectors.

Golden rice is a kind of rice (*Oryza sativa*) that has undergone genetic engineering for the edible sections of the rice to biosynthesize beta-carotene, a precursor of vitamin A. The goal is to create fortified food that can be cultivated and eaten in regions that lack dietary vitamin A. A lack of vitamin A results in xerophthalmia, which includes permanent blindness as well as a variety of eye diseases ranging from night blindness to more serious clinical consequences including keratomalacia and corneal scarring. Additionally, it raises children's mortality risks from both diarrhoea and the measles. In 2013, South Asia (44%; 13-79) and sub-Saharan Africa (48%; 25-75) had the greatest frequency of deficiency.

More than 100 Nobel laureates advocated the use of genetically modified golden rice in 2016 even though it has faced major resistance from environmental and anti-globalization campaigners and can generate up to 23 times as much beta-carotene as the original golden rice.A Rockefeller Foundation project started the research into the creation of golden rice in 1982. Peter Bramley found in the 1990s that a single phytoene desaturase gene (bacterial CrtI) may be used to convert phytoene into lycopene in a genetically modified tomato, as opposed to needing to add numerous carotene desaturases, which are typically utilised by higher plants.

The endogenous cyclase in golden rice then cycles lycopene into beta-carotene. After an eight-year effort by Ingo Potrykus of the Swiss Federal Institute of Technology and Peter Beyer of the University of Freiburg, the scientific specifics of the rice were first published in 2000. The Louisiana State University Agricultural Center carried out the first field tests of golden rice varieties in 2004. Additional trials were performed in Bangladesh, Taiwan, and the Philippines (2015). Field testing made it possible to carry out feeding studies and gave an accurate determination of nutritional value. Golden rice produced in the wild generates 4 to 5 times more beta-carotene than golden rice grown in a greenhouse, according to preliminary findings from field studies.

Crossbreeding

Breeders were creating golden rice variants of current rice varieties utilised by their local farmers as of 2018 at the Philippine Rice Research Institute, Bangladesh Rice Research Institute, and Indonesian Centre for Rice Research while maintaining the same yield, insect resistance, and grain quality. Farmers may pay the same for golden rice seeds as they do for other rice kinds.

Golden rice was given the go-ahead in 2018 by both the US Food and Drug Administration (FDA) and Health Canada, who both deemed it safe for ingestion. This came after the FDA declared in 2016 that the level of beta-carotene in golden rice did not supply enough vitamin A for US markets. Health Canada said that other than the expected high amounts of provitamin A, the nutritional composition of golden rice was identical to that of regular rice types and would not alter allergies. Golden rice may now be processed in the Philippines or used as food for people and animals. The Philippines was the first nation to formally grant the biosafety permit for the commercial propagation of vitamin A-infused golden rice on July 21, 2021. The clearance marked South and Southeast Asia's first legalisation of the commercial cultivation of genetically modified rice. The authorization allows for the commercial cultivation of golden rice under the criteria and circumstances outlined by the Philippine government. To ensure that they are solely produced in the endosperm, the psy and crtI genes were inserted into the nuclear genome of rice and put under the control of an endosperm-specific promoter. The transit peptide sequence on the exogenous lcy gene directs it to the plastid, which is where geranylgeranyl diphosphate is produced. Since it can catalyse numerous stages in the production of carotenoids up to lycopene, but these processes need more than one enzyme in plants, the bacterial crtI gene was crucial in completing the pathway. Lycopene is the result of the designed route however, rice would turn red if lycopene built up in the plant.

According to recent research, the plant's internal enzymes convert lycopene to beta-carotene in the endosperm, giving rice its recognisable yellow colour. Under greenhouse circumstances, the original golden rice, known as SGR1, generated 1.6 g/g of carotenoids. Golden Rice 2 was created in 2005 by a Syngenta research team. They coupled the crtl gene from the original golden rice with the phytoene synthase (psy) gene from maize. Due to the psy gene of maize being the most efficient gene for carotenoid synthesis and preferentially accumulating beta-carotene (up to 31 g/g of the 37 g/g of carotenoids), Golden Rice 2 generates 23 times more carotenoids than golden rice (up to 37 g/g).

Vitamin A deficiency's prevalence

Golden Rice was developed as a result of research aimed at assisting kids with vitamin A deficiency (VAD). According to estimates, micronutrient deficiencies affect over 1.02 billion individuals worldwide, with vitamin A being the nutrient most often deficient in the body. Around 250 million preschoolers are afflicted by VAD, according to a 2012 assessment from the World Health Organization, and giving those kids vitamin A might save approximately a third of all under-five fatalities, saving up to 2.7 million kids from needless deaths. About one-third of children aged 6 to 59 months in 2013 had vitamin A deficiency, according to the World Health Organization, with sub-Saharan Africa (48%) and South Asia having the highest rates (44 per cent). The 1990s saw the start of VAS initiatives in response to data showing a link between VAD and higher infant mortality.

More than 40 effectiveness trials of VAS in infants aged 6 to 59 months were carried out between 1990 and 2013, and two systematic reviews and meta-analyses concluded that VA supplements may significantly lower infant mortality and morbidity. As of 2017, more than 80 nations across the globe were running semi-annual national campaigns to develop universal VA supplementation (VAS) programmes for infants aged six to 59 months. Periodic supplementation with high doses of vitamin A is a well-researched, low-cost intervention that has been demonstrated to decrease all-cause mortality by 12 to 24%, making it a crucial programme in support of initiatives to lower child mortality. Nevertheless, UNICEF and several NGOs engaged in dietary supplements indicate that regular low-dose dietary supplementation is preferred.

Since rice is a staple food for many children in VAD-affected nations, genetically altering rice to produce the vitamin A precursor beta-carotene was thought to be an easy and less expensive alternative to continuing vitamin supplements or increasing the consumption of green vegetables or animal products. Initial studies on the possible nutritional advantages of golden rice revealed that although it wouldn't solve the issues associated with vitamin A deficiency, it may complement other supplements. Golden Rice 2 has enough provitamin A to meet the complete daily requirement with a daily intake of around 75g. An imbalanced diet is often associated with a vitamin A deficit. Golden rice or the majority of other vitamin A supplements cannot treat vitamin A insufficiency because carotenes are hydrophobic; thus, a significant amount of fat must be consumed in the diet. A bowl of the most recent variety of Golden Rice delivers 60% of the RDA for healthy youngsters; this claim, however, applied to an early cultivar of the grain.

The RDA values recommended in affluent nations are far higher than what is required to avoid blindness.

Those who oppose genetically modified crops have voiced several concerns. Golden Rice's initial lack of enough beta-carotene content was a problem. The GR2E event's advancement provided the solution to this issue. There is disagreement on how quickly beta-carotene degrades after the rice is harvested and how much is left behind after cooking. However, a 2009 research found that people can successfully convert the beta-carotene found in golden rice into vitamin A. Greenpeace contends that the production of golden rice would pave the way for the use of genetically modified organisms (GMOs) to become more pervasive. They also oppose the use of any patented GMOs in agriculture. By stating that "None of the companies listedis involved in carrying out the research and development activities of IRRI or its partners in Golden Rice, and none of them will receive any royalty or payment from the marketing or selling of golden rice varieties developed by IRRI," the International Rice Research Institute (IRRI) has highlighted the non-commercial nature of their project.

Indian anti-GMO campaigner Vandana Shiva claimed that rather than the plant itself, there may be problems with biodiversity loss. Shiva said that advocates of golden rice were hiding the restricted supply of varied and nutrient-dense food. Other parties contended that children would receive enough vitamin A through a balanced diet that included foods high in beta-carotene such as sweet potatoes, leafy greens, and fruit.

But according to Keith West of the Johns Hopkins Bloomberg School of Public Health, vitamin A-rich foods are sometimes hard to find, only accessible during certain seasons, or are too costly for low-income families to afford. [Francesco Branca, a WHO expert on malnutrition, stated in 2008 that "giving out supplements, fortifying existing foods with vitamin A, and teaching people to grow carrots or certain leafy vegetables are, for now, more promising ways to fight the problem." He cited the lack of real-world studies and uncertainty regarding how many people will use golden rice.

A research that was published in The American Journal of Clinical Nutrition in 2012 was the subject of dispute. It was eventually discovered that the trial, which included giving GM rice to children in China aged 6 to 8, had broken federal and Tufts University regulations on human research. Subsequent evaluations discovered concerns with incomplete permission forms, unauthorised revisions to the research protocol, and a lack of clearance from an ethical review board located in China, but they found no indication of safety issues with the trial. The GM rice used was also illegally imported into China. The International Rice Research Institute is being aided in the creation of golden rice by the Bill and Melinda Gates Foundation, which also promotes the use of genetically modified organisms in agricultural development. In a letter published in June 2016, 107 Nobel laureates pleaded with Greenpeace and its allies to end their campaign against GMOs in general and golden rice in particular. In May 2018, the U.S. Food and Drug Administration cleared the use of golden rice for human consumption, noting that it "had no more issues about human or animal food produced from GR2E rice at this time" based on the evidence IRRI had provided to the FDA. This is the fourth national health organisation to endorse the consumption of golden rice in 2018; earlier this year, Australia, Canada, and New Zealand did the same.

The National Academy of Sciences of the United States of America published an opinion piece in December 2021 urging regulators to "allow Golden Rice to save lives," which the authors claim has been delayed because of "fear and false accusations," resulting in an estimated 266'000 lives lost per year due to vitamin A deficiency. Artificial seed technology was required right away once it was found that numerous plant species could create somatic embryos in vitro. The oldest description of synthetic seeds, or synsets, comes from Murashige. Artificial seeds were characterised by the author as encapsulated somatic embryos. Later, the definition of an artificial seed stated that it is a somatic embryo created for use in actual plant development for commercial purposes. The concept of synthetic seeds was then limited to plant species where somatic embryo development could be seen.

What defines fake seeds depends on the similarity between the physiology, morphology, or biochemistry of somatic and zygotic embryos. The concept of artificial seeds was subsequently extended to cover a range of in vitro propagules due to certain plant species' resistance to somatic embryogenesis.

Later, the definition of "artificial seeds" was broadened to include any micropropagules that can be planted as seeds and develop into plants in an in vitro or ex vitro environment, as well as synthetically coated somatic embryos typically and other vegetative components like shoot buds, cell aggregates, auxiliary buds, or any other micropropagules.

They should also be able to continue practising this talent for a very long period of storage ability. The value uses, and advantages of synthetic seeds utilizing the benefits of a vegetative regeneration system with the potential for long-term preservation, several artificial seed applications in agriculture have been created as shown in figure 10.1. For the production of artificial seeds, two kinds of crops are grown: those with outstanding somatic embryo quality and those with reliable business models.

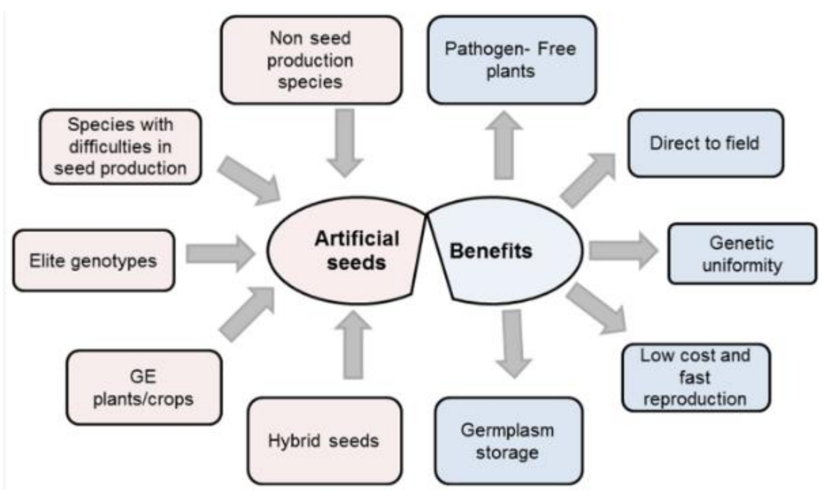

Figure 10.1: Illustrate the Use of Artificial Seeds and Their Advantages.

Encapsulation technology can be seen as a promising approach that can be used to achieve germplasm conservation or the propagules that are produced in vitro or by micropropagation added topically in nurseries or a field, as well as for the buying and selling of plant materials between public and private plant tissue culture laboratories. Since artificial seeds are produced using aseptic tissue culture techniques, they are also pathogen-free, which considerably facilitates their ability to be sent internationally and stops the spread of plant diseases. Artificial seeds are also helpful since they serve as a protective covering, increasing the success rate of field micropropagation. When being handled, transferred, and stored, artificial seeds are also more durable. Artificial seed creation is also a useful technique as a clonal propagation approach in terms of preserving the genetic homogeneity of plants, direct distribution to the field, low cost, and speedy plant reproduction.

Artificial seeds might be beneficial for many species, including grass plants. Artificial seeds, or more accurately encapsulated somatic embryos, may open up new avenues for the regeneration of natural areas (such as rangelands, meadows, woods, abandoned mining lands, etc.) damaged by overgrazing or climate change. Unfortunately, the soil's seed bank or the mother plants' natural seed production cannot make up for the loss of naturally stored seeds brought on by pressure year after year due to the aforementioned issues. The future of land restoration will be determined by how often embryos or embryogenic calluses are produced and how they are used to create artificial seeds. Artificial seed production may serve as a technique for the significant scale-up required for multi-clone commercial production. Additionally, compared to traditional tissue culture procedures, this process requires less time, space, and medium. There are various advantages to comparing artificial seed creation to traditional tissue culture methods. Artificial seeds are made at a fair price and are easy to handle, plant, and transport.

The efficient creation of synthetic seeds using plant propagules from several plant species that have been encapsulated. Once methods were optimised, the proper plantlets were generated. This technique offers several advantages, including reduced plantlet costs, a simple process with excellent potential for scale production, a viable approach for employing artificial seedlings directly in vivo, and a big storage capacity. The extent to which this process will advance depends on the plant species employed in the first stage. Nevertheless, despite the advantages of artificial seeds, further research is required to improve the capacity of non-embryogenic artificial seeds to establish roots. More study is needed to improve the capacity of artificial seed growth on commercial substrates and outside of sterile conditions. Although more thorough research is needed, it may be possible to improve the ability of artificially preserved seeds in some plant species by applying the proper kinds and dosages of antibiotics and anti-disease agents.

Mushroom Cultivation

Similar to how apples are the fruiting bodies of an apple tree, mushrooms are the fruiting bodies of a fungus. A fungus with the Latin name *Agaricus bisporus* is referred to as a mushroom. The oyster mushroom (*Pleurotus ostreatus*) and shiitake are two other types of mushrooms grown in the Netherlands. The mushroom is considered to be a heterotrophic creature in the vegetable world (lower plants). These heterotrophs cannot photosynthesize, in contrast to higher, greener plants. The scavengers of nature are fungi. Waste materials including chicken manure, horse manure, straw, gypsum, and wastewater (from their own composting) are also utilized in the growing of mushrooms to create a high-quality substrate from which the mushrooms will develop. The process air is cleaned of ammonia using an ammonia washer before being released back into the environment. In the process of composting, even airborne ammonia is utilized as a source of nitrogen. The mycelium-like fungus uses compost as a source of energy for its combustion, which releases energy for growth.

In climate-controlled cropping houses, button mushrooms are produced in India according to the season. The vegetative (spawn run) growth of the white button mushroom requires 20–28^{0}C, while the reproductive growth needs 12–18^{0}C. additionally, it needs sufficient ventilation and relative humidity of 80–90% for cropping. It is grown eight to ten months out of the year on the hills as well as in winter in India's northwest plains. But because of advancements in growing techniques, this fungus can now be grown wherever in India. Depending on the kind and species of mushrooms grown, the farmers can harvest an average of 3–4 crops of white button mushrooms every year. Pest/pathogen occurrence and the lack of pure, high-quality spawn are two factors that have an impact on the crop's output, both in terms of quality and quantity.

As has been done for hundreds of years, mushrooms may be cultivated on logs that have been stacked or piled outside. This procedure doesn't sterilize anything. Less than 5% of available commercial mushrooms are grown in this manner due to output being erratic and seasonal. Here, spawn is used to inoculate tree logs, which are then allowed to develop naturally. Seasonal fluctuations or short immersing the logs in chilly water can cause fruiting, or pinning. The outdoor log method has historically been used to cultivate shiitake and oyster mushrooms, while more regulated methods such as indoor tray growth or fake logs composed of the compressed substrate have now taken their place.

Oyster and Mushroom Farming Inside

Around the world, oyster mushroom farming is developing quickly. Mushroom farming is one of the most popular industries among rural communities due to growing consumer demand and awareness of its nutritional benefits.Although it takes up less land than other crops, oyster mushrooms are cultivated on a substrate that includes paddy straw, sterilized wheat, and even discarded coffee grounds. Compared to other crops, it produces more per unit and earns more money. The most typical equipment for cultivating oyster mushrooms indoors is a box with growth media and spores.

Mushroom Cultivation in India

In India, fifty percent of mushrooms are produced by marginal farmers and small manufacturing businesses, and the remaining twenty percent is produced by industrial organizations. In India, there are two different kinds of mushroom farmers: seasonal farmers and small-scale producers. While a commercial mushroom grower continues year-round large-scale output. Most often, both domestic and international markets for white button mushrooms are developed. Farmers in temperate places like Himachal Pradesh, Jammu and Kashmir, hilly sections of Uttar Pradesh, hilly areas in Tamil Nadu, and North Eastern areas can only produce seasonal button mushrooms there, where they can harvest two to three plants each year.

Commercial mushroom farming needed significant financial outlays for infrastructure construction, machinery and equipment purchases, raw material purchases, labor costs, and energy costs. A mushroom farmer must participate in a training program that emphasizes practical application.

For effective participation and monitoring purposes, the mushroom farm should be located closer to the farmer's home. Lots of water is available on the farm, and it's simple to find raw materials in the area at reasonable rates. It's also easy to find workers at lower costs. The availability of power at affordable rates, as electricity is an important input in the production of mushrooms.

There should be protection for the farm from industrial pollutants such as chemical fumes. There should be provisions for sewage disposal; and there should be provisions for the farm's potential future expansion.

Pests and Diseases

Production inside is in danger from fungus, bacteria, and parasitic insects. In the development media, phorid or sciarid flies might lay their eggs, which hatch into maggots and harm budding mushrooms at all growth stages. During the fruiting stage, bacterial blotches brought on by Pseudomonas bacteria or patches of Trichoderma green mold can potentially be dangerous. There are various pesticides and sanitizing treatments to use against these pests. Sciarid and phorid fly biological controls have also been suggested. Trichoderma green mold can have an impact on mushroom output; for instance, in Pennsylvania in the middle of the 1990s, it caused major crop losses. The contaminated fungus was caused by the staff' inadequate hygiene practices and shoddy growth substrate preparation.

Plant Gene Modifications

Genetic engineering techniques are used to change the DNA of transgenic plants. The idea is to give the plant a unique characteristic that does not occur in the species normally. An intentionally inserted gene or genes are present in transgenic plants. Transgenes are gene sequences that have been added; they may originate from unrelated or entirely unrelated plant species. A gene combination is introduced into a plant to boost its output and usefulness. A few benefits of this approach include increased yield, better quality, insect resistance, heat, cold, or drought tolerance, as well as resilience to various biotic and abiotic stressors. Another option is to create transgenic plants that express foreign proteins useful in industry and medicine. Since plants don't get human illnesses and so need less frequent screening for viruses or bacterial toxins, it is particularly challenging to find plants with vaccinations or antibodies (Plantibodies).

Transgenic Plant Creation

The genetic makeup of plants is changed in a lab, often by adding one or more genes to the genome, to create genetically modified plants. The new transgenic DNA is intended to be inserted into the nucleus of the plant cell. The biolistic method or transformation process mediated by *Agrobacterium tumefaciens* is used to manufacture the majority of genetically engineered plants. Maize and rice are the two most often used crops for Gene Gun technology, commonly referred to as "Micro-Projectile Bombardment" or "Biolistic." This technique involves firing DNA-coated gold or tungsten particles into plant tissue or individual plant cells at high pressure. The membranes or cell walls are being penetrated by speeding particles. Within the nucleus of the plant, the DNA separates from the coated metal and combines with the genome. Many crops, including well-known monocots like maize or wheat, for which transformation using *Agrobacterium tumefaciens* has been less successful, have been successfully converted using this approach. This strategy is hygienic and secure. The risk of severe cellular tissue damage is this method's main drawback.

Agrobacterium Mediates Gene Transfer

The pathogen *Agrobacterium tumefaciens* infects plants. Crown gall disease, which produces swelling in plants just above the soil line, is one of its well-known consequences. After being infected, the pathogens provide the plants with their genetic material, which is eventually integrated into the plant genome. To do genetic engineering, a Ti plasmid with the necessary genes is added to the bacteria or made to infect the plant. The Ti plasmid, a circular plasmid that generates tumours and provides the host chromosomes to the plants, also contributes to the enlargement. In this procedure, the target gene is hammered into the plant cells while being covered with a gold or tungsten particle. Tissue culture techniques may help the plant cells multiply once the sequence has been supplied and picked up by the plant cells.

Transgenic Plant Uses

Stress tolerance, both biotic and abiotic As a result of the presence of living things like bacteria, viruses, pests, and illnesses, plants are exposed to biotic stress. Disease-resistant genes are inserted into plants to lessen this stress and improve crop output and quality. Abiotic stress, which is brought on by environmental changes, causes serious harm to plants. Temperature, water content, humidity, and soil type are all important for plant development. Everything seems to have changed as a result of climate change. Plants are given stress-tolerant genes to increase yield.

A Growth in Nutritional Value

The process of increasing a crop's nutritional worth is called biofortification. Malnutrition is a widespread problem in developing nations. Plants are modified to provide foods with improved nutritional value as a treatment. Recombinant human proteins were previously created utilising animal and microbial systems, but this approach had several drawbacks. Transgenic plants have been used to create medications and vaccinations. This application is still in the development stage and has not yet been released on the market.

Examples of Transgenic Plant

Golden rice: Golden rice was created as a therapy for children who lack vitamin A. The phytoene synthase genes were inserted into rice species using gene gun techniques, boosting the amount of vitamin A in the rice grains. Cotton, BT Other plants, including the potato, papaya, maize squash, corn, pumpkin, and alfalfa, have also been engineered to generate crops with higher yields and resilience. This cotton has been genetically altered to be resistant to the bollworm pest.

Application of GM Crop

Increase Crop Productivity

Genetically modified seeds have the potential to boost agricultural production or, at the very least, preserve the maximum yield of vegetation. With reduced crop losses and improved yields, GMO plants with insect and herbicide tolerance can substantially simplify crop management. According to Mannion and Morse, compared to non-genetically modified varieties, GM soybean, cotton, and maize cultivars yielded yields that were 15%, 20%, and 7% greater, respectively.

Farmers all around the industry were convinced that businesses selling genetically modified seeds would boost output and profitability. According to GM seed producers, farmers were expected to accept GM plants because the changes they were making provided farmers with immediate, tangible benefits that may be linked to higher profits. The adoption of genetically modified plants, according to its proponents, would increase farming's productivity, adaptability, and profitability. Additionally, GM seed companies contend that the acceptance of GM crops lowers the usage of pesticides, which has a direct impact on the sustainability of cropping systems as well as farmer profitability. Some people have even suggested that growing GM plants can benefit nearby non-GM plants by lowering pest pressure in places where GM crops are often cultivated.

Favourable Effects on the Environment

Commercialized genetically modified plants often have lower pesticide and tillage requirements, which have positive environmental effects. Reducing the use of pesticides can conserve species that aren't the intended targets while also increasing the conservation of beneficial insects. As well as delivering indirect environmental advantages including lessened water contamination from fertilizer and pesticide runoff, lower tillage helps to mitigate soil erosion and pollution. The development of Bt maize is supposed to help cut down on the use of chemical pesticides as well as, to some extent, lower production costs. Reviewing potential environmental issues and unforeseen repercussions that might result from the introduction of a novel gene is part of the deregulation approach for GM crops. By introducing genes conferring tolerance to abiotic stresses like drought or inundation, extremes of heat or cold, salinity, aluminium, and heavy metals, improvements in GM technology will almost certainly allow marginal land to become more productive and may facilitate the remediation of contaminated soils. Consequently, the GM era provides the possibility of increasing agricultural land output while lowering the impact on the environment.

Most GMOS are Inexpensive

GMOs help farmers to spend less time on assets, which allows them to generate more income. Because these organisms are created to be pest-resistant, which removes the need for pesticides and saves money, it is also cost-effective. Because GMO crops are genetically modified to grow rapidly, farmers can produce the same quantity of food with a lot less land, water, and pesticides than they could with conventional crops.

By hoarding resources, meal producers may be able to lower the cost of GMO ingredients. Ingredients like beets, corn, and soybeans may also be lowered by 15 to 30 percent in other situations. A DNA sequence that indicates the presence or absence of a specific feature or characteristic gene.

They Enhance the Worth of Crops

The purpose of genetically modified organisms is to provide more vitamins, minerals, and other nutrients to the diet. For instance, scientists were able to create a modified form of African maize that has 169 times as much beta-carotene as regular plants, 6 times as much vitamin C, and 2 times as much folate as standard crops. This is especially helpful in areas where there are dietary deficiencies among the populace. The main justification for creating GMO plants is that these flowers contribute to the nutritional content of food, especially for those who previously lacked vital vitamins and minerals. These crops may be genetically modified to increase their nutritional content, which is crucial for those who are hungry. As a result of GMOs' ability to withstand pests and other plant illnesses, agricultural output can be increased without the usage of pesticides. Superior plants or yields almost usually imply reduced costs, a benefit that may be passed on to customers in the shape of more affordable food items. Families that are unable to afford to shop for needs regularly may find this to be extremely beneficial. Additionally, this makes it feasible to stop starvation.

Several GMO crops have been modified to reduce their susceptibility to insects and pests. For instance, the GMO crop Bt-corn has a gene from the soil bacterium Bacillus thuringiensis. This gene instructs the maize to produce a protein that kills a variety of bugs and pests, helping to safeguard the grain. As a result, farmers will be required to use less pesticide on crops like Bt-corn since they don't need to be sprayed with sophisticated pesticides because they already have an inbuilt pesticide, according to Norris. Farmers that used GMO plants decreased their pesticide usage by 775.4 million kilograms (8.3%) between 1996 to 2018, according to 2020 research. In addition to posing fewer health risks to individuals who consume the plant, using fewer pesticides might also have a positive impact on the environment. After extensive testing and evaluation, it may be determined that GMOs and other related products are safe for human consumption. When examined closely, it is discovered that they are even more secure than conventional crops.

Genetically Modified Rice

About 2 billion individuals worldwide suffer from micronutrient malnutrition, which is defined as inadequate consumption levels of vitamins and minerals. Biofortification is increasingly being promoted as an alternative to the existing micronutrient therapies to lessen the burden of this "hidden hunger."

It might alleviate micronutrient deficiencies where the need is greatest by raising the number of micronutrients in staple crops. Because staple crops typically have low amounts of micronutrients, genetic breeding techniques are frequently used to raise concentrations of certain vitamins, such as folate and provitamin A. This investigation clarifies the current state of biofortification, micronutrient deficiency, and GM biofortified rice as a GM food product with health advantages and a micronutrient intervention.

Rice varieties that have undergone genetic modification are known as genetically modified rice (also called genetic engineering). Rice plants have been altered to synthesise human proteins, withstand pesticides, tolerate herbicide tolerance, tolerate herbicide tolerance, enhance grain size, and boost photosynthesis. Through gene transfer mediated by natural vectors, rice may also experience the natural flow of genes between species, often known as horizontal gene transfer or lateral gene transfer. There have been found transgenic interactions between Setaria millet and rice. The usage and production of rice that has undergone genetic modification is still debatable and is not permitted in certain nations. According to the Qingdao Saline-Alkali Tolerant Rice Research and Development Center, salt-tolerant "seawater" rice has been grown on 400,000 hectares (990,000 acres) of land in China as of 2021, with yields average 8.8 tonnes per hectare on soils with up to 4 grammes of salt per kilogramme.

Resistance to herbicide

Monsanto looked at making rice glyphosate-tolerant in 2000–2001 but didn't try to commercialise a variety. LibertyLink rice is glufosinate-resistant (the active chemical in Liberty herbicide). Bayer CropScience is working to convince the EU to accept their most recent variety (LL62). Although the strain has US approval, it is not widely used. Clearfield rice was developed by the selection of variants produced in conditions known to hasten the pace of mutation. Imidazole herbicides are tolerated by this variety. It was produced using conventional breeding methods, which are not regarded as genetic engineering. To create an all-around tougher plant, Clearfield is also mated with better-producing cultivars.

Nutritive worth

Ingo Potrykus and his crew were the ones who first developed golden rice with greater vitamin A concentrations. This genetically altered rice can produce beta-carotene, a precursor to vitamin A, in the endosperm (grain). A portion of the intellectual property that Syngenta controlled and was engaged in the early development of Golden Rice was transferred to nonprofit organisations, such as the International Rice Research Institute (IRRI), for their non-profit development. In 2000, Science Magazine was the first publication to reveal the rice's scientific specifics.

According to the World Health Organization, 30% of people worldwide suffer from iron deficiency. To improve the iron content of rice, researchers from the IRRI and the Australian Centre for Plant Functional Genomics (ACPFG) are collaborating. By over-expressing the OsNAS2, OsNAS1, or OsNAS3 genes in three populations of rice, they have altered those populations. The study team discovered that the concentrations of nicotinamide, iron, and zinc all rose in comparison to controls in all three groups. The cryIA(b) gene of the *Bacillus thuringiensis* bacteria is mutated and expressed in BT rice.

Through the synthesis of endotoxins, the gene gives resistance to several pests, including the rice borer. The Chinese government is conducting field tests on cultivars that are pest resistant. The advantage of BT rice is that farmers can prevent bacterial, viral, and fungal infections without using pesticides on their harvests. To keep pests under control, conventional rice is treated three to four times throughout the growing season. Increasing agricultural output and crop cultivation income are other advantages. As of 2009, China authorised rice for widespread usage. Southeast Asia has to control resistance to avoid Bt in rice from losing its effectiveness.

Resistance to allergies

Japanese researchers are working to create hypoallergenic rice varieties. Researchers are working to prevent the allergen AS-Albumin from forming. Rice that had been genetically altered to stave off allergies to cedar pollen, which causes hay fever, was tested on macaque monkeys by Japanese researchers. Itchy eyes, sneezing, and other significant allergic responses are some of the signs of cedar allergies. Seven proteins from cedar pollen (7Crp) are included in the modified rice to suppress these effects by promoting oral tolerance. Takaiwa is putting this 7Crp protein, which is an oral vaccination, through human clinical trials.

Photosynthesis using C4

A cultivar that demonstrated a primitive form of C4 photosynthesis (C4P) to improve development by absorbing carbon dioxide and concentrating it in specific leaf cells was created in 2015 by a collaboration of 12 labs across eight different nations. Corn and sugarcane grow so quickly because of C4P. Rice yields per hectare might be increased by around 50% by engineering C4 photosynthesis.

Today's cultivar continues to rely mostly on C3 photosynthesis. The plants must create specialised cells in a certain configuration to convince them to fully adopt C4P: one set of cells to catch the carbon dioxide and surround other cells that concentrate it. It is yet unknown which genes (perhaps several of them) are responsible for creating these cells. Wheat, potatoes, tomatoes, apples, and soybeans are among other C3P crops that potentially benefit from this information.

Recombinant protein creation

A blood protein found in human blood plasma is called human serum albumin (HSA). It is used to treat hemorrhagic shock, liver cirrhosis, and severe burns. Additionally utilised in donated blood, it is in low supply globally. Chinese researchers altered brown rice to generate HSA protein more cheaply. Using Agrobacterium, 25 rice plants received recombinant HSA protein promoters from Chinese researchers. Nine of the 25 plants have the HSA protein in them. The genetically altered brown rice produces the same HSA-like sequence of amino acids. This protein was given the name Oryza sativa recombinant HSA (OsrHSA). The genetically altered rice was clear. Soon, OsrHSA was commercialised to replace cow albumin in cell growth. In China, clinical trials began in 2017, while in the US, they began in 2019. Other recombinant human proteins are produced from rice by the same Oryzogen business.

Recombinant human proteins are made in rice grains using a unique process called Express Tec, which is used by Ventria Bioscience. Their most famous variation produces human Lysozyme and Lactoferrin. These two proteins, which are naturally generated in human breast milk are utilised in baby formula and rehydration products all around the world.

Golden Rice

Golden rice is a kind of rice (*Oryza sativa*) that has undergone genetic engineering for the edible sections of the rice to biosynthesize beta-carotene, a precursor of vitamin A. The goal is to create fortified food that can be cultivated and eaten in regions that lack dietary vitamin A. A lack of vitamin A results in xerophthalmia, which includes permanent blindness as well as a variety of eye diseases ranging from night blindness to more serious clinical consequences including keratomalacia or corneal scarring. Additionally, it raises children's death rates from measles or diarrhe.

History

Instead of needing to add several carotene desaturases, which are typically employed by higher plants, Peter Bramley found that a single phytoene desaturase gene (bacterial CrtI) may be utilized to create lycopene from phytoene in GM tomatoes. Golden rice's endogenous cyclase converts lycopene next to beta-carotene. Louisiana State University Agricultural Center carried out the first field tests of golden rice varieties in 2004. Additional trials were performed in Bangladesh, Taiwan, and the Philippines. Field testing made it possible to carry out feeding studies and gave an accurate determination of nutritional value. Golden rice produced in the wild generates 4 to 5 times more beta-carotene than golden rice grown in a greenhouse, according to preliminary findings from field studies.

Golden rice was authorized in 2018 by both the US Food and Drug Administration (FDA) and Health Canada as safe for human consumption. This came after the FDA declared in 2016 that the beta-carotene levels in golden rice did not supply enough vitamin A for US markets. Health Canada stated that, apart from the expected higher amounts of provitamin A, the nutritional composition of golden rice was similar to that of regular rice varieties and would not turn up allergic.

Golden rice can now be processed in the Philippines or used as food for people and animals. The Philippines was the first nation to formally issue a biosafety permit for the commercial propagation of vitamin A-infused golden rice on July 21, 2021. The approval marked the first legalization of the commercial dissemination of genetically modified rice to South and Southeast Asia. The authorization allows for the commercial cultivation of golden rice under the criteria and circumstances outlined by the Philippine government.

Gold Rice Risks

Many anti-GMO campaigners warn about the possible harms of growing and eating golden rice. Potential allergies or antibiotic resistance are risks. Additionally, when GMO crops are grown next to non-GMO crops, there is a chance that genetically modified foods will accidentally infiltrate the food system without the customers' awareness. There are worries about the impact genetically modified crops would have on the environment because they would need to be farmed. When GM crops cross with wild species, it might pose a threat to biodiversity.

The transfer, escape, or crossover of genes from genetically engineered crops is another problem. It could lead to unintended herbicide or pesticide resistance. There is a chance that other creatures that consume genetically modified crops will be impacted, just as there are safety issues for humans. There haven't been many studies on the long-term effects of growing and eating golden rice. Many experts now concur that genetically modified crops are just as safe to consume and cultivate as conventional crops, even though these extremely low dangers are still mentioned in common discourse.

A different issue is the potential economic effects that genetically modified food may have on underdeveloped nations. Some worry that since for-profit businesses support genetically modified foods, its potential market domination may severely affect small-scale farmers, especially impoverished farmers who cannot compete with big biotech firms for land and a piece of the rice market.

Benefits of Golden Rice

Golden rice holds the potential to lessen the suffering of both children and adults in poor nations who have VAD and micronutrient malnutrition as well as assist save millions of lives. The major advantage of golden rice may be improved by enabling for future development of genetically engineered, bio-fortified crops to fight micronutrient deficiencies in underdeveloped nations. Project backers think that reducing the hazards connected with golden rice surpasses improving public health in underdeveloped nations.

BT Cotton

Over 200 distinct Bt toxins, each hazardous to a different type of insect, are produced by various *Bacillus thuringiensis* bacterial strains. Most notably, Bt toxins are safe for other forms of life but insecticidal to the larvae of moths, butterflies, beetles, cotton bollworms, and flies. The Bt toxin gene has been transgenetically introduced into cotton, allowing it to manufacture this organic pesticide in its tissues. Lepidopteran larvae are the primary pests in commercial cotton in many areas, and the Bt protein found in the genetically engineered cotton that they consume kills them. As a result, lepidopteran pests can no longer be killed by using massive quantities of broad-spectrum pesticides. This helps to manage pests without using insecticides and saves the natural insect predators that are essential to agricultural ecology.

In certain circumstances, it may be desirable to use insecticides to prevent infestations since many cotton pests, such as stink bugs, plant bugs, or aphids, are ineffective against Bt cotton. A

2006 study on Bt cotton farming in China by Cornell researchers, the Center for Chinese Agricultural Policy, and the Chinese Academy of Science found that after seven years, these secondary pests that were previously controlled by pesticides had increased, necessitating the use of pesticides at levels comparable to those used on non-Bt cotton and leading to lower profits for farmers due to the additional cost of GM seeds.

In numerous nations across the globe, the cultivation of crops that have been genetically engineered (GE) to tolerate certain herbicides and resist particular insect pests has taken over. Globally, GE crops were cultivated on around 1 billion hectares of cropland between 1996 and 2009. Since 1996, an average of 10 million new hectares of production have been added yearly, reflecting the adoption's continued fast growth. On 134 million hectares of agriculture in 25 countries in 2009, GE crops were planted. The cultivation of plants resistant to the herbicides glyphosate or glufosinate continues to account for the majority (63%) of all GE crop output as of 2009. The majority of the remaining market share is made up of crops that produce the *Bacillus thuringiensis* (Bt) toxins and are resistant to insects (57% of these are stacked types that also tolerate herbicides), while just 1% of crops are altered to be resistant to various viral illnesses.

In 78 nations from temperate, subtropical, and tropical parts of the globe, cotton is commercially grown, making up around 40% of the world's output of natural fibres. More than 1300 species of herbivorous insects have been identified as inhabiting cotton according to surveys (3), but even though only a small number of them are considered economic pests, cotton has traditionally been one of the major consumers of pesticides globally. (4) Over the past 20 years, there have been numerous advancements in the management of insect pests in cotton that have reduced the use of insecticides in this crop. Perhaps the most notable of these advancements is the development of biotechnology, which has enabled the engineering of plants to provide highly effective and selective control of caterpillar pests (Order Lepidoptera), the most significant pest group of cotton globally.

It should come as no surprise that Bt cotton technology has been quickly accepted given the significance of this pest group. Bt cotton was initially made commercially available in 1996 in Australia, Mexico, and the United States; two years later, South Africa, China, and Argentina followed suit. India, the world's biggest producer of cotton by land area, first legalised commercial production of Bt cotton in 2002. Since then, adoption rates have increased substantially, with 87% of output in Bt types by 2009. In 2008, Burkina Faso became the newest significant cotton producer and the second country on the African continent to permit Bt cotton planting. In 2009, Costa Rica allowed manufacturing, however all of its little output is exported as seeds. 11 countries in all currently cultivate Bt cotton, including four of the top five cotton-producing countries in the world, with adoption rates in three of them above 60%.

The abbreviation Bt stands for the common soil bacterium Bacillus thuringiensis. This gram-positive, spore-forming bacteria produces parasporal crystals when it is in the stationary phase of its development cycle. For certain insects, the synthetic crystalline proteins known as "endotoxins" are very hazardous. They do this by acting on the caterpillars' midgut epithelial tissues, which kills the insect. These proteins makeup roughly 20–30% of the dry weight of sporulated cultures and often show microscopically as clearly formed crystals. These proteins are classified into four types, namely Lepidoptera-specific (Cry I), Lepidoptera and Diptera-specific (Cry II), Coleoptera-specific (Cry III), and Diptera-specific, based on their insecticidal action (Cry IV). More than 25 distinct yet similar insecticidal crystal proteins are produced by various

Bt strains (ICPs). These are poisonous to the larvae of several insect species, including many agricultural pests and disease vectors. Because they are members of the Lepidoptera order, cotton bollworms are susceptible to the Bt Cry I and Cry II proteins. These proteins do not affect other helpful insects. The Cry (Crystal), Cyt (Cytolytic), and VIP genes, either synthetic or modified forms from B. thuringiensis, are included in the gene bank data repository of the Bacillus Genetic Stock Centre (BCSC). A Crt gene, three Vip (Vegetative insecticidal protein) genes, as well as about 22 classes of cry genes, totaling 126 cry genes, have all been registered. Cry 1 Ac and Cry 1 Ab, however, are widely and successfully used in several crops.

Transgenic refers to a genotype or person created by genetic engineering procedures. In other terms, transgenics refers to species that have undergone genetic engineering. A transgenic might be a bacteria, an animal, or a plant. Transgenic plants include genes from other species or changed genes from the same species. The alien gene may originate from a species that is distantly related, closely related, or unrelated, or from microorganisms like fungus, bacteria, and viruses. Bt cotton is a kind of transgenic cotton that has been injected with the endotoxin protein-inducing gene from the *Bacillus thuringiensis* soil bacteria. The first transgenic plant was created in the United States in 1983 using tobacco. The first transgenic cotton plant was created in the United States in 1987 by the Monsanto, Delta, and Pine firms. Later, research on the creation of transgenics was stepped up globally, and various transgenic plants were created. There are two varieties of transgenic cotton: cotton that is bollguard and cotton that is roundup ready. While the latter is herbicide resistant, the former offers resistance to bollworms. The USA is the only country where transgenic cotton that is herbicide resistant is allowed. However, Bt transgenic cotton that is resistant to bollworms has spread to several nations. There are currently no transgenic disease-resistant cottons available. At the USDA, antifugal factors are being characterised (Rajasekharan et.al.1999). A few Fusarium and Verticillium wilt resistance genes have been discovered in India and are being incorporated into cotton. Chinese researchers have isolated the "GO" gene and used it to create cotton that is resistant to both wilts.

Mechanism

Bt cotton was created by adding genes that generate endotoxins in the Cry class which are poison crystals. When it is attacked and consumed by an insect, the high pH in the insect's stomach causes cry poisons or crystal proteins to break down. The scattered and activated Cry molecules engage with cadherin-like proteins on cells that have brush border molecules. The epithelium of the brush border membranes separates the body cavity from the gut while still allowing access to nutrients. When the Cry toxin molecules connect to specific places on the cadherin-like proteins present in the midgut epithelial cells, ion channels are formed, enabling the passage of potassium. Improper potassium concentration control, which is critical, causes cell death. As a consequence of the formation of Cry ion channels, insufficient potassium ion control is lost, which leads to the death of the epithelial cells. When such cells pass away, the brush boundary membrane develops holes.

There are five crucial processes in the development of any crop that is transgenic: The ability to regenerate from protoplasts, calluses, or tissues; gene expression of the product at the desired level; identification of an effective gene or genes; gene transfer technology; and the proper integration of genes so that they are passed down for generations through conventional methods of reproduction. To create flawless transgenics, molecular scientists had to first identify the genes that inhibited the growth of the bollworm. Agrobacterium-mediated gene transfer has mostly been exploited in the instance of cotton. Biolistic gene transfer tools are now accessible for direct gene transfer to protoplast. There are currently only a few "Coker" genotypes that can regenerate cotton plants from callus and somatic embryogenesis.

One significant barrier to gene transfer is that not all cotton genotypes are regenerative. Induction of somatic embryogenesis has been documented in China and Australia as well, but efforts to replicate it in India using Indian genotypes have been unsuccessful. Transformation and regeneration from meristematic tissues were tried to get around the issue of genotype-limited regeneration of callus or leaf tissues, and it was shown to be helpful. Transgenic cotton with complete integration, expression, and reproduction was first accomplished in the USA in 1987 using the Cry 1 Ab and Cry 1 Ac genes. Then there are stories from Australia and China. The methods are being developed, and in the next years, the issues with genotype-dependent regeneration will be resolved. Crop plants may acquire foreign genes (DNA) through four key techniques: the plasmid approach, particle bombardment, direct DNA uptake, and micro-injection. These procedures are sometimes referred to as DNA delivery systems for genetic modification. Transgenic plants are developed using the soil-borne bacteria Agrobacterium tumifaciens, often known as Nature's Genetic Engineering. Host specificity, somaclonal variation, and sluggish production are the three primary drawbacks of this approach. The DNA transfer technique mediated by agrobacterium has two key benefits. First off, unlike the particle bombardment approach, this method allows for some control over the transgene's copy quantity and location of integration. Second, compared to particle bombardment, this technique for genetic transformation is less expensive.

Agrobacterium with a CaMV promoter was used by Perlak et al. (1991) to effectively transfer the Cry 1 Ac gene to cotton, and the Cry protein produced by the transgenic cotton was discovered to be very poisonous to bollworms. Others subsequently made great use of this technique. Compared to the Agrobacterium-mediated technique of DNA transfer, the particle bombardment approach, which introduces foreign DNA into plant cells using high-velocity metal particles, offers several benefits. Host specificity is not present in this technique. As a result, it may be utilised successfully to generate transgenic plants in a variety of plant species. Technically speaking, this procedure is simpler than the Agrobacterium-mediated DNA transfer method. This approach does not need protoplast isolation. Direct DNA transfer and the microinjection approach, the other two methods, are seldom ever employed to create transgenic cotton.

A breeding method known as genetic engineering (GE) aims to prevent the issues that might arise when big genetic blocks are transferred between two parents. Only a very small number of foreign genes (from any source of life) may currently be introduced into a plant at one time due to technological limitations. Single gene features, however, are significantly simpler to create in successive breeding attempts and result in the least amount of disturbance to the plant genome. Genetic engineering requires the cooperation of two elements. Knowing the structure of a single gene and the genetic makeup of plants are the first two. The capacity to create a whole plant from a single cell is the third (regeneration).

Direct GE is only possible with a select few kinds since not all cultivars can be regenerated. These are regrettably inferior in terms of agronomy, thus a period of backcrossing and selection is necessary to incorporate the new gene into the finest kinds. DNA, a linear collection of four fundamental molecular building blocks, makes up genes. The regulation and expression of genes are determined by the linear order of these subunits. One very long double-stranded DNA molecule makes up each chromosome, and genes are placed linearly down the strand, often with lengthy periods of non-functional DNA sequence, each with a particular purpose.

1. Terminal area, where the gene terminates.
2. A sequence at the start of the gene called the promoter determines when, where, and how much of the gene product will be generated.
3. A central section called the coding region supplies the genetic code for the gene product.

With rare exceptions, a protein is often the gene's end output. Each gene and protein has a unique purpose but taken as a whole, their functions span from food storage and cell structure to metabolic catalysts (enzymes) and plant defence mechanisms. In Bt cotton lines, proteins having the latter functionalities are employed. Individual plant cells undergo "transformation" due to the introduction of foreign DNA. There are several methods for doing this, but the most popular one depends on a system created by nature. The germ that causes crown gall disease the genetic engineer of nature is *Agrobacterium tumefaciens*.

As part of the disease process, it transfers a portion of its DNA to plant cells. Selective bacterial strains have had their "disease-producing DNA" removed by scientists, and they have found that although these bacteria no longer cause crown gall disease, they still can transmit any deleted DNA to a plant cell. Thus, any gene may be delivered to a plant cell by this bacterium via this natural method. Due to the precise location on the chromosome where new DNA is introduced into an existing gene, several transformations and regeneration processes must be performed before choosing the transgenic plant that performs the best. Agrobacterium-mediated gene transfer is the term for this. There are now more ways of gene transfer accessible, such as direct gene transfer to protoplasts and biolistic gene transfer, which involves the absorption of foreign genes into plant cells by the high-velocity bombardment of regenerable tissues with DNA-coated microprojectiles. Chromosome blocks are used in traditional breeding techniques based on sexual hybridization and recombination. A relatively small number of designated genes are used in GE to provide crop characteristics that are not available in the typical breeding pool of germplasm.

Advantages

Growers now have a new weapon for controlling cotton bollworms thanks to the advent of Bt cotton. This technique offers the cotton producer, the global cotton business, and society several advantages on the economic, environmental, and social levels. These advantages include immediate advantages like decreased pesticide usage, increased crop management efficiency, decreased production costs, increased yield and profitability, decreased farming risk, and increased potential to cultivate cotton in regions with severe pest infestation. Improved populations of beneficial insects and wildlife in cotton fields, decreased pesticide runoff, waste from the use of insecticides, improved safety for farm workers and neighbours, decreased labour costs and time, decreased reliance on fossil fuels, and improved soil quality are just a few of the technology's indirect but significant advantages.

The most notable advantage of biotech cotton to far has been the decrease in the need for insecticides in the management of certain bollworms. Numerous studies showing a general decrease in spraying for Lepidoptera pests have been carried out throughout the United States as well as in Australia, China, Mexico, and Spain. Per crop season, there are somewhere between

1.0 and 7.7 fewer sprays used. Large-scale DBT testing of MAHYCO of hybrids in India during the 2000–2001 season showed an average decrease of 3.6 sprays per crop. In a report titled Transgenic Plants and World Agriculture, seven scientific academies from different parts of the world. The document calls on governments to base their biotechnology decisions on reliable research and emphasises the need for using the best available knowledge to make informed judgements about these technologies.

It was emphasised that, just as with any novel plant variety, public health regulatory frameworks must be established in every nation to recognise and track any possible negative impacts of transgenic plants on human health. The agricultural methods now in use that hurt the environment must also be considered. A more formal risk-assessment method may be modelled after the procedures that the majority of countries presently use to authorise the use of new agricultural plants. Additionally, the U.S. National Academy of Sciences' report Genetically Modified Pest-Protected Plants: Science and Regulation, which was released in April 2000, found validity in the statements that "There is no evidence that unique hazards exist either in the use of recombinant DNA techniques or in the movement of genes between unrelated organisms" and "Assessment of the risks of introducing recombinant DNA engineered organisms into the environment should be based on the naturopathic model." The primary goal of the first commercial GE cotton crops is to combat pests. They lessen the risk of collateral harm to species that are not the target, including humans, to the degree that they minimise pesticide usage as a whole. The method may lessen harmful environmental effects even if its only impact is to just replace one herbicide with another.

Bt cotton has a few advantages over non-Bt cotton. Here are a few of the main advantages of Bt cotton: Boosts cotton production by effectively controlling American, Spotted, or Pink bollworms. The Bt gene produces a crystalline endotoxic protein that protects cotton against bollworms but is poisonous to Lepidopteran insects including bollworms. Reducing pesticide usage in the cultivation of Bt cotton, where bollworms are a significant pest. Potential reduction in cultivation costs depending on seed cost versus insecticide costs. A reduction in the number of predators that eat bollworm eggs and larvae to help control the worms.The main selling factors of Bt cotton are the decrease in the number of pesticides that need to be used on a crop and the environmental benefits that follow. In response to a cotton bollworm infestation that farmers were having problems controlling with conventional pesticides, China was the first nation to utilise Bt cotton in 1997. Bt cotton first decreased pest issues while boosting yields and bringing in more money for farmers, much like how it did in India and the US.

Studies show that the use of lower pesticide dosages on cotton fields improved biodiversity by permitting the emergence of non-target species including ladybirds, lacewings, and spiders. The agri-biotechnology company Mahyco provides and distributes bt cotton in Maharashtra.Before the 2001 approval of Monsanto/Mahyco Bt cotton, Navbaharat Seeds provided unlicensed, illegal Bt cotton grown on 11,000 hectares in Gujarat. In India, the use of Bt cotton has significantly expanded since its introduction in 2002. Eight years after Bt cotton was first introduced, India surpassed other countries in the globe to become the second-largest cotton producer and exporter. In India, bt-cotton hybrids like NHH-44 and variations like Bikaneri Nerma were created.

According to socioeconomic research, Bt cotton continues to provide Indian farmers and society with a wide range of significant and diversified agronomic, economic, environmental, and social advantages, including halving pesticide consumption and doubling yields. India's achievements have drawn criticism. The Indian Council of Agricultural Research developed a less expensive Bt cotton variety with reusable seeds since Monsanto's seeds are expensive and lose viability after one generation. The cotton became deadly to bollworms after integrating the cry1Ac gene from the soil bacterium *Bacillus thuringiensis* (Bt). This cultivar had a poor yield, was abandoned after a year, and an investigation was made because its DNA sequence belonged to Monsanto.

Risks and Potential Health Effects of Bt Cotton

Before being used in the US, the U.S. Food and Drug Administration looked into and approved Bt cottons' effects on human health (FDA). The FDA is creating rules for optional labelling and making this review obligatory before use. Strong regulatory requirements are also present at Australia's Office of the Gene Technology Regulator, which organises evaluations from the relevant health and environmental agencies. Similar assessments are conducted before approval by other nations and international organisations. Science-based and risk-based analyses of the effects of Bt cotton on human and animal health have concentrated on the following: A thorough knowledge of cotton biology, particularly how cotton-derived products are used. A thorough evaluation of the safety of the added proteins, determination of the protein levels in significant plant products, and biochemical characterisation of the introduced proteins. The safety evaluation includes:

(1) A history of the proteins' safe consumption by people or animals;
(2) Any earlier tests on animals to determine whether the proteins were toxic;
(3) Findings from field and laboratory safety studies to determine the allergic effect, toxicity, and digestibility of the expressed proteins; and
(4) Evaluation of the dietary consumption of the proteins by people and animals of cotton products.

A determination of any unexpected consequences on the crop's quality attributes as a result of the genetic material's insertion or the protein expression that follows. The word "Substantial Equivalence" refers to the idea. When testing this idea with cotton, several locations were used to examine agronomic traits, plant morphology, fibre quality, and the nutritional value of cottonseed meal and oil. These nutritional composition studies include gossypol, fatty acid spectrums, amino acid spectrums, and proximates (protein, fat, carbs, ash moisture, and calories). The equivalents of cottonseed meal and oil were also established. Review and testing of cotton goods used in food, medicinal items, and personal hygiene products. Feeding trials with rats or other animals using cottonseed or cottonseed meal to ascertain any negative health or behavioural impacts.

It is possible to alter molecules at the molecular level to create a specific chemical that might set off very significant events for the cotton industry. For instance, after years of study, researchers in the public and commercial sectors created a mechanism that would force the plant to only generate the unviable seed. This method, known as the Technology Protection System (TPS), required farmers to purchase seed year. TPS might be used to non-GE cotton types as well. TPS's proposed commercialization has been shelved in part due to widespread opposition to the technology. Due to their conventional methods of seed usage and/or production techniques, some farmers may oppose the use of GE to develop genetic features. There were concerns expressed about insects becoming resistant to the poison generated by the Bt gene even before GE cotton was commercially accessible. Since it is already virtually commonly acknowledged that insects will ultimately become resistant to the poison, steps have already been taken to prevent this from happening.

It is also necessary to regularly reengineer cotton with new genes that will create poisons with alternative modes of action since there is a risk that resistance will emerge in the target insects. There are now just two varieties of commercially available GE cottons, each of which contains three distinct genes, and none of them interacts negatively with the genetic makeup of the cotton plant in any way. Such interactions are feasible, however. According to a study of all available safety data, Bt cotton doesn't present any additional risks to human or animal health than regular cotton. The U.S. Environmental Protection Agency has shown that each protein added to Bt cotton that has been marketed so far does not need to be tolerated at any level (EPA). This indicates that these proteins are safe for intake by both humans and animals. The EPA's tolerance standards define the permissible, acceptable levels of pesticides in food (such as cottonseed oil) and feed (i.e. cottonseed, cottonseed meal, cottonseed hulls). Following a scientific evaluation, products made from Bt cotton were given further licences for use in food and feed in Japan, Australia, Argentina, South Africa, Mexico, Canada, and China. Scoured and bleached cotton does not include DNA or protein from a transgenic plant, despite being utilised for chemical goods as well as medicinal and personal hygiene items.

The Impacts on the Environment

Science- and risk-based analyses of *Bt* cotton's effects on the environment have centred on the following factors:

- Field observations are often used to evaluate the agronomic performance of new cotton varieties. These observations look at things like morphology, yield, lint quality, plant growth traits, and sensitivity to pests and diseases. Except the intended variations in the proteins produced and the corresponding improvements in yield as an insect result, none of these parameters was impacted by the insertion of genetic material.
- Capacity for cross-pollination to weedy cousins, alterations in dormancy and germination, and overwintering potential are all taken into account when comparing the biology of Bt plants to normal cotton for pest or weediness potential. These cotton products' genetically modified DNA acts just like any other DNA that is passed down via Mendelian inheritance to offspring.

The two parents must be sexually compatible, their flowering times must coincide, a suitable pollen vector must be present and able to transfer pollen between the two parents, and the offspring must be fertile and ecologically suitable for their environment for gene flow to occur via normal sexual transmission. G. hirsutum wild progeny are uncommon and often scattered far. Most thrive outside of agricultural zones. Although cotton is often thought of as a self-pollinating crop, several insects have been shown to cross-pollinate cotton. Cross-pollination experiments have shown that the likelihood of the inserted genes from Bt cotton spreading to other Gossypium species or other members of the same plant family is very low to none for the reasons listed below.

(1) Because cultivated or wild diploid cotton species have 26 chromosomes and Upland and Egyptian/Pima cotton has 52, they cannot cross and produce fruitful offspring.

(2) Although cross-pollination to 52-chromosome species is possible, commercial cotton cultivation often does not take place in the same geographic regions as wild cousins. Hawaii, for instance, has the potential for cross-pollination with G. tomentosum, despite the absence of industrial cotton cultivation there.
(3) There are no known organisms outside of the cotton family that can reproduce with grown cotton. The effects on insect species that are not the target have been evaluated. The Bt protein was used for testing because of its ability to kill insects.

The sprayable Bt products have undergone extensive testing, with results showing that they are safe for non-target species. For Bt cotton, these findings have been verified. The insects studied are representative of the main insect groups and include earthworms, springtails, green lacewings, ladybird beetles, adult and larval stages of honeybees, green lacewings, and parasitic Hymenoptera. The lack of toxic effects in investigations on non-target creatures, despite protein (Cry 1 Ac) concentrations that were much higher than the maximum expected ambient exposure, shows that Bt protein would not be harmful to these and similar non-target animals. Additional field observation studies on the effects of Bt cotton on non-target species have shown population growth as a result of a decrease in the usage of general pesticides.

Study the decrease in the usage of general pesticides using Bt. The protein (Cry 1 Ab) is produced in root exudates from Bt maize cultivated in the lab and natural soil in the field, according to research with Bt cotton on the persistence of these toxins and their potential ecological and environmental impacts in soil. However, there was no discernible difference in the quantity of toxin in the soil between Bt corn and non-Bt maize, nor was there any impact on non-target species like nematodes, earthworms, or soil microorganisms. The results of a field study on the impact of Bt pollen on monarch butterflies revealed that even tiny monarch caterpillars that might be present during pollen shed were typically not killed by the concentration of Bt pollen adhering to milkweeds, the larvae's main source of nutrition, within a few (1–5) metres of corn fields.

Most maize pollen deposition remains in the cornfield because of the high particle size (90–100 microns). Similar in size to corn pollen, cotton pollen is spiky and never carried by the wind, unlike corn pollen. Only when bees collect cotton pollen from a flower to use as food can Bt proteins have an impact on bee health. Bt proteins are not exposed to non-target Lepidopteran larvae. Btcotton grown apart from the plant itself protects non-target Lepidopteran larvae from exposure to Bt toxins. A target pest is by definition any larva that feeds on cotton. The environmental destiny of the imported proteins has been assessed. Adult butterflies and moths may visit a cotton field in search of nectar, but they do not consume pollen, and nectar has no protein.

In both lab and field studies, the protein (Cry 1 Ac) alone or in cotton tissue's soil degradation, insecticidal action was rapidly eliminated, which was equivalent to half-lives reported for microbial products. There are no expected negative environmental effects, and none have been reported since the introduction of Bt cotton in 1996 in any nation where it is grown, based on the low levels of environmental exposure to the introduced proteins and the data generated in the environmental safety assessments mentioned above. The adoption of Bt cotton has a major negative environmental effect despite several of the technology's advantages, such as decreased pesticide usage.

The least expensive and most effective way to protect agricultural plants from pests is via genetic resistance. The natural adversaries of insect pests, such as predators and parasites, will be protected by the Bt transgenic cotton with built-in genetic resistance to bollworms. Using fewer pesticides, will also assist in lowering the cost of farming. Additionally, it will lessen the health risks and environmental degradation brought on by pesticide usage. The use of pesticides is decreased thanks to transgenic cotton containing the Bt endotoxin protein, and an eco-friendly atmosphere is created without a drop in yield. The following areas need to be the focus of future study on Bt transgenic cottons: The primary concern posed by the extensive production of Bt transgenic cotton is the emergence of insect tolerance to the toxin.

Therefore, to reduce the chance of acquiring insect resistance and herbicide-resistant weeds, numerous sources of resistance should be found and employed to generate bollworm and herbicide-resistant Bt transgenic kinds of cotton. Recently, a few transgenic Bt cotton hybrids were made available for industrial farming in India. These transgenic hybrids seeds are quite expensive. A packet of 450 g of seed costs Rs. 1600, which is too expensive for small and marginal farmers to pay. Therefore, it is necessary to provide Bt transgenic seeds at a lower cost than small and marginal farmers can afford. Abiotic factors like salt and drought also harm cotton crops.

It is necessary to create Bt transgenic kinds of cotton that are resistant to salt and drought. With hybrids, the farmer must spend a lot of money on new seeds every year. As a result, efforts should be undertaken to create Bt transgenic straight cotton cultivars, the seed from which farmers may harvest for three to four years. Cotton is a crop that produces fibre, oil, and protein. In addition to improving the quality of fibre, genetic engineering is required to increase the quality of proteins and oil. In addition to the Bt gene, numerous additional genes may be utilised in the future to create cotton genotypes that are resistant to certain insects. For instance, genotypes resistant to the boll weevil may be created using the cholesterol oxidaze gene from the fungus Streptomycetes. Venom genes from spiders and scorpions may also be exploited to create cotton genotypes that are resistant to insects. Three genes in the Helicoverpa armigera stunt virus assault the Heliothis midgut and prevent it from eating. To create transgenic cotton, the protease inhibitor gene from cowpea, soybean, and African taro rhizomes is being employed. About 25% of India's cotton land is covered by diploid kinds of cotton. Therefore, it is necessary to create transgenic Bt cotton cultivars and hybrids.

Genetically Modified Potato

Production of genetically modified plants continues to play a major role in experimental investigations and plant biotechnology over four decades after the original breakthrough. To get around the primary drawbacks of traditional plant breeding, genetic engineering has made it feasible to introduce advantageous features from unrelated plants, bacteria, viruses, fungi, or animal species. Because transgenic lines are more resistant to pests, abiotic stress, or pathogens, or because metabolic pathways have been altered, the introduction of one or more genes into commercial crop species has increased crop yields. This has improved the nutritional or industrial value of genetically modified plants. Additionally, plants have been created to function as "factories" that manufacture large quantities of different nutrients, pharmacologically significant chemicals, or other beneficial materials.

A potato that has had its DNA altered through genetic engineering is said to be genetically modified. The objectives of modification include adding insect resistance, adjusting the concentrations of certain compounds generated by the plant, and stopping the tubers from browning or bruised. It's possible that varieties that have been altered to generate a lot of starches won't be allowed for use in human meals.Techniques for Plant Genetic Modification

An organism that has had its genetic makeup changed via the use of genetic engineering methods is known as a genetically modified organism (GMO). A second green revolution has been sparked by biotechnology and genetic engineering, just as the first green revolution was sparked by the use of classical genetics in plant breeding. The first foreign DNA was inserted into a plant in 1983 using *Agrobacterium tumefaciens* transformation, which marked the beginning of genetic engineering. This technique included deleting harmful oncogene-related genes and swapping them out with gene-of-interest (GOI) sequences in a bacterial (Ti) plasmid that was needed to infect the plant. The first genetic modification technology utilised in crops was Agrobacterium-mediated gene delivery, sparking a revolution that has changed the customary landscape long established by plant breeding. Gene introductions may be classified as either trans-genesis or cis-genesis. While cis-genesis employs DNA from the same or a closely related species to reproduce an alteration that may have happened naturally, trans-genesis requires introducing a gene from a sexually incompatible species, such as bacteria.

The discovery that double-stranded RNA was the starting point for gene silencing led to the development of RNA interference (RNAi) technology in plants a few years later (dsRNA). In these first tests, viral RNA from Potato Virus Y (PVY) was degraded using sense and antisense sequences. This discovery would pave the way for the creation of inverted repeat (IR) or hairpin RNA (hpRNA) transgenes, which are now heavily employed for the targeted silencing of genes in both plants and animals.

Sequence-specific nucleases (SSN), proteins with nuclease activity that produce sequence-specific double-strand breaks, are the foundation of the next generation of genetic manipulation tools (DSB). The Transcription Activator-Like Effector Nuclease (TALEN) Clustered Regularly Interspaced Short Palindromic Repeats/CRISPR associated protein (CRISPR/Cas9), and Zinc Finger Nuclease (ZFN) are three SSNs used in crops. Both homology-directed repair (HDR) and non-homologous end joining (NHEJ), which is the more frequent repair process, may be used to fix DSBs caused by SSN. Although NHEJ's repairs are often flawless, sometimes mistakes can happen, resulting in indels in the DNA sequence that might interfere with gene function.

One of the main pests harming potato crops is the Colorado potato beetle. Native to North America, the defoliating bug has now migrated to Europe and other continents. The consumption of potato leaves by both adult and larval stages damages the tuber and causes significant output losses. To prevent these losses, a variety of insecticidal treatments may be used throughout the growing season. However, as these treatments also result in the death of certain beneficial insects, production costs and environmental impact are often increased. Additionally, the insect has become resistant to various pyrethrins, one of the active constituents in many synthetic pesticides. These problems have sparked an investigation into alternate pest control methods.

The Colorado potato beetle and other coleopterans belonging to the Chrysomelidae family are selectively killed by the Bt protein, which is produced by the CryIIIA gene of Bacillus thuringiensis. Bt is a protoxin that is normally inactive and is activated by serine proteases and a basic pH in the insect stomach. After being active, it binds to certain receptors on the intestinal epithelium and activates membrane cation channels, resulting in the lysis of digestive tract cells and the insect's starving death. The NewLeafTM variety of genetically modified Bt potatoes was created by MonsantoTM. The CryIIIA gene was cloned into A. tumefaciens in a transformation vector that used the CaMV 35S promoter to activate the gene. The Bt protein was expressed in the leaves of the Russet Burbank, Superior, and Atlantic potato cultivars after each of them underwent CryIIIA cassette transformation.

In addition to resulting in increased insect mortality, it was found that female Colorado potato beetles had dramatically smaller ovaries, which had an impact on reproduction. The USDA approved all three potato types for sale in the US in 1995, and by 1998, crop output had increased to 55,000 hectares. In 1998, Monsanto introduced NewLeaf PlusTM potatoes, a variation of Russet Burbank with increased resistance to the potato leafroll virus (PLRV). However, by 2001 commercialisation had come to an end owing to poor revenues, which were probably brought on by food corporations rejecting GM potatoes. The great specificity of Bt protein for coleopterans, which had little impact on predator species like spiders and hemipterans, and the decreased usage of expensive synthetic and ecologically hazardous pesticides were two benefits of NewLeafTM potatoes. Even though beetles could become resistant to this form of control, it has been shown that commercial Bt preparations are less successful due to their photosensitivity and the fact that they are often washed away by rain or irrigation.

Because they may impart bitterness and are hazardous to humans, glycoalkaloids are substances that are often targeted for decrease in potatoes. The two glycoalkaloids that makeup 90% of the total in modern potato cultivars are -solanine and -chaconine. However, they also serve as deterrents, reducing the threat of assault by insects that feed on plants, such as the Colorado potato beetle. Therefore, their decrease in the plant's aerial portion may have made it more vulnerable to pests. There is interest in inhibiting solely the synthesis pathway in the tuber and raising levels of glycoalkaloids in the leaves because the accumulation of glycoalkaloids varies throughout the plant. S. chacoense contains the glycoalkaloids leptins and leptinins, which exclusively build up in aerial organs. These glycoalkaloids may be a genetic resistance source that warrants more investigation since they were shown to positively correlate with resistance to the Colorado potato beetle98. Using RNAi technology to produce dsRNA in chloroplasts that target the beetle -actin gene, 99 modified potatoes are being used as a new defence against the Colorado potato beetle.

99 DsRNA builds up in chloroplasts because they are unable to break it down due to a lack of RNA silencing machinery. The dsRNA is produced from the chloroplasts when the insect eats on the leaves and is absorbed by the intestinal cells, where it destroys the -actin mRNA via post-transcriptional gene silencing (PTGS). With less foliar biomass loss and more beetle death, this method was protected without expressing dsRNA in the tubers. However, since insects lack the genes for RNA-dependent RNA polymerase, the dsRNAs are not amplified, and only the insect cells that take up the ingested dsRNA are impacted. To effectively control beetles, the plant would need to create and store a considerable quantity of dsRNA. The development of comparable techniques based on PTGS of the insect's key genes is anticipated to transform pest management.

The continuing improvement of gene editing platforms will boost their efficiency and efficacy and enable more complex gene changes. To solve the difficulties with gene editing in crops with greater ploidy levels, particularly auto-tetraploids, this will be essential. For instance, it might be quite difficult to screen plants for several haplo-allele mutations in various genes. Mutant characterisation will benefit considerably from the advent of cheap long-read sequencings methods like amplicon sequencing and Nanopore®. The use of methods that restrict transgene integration without lowering reagent efficiency will also be a key technological objective. Currently, transgene-free edits are produced via ribonucleoprotein delivery, but this work could be broadened to take use of other potential methods, such as nanoparticle-mediated gene delivery or negative selectable markers like the bacterial coda gene.

Used As Food

The US FDA and the Us Department of Agriculture both authorized the genetically altered innate potato in 2014 and 2015, respectively. J. R. Simplot Company created the cultivar. It is made to have less of the amino acid asparagine, which converts into acrylamide when potatoes are fried and to resist browning and blackspot damage. Reduced amounts of acrylamide in dishes made with fried potatoes are preferred since it is a possible human carcinogen. Although the quality of the potato is unaffected by browning, buyers do not often want to buy damaged or potentially spoilt items. The variety's name, "Innate," refers to the fact that it employs RNA interference to turn off genes and does not contain any genetic material from other species the genes utilized are "innate" to potatoes. Simplot believes that by excluding genes from other animals, customer concerns about biotechnology will be allaye.

The Innate potato is a collection of several potato cultivars that have all undergone the same genetic modifications. The modified features of five separate potato varieties have been combined to create innate versions of the variety with all of the original qualities. Simplot has modified the Russet Burbank, Ranger Russet, or Atlantic potatoes in addition to two exclusive types. Two modifications were made to each variety, one for each of the two additional qualities. Thus, the development of the various innate types involved a total of 10 transformation episodes.

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Every nation on planet consumes potatoes daily. An agricultural crop that is well-known to people from many cultures provides advantages to traditional varieties owing to inherent characteristics. Regardless of the environment in which they are grown or the difficulties that a crop confronts as a consequence of the grower's management tactics, innate potatoes will yield a better crop than conventional ones. The browning potential of innate potatoes is predicted to be one-tenth (or less) that of the control grown under the same conditions. One may assume that such naturally occurring potatoes will have much less black-spot bruising and less reducing sugars because they were harvested fresh from the field and were not stored. Fewer potatoes will succumb to the crop-destroying P. infestans due to intrinsic changes. The distinctive feature of genetic modification was the ability to correct a few defects in crops that had been meticulously created and established throughout a broad region. Genetic modification is still a useful method for potato genetic improvement in addition to cutting-edge breeding approaches like genome editing and genomics-aided breeding.

Effects on the Environment

Livestock or dairy operations emit greenhouse gases as a result of the breakdown of manure and the digestion of ruminants mostly cattle and sheep. By making dietary changes to their animals, livestock managers may reduce methane emissions. Dairy and hog farms may construct digesters to capture the methane produced during manure storage and utilise it to generate electricity. Digesters reduce emissions by converting methane from alternate waste disposal methods into less potent CO2 and by creating energy that replaces CO2 emissions from fossil fuel-based power. Impacts on the environment

Greenhouse gases are produced when raising crops and livestock

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Farmers may use ways to increase the quantity of organic matter retained in the soil and the amount of agricultural waste left on the field by boosting carbon sequestration on agricultural land. These methods include switching from conventional to conservation or no-till tillage, minimising or eliminating fallow as part of planned crop rotations, switching from annual to perennial crops, and increasing field residues through irrigation, fertilisation, planting hay or cover crops, or adding more organic material, such as manure. Conservation tillage may boost both nitrous oxide emissions, which cause climate change, and carbon sequestration, which mitigates it. This method may include a trade-off between two greenhouse gases. If these strategies result in reduced yields, indirect changes in how land is used may also occur.

The study looks at how genetically modified (GM) crops have affected society and the environment globally in the 20 years since they were first extensively employed for commercial reasons. The effects on output, the environmental impact of modifying the use of pesticides and herbicides, the economic ramifications at the farm level, and the contribution to reducing greenhouse gas (GHG) emissions are the main topics of this study. In order to significantly reduce agriculture's greenhouse gas emissions, farmers have adopted more sustainable practises including reduced tillage, which reduces the burning of fossil fuels and maintains more carbon in the soil. For instance, if transgenic crops had not been grown in 2015, an additional 26.7 billion pounds of carbon dioxide would have been emitted into the atmosphere, which is the same as adding 11.9 million more cars to the road [13].

Between 1996 and 2015, agricultural biotechnology reduced the spraying of crop protection chemicals by 619 million kilogrammes, or 8.1% globally. This is more than China uses in a single year in terms of crop protection products. Farmers that use transgenic crops have thereby reduced the damaging impact of their crop protection practises on the environment by 18.6%. Crop biotechnology has reduced the need for further farmland and increased global food security. With transgenic crops, farmers may produce more food without utilising more land. For instance, to sustain global production levels in 2015 without the use of agricultural biotechnology, an additional 8.4 million hectares (ha) of soybeans, 7.4 million ha of maize, 3 million ha of cotton, and 0.7 million ha of canola would have had to be planted. This would need an additional 11% of arable land in the United States, around 31% of arable land in Brazil, and 13% of farmland in China.

Crop Biotechnology Aids Global Economic Growth

Crop biotechnology is still a good investment for millions of farmers. For every extra dollar invested in transgenic agricultural seeds worldwide in 2015, farmers earned an average of $3.45. In 2015, farmers in developing countries benefited from $5.15 for every extra dollar spent on transgenic seeds, whereas farmers in developed countries only received $2.76. To reduce the emission of nitrous oxide, a greenhouse gas with 300 times the potential to cause global warming as carbon dioxide, chemical fertilizers, herbicides, and manure must be used properly. It is also advised to utilise cheap inhibitors that regulate nitrogen processes in soils. Understanding the processes by which soil bacteria create greenhouse gases is essential for all of this. In comparison to traditional methods, nuclear techniques provide several benefits for assessing the effects of climate change. To develop strategies to lessen the emission of the gas, scientists must pinpoint the source of nitrous oxide production using the nitrogen-15 isotopic approach.

For genetically modified potatoes to be commercially successful, producers and consumers must favour features that minimise production's negative environmental effects. For instance, since amylose-free potato varieties like AmfloraTM generate starch that doesn't need chemical pretreatment, they are advantageous to industry and help protect the environment. The most efficient gene targeting for each attribute needs more study. For instance, investigating multiple target genes to reduce the amount of acrylamide found that knocking down Vlnv was the best course of action. However, as various studies have shown, it is uncertain which approach is most effective for eradicating Colorado potato beetle infestations. Agriculture will be more sustainable if pesticides and fungicides are used less. Future work should focus on creating potatoes with long-lasting resistance to pathogens and pests. To combat the Colorado potato beetle, for instance, raising the number of glycoalkaloids in the leaf looks to be beneficial, but P. infestans defence may need for pyramiding or editing of R genes.

Since it enables a variety of modifications to be done with high accuracy, we believe that the CRISPR gene editing method will continue to be the most popular technology. Base and prime editing in potatoes have a lot of possibilities. Specific procedures should, however, be created if necessary since they are unique technologies. Tools with less regulatory barriers should be given priority since they do not leave any traces of external DNA. In this respect, it is necessary to look at the qualities that RNAi-based gene editing has altered. Additionally, it will remain essential to examine the germplasm of closely related wild species to find features in gene pools that are available for introgression into potato cultivars. Finally, advantages and general acceptability must be balanced while creating enhanced kinds. For this, extensive and transparent scientific dissemination about GMOs and the methods utilised is required, with an emphasis on the scientific proof of their safety. In several nations, GMOs have been consistently rejected, with a notable fall in acceptability over the last ten years. Deregulation of genetically modified plants in the US is a step in the right direction toward increased access to crops that have increased agricultural sustainability and may help feed the worlds needy.

Agriculture Biotechnology's Future

Over the last ten years, the use of biological sciences in agriculture has gained popularity. In 1989, molecular methods were used for the first time to introduce genes into maize, and by the late 1990s, farmers were growing transgenic corn on millions of acres. Even though the science of biotechnology for agriculture is still in its infancy, it already has a significant impact. The preceding chapters go through what is known about how marketed transgenic crops affect the environment and monitoring techniques that may be modified to check for any unintended consequences. One important discovery is that a transgenic plant's specific phenotypic traits dictate its potential interactions with its environment; the employment of recombinant DNA techniques throughout its growth only indirectly impacts these interactions by changing the phenotypic traits of the transgenic plant.

In reality, the importance of biotechnology for environmental risk is mostly because agricultural plants may now contain a considerably wider variety of phenotypic features than was previously conceivable roughly ten years ago. As a result, our knowledge of the few insect- and disease-resistant and herbicide-tolerant varieties that have been commercialised to date offers very little support for the questions that will need to be investigated when future plants with very divergent phenotypic traits are evaluated for environmental risks. The second portion, which focuses on policy, starts with a broad discussion of how environmental risk from transgenic crops should be presented before going on to particular subjects that may come up when regulations for the next generation of transgenic crops develop. The explanation of certain research needed to address upcoming problems comes in the concluding part.

This section describes anticipated future transgenic crops, some of which are anticipated to be commercialised in the next couple of years, others of which may become so in the mid-term horizon sometime during the next decade, and others of which are merely twinkles of ideas for transgenic crops which will require research breakthroughs before they can become a reality. It is not feasible to categorise the environmental risks that could be connected to all of these crops without first having information about their phenotypic traits and the agricultural ecology of the environments in which they will be cultivated. A preliminary review of a few sample environmental risk problems that may be connected to these new transgenic crops is provided in the second half of this section, however.

Recent Transgenic Crops

Based on single-gene features, the first transgenic crops were to be grown commercially. The "Flavr-Savr" tomato was one of them; it did this by using gene silencing to prevent the production of an enzyme involved in fruit ripening. The Flavr-Savr tomato was not a commercial success, but the technique worked because the fruit was less prone to pathogen infection and had a delayed pace of ripening. On features that affected agronomic performance, other early transgenic products were developed (i.e., pathogen, insect, or herbicide resistance). The American farmer's quick adoption of glyphosate-resistant soybeans as well as Bt-expressing cotton and maize is evidence of the transgenic crops' economic success.

Due to the success of these first transgenic crops, several features and genes are now being researched in research facilities throughout the globe to significantly broaden the range of goods that may be produced by such plants. The pace at which new transgenic features may be anticipated to develop in the future will primarily rely on the number of genes encoding them, as was true with the initial genetically altered crops. As a result, features regulated by a single gene or qualities that may be altered or deleted by silencing a single gene or a collection of related genes are likely to be the first to be made public. Integration of single-gene features is the natural next stage in growth. There are currently crops in use that have a collection of single genes for a variety of unique features. The number of genes influencing plant growth, architecture, and the different physiological processes that affect yield cannot be known with certainty. But it seems reasonable to think that understanding genetically complicated features, much alone expressing and regulating them in a species of genetically modified crop, would need several years of study. However, complex traits, such as those regulating flowering and reproduction, hybrid vigour, and adaptation to abiotic stresses like salinity and drought, are actively being investigated. It would not be surprising if some of these could be controlled in crop plants by genetic engineering within the next 5 to 10 years.

In addition to enhancing agronomic performance, these products have the potential to increase the nutritional value of grains consumed by humans and livestock, get rid of allergens and antinutritional elements, lengthen the shelf life of fruits and vegetables, and boost the concentration of vitamins and micronutrients in seeds, resulting in healthier foods. While there are many different types of transgenic crops being developed, the majority of them are focused on meeting one of four major societal needs: better agricultural traits, increased adaptability to post-harvest processing techniques, improved food quality and other human uses, and better pollution mitigation.

Enhanced Agricultural Features

New Bt genes that provide defence against various varieties of insect pests are among the transgenic features on the verge of commercial release. One of these is a gene that guards maize against harm from corn rootworms. This insect is estimated to cause losses of up to $1 billion yearly via damage to maize roots. It is anticipated that minimising the effect of this insect would improve maize yields as well as drought tolerance and fertilizer uptake because of the stronger root structure. Additionally, work is being done to genetically modify tree crops to make them more vigorous and resistant to pesticides and herbicides. For instance, a Bt gene has been added to hybrid poplars to guard them against leaf beetle defoliation. Due to their excellent wood pulp qualities, hybrid poplars have grown in number; nevertheless, because of their susceptibility to insect attack, pesticide treatments have been made. Many of these novel features for increasing agricultural output on farms have the potential to have environmental effects like those of the current transgenic crop generation. Only indirectly do other societal segments benefit from them; instead, the farmer and the seed firm get their value directly. However, a larger portion of society is responsible for assuming their potential hazards. As a result, conversations and arguments over biotechnology in the present are likely to be similar to risk analyses of this future generation of features. As the spectrum of transgenic crops broadens beyond the primary grain crops to the more untamed and perennial plants, such as pines and poplars, the assessment of these concerns is anticipated to grow more challenging and complex.

Long-term advancements in the understanding of plant physiology, growth, and interactions with microbes may potentially provide the groundwork for modifying plant structure or reproduction. Crop plants that can be genetically modified may be able to withstand drought, salinity, or other abiotic stresses better (see below), grow more effectively in acidic, aluminum-rich soils found in tropical regions, compete with weeds more successfully, reproduce more quickly, and possibly fix their nitrogen.

Post-Harvest Processing Improvements

Several economically significant tree species, including poplar, sweet gum, eucalyptus, aspen, walnut, white spruce, and apple, are also being treated using transgenic technology. Along with the increase in the global population, there is a rising need for wood and wood products. Transgenic tree plantations are anticipated to play an increasingly significant role in supplying the demand for tree products, alleviating strain on existing forests. Herbicide tolerance and insect resistance, which help establish and sustain young trees, are the first qualities being genetically engineered into trees, as was previously indicated. To better adapt trees to postharvest processing, several characteristics are now being developed and might soon be made commercially accessible. For instance, research is being done to alter the lignin concentration of certain tree species to enhance pulping, the process of separating wood fibres to manufacture paper. Reduced lignin may increase paper manufacturing efficiency and decrease environmental damage caused by the paper-making process.

It is commonly accepted that simultaneous genetic engineering of reproductive sterility is necessary to prevent the spread of transgenic features to natural forest and orchard tree populations. There are now techniques to achieve this in agricultural plants. In addition to limiting gene flow, sterility is anticipated to accelerate tree growth and increase wood production since less energy would be used on creating fruit or blooms. Undoubtedly, a future National Research Council (NRC) committee will look at this topic.

The idea of employing genetic engineering to transform annual crop plants into factories that manufacture useful chemicals and antibodies is also being explored. Given the straightforward inputs of a few minerals, carbon dioxide, water, and sunlight, plants can manufacture a range of complex compounds. It is commonly believed that plants might provide an environmentally friendly, sustainable alternative to the chemicals now derived from petroleum. This may also be a way to use surplus agricultural commodities production and open up new markets for plant-based goods. Several years ago, it was shown that plants could produce polyhydroxy butyrate, a precursor to plastic, but that this was not an economically feasible technique. However, plants have great potential for manufacturing a wide range of fatty acids that act as building blocks for priceless polymers like nylon. As more is discovered about the biology of starch production, the characteristics of plastics that include starch may likewise be considerably enhanced.

Additionally, research is being done to lessen contamination in post-harvest production. For instance, research is being done to lower the amount of phytic acid in maize. Phosphorus is stored as phytic acid in the growing seed. Since animals cannot digest a large portion of this mineral complex, it ends up in the waste stream. It is eventually discharged into lakes and ponds, where the phosphorus may cause algal blooms. To lower the phytate level in maize, many molecular strategies are being used, including genetic engineering.In contrast to the previous generation of goods, several of these novel plant products present several risk-related concerns. Enhanced Food Quality and Innovative Human Use Products

Two of the most significant food and feed ingredients in both the United States and the rest of the globe are corn and soybeans. The majority of the 9 billion to 10 billion bushels of maize that are produced in our nation each year—65 to 70%—are used as animal feed; around 25% are exported; and the remaining 10% are converted into ethanol, non-food coatings and adhesives, and food additives. Additionally, lipids derived from plant seeds make up around 20% of the dietary calories (of individuals) in the United States, with soybean oil making up about one-third of the total. These seeds' lipid, protein, and carbohydrate content may potentially be changed to produce food that is more nutrient-dense and byproducts that have better functional qualities. Several of the transgenic goods included here are now undergoing field testing or will be put into production shortly.

Due to its high carbohydrate and oil content, corn seed has a high caloric density, but the protein it contains lacks numerous necessary amino acids for swine, poultry, and human nutrition, including lysine, methionine, and tryptophan. Although they have not yet been put into commercial production, transgenic maize lines that have higher than average concentrations of these amino acids and/or that make proteins with greater amounts of these acids have been developed. Nontransgenic technology has been utilised to create high-oil maize varieties, but transgenic technology is also being employed to improve the amount and quality of corn oil. Similar to soybean oil, more monounsaturated fatty acids would increase the stability and nutritional value of maize oil, and attempts are being made to accomplish this via genetic engineering.

Although these unsaturated fatty acids are typically thought to be healthier to eat than the saturated fatty acids found primarily in animal fat, natural soybean oil contains a significant proportion of them (linoleic and linolenic). However, these unsaturated fatty acids have the propensity to oxidise and go rancid. Additionally liquid at room temperature, these unsaturated fatty acids have limited use in the production of certain foods, such as margarine. By hydrogenating the oil, soybean oil is made more stable and has better functional qualities. As a result, monounsaturated trans-fatty acids are produced by weakening the double bonds in the unsaturated fatty acids. Even though trans-unsaturated fatty acids have been ingested for a long time, mounting evidence indicates that they are harmful. To solve this issue, cismonounsaturated fatty acid-rich soybean oil was created using genetic engineering. This was accomplished by genetic engineering by silencing the genes that, through a desaturation process, convert oleic acid into linoleic and linolenic acid. The new product is soybean oil, which contains around 85% monounsaturated fatty acids, is healthier to eat, has high stability, and has less off flavours.

Proteins with great functional qualities are abundant in the meal that remains after soybean oil extraction and may be used to make a range of dishes. However, a number of the most prevalent soy proteins are lacking in methionine and cysteine, two necessary amino acids for people and certain types of animals. One soy protein is a frequent dietary allergy, and there are other antinutritional soy proteins. Therefore, transgenic research has been conducted to increase the protein quality of soybeans and eliminate the antinutritional components and allergenic proteins. Conventional breeding cannot solve the lack of critical amino acids in soy protein that include sulphur since there aren't any superior genes in the natural gene pool. Genetic engineering, on the other hand, may be used to solve the issue by increasing the production of a protein containing methionine and cysteine or by changing the activity of the enzymes that manufacture those amino acids. Blocking the production of the primary soy proteins that are deficient in methionine and cysteine is a complimentary strategy that will raise the proportion of these amino acids in the remaining proteins. These two tactics are being looked at. Although it has been shown that transgenic soybeans and other pulse crops are capable of manufacturing methionine-rich proteins, the trait has not yet been made available for purchase. The main soybean allergy is successfully eliminated by gene silencing, while additional anti-nutritional proteins have been eliminated using mutagenesis. One of the main classes of soy proteins that lack methionine and cysteine is efficiently silenced by the promoter employed to silence the fatty acid desaturase genes in the high oleic acid transgeneic soybean. The transgenic seed that was altered to have a high oleic acid content, therefore, has better protein quality.

Plant meals also include a number of the micronutrients that are crucial for human diets, in addition to the macronutrients like protein, carbohydrate, and fat. Biotechnology study has been drawn to the 17 minerals and 13 vitamins that must be consumed in minimal amounts to avoid nutritional diseases. Numerous minerals (iron, calcium, selenium, and iodine) and vitamins (A, B6, E, and folate) are crucial for maintaining health, according to clinical and epidemiological research, yet they are often insufficiently present in many diets across the globe. Many people's diets are restricted to the micronutrients these seeds provide because of the widespread dependence on rice, wheat, maize, and soybean as sources of macronutrients. These foods are particularly poor in iron, zinc, iron, riboflavin, selenium, vitamin A, and vitamin C.

Inadequate intake of micronutrients causes major dietary issues for more than two billion individuals. For instance, iron deficiency causes anaemia in 50% of pregnant women and 40% of all women, and it's considered to be the root cause of up to 40% of the 500,000 maternal fatalities that occur each year. The mental development of youngsters is hampered by inadequate iron intake. A worldwide pandemic of vitamin A deficiency is said to exist. Vitamin A deficiency affects 250 million children worldwide each year, and it's linked to 10 million illnesses and fatalities. Up to 500,000 children, every year develop blindness due to vitamin A deficiency, and half of these youngsters pass away after losing their sight. Vitamin A deficiency may result in protein malnutrition and weakened immune systems in addition to compromising eyesight. Lack of folic acid raises the risk of heart disease, stroke, and birth problems.

There is still much to learn about the absorption and accumulation of minerals and the synthesis of vitamins in plants, but substantial advancements are being made in several fields of study, leading to the development of transgenic plants that produce higher amounts of several micronutrients. For instance, white rice has been genetically altered to generate enormous amounts of beta-carotene, which is converted to vitamin A, by introducing three genes one from a daffodil and two from bacteria. To increase the amount of beta-carotene in transgenic rice to the point where a daily serving offers the recommended daily intake (RDA) of vitamin A, more genetic engineering may be required. This strategy's ability to reduce vitamin A deficiency is still up for debate.

The lipid-soluble antioxidant tocopherol, often known as vitamin E, was increased in plant oils using similar genetic techniques. The recommended daily allowance (RDA) for vitamin E is 10 to 35 international units, and it is often attainable by eating dietary items produced from plants, such as soybean oil. However, it has been shown that an excessive consumption of vitamin E is linked to increased immune function, a decreased risk of cardiovascular disease and certain malignancies, a decreased chance of various human degenerative disorders, and a slowed advancement of those conditions. Consequently, boosting the vitamin E content of regularly eaten foods like soybean may have health advantages. The effective vitamin E level was roughly 10-fold raised by overexpressing the gene for the last stage of vitamin E production in the model plant Arabidopsis thaliana. The development of transgenic soybean and canola plants with increased vitamin E levels is now being done using a similar method.

Our food also contains a variety of additional compounds from plants that are beneficial to health. It is believed that the glucosinolates in broccoli and other cruciferous vegetables assist in the detoxification of cancer-causing agents. Soybean isoflavones, which are phytoestrogens, seem to lower the risk of cardiovascular disease, osteoporosis, and the occurrence of breast, prostate, and colon cancers. Carotenoids, the red, orange, and yellow pigments found in tomatoes and green leafy vegetables, may lower your chance of developing some malignancies, heart disease, and macular degeneration-related blindness. It is unclear how much glucosinolates, isoflavones, and carotenoids from different plant sources should be ingested to have the greatest health advantages as well as how genetic and metabolic variables affect these levels. These compounds are often insufficient in Western diets, and there is rising interest in learning how to enhance their presence in food and establish their proper health-promoting levels.

Vegetarian vaccinations might be made from plant-based diets. Many seeds include proteins that some individuals may be allergic to. Small fragments resulting from these allergenic proteins are absorbed into immune system-related regions of cells on the small intestine during digestion. When these proteins are exposed again, antibodies are created against them, triggering an immunological reaction in the person that might have serious repercussions. By generating antigenic proteins derived from common viral and bacterial pathogens in edible plant components, the same method may be utilised to develop immunity against them. A collection of diseases, including the Norwalk virus, Vibrio cholerae, and enterotoxigenic Escherichia coli, are of special concern because they kill several million children annually, mostly in impoverished nations. Uncooked plant foods like potatoes or bananas, according to preliminary investigations, may be utilised to create pathogen-derived proteins (such as virus coat proteins). Then, these meals might be utilised to immunise both kids and adults against a range of common ailments. Although there is still a lot more study to be done, first studies show promise for this approach's effectiveness and cost sustainability.

Ability to Handle Abiotic Stress

Global food output is strongly constrained by abiotic stressors. It is estimated that these variables together have reduced agricultural productivity by an average of 70%. In addition to lowering the average yield of crops, drought stress also results in yield instability due to large interannual variance in production. Globally, arid or semiarid conditions apply to about 35% of arable land. About 25% of the remaining area comprises of soils that are vulnerable to drought. Drought stress happens often for a short term or at a moderate intensity, even in nonarid areas with fertile soils. Furthermore, it has been anticipated that owing to rising global temperatures, rainfall patterns may change and become more erratic in the next years. Therefore, greater resilience to stress may boost agricultural output.

Research is being done to develop agricultural plants that can withstand abiotic conditions such heat, drought, cold, salt, and aluminium toxicity. To study the molecular underpinnings of salt responses, agricultural plant mutants have been isolated as part of current research on drought tolerance. Studies on the transduction network for signalling guard cell responses and how they regulate water loss and carbon dioxide uptake, as well as genetic activation and suppression screens that affect how many signalling systems interact to regulate plants' stress-adaptive responses. Due to the intricate genetic pathways and multigene systems involved in plant abiotic stress tolerance, it is expected that the actual creation and field testing of new agricultural plant types will take 5 to 10 years. Since the genetic mechanism of stress tolerance will considerably influence the spectrum of potential concerns, accurate evaluations of the environmental risks presented by any of these stress-tolerant plants will not be achievable until they are developed.

Stress-tolerant transgenic plants have sparked worries about environmental threats despite this ambiguity about their nature. Abiotic variables that affect plant communities globally include soil nutrient content, water availability, temperature, salt content, and metal toxicity. These factors also have a significant impact on the geographic spread of many plant species. Therefore, when plants are modified to more effectively withstand these abiotic conditions, it raises risk concerns regarding the potential effects on plant community structure and the growth of a plant species' geographic range. While similar concerns have been brought up while talking about the current crop of transgenic crops. Most of these characteristics were not anticipated to affect how invasive or weedy the converted plants were. Such stress-tolerant crops come with subtle and complex environmental dangers.

Here, the committee concentrates on drought-tolerant crops to further explain their findings. Higher water usage efficiency (WUE), which results in more biomass output per unit of water, or a stronger capacity to draw water from the soil are two possible bases for drought-tolerant phenotypes. These processes will have different consequences on the environment. Potential environmental consequences may often be connected to competition for sunlight or nutrients in the soil owing to the plant's metabolic demands associated with larger biomass because plants with superior water extraction will still need the same quantity of water to thrive. Contrarily, ecological theory predicts that a plant with a higher WUE would be a stronger water competitor than a plant that has not transformed. Concerns regarding the environmental implications of drought-tolerant transgenic plants, whether they are a crop or a wild cousin that may acquire the transgenes via horizontal gene flow, stem from this projected greater competitive capacity.

However, a plant's geographic range may not always grow as a result of greater water competition. Better WUE lupine plants in oak savannas may grow more luxuriantly than their conspecifics, but they may not spread into neighbouring habitats because of excess shade, water, or nitrogen in the soil, which might offset their advantage in the savanna. Because maize still requires water over a longer growing season than wheat, a maize variety with a higher WUE may perform better in the dryland production systems of certain areas of Nebraska and Kansas but may still not replace spring wheat in the surrounding counties. Additionally, a farmer may clear the dry ground and plant this kind of maize, which would result in a marginal increase in the area planted to maize and a marginal reduction in the area occupied by xeric prairie remnants. It is unlikely to be possible to develop maize into a plant that can survive in arid or semiarid conditions without watering. Because of the intrinsic traits of the plant as well as seasonal restrictions imposed by other abiotic and biotic variables, there is a limit to this potential even if it is obvious that plants modified to endure drought might increase their global range. The plant, characteristics, and environment will all need to be taken into consideration while assessing these hazards. Similar to this, effects on plant community structure, non-target species, and interactions between characteristics described below may happen, but their evaluation will depend on individual circumstances. For instance, certain transgenic plants that can withstand salt may also withstand other conditions including cold, freezing, heat, and drought.

Phytoremediation

In the future, transgenic plants could be cultivated for phytoremediation the removal or detoxification of contaminants from soil. Mercury poisoning of soils is one ongoing issue with pollution. There are already modified plants that provide several solutions to this issue. Converting the very poisonous organic mercury found in soil into the less dangerous, volatile elemental mercury is one method of pollution mitigation. Another strategy is to store mercury in the tissues of plants, where it may be more securely collected, removed, or disposed of. The ability of these "phytoextraction" plants to accumulate more than 1% of their biomass as mercury is currently present, and crop improvement methods like genetic engineering may be able to raise that percentage.

These mitigation techniques' effects on the environment presumably depend on their magnitude. While phytoremediation using volatilization may have advantages locally, the effects on a larger scale are less certain. If the overall quantity of volatile mercury produced is negligibly little, there won't likely be much of an impact on the environment. Therefore, using the volatilization approach sparingly may be good for the environment. However, levels of atmospheric mercury may increase at regional or greater geographical scales if the scale of volatilization is enormous and huge quantities of mercury are volatilized. When it rains or snows, atmospheric mercury is carried back to terrestrial, aquatic, or marine environments. It changes into more physiologically hazardous forms after deposition. There may be a significant environmental issue with the atmospheric mercury deposition caused by the burning of fossil fuels, trash, and medical waste.

Various transgenic traits combined

The effects of certain features such as herbicide tolerance on the environment and public health have been the subject of risk evaluations of transgenic crops. Commercialized transgenic crops with numerous characteristics, including cotton and maize with herbicide resistance and pesticidal qualities, already exist. It is crucial to determine whether the health-related and environmental effects of multiple genes are simply the sum of the effects of each gene or if interactions among the introduced genes change the impacts of these cultivars quantitatively or qualitatively. This is because many more cultivars with "stacked" genes and multiple transgenic traits are anticipated to be commercialised soon.

There are many levels at which we might search for interactions between inserted genes while focusing on environmental impacts. Two levels the level of the individual plant genotype and the level of the whole field or agricultural system are the subject of this discussion. The ability of alternative herbicides to control "volunteer" plants with the herbicide tolerance gene is a key factor in APHIS's evaluation of requests for nonregulated status. If plants with the two genes are resistant to the complete range of registered herbicides for the crop, then the answer to this question may be no even if it may be yes for plants with single-gene insertions. Currently, if each of the features has been deregulated independently, APHIS does not regulate the plant with combination herbicide tolerance.

Consider a plant that has a gene for insect resistance as well as a gene for drought tolerance (such as Bt toxin expression). Most Bt-expressing plants are required to generate a high enough dosage for the Environmental Protection Agency (EPA) to control resistance effectively. Is it realistic to believe from a scientific standpoint that the drought tolerance gene, which modifies plant physiology, won't also modify the expression of the Bt gene? The EPA can and may even be forced to assess Bt toxin expression in such a drought-tolerant cultivar under the legal authority of the Federal Insecticide, Fungicide, and Rodenticide Act.

The interplay of characteristics in transgenic plants may include intricate indirect causal pathways at the field or agricultural systems level. One example is how, in certain situations, the use of integrated pest management (IPM) and pesticide resistance management may be hampered by stacked transgenic characteristics. IPM advocates for using pest suppression methods only when the pest's population has risen over a certain economic threshold. The normal constitutive expression of Bt genes in themselves raises questions regarding how they can affect IPM.

When transgenic cottonseed with only one gene for glyphosate herbicide resistance was in insufficient supply during the 2000 field season, a more significant worry was raised. Farmers in a few southern states were forced to plant either a traditional nonherbicide-resistant cultivar or a transgenic cultivar with stacked Bt and herbicide tolerance genes since there was a considerably greater demand for glyphosate-tolerant cotton than there was a supply. In North Carolina, Bt-expressing cultivars were planted on around 22% of cotton acres in 1999; by 2000, that number had increased to 54%. About two-thirds of the rise, according to cotton entomologists, was brought on by farmers who wanted to utilise glyphosate-tolerant cotton and so had to buy a cultivar that included the Bt gene. Similar increases in the number of acres planted to Bt cotton were seen elsewhere including in certain parts of Texas. By generating geographical areas where resistance might quickly arise, such artificial expansions in the area of Bt cotton can imperil the control of resistance in all target pests. Additionally, the chance of resistance developing for one significant cotton pest, Helicoverpa zea, the cotton bollworm, is increased by the unduly extensive use of Bt cotton. The danger of resistance evolution has increased as a result of stacking Bt and herbicide tolerance genes.

The industry plans to release maize varieties containing Bt genes to prevent corn rootworms on the market within the next three years. In some of the new types, it is conceivable that these rootworm Bt genes will be combined with the Bt genes now in use for controlling the European corn borer. The Bt genes that regulate the European corn borer were present in around 20% of the maize planted in the United States in 2000. The main explanation for the high percentage of nontransgenic corn is that, in many regions, the losses brought on by the European corn borer are not sufficient to offset the extra expenses incurred by cultivars that express Bt. There are geographical (micro and macro) zones where planting corn cultivars with the new corn rootworm-active Bt toxins will be economically advantageous but where European corn borer control is not necessary. Bt toxins will also be used in certain geographical areas and farm-specific circumstances to control European corn borer but not corn rootworm. It will become more and more difficult for all but the biggest seed firms to have complete inventories of all combinations of transgenic traits and agronomic qualities as traits proliferate. If this forces farmers to choose between varieties of maize with both rootworm and corn borer Bt poisons or cultivars lacking either toxin, we could have a scenario similar to the one that occurred with cotton. Neither the EPA nor the USDA has openly addressed this problem as of yet.

It is anticipated that innovative transgenic features incorporating many genes will increasingly be introduced into agricultural cultivars in the future. The altered features could include things like fruit taste and salt tolerance. The kind of environmental interactions that may be brought on by the combination of three or more transgenic characteristics is difficult to predict. Such contacts must be evaluated on a case-by-case basis based on prior experience.

Industrial inputs and agronomic characteristics

The ability of plants to create a variety of innovative biological compounds and proteins that may be employed in various industrial processes can be significantly increased by altering their biochemistry. Several danger considerations are brought up by this technology. These transgenes might be coding for mammalian poisons or enzymes that produce inedible compounds. An environmentally induced transgenic movement that results in transgene products entering the human food system carries a definite danger. Sterilization, segregation, or other risk management techniques may be necessary, but there are still many questions concerning their cost and effectiveness.

QUESTIONS FOR REVISION

1. Describe various aspects of agricultural biotechnology.
2. How can biotechnology can be applied for sustainable agriculture?
3. How does genetic engineering works for Ago Crop improvement?
4. How agro-biotechnology increases crop productivity?
5. How biotechnology is employed for the production of insects' resistant crop plants?
6. Howagro producers and customers are benefited from agriculture biotechnology?
7. Describe various biotechnological tools adopted for agricultural practices.
8. Describe various steps and processes of mushroom cultivation.
9. What is golden rice? Describe its significance.
10. What is antisense technology? How it is implemented for crop improvement?

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