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APPLICATIONS AND FUTURE PROSPECTS OF GENETIC ENGINEERING: A NEW GLOBAL PERSPECTIVE

SIDRA TUL MUNTAHA[1], ALEEM AHMED[1], KALEEM AHMED[1], NADIA MUKHTAR[1], UZMA NAUREEN[2], MIANANJUM MURTAZA[3] AND TANVEER HUSSAIN[1*]

[1]*Virtual University of Pakistan, Lahore*
[2]*University of the Punjab, Lahore*
[3]*University of Sargodha, Pakistan*
Corresponding author e-mail: tanveer.hussain@vu.edu.pk

Abstract

Genetic engineering (GE) is often termed as gene manipulation or recombinant DNA technology with all three often used interchangeably--implying to the manipulation and alteration of the genetic make-up of an organism through introduction of certain traits of interest. It is a combination of techniques used for identification, replication, modification and transfer of genetic material. The techniques mentioned above are by and large in place since the 1970's and has found its applications in fields like agriculture, pharmaceuticals, health, environment and industry. With the advancement of GE, its application area is also broadened which gives an advantage to the humans such as various genetic disorder are now curable through this technique which was not possible in earlier period. The applications of GE in medical science include production of vaccines, proteins, growth hormones and treatment of many diseases and genetic disorders such as Down's syndrome, cystic fibrosis, cancer, Alzheimer's disease and Huntington's disease through gene therapy, animal breeds with superior traits and transgenic animals for biomedical research. GE is also taking strides in making the environment a better place for all living organisms by reducing toxic elements through various methods. Transgenic plants with desirable traits such as herbicide tolerance, resistance towards pests, stress tolerance (biotic and abiotic) and enhanced nutritional values. In agriculture, the applications of genetic engineering are most pronounced in producing genetically modified food (GMF). Various regulations for GE have been introduced. The level of acceptance and awareness is much higher in developed countries while developing countries face certain challenges in this regard.

Introduction

The process of gene manipulation and genetic engineering (biotechnology) is in practice for so many years and dates back to the early days of civilization, embarked by the process of fermentation, beer and yogurt production. In the language of molecular biology, GE is defined as a set of methodologies that are frequently used to alter the genetic composition of an organism or a gene (Sarkar *et al.*, 2014). This innovation plays a crucial role in the discernment of genes and characteristics of genes of various life forms including humans, microorganism, plants, and animals. Various applications of genetic engineering are described precisely (Au, 2015).The advancements being made in GE can very well be attributed to the discovery of DNA molecule in 1953 (Watson-Cricks-Wilkins-Franklin model WCWF Model). Talking about the tools of the trade--every cell in the human body contains DNA as the genetic material. We know that other than the identical twins, every organism has a different genetic component. DNA has a double helical structure with both strands complementary to each other and comprises of phosphate, sugar and nitrogenous bases (Watson and Crick, 1953). The purine bases are adenine and guanine, whereas the pyrimidine bases consist of cytosine and thymine. Adenine forms a double hydrogen bond with thymine while cytosine forms a triple bond with guanine. The sugar in DNA is deoxyribose, while that in case of RNA it is ribose. In RNA, the thymine base is replaced by uracil. Since the discovery of DNA, a number of developments have taken place in the area of GE. *Bacillus* species has been completely sequenced, thus improving our understanding on processes such as genetic manipulation. One of the major advancements was made in 1970's, when the restriction enzymes were discovered and these enzymes and ligases were used by Paul Berg to develop recombinant DNA molecule (Jackson *et al.,* 1972). DNA from the SV40 virus was combined with lambda virus. Later on, during early 1980's, DNA microarray was developed for screening of genes expressed in healthy and cancerous colon cells of mouse. During 1983, that Ti plasmid of *Agrobacterium tumefaciens* was used to insert foreign genes in the plant. It is mainly useful to insert genes in cereals and trees (Caiping *et al.*, 2004). In 1983, Kary Mullis invented Polymerase Chain Reaction (PCR) which has revolutionary applications in clinical studies, diagnostics, plant and animal genome studies, studying mutation, detection of viruses, microbes, pathogens and many more areas. Another development that took place in 1984 was the characterization of virus that is responsible for AIDS. The year of 1985 was marked with the introduction of DNA fingerprinting technique byJeffreys which has profound applications in forensics, paternity testing, criminal investigations, rape and murder cases, plant and animal genomics, archaeology and many more (Jeffreys F *et al.,* 1985). Moving forward, during 1986, breakthrough was made in developing the first recombinant hepatitis B vaccine. Same year, Leroy Hood and colleagues made advancement in fluorescence detection in automated DNA sequence analysis. During mid1990's, breakthrough was made in planting genetically modified (GM) crops worldwide which now occupy more than 180 million hectares worldwide with a number of benefits (James, 2013). GM crops are those crops in which genetic material is altered in order to obtain novel characteristics which are not there naturally i.e. resistance regarding ecological circumstances, diseases, pests and also the creation of such traits which are useful for the medical purpose (Deb *et al.,* 2015).Transgenic animals have been produced through various techniques including retrovirus-mediated gene transfer, microinjection of fertilized ovum and embryonic stem cells mediated gene transfer. There are many benefits of producing transgenic animals like an expression of the unfamiliar gene is proficient, the size limit is not obvious for the foreign DNA, low-cost method, no complexity in the procedure, this technique is applicable to the large species diversity (Wakchaure *et al.,* 2015).In 1997, the Scottish scientists succeeded in creating the first cloned sheep named Dolly by using adult sheep cells. Another application of GE include environmental biotechnology in which the solutions of many environmental issues can also be made through biotechnology applications which consist of injurious substances exclusion from the environment through microorganism and plants that are called filter-feeders(Fahmideh *et al.,* 2014). The year 2003 brought the significant news regarding the completion of human genome project which is believed to be one of the world's largest projects undertaken through collaboration. Human genome project (HGP) holds great promise in fields such as molecular drugs and evolutionary studies. With the completion of human genome map, the scientists are targeting to understand the function of each gene. National Center for Biotechnology Information (NCBI) stores the gene sequences in a database called GenBank, the other databases include DNA databank of Japan (National institute of Genetics) and EMBL (European Bioinformatics Institute)

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Applications of genetic engineering in producing GM crops/transgenic crops: Conventional breeding has remained a mainstay of agricultural farming practices since centuries. Traditional breeding has resulted in a number of very high yielding crop varieties that occupy a large agricultural area in the world. Green revolution is a fine example of conventional breeding, whereby, the production mainly that of wheat increased manifold, thus addressing the issue of hunger very effectively in India, Pakistan and countries like Mexico. Dr. Norman E. Borlaug (Nobel Laureate) is credited for being the father of green revolution (Borlaug, 2000). There are a number of benefits associated with traditional breeding but one thing that goes against it is that it is time intensive and is a random process to assort the genes. The breeders and farmers have to wait for years to produce the desired variety. However, with the advent of GE techniques, it has become possible to obtain results within a shorter period of time with increased specificity. It has become possible to produce the crop or animal with the desirable qualities. The combination of GE and traditional breeding can yield better results than any of the techniques applied in isolation. In GE, the genes can be transferred from one organism to another be it of the same kind or not and express these genes through the anti-sense technology. The technique has been in use since early 1970's (Jeffrey *et al.,* 1985).Figure 1 explains the steps involved in modern plant breeding. (understanding the tools of the trade)

GM Crops……Scaling up: In 1994 genetically modified crops were first accepted for marketing purpose and then speedily expanded in those countries of the world which are known to generate main crops. And it is reported that until 2014, 29 countries have developed genetically modified crops with 181.5 million hectares land. In past, the means to control weeds and pests, the crops were treated with various chemicals of herbicides and pesticides which were harmful not only to human but also for the protection of the environment. This dilemma is eliminated by the production of BT toxin and genes specific for herbicides that were isolated from microorganisms and introduced into plants to get better results. Though in some regions of the world there are still some problems for hereditarily modified crops but it is also a fact that in the preceding century the genetic engineering technique was very dominant discovery(Yu *et al.,* 2015).A number of benefits have been associated with these crops including; herbicide, stress and pest resistance, drought, and salinity tolerance and improved nutritional value. A very common example in this regard is that of Bt cotton and corn in which the genes from a bacterium are transferred to the crop for resistance against pests. This has resulted in decreased use of pesticides. (Moellenbeck *et al.,* 2001). There are many crops which are GM which include maize in which methionine concentration is enhanced, in canola lysine amount is increased and in the soybeanplant, there is protein bounded. To deal with diseases associated with domestic animals, there are many plants like Arabidopsis thaliana, potato, and alfalfa which are used to cure animal diseases such as bovine rhinotracheitis, bovine viral diarrhea virus and foot and mouth disease(Deb *et al.,* 2015).The other examples of GM crops include; GM soybean, GM canola, BTbrinjal, GM papaya and many more. Currently, USA produces the highest number of GM crops in the world followed by countries like Brazil, Argentina, Canada, China, and India. The consumer acceptance and awareness on GM crops is greater in developed countries as compared to developing countries.

GM plants are developed through the transgene technique in which the gene of desired traits is isolated from other organism and intentionally launched in the target organism. More often transgene is created through fastening the gene of interest to supposed promoter regulatory sequence of DNA in order to allocate the gene of interest as well as to control the expressions (Adams, 2015).The proponents consider that GM crops can play a very important role in increasing crop production from limited resources. With the population of the world growing like a snow ball and expected to double in the next 40-50 years, feeding the world will require use of innovative technologies. GM crops are believed to be disease resistance. Each year billions of rupees are lost due to occurrence of diseases in crops. The main purpose of GM technology is to create crops that can resist diseases caused by viruses, bacteria, and fungi (Dahleen *et al.*, 2001). Similarly, the drought resistance is another very important aspect of GM crops in which the transcriptional factors plays the influential part which is considered high-quality contestant for genetic engineering(Sanabria, 2014).Due to global warming and climate change, the weather is becoming hot and the crops have to sustain extended heat periods. The scientists around the world are aiming at producing crops that can resist higher periods of heat and at the same time are resistant to salinity (Zhang and Blumwald, 2001). Another very important front of GM technology is to produce edible vaccines in crops such as tomato and potato. Main benefit through this will be in shipment and storage of vaccines as compared to traditional vaccines (Daniell *et al.*, 2001).

Producing crops with enhanced nutritional qualities is another very important area of GM technology. A transgenic plant is the type of plant in which a gene is introduced that is taken from the foreign source and contains desirable characteristics in order to modify the plant with advantageous traits i.e. Droughtgaurd hybrid maize. The trait is present over protein that is located inside the gene, so to obtaina transgenic plant, first of all, most wanted trait is recognized than separated and finally cloned. The foremost transgenic plant was reported in 1983 named kanamycin-resistant transgenic tobacco line(Sarkar *et al.,* 2014). One very common example in this regard is that of golden rice which contains additional vitamin A, iron and high-level protein potatoes have also been grown in various regions of the world(Ahmed *et al.,* 2011) to overcome the deficiency mainly in the countries where rice is the staple crop. Golden rice contains high quantity of beta carotene which is believed to protect from night blindness. Children and women are highly vulnerable to the deficiency of vitamin A (Rockfeller foundation).A number of independent studies have been carried out which reveal that GM food is safe for human and animal consumption and pose no serious threat to the environment (DeFrancesco, 2013). The GM crops have under favorable conditions shown to increase production and save resources (Pray *et al.,* 2002). These benefits are mainly due to better pest management and reduced loss of crop. The GM crops can be complementary to the conventional crops but they are not replacement for traditional crops. Precision Genetic Engineering is most advanced technology that is used in plants which specifically paying attention to combining new characteristics in the varieties of marketing value that was impractical in past. In order to recognize the DNA double-stranded breaks and to contact specific sites of the genome, numerous policies have been made to make advancement in most wanted genetic alteration (Nakayama and Nepomuceno, 2014).

In a meta- analysis of the impacts of the GM crops, it was revealed that GM technology has helped in reducing chemical pesticide use by more than 30%, further it increased crop yields by more than 20%, and resulted in increased farmer profitability. Insect resistant crops have shown more yield gains. Yield and profit gains are higher in developing countries than in developed countries (Klumper and Qaim, 2014). Small farmers can greatly benefit from reduced pesticide usage.

Applications in producing transgenic animals: In 1981, the primary successful experiment was done on the mice genome by modifying its genetic material through genetic engineering technique. Soon after, in 1982, Richard Palmiter and his fellows revealed that the growth of those mice increased which were produced from a GM egg which was the combination of growth hormone gene of rat and metallothionein gene of the mouse which leads to growth hormone production. This fusion transgene is very helpful in the studyof the composition of growth hormone, also, it enhanced the growth in animals and was also helpful in the analysis of over production disease model to consider various diseases in pathobiology as well as human diseases i.e. Alzheimer' disease, Down's syndrome, epilepsy etc. The following steps are needed to produce transgenic farm animals. 1. Superovulated female' eggs are collected. 2. In in-vitro culture environment, these eggs are matured. 3. Transfection with transgene practice needs artificial fertilization of the eggs. 4. After transfection embryo is cultured artificially. 5. Then embryo is transmitted to substitute block. Knock-out animals are produced by selectively or entirely removing the gene actions. Knock-in animals are produced through an initiate point mutation in genes(Adams, 2015; Faizi, 2013). In 1997, the sheep was developed through cloning technique in which nucleus of somatic mammary gland cell was transported into the oocyte(Maksimenko, 2013). In animals' food in order to enhance the nutritional value of bioactive elements are added in food that not only influenced metabolic system but also has an effect on humans' wellbeing. It is needed to enhance the quantity of long chain n-3 polyunsaturated fatty acid and conjugated linoleic acid along with vitamins and minerals addition within the arrangement of lipids in food. In animals, adipose tissue arrangement and also the genes expression that is associated with the production of lipids are influenced by nutritional fat (Swiatkiewicz *et al.,* 2015). In the field of genetic engineering the novel technology, CRISPR (Clustered Regularly Interspaced Short Palindromic Repeat) has made a striking reflection. In 2012, the description was made about controlling the eukaryotic genome through CRISPR system.

Applications in medical science: GE has made some remarkable achievements in medical science dealing with the diseases and reducing the chances of it being passed to the next generation (Sandel, 2014). For so many years, humans have gained knowledge on the transmission of traits from one generation to the next. Similarly, there are certain disorders and diseases that are genetic and pass on from parents to children. Few important application areas of GE are in preventing diseases and genetic disorders such as Down's syndrome, cancer, cystic fibrosis Alzheimer's and Huntington's disease, cardiovascular diseases, viral infectious diseases such as AIDS and many other (Knoell and Yiu, 1998). Treating these diseases through gene therapy will mean helping the future generations in a big way. The advancements being made in biotechnology and GE have brought gene therapy in the limelight. Gene therapy which is developed with the establishment of recombinant DNA and gene cloning methods is considered an innovative therapeutic technology. It is basically associated with alteration of human hereditary material use to deal with biomedical abnormalities (Hongxin and Yuguan, 2015).Gene therapy aims at correcting the defective genes which have caused the genetic disease. For instance, there has been success achieved by researchers in genetically modifying the lymphocytes of patients having cancer, eye, immune system or blood diseases(Aubourg, 2016).The role of gene therapy in treating cancer patients is becoming increasingly important.
There are different approaches that can be used in the process of gene therapy;

- Firstly, a normal gene can be inserted in the genome at a non-specific site to replace the defected gene.
- Secondly, the defected gene can be exchanged with a homologous recombination of a normal gene.
- Thirdly, there is a possibility to repair the defective gene through reverse mutation.
- Lastly, the expression of a gene can be altered (Miller, 1992).

Gene therapy was mainly discovered in the 1980's after the breakthrough to isolate genes from the DNA was made (Friedmann, 1992). Nowadays, the therapy of cancer is the foremost objective of the gene therapy. Though cancer gene treatment medicines are not available in the market but considerable advancement has been completed in determining the possible targets and also in the production of viral and nonviral gene deliverance method (Akbulut *et al.,* 2015).The technique requires a lot of funding and expertise. For this reason, the gene therapy research is mainly being carried out in USA, European countries and to some extent in Australia. The gene therapy can be of two types;

a) Gene therapy involving the germ line: in this method the insertion of healthy genes takes place in the germ cells (Mathews and Curiel, 2007). This means that any change in the germ cell will be transmitted to the future generation. Although, a very effective technique to treat genetic disorders, there are certain ethical and moral limitations to this method.

b) Gene therapy involving the somatic cells: in this method the insertion of genes take place in the somatic cells and hence are not passed to the next generation (Bank, 1996). The gene delivery during the process takes place through vectors. Effective and safe methods have been developed for this purpose. The vectors can either be delivered through ex-vivo (more commonly used) or in-vivo technique (Romano *et al.,* 1999). The commonly used viral vectors include; retroviruses, adenovirus, adeno-associated viruses, and herpes simplex virus (Rochat and Morris, 2002). Non-viral vectors have also been introduced for purpose of gene therapy. Direct DNA transfer is the simplest way of non-viral transfection.

Genetic Engineering for Biopharmaceuticals: With the ever changing dynamics of biotechnology, more and more drugs are being developed by the biological process. To be precise, about one third of the drugs being developed, fall under the category of Biopharmaceuticals. These are those drugs that are being produced by the process of Biotechnology including "Genetic Engineering" or "hybridoma technology". In some cases these may be produced using Biopharmaceutical techniques such as recombinant human technology, antibody producing methods or gene transfer. Generally speaking, any drug produced by using microorganisms or process of genetic engineering falls under the category of Biopharmaceuticals. Over the last two decades, nearly 95 percent of Biopharmaceutical drugs have been approved by various regulatory bodies including FDA, EPA and other European authorities. Most of these approvals were against some of the challenging diseases like diabetes mellitus, growth disorders, inflammatory conditions and neurological conditions (Table-1). Pharmaceutical giants including GSK, Pfizer, Novartis, Roche, Eli Lilly and others are spending huge amounts to produce Biopharmaceutical products targeting key therapeutic areas.

Human Insulin….A classical example of recombinant DNA Technology: Insulin is a hormone which is responsible for regulation of glucose in the body. Diabetics are often treated by insulin which is derived from pancreatic glands of abattoir animals. Generally the bovine and porcine insulin is quite similar to the human insulin but vary slightly in composition. Resultantly, many patients develop antibodies against it causing inflammation at the site of injection. These facts and the adverse events of porcine and bovine insulin raised question marks on its safety aspects and forced researchers to produce recombinant insulin **(Humulin)** produced by inserting the insulin gene in a vector (E. coli). This form of insulin is similar in composition but more safe and effective than the normal insulin.

Applications in environmental biotechnology: Environmental biotechnology is defined as the use of natural elements like bacteria, plants, animals, molds and mushrooms in order to generate sustainable energy and in order to produce of earning methods the food and nutrients use in the synergistic corporate cycle in which each route waste material is used by another process as raw material (Khraiwesh, 2012). There are several applications regarding gene therapy which include the analysis and execution of actions related to microbes and ecology through complex examination techniques, new classes of noxious waste are identified through gene therapy, contaminants reduction methods are introduced, depending upon biochemical active degraders (Harms and Junca, 2014). In some countries, there is tropical and subtropical climate and biological diversity is present in a wide range and it is very helpful in solving environmental issues by accomplishing solutions regarding biotechnology. Environmental biotechnology is valuable in improving waste recovery, biodegradation and also eliminates environmental collisions through biofertilizers, biosensors etc.(Rabara and Tripathi, 2014).With the help of oil-eating bacteria, oil contaminants can be eliminated. Heavy metals, harmful chemicals can also be removed. Vegetable protein is used to produce eco-friendly plastics. For recognition and removal of minerals and contaminants indicator organisms are identified. Moreover, non-fossil fuels and eco-friendly chemicals can also be generated and water, air, soil contaminants are also eliminated through biotechnology (Fahmideh *et al.*, 2014). Biodiesel or biofuel which is manufactured with the help of genetic engineering techniques proved to be a major breakthrough and also most recent technology. The sources include plant, algae and yeast(Hedge *et al.*, 2015).

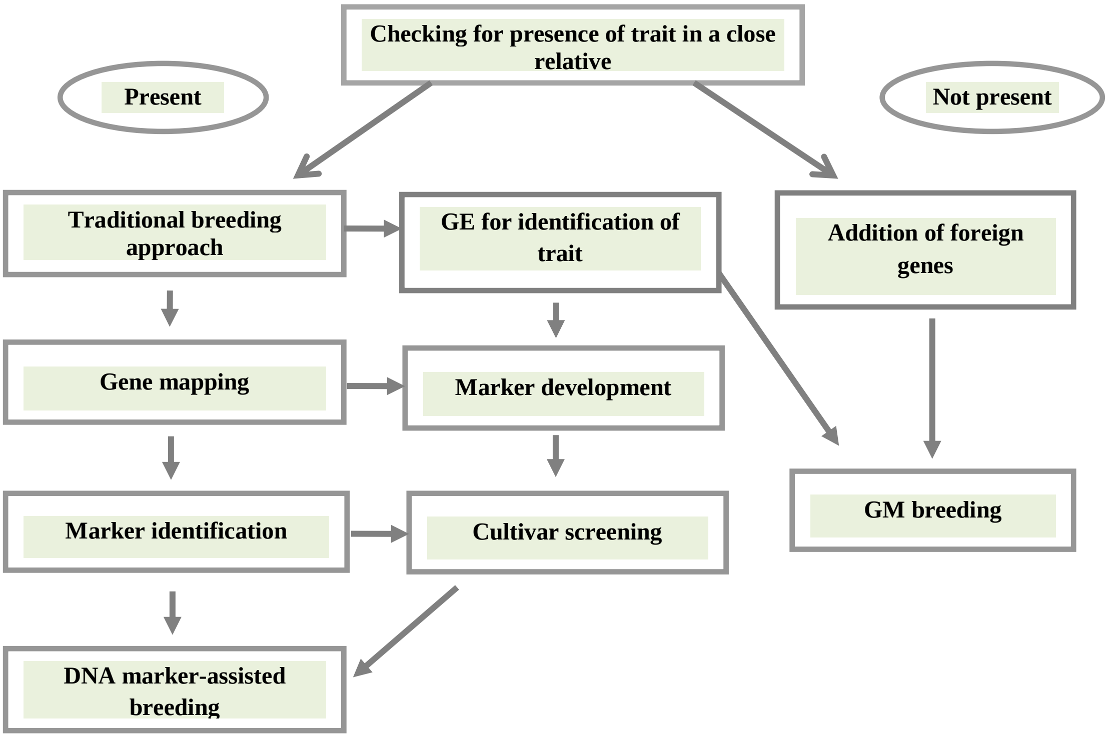

Fig. 1. Steps involved in modern crop breeding

Table 1. Some of the key drugs produced by recombinant DNA technology

Active substance	Drug Name	Therapeutic Indication
Insulin	Humalog, NovoRapid	Diabetes
Factor VIII	Factor VIII from Bayer	Males suffering from Haemophilia
Erythropoetin	Eprex, Epogen	Anemia

Discussion

Over the last decade or so, we have seen a paradigm shift in the approach of scientists, researchers and pharmaceutical companies at large Issues, risks, and disadvantages are integral parts of any technology. Same is the case with GE. This holds true for applications of GE in agriculture sector as well as in medical science.First talking about the issues of GM technology in agriculture, certain cases have been reported which suggest that GM food can cause harm the health of humans, animals and even affect the environment. A study was reported in Nature in 1999, suggesting that butterflies that fed on pollen from Bt corn had higher mortality ratios (Losey *et al.,* 1999). Similarly, a study was conducted by Lappe and colleagues in 1998 and was published in the Journal of Medicinal Food (Lappe *et al.,* 1999). The study revealed that certain GM foods have lower levels of important nutrients, especially phytoestrogen compounds which protect humans against cardiovascular diseases. At international level, it is agreed that if the GM food and the traditional food have only a minimal difference in composition, they can be termed equivalent and safe for consumption.

In future, GM technology should aim to overcome some of the concerns associated with this technology. It should aim at reducing the allergenic potential and addressing the possible effects of GM food on health and environment, the gene transfer to non-target species and interaction with natural species. The legislations and international protocols must be strictly followed and labeling must be made mandatory to improve the consumer satisfaction for improved decision making. Some of the regulations include the Convention on Biological Diversity (CBD) and the International Plant Protection Convention (IPPC).

In order to have efficient breakthroughs in the field of genetic engineering, it is needed to use bioinformatics tools along with high speed structured method so that multiple genes will be identified and usedin the field of genetic engineering. Secondly, the collection of useful genes also becomes possible with the discovery of synthetic biology and with this field instead of one or some genes, the creation and alteration of numerous genes is possible. The third factor to insert, remove or change the transgenes in the genome is possible through the site-specific system and recent genome editing technique(Yu *et al.,* 2015).

GMO not only gives benefits only but there are also shortcomings like there is no idea of long lasting effects of GMOs, pests which are controlled through these techniques develop resistance to pesticides and GM plants also got resistance and it is also possible to get affected with their toxicity instead of their usefulness. Limitations regarding to this techniques including this method cannot be applied afterward to growth stage, these methods give very little guarantee to produce fit transgenic animals, parental animal which is required for the creation of transgenic offspring can feel distressed during the experiments(Wakchaure *et al.,* 2015). Now certain limitations and concerns of GE technology in medical sciences will be discussed. Since the introduction of the technique, a number of clinical trials have taken place. The results of the first clinical trial that undertook in 1980 for treating patients with beta thalassemia were published in New England Journal of Medicine. The beta globin gene was inserted in the bone marrow cells of the human. Due to certain ethical concerns, the protocol was stopped later on. The study revealed that perhaps expression of both alpha and beta genes will be required for successful gene therapy in this case (Mercola and Kline, 1980). An Italian scientist, in 1992, carried out the gene therapy by making the use vector in the form of hematopoietic stem cells. These were used to treat the genetic disease (Abott, 1992). During 1999, several concerns were raised regarding the gene therapy after a young boy who was part of the trial suffered from failure of multiple organs and eventually died during the first week of the treatment who was being treated for deficiency of transcarboxylase(Sibbald, 2001). Similarly, a team of doctors from UK announced the results of the gene therapy trial for an inherited retinal disease. The vision of the patient increased with apparently no undesirable effect (Maguire *et al.,* 2008). Moreover, gene therapy based on nanotechnology has been experimented in 2009. In this process, the genes are covered in nanoparticles to reach the target site and the areas which otherwise cannot be reached, for instance, cancer cells (Fletcher, 1990). Gene therapy has also promised a lot to treat colour blindness in humans (Misra, 2013).

It can be said that GE should be used only in the supreme interest and benefit of the society. The bioethics must be at all cost be guaranteed while dealing with the human lives. Therapeutic cloning must be allowed for treatment of diseases and for preventing the genetic disorders, whereas the cloning of human beings has a number of ethical, moral and safety issues associated with it and hence, should not be allowed.

Similarly, in the area of agriculture, the GM technology should target at increasing crop production, enhance nutritional content and introduce traits such as herbicide and pesticide resistance etc. There is very little amount of genes that is used for the purpose to control weeds or insects. Possibly the reason is that the genes which are used are of limited functions or in the existing technology there is a deficiency to deal with huge amount of genes. No doubt the farmers get benefitted with the primary invention of genetic engineering and it's a challenge for the subsequent followers to attain advantage from numerous genes from which not only customers but also general public get benefits. There are some of the aspects are mentioned here which are very helpful to plan the transgenic crops with features of various genes (Yu *et al.,* 2015).Consumers must have the right to choose which food they want to eat. This can certainly be ensured through mandatory labeling.

Medicine, agriculture and food industry are the areas where GM animals can be used for various useful purposes. Researchers' main focal point is to introduce such animals which have improved characteristics. Recently, protection and nutritional value of animal food got better with the help of assembling lipids that are of milk and meat (Swiatkiewicz *et al.,* 2015).

Conclusion

Undoubtedly, GE has enormous applications in agriculture, medical science, pharmaceuticals, industry, and environment. The technique should be used for the sole benefit of the human kind. It is high time that awareness and education of GE should be promoted. The curricula at college and university level must contain useful contents related to applications and at the same time ethical and moral aspects of GE. Collaboration and close cooperation must be ensured between researchers and scientists of developing and developed world. Laboratory facilities and equipments required for undertaking research on GE should be upgraded and maintained by skilled manpower. Some necessary steps for fully capitalizing on the applications of GE include; ensuring necessary funding and training manpower at the world's best laboratories. The scientists and researchers must move more freely and frequently to interact and discuss the advancements in the area of GE. Collaboration and close cooperation needs to be established between the countries that are advanced in GE technology and those where the technique is still at an early stage of development. Therapeutic cloning holds a great promise for treatment of diseases and hence must be carried out in all countries.The role of GM crops for disease resistance, herbicide tolerance, pest resistance and enhanced nutritional value should be propagated. Adequate research grants must be available to scientists for undertaking research on the potential areas of GE.A concerted effort on part of scientists, researchers, government, and legislators will be required for effective utilization of GE while considering the ethical and safety related aspects of the technology. Long term studies are required to study the effects of GE on human health, plant health and on environment. The regulatory bodies need to be strengthened for implementing the international protocols. In order to maintain the interest of public, the advancements and applications will have to be conversed with the public through regular conferences, seminars, workshops and media programs.

Though genetic engineering is doing wonders in many aspects but if it is about a health concern, there is still need to make more improvements in this field because there are certain limitations as genetically modified food cause allergies, it also produces resistance for antibiotics and may lead to the creation of novel toxins. The value of dietary food is degraded through GM food and there are other unidentified threats regarding this technique (Bakhsh and Ozkan, 2015). No doubt, the future of genetic engineering is very promising and it is needed to make more advancement and eliminate the shortcomings regarding this technology.

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