Available online at www.ijpab.com

DOI: http://dx.doi.org/10.18782/2582-2845.8662

ISSN: 2582 – 2845

Ind. J. Pure App. Biosci. (2021) *9*(2), 284-296

Indian Journal of Pure & Applied Biosciences

Peer-Reviewed, Refereed, Open Access Journal

Review Article

Application and Potential Use of Advanced Biotechnology Techniques in Agriculture and Zoology

Muhammad Nouman Khalid[1], Muhammad Hassan Tahir[1], Asad Murtaza[2], Muhammad Murad[1*], Ahsan Abdullah[3], Subtain Dawood Hundal[1], Muhammad Khubaib Zahid[1], Faisal Saleem[1]

[1]University of Agriculture, Faisalabad, Pakistan

[2]National Pingtung University of Science and Technology, Taiwan

[3]China Agricultural University, 100193, Beijing, China

*Corresponding Author E-mail: 2012ag3289@uaf.edu.pk

Received: 3.03.2021 | Revised: 10.04.2021 | Accepted: 16.04.2021

ABSTRACT

Biotechnology is the use of science and technology in living entities, their parts and models to form useful products by transforming living or non-living things and produce novel tools, services and knowledge according to the need. Biotechnology has numerous other beneficial applications besides medically associated but most of them are related to agriculture and Zoology. This review aims to summarize the recent literature about the application and potential use of various approaches of biotechnology used in agriculture sector and zoology. Besides, the application of advanced genetic engineering practices powered by the new breakthrough and innovations are the keystone of this review. The effective use of genetic manipulation has encouraged the researchers to use plant-breeding tools in agricultural sciences which led to the development of novel variations in plants species by avoiding existing biological barriers to exchange of the genetic materials. The selection, regeneration and testing of plant is done later under field settings to ensure that the genetic variations are sustainable and also the characteristics of the new species fulfil commercial needs. Strategies existing for the manipulation of plants regeneration are then validated for the genetic basis of the new traits. The animal biotechnology is the base of advancements in plant biotechnology helping in high yield, adapting to certain stress conditions, and developing defence mechanism against plant pathogens. The Livestock is long been used for development of medicines i.e., insulin, heparin as anticoagulant, certain serum and helped to serve human by developing antiserum organs for human transplantation. Certain pharmaceuticals have been developed in genetically engineered animals. Biotechnology adds remarkable value to the genetic resources and extraordinarily improved the potential return from development of genetic products. With the advancement of biotechnology, automation and science collective efforts continue to eradicate hunger and poverty, focusing on food security, safety and sustainability. Also, biotechnology will improve the use of plants in the protein products production, like consuming plants as biological industries.

Keywords: *Biotechnology, Agricultures biotechnology, Animal biotechnology.*

Cite this article: Khalid, M.N., Tahir, M.H., Murtaza, A., Murad, M., Abdullah, A., Hundal, S.D., Zahid, M.K., & Saleem, F., (2021). Application and Potential Use of Advanced Biotechnology Techniques in Agriculture and Zoology, *Ind. J. Pure App. Biosci.* *9*(2), 284-296. doi: http://dx.doi.org/10.18782/2582-2845.8662

INTRODUCTION

According to the Food and Agriculture Organization of the United Nations (FAO) report, "The future of Food and Agriculture" the population of world is predictable to upsurge by 2 billion people in the next 3 years, from 7.7 billion recently to 10 billion by the end 2050. To this effect, food production must be doubled by 2050, to meet the need of world's growing population and novel approaches are required to cope with hunger which already affects more than 1 billion population of the world (Alemu, 2020). Due to rapid increase in population, it is imperious to practice new advance scientific tools and technologies like nanotechnology in agriculture (Ghosh & Bera, 2021). Genetic engineering has been extensively reviewed in literature for enhanced nutritional and agronomic traits. In short, genetic engineering manipulates the genetic material of crops and introduces a novel trait. The incorporation of new genetic material in the genome of plant can be performed either by delivery via biolistic (gene gun) or Agrobacterium-mediated transformation. Prompt technological advancement accelerates the method of application to plants with abnormal genetic expression (Wu et al., 2021). A major breakthrough has been introduced in form of precision breeding in case of animal biotechnology. This concept is allowing necessary changes to combat the issues of global food security along with environmental protection and animal welfare. The Livestock is long been used for development of medicines i.e., insulin, heparin as anticoagulant, certain serum and helped to serve human by developing antiserum organs for human transplantation. Certain pharmaceuticals have been developed in genetically engineered animals (Funahashi, 2020). Protein is a key component of the body and under nutrition of protein can lead to numerous adverse effects. Proteomics offers a comprehensive knowledge of the metabolic networks leading to the prediction of roadway changes to achieve the desired formation of end product. In biotechnology, the forthcoming future will include modifications in proteins that will alter metabolic networks to improve significant agricultural phenotypes, irrespective of the complexity in their genome (Saravanan et al., 2020).

1. **Application and use of biotechnology approaches in Agriculture**

Agricultural Biotechnology is the branch of biotechnology that involves the application of innovative scientific techniques based upon our knowledge of DNA for improvement of livestock and crops that do not occur by normal breeding only. Biotechnology tools and techniques can be used in plant breeding, genetic engineering is studied extensively regarding plant breeding and it offers a wide variety of techniques to tackle with plant genome in order to achieve higher yields and excellent quality.

2.1 Marker-assisted selection (MAS)

MAS (Figure. 1) empower the breeders of plants to be able to recognize the best traits in plants at a much faster rate than conventional breeding alone.

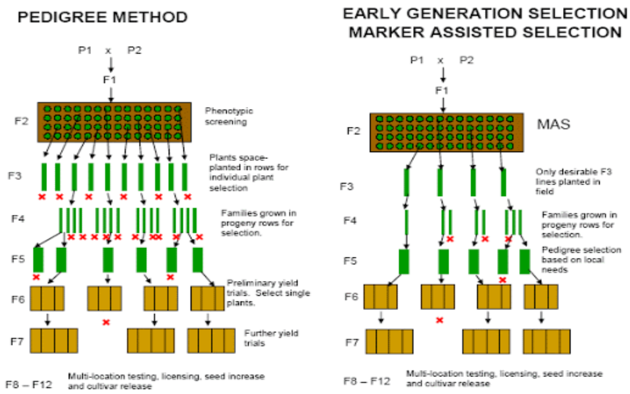

Figure 1: Breeding through Marker-assisted selection (MAS)

2.2 Recombinant DNA Technology

Another feature of the agricultural biotechnology comprises of recombinant DNA use (Nath et al., n.d.; Rischer et al., 2020; & Yadav et al., 2021). Unlike the reproduction of molecular plants, though, Recombinant DNA technology leads to novel traits development that cannot be produced by typical procedures (Figure. 2). Genetic engineering has been extensively reviewed in literature for enhanced nutritional and agronomic traits. In short, genetic engineering manipulates the genetic material of crops and introduces a novel trait Figure. 1. The incorporation of genetic material in the genome of plant can be performed either by delivery via biolistic (gene gun) or Agrobacterium-mediated transformation. The genetically modified (GM) or transgenic crops, have been available commercially since 1996, in the United States. Golden Rice is a well-known transgenic plants example, which produces b-carotene and was made with the aim of reducing the deficiency of vitamin A (VAD) in the developing states (Marrone, 2020). Cisgenic or plants from close relatives in the wild, are also being developed to recover resistant genes that have been lost over years of plant breeding. The Initiative of Wheat Stem Rust for instance, is now producing genetically modified wheat varieties that are resistant to the fungus (Puccinia graminis f. sp. tritici Ugg99) of the wild relative strains. RNA interference or RNAi technology is another technology associated with the genetic engineering (Marrone, 2020; & Mastroeni et al., 2019). In this technology the plant is manipulated for production of antisense RNA for a specific gene, which blocks the expression of the gene through gene silencing. Example of applications of this technology are genetically modified papayas' that are resilient to the Papaya ring spot virus. This approach is liable for saving of the industry of Hawaiian papaya.

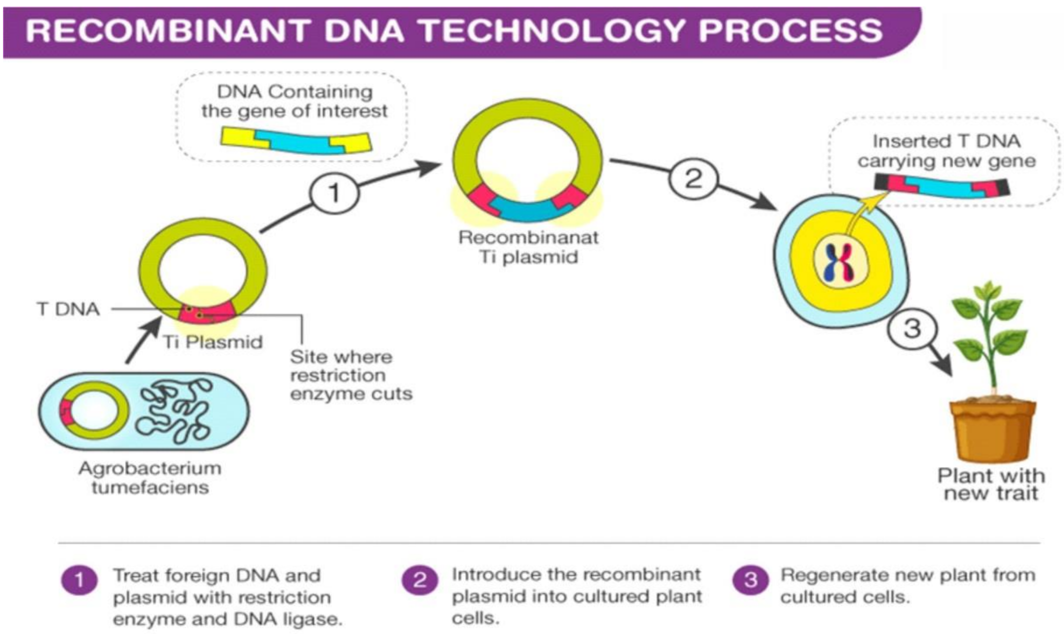

Figure 2: Recombinant DNA Technology Scheme for enhancing traits in plants

2.3 Gene Editing:

Lately, another technology called 'gene editing' is established. Gene editing (Figure. 3) does not introduce new genetic sequences; but, it can regulate single or 2 nucleotides modifications into the plant genome and is therefore free from laws governing the genetically modified organism's production. Although no gene edited plant models are available commercially at the moment, considerable research is being done in this area and many new plant species will be discovered in the coming years by utilizing this biotechnological method (Nath et al., n.d.; & Yadav et al., 2021).

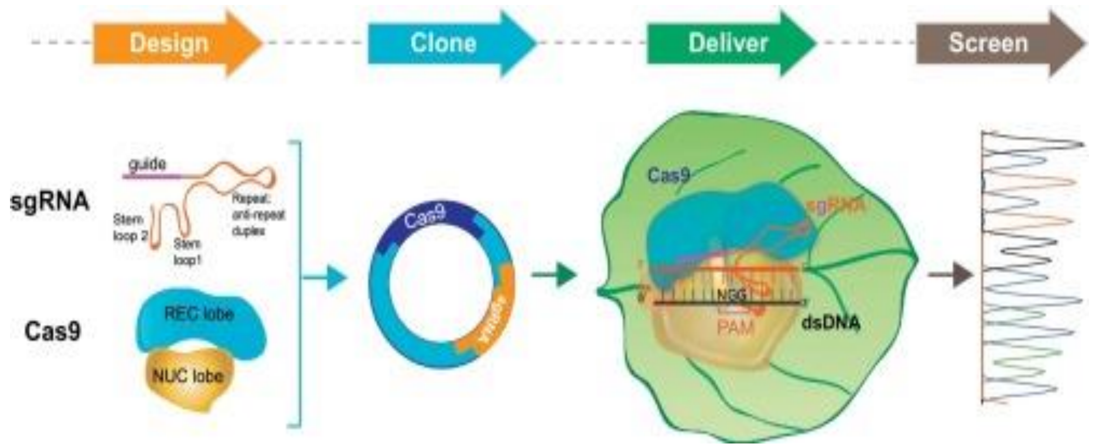

Figure 3: Gene editing scheme

2.4 Breeding through Mutagenesis

Many species of plants present today are made using breeding through mutagenesis (Fig. 4). Not considered as genetic engineering approach, breeding through mutagenesis encompasses the introduction of random mutations by chemical or irradiation mutagenesis into plant cuttings (Figure. 4). Then, the explants with novel traits are proliferated from these mutagenesis trials. As indicated by Mutant Variety Database, there are more than 17,000 species of plants that have been created using the mutagenesis breeding. Single malt scotch and Ruby red grapefruit both are developed by mutagenesis breeding (Farre et al., 2011).

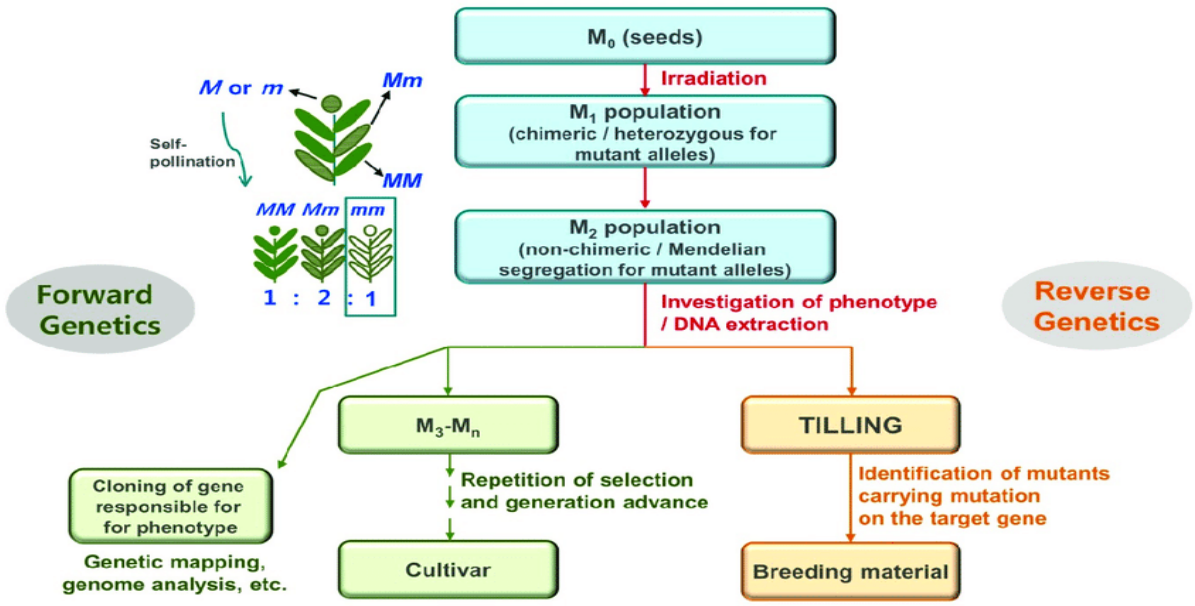

Figure 4: Breeding through Mutagenesis

2.5 Bio fortification through genetic engineering

Bio fortification is considered economical than other conventional supplementation methods (Figure. 5). Bio fortified plants can be produced by the farmers and thus can be replaced with existing distribution channels. Supplements of minerals and vitamins, on the other hand, need to reach out to people who are far away and will involve constant monitoring as well as large investments. Propagating micronutrients via agronomic bioavailability, on other hand, using fertilizers in poor soils can also be very effective, but depending on the type of crop and mineral, it cannot identify certain edible parts of plant, and will not be a solution for compounds that need to be synthesized by plants. Similarly, normal breeding of mineral species can be very time consuming and highly dependent on the previous genetic type of plant species. Because of this, genetic engineering is the only possible way to proliferate the availability of micronutrients at speeds that do not contain that micronutrient naturally (such as, vitamin A in the rice grains) (Kumar et al., 2018). There are other barriers, however, to the production of bio fortified plants by genetic modification. Some regulatory restrictions may delay or prevent the sale of bio fortified transgenic plants. Metabolic engineering can be hard to accomplish, as producing of the anticipated compounds may need to increase, while undesirable or competitive products should be reduced. In some cases, all metabolic pathways should be integrated into the novo in plants. The following section explains few of the advances in the production of fossil fuels for minerals, vitamins and other organisms that play a vital role in human health (Bielecki & Tramper, 2000). Embrace Research and Development partnerships at every level and develop a tool that will facilitate incubation for the agricultural development in reaching the market with a commercial spirit. Therefore, biotechnology services and products require a crucial point of matching and emerging domain coverage that is consistent with pre-commercial clinical trials. Thus, advisory mechanism, testing and governing should be transparent in the development of biotechnology. Ultimately, endure advances in biotechnological research capacity although the biosafety guideline's protection be flexible and clear (Altman & Hasegawa, 2012; & Hefferon, 2016) (Nath et al., n.d.; Rischer et al., 2020; & Yadav et al., 2021).

The major breakthrough in biotechnology is mainly genetically modified organisms (GMOs) that allowed to regulate and to control genetic manipulations, to brace plants fight against diseases, adverse environmental circumstances and pests. Additionally, these crops are highly resistant to viruses, viroids, fungi and herbicides. For instance, Transgenic potatoes have increased starch content and are resistant to the potato stalks, viruses and herbicides. New varieties of potatoes created by addition of thaumatin (sweet protein). Transgenic potatoes are free of toxic glycoalkaloids and resilient to enzymatic darkening (Kumar et al., 2018), transgenic sweet strawberries, are highly resistant to long ripening and frost, transgenic oilseed rape, have low unsaturated fatty acid content, and resilient to herbicides (Sawicka et al., 2019), increasing their sale due to better appearance and taste, reducing the usage of chemical products for plant protection (Sawicka et al., 2019), reduces food shortage by increasing crops size, the modern bio-pharmaceuticals development and the developing of novel therapeutic strategies, such as, genetic therapies (Sawicka et al., 2019).

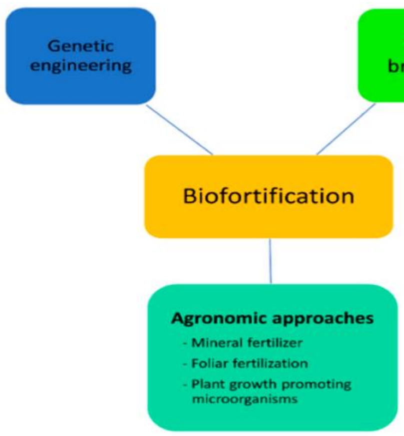

Figure 5: Biofortification

2.6 Novel biomaterials:

Increased production of food via agricultural and plant biotechnologies remains a main goal; though, over the past twenty years there has been a transference from low-cost food and the bulk goods production to high cost, particular, plant-based, and non-food products, jointly called biomaterials. This change is also in line with the growing demand for industrial products resulting from biotechnology (such as, bio-glues, bioplastics), medical devices, pharmaceuticals (like vaccines, collagen and other drugs), and bioenergy derived from plant sources for production. Looking at the past, the growing production of biofuels from the food plants is expected to affect the cost as well as supply of food (Altman & Hasegawa, 2012; & Sawicka et al., 2019). So, it is essential to shift from first generation biofuel plants to the second-generation biofuel plants. Additionally, in the continuous traditional agricultural development practices, merely two main solutions are present to increase the supply of agricultural and food commodities: (1) demand for the alternate food sources (such as, marine or additional land products like single-cell protein); or (2) improve efficiency of plant breeding to improve yields through new biotechnological tools, including flexible crop production and selection assisted by markers (Sawicka et al., 2019). Expectations of reliable alternative food sources have never been met. However, recombinant DNA technology and agricultural biotechnology products, that primarily appeared on the market in 1996, have grown exponentially since their launch. More than a billion hectares of the genetically modified crops (at present grown by 4 main crops, however more will be commercially produced) are now being cultivated by the 15.4 million farmers (mostly small holder farmers, poor in resources of the developing countries) in approximately 29 countries worldwide (Yadav et al., 2021). It is worth mentioning that the developing countries planted 48% of the world's biotech crops in the year 2010 and will outperform developed countries where they plant biotech crops by year 2015. The influence of agricultural change in just 30 years has not been seen (Rischer et al., 2020; & Yadav et al., 2021).

2. Applications and use of advanced Biotechnology techniques in Zoology

The animal biotechnology is the base of advancements in plant biotechnology helping in high yield, adapting to certain stress conditions, and developing defence mechanism against plant pathogens. The Livestock is long been used for development of medicines i.e., insulin, heparin as anticoagulant, certain serum and helped to serve human by developing antiserum organs for human transplantation. Certain pharmaceuticals have been developed in genetically engineered animals (Funahashi, 2020).

3.1 Artificial insemination

It leads to selective breeding while embryo transfer is another asset due to use of animal biotechnology. The advancement in techniques in terms of semen collection, dilution and its cryo preservation, has made it able to develop same bull type in certain countries at same time and may be used for about 100,000 insemination a year (Niemann & Wrenzycki, 2018). Chemical induction to super ovulates, a female of superior breed is selected. The resultant egg is developed to embryo after fertilization and is transferred to recipient female.

3.2 Cloning

The well-known technique is an asset to this field by creating genetically identical cells. Donor cell/nucleus is inserted an enucleated egg is the basic mechanism of cloning. The surrogated mother receives and gestates the developed embryo. Sheep, gaur, pigs and cattle are the products of such methodology (Said et al., 2020).

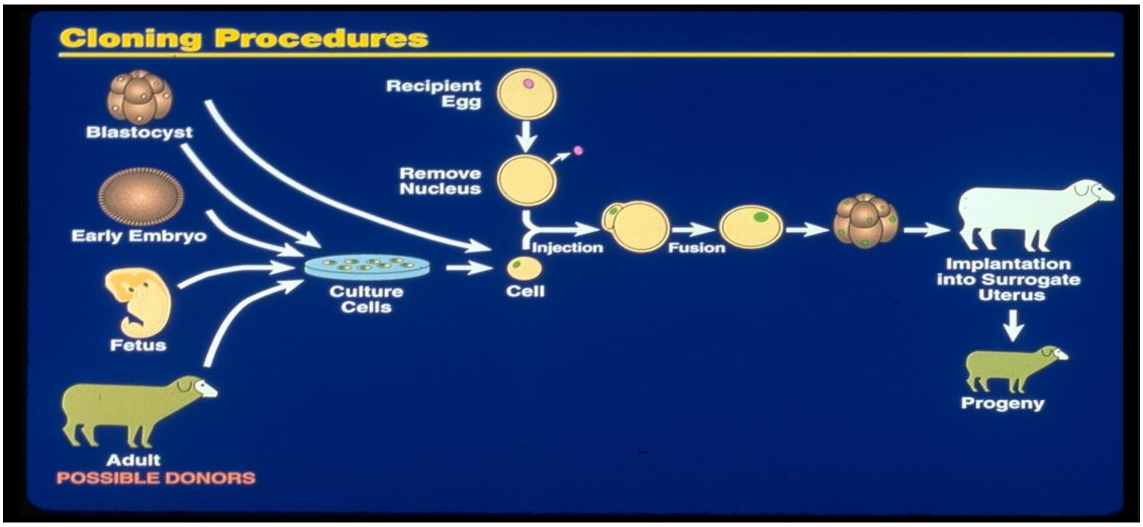

Figure 6: Conventional Cloning technique

3.3 Cattle breeding

This type of breeding was first developed in India. The crossbreed cattle were developed for the purpose of increasing in milk production. This technique is welcomed as it helped the farmers to raise their economy as it was more economical than indigenous cows due to high yield of milk. It also helped the dairy entrepreneurs as it is beneficial round year, and it became a source of regular employment. So far that much benefit, it is in need to use it simultaneously along with artificial insemination programme to evolve the profitability of farmers and in turn dairy industry.

3.3.1 Cross breeding: is the mating of established breeds resulting in progeny known as crossbreed. Crossbreeding programmes was first launched in 1950s in India, crossing indigenous and exotic cattle mainly with Holstein Friesian (HF) and Jersey to gain high yield of milk. The crossbreeding experiments resulted in evolution of a new strains of crossbred cattle, viz., Taylor, Jersind, Jerthar, Karan Swiss, Karan Fries, Sunandini, Frieswal, Phule-Triveni and Vrindavani cattle able to produce high yield milk than native breeds. Increase in crossed cattle population, milk production and per capita of milk availability, lactation length, growth rate, decrease in age at puberty, age at first calving and calving interval (Mar, 2014; Montaldo, 2006; Niemann & Wrenzycki, 2018; & Verma, 2013), higher birth weight of calves, better growth rates, better reproductive efficiency, advantage of breed complementarity and non-additive effects (dominance and epistatic) helped to develop heterosis (hybrid vigor). Heterosis was very crucial for lowly heritable traits such as fertility and survival. Heterosis produces crossbred animals resultantly gives high yield and more productive than either of the parental breeds. Crossbred animals are docile, smoothly handled and machine milking is quite easy with them while easy to detect heat stage and successful in artificial insemination. Very economical in terms of price than native breeds (Niemann & Wrenzycki, 2018). The genetics and physiology are somewhat similar between human and animals. The human medical biology research is mostly done on using these research animals. Genetically engineered technology is used to develop recombinant vaccines developed by using microbial genes for desired antigens are transferred into a vector ant transformed into a production system such as Pichia pastoris. DNA, subunit, gene deleted vaccines, and synthetic peptides are all the types of recombinant DNA vaccines (Funahashi, 2020; & Said et al., 2020).

3.4 Molecular Breeding Technique

The molecular breeding (Figure. 7) technique recognize and confirms the vicenary trait loci markers that are associated with the interesting genes traits which can be inserted into the elite lines via markers assisted introgression (Kumar et al., 2018). The land use is more by the agriculture so a shortage to the animal breeding demands more efficiency in terms of sustainable production (Niemann & Wrenzycki, 2018). Genetic engineering seems to be the only way out as to meet these demands. DNA based approaches to selection and breeding of animals can ensure a healthy and sustainable production and not only sustainability can be ensured but also at a much lower cost of the environment. Not only production but this research can boost the quality of many developments specially in medical terms, human disease studies, transplantations, protein production, environmental safety, and medicines. in March 2018 USDA accepted that precision editing is very much similar to the natural rear mutation. These mutations do occur but very rear yet possible and so it will not plan to regulate those mutations, but it will still recognize them as GMOs as they are the plants with foreign gene introduction (Laurinčík, 2012; Mar, 2014; & Niemann & Wrenzycki, 2018). Experience gained from repeated attempts to gain acceptance of genetically modified meat products suggests that there is still a way to go for even the most subtle gene modifications. Public approval of Genetic editing technologies and their product is rather an indirect process. This process will have to consist not only of demonstration of the safety of the product but the safety of animals, human health, and sustainability as well. Then can be the approval of the public gained. more accurate procedures need to be introduced to avoid any off-target effect in animals as for their own safety as well as the safety of the environment and products.

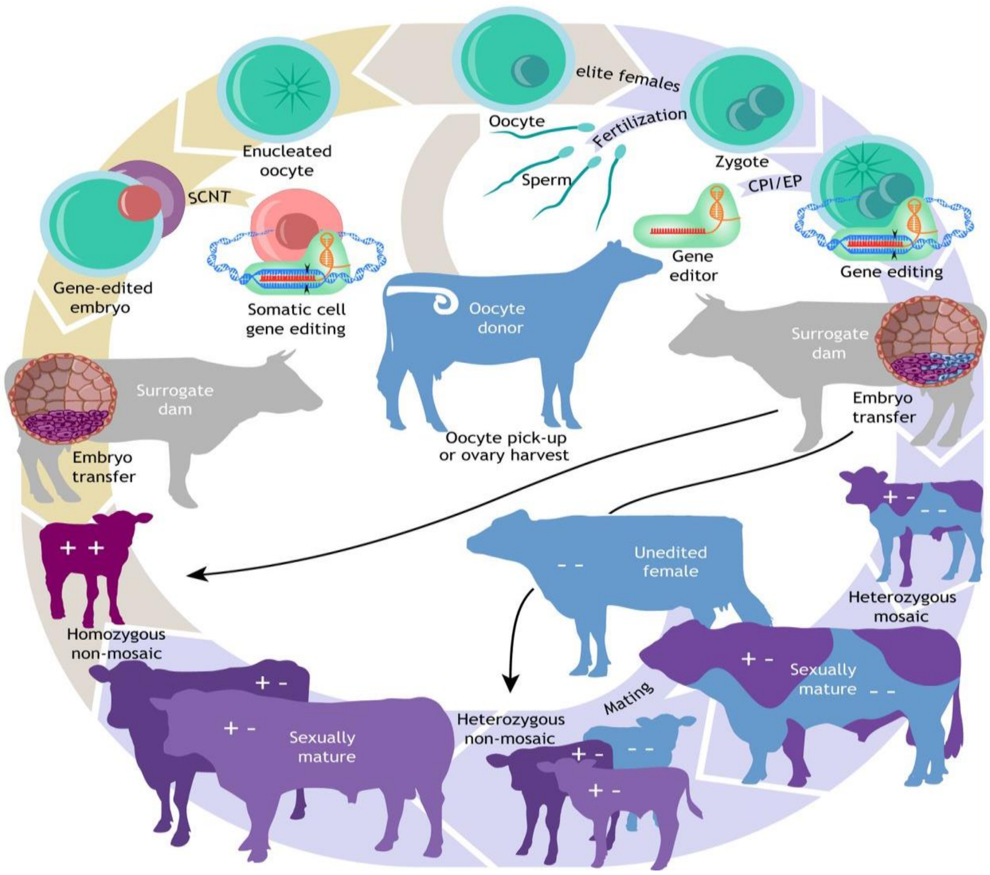

Figure 7: Molecular Breeding thematic diagram

3.5 Gene editing through CRIPSER Cas

CRIPSER Cas is a tool that provides solution to avoid off target effects of gene editing. The proof that these technologies are becoming more valuable is that they are being persuade more persistently in farm breeding for both long term and medium-term gain of the products (Figure 8). By applying gene drive concepts using genome editing tools, increasing the allele frequency using gene drive mechanisms would accelerate genetic gain even further and without the risk of increased inbreeding (Russian, 2020). This these technologies have been confirmed via simulation that increasing the frequency of favourable alleles using gene drive and decreasing the fix time for gene in the germ lines can actually increase the gain from that particular gene. This could be done by labelling nucleotides, for a more accurate and rapid targeting of favourable traits. This can increase the efficiency of the genes and in turn the yield (Niemann & Wrenzycki, 2018), all desirable capacities for inclusion in future breeding concepts In shorts breeding can be done with more precision considering more advanced genetic tools and can be far more better understood to achieve desirable results. The increasing of a certain gene in a gene pool Is the desired target for more genetic gain. this in turn increase the economic importance of that particular gene set or a gene. Full potential of these techniques needs to be explored in order to get the maximum out on a very lower environmental cost (Funahashi, 2020). This exploration is vital for to meet the challenges of food security challenges in contemporary vs upcoming times both for enterprises and public welfare and safety. Also, these explorations need to be transparent and the public and stack holder get to the more of the information so that can result in a higher approval rate and higher understanding of these technologies which can lead to more advanced initiatives and exploration (Mar, 2014; Niemann & Wrenzycki, 2018).

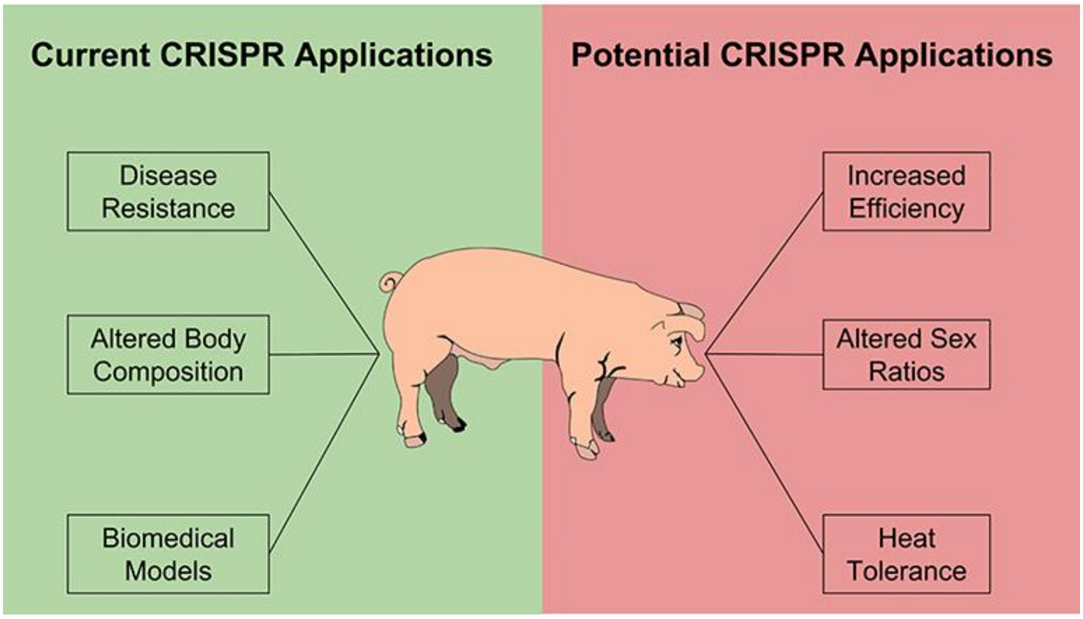

Figure 8: Application of CRISPER

DISCUSSION

Significant advances in transcriptomic and genomics have stimulated interest in metabolomics and proteomics. Currently, modern methods may characterize structurally and measure the proteome, along with any translational changes that are not essential for body function and consequently biological activity. Proteomics offers a comprehensive knowledge of the metabolic networks leading to the prediction of roadway changes to achieve the desired formation of product. In biotechnology, the forthcoming future will include modifications in proteins that will alter metabolic networks to improve significant agricultural phenotypes, irrespective of the complexity in their genome. Also, biotechnology will improve the use of plants in the protein products production, like consuming plants as biological industries. These yields will include storage proteins, enzymes, hormones, reagents, antigens, peptides hormones, vaccines and antibodies (Funahashi, 2020; Marrone, 2020; & Yadav et al., 2021). This volume is the outcome of decades of surgical procedures and procedures involved in internal protein smuggling and identification; cell, tissue, or body conformation; and developing the engineering programs that can transform this data into small and large productive and economically viable productions. The plant's metabolome is estimated to contain 200,000 to 1,000,000 diverse molecules (Kumar et al., 2018). This represents the chemical capability of the cells. Certain metabolites with their concentration form metabolic signatures that guide the responses of plants to environmental and developmental processes. Metabolic profile clearly indicates the plant condition and a powerfully regulates the processes. These metabolites are sources of nutraceuticals, pharmacies, fibre, food and various other primary and secondary products, as well as biofuels. Profile changes based on previous product modifications and mutations will significantly affect the production of bio-molecular resources and changes in development as well as environmental responses. Tissue culture, like it is naturally referred to, is primary and foremost plant biotechnology. It was initially established as a platform for the basic research on cell division and tissue, as well as hormone identification, function and morphogenesis (Zhu et al., 2020). The tissue culture has resulted in various biotechnological duplications. These comprises of rapid clonal replication, somatic breeding methods (such as., protoplast fusion, haploid production by cell selection, pollen culture etc.), transgenic plants, disease eradication, and conservation of -germplasm. A key breakthrough in the plant biology has been the developing of genetic resources and genetic transfer techniques, which include integration with genome capture and stable reproduction (Marrone, 2020; & Rischer et al., 2020). Combined with information based on research in tissue culture, the plants can be reconstructed from modified cells, able to communicate stable and inherited from the offspring of the transgenes; called as genetic transformation. The Agrobacterium-Mediated mutation is a widely used technique in biotechnology. The Agrobacterium's "disarmed" forms have genetic markers which are involved in the recognition of host, replication of transgene, and transfer to host genome and cells. Micro projectile bombardment and the non-Agrobacterium plant modification approaches are used to produce species of transgenic plants out of the host range of the Agrobacterium (Kumar et al., 2018). In connection with the development of the omics technology and the effectiveness of genetic transformation, a novel basic knowledge of the biological processes and cellular utilization of the plants is also driving biotechnology evolution. Apomixes is the development of somatic embryos from ovulatory tissues or undamaged gametes. This natural process permits for high-quality traits that are genetically modified and genetically engineered and inherited. This development is believed to preserve the kind of genetic diversity needed for evolution in order to preserve particular plant species. Meanwhile the important genes of apomixes are well-known, so it may be possible to select apomixes for the facilitation of the hybrid seed production. The selection assisted by the DNA marker cooled the process of testing the phenotypes for human segregation, significantly accelerating the crop development (Sawicka et al., 2019). Male reproduction serves as basis for the hybrid reproduction of various important plants. The genetic basis of the cytoplasmic cells male reproductive and reproductive mechanisms is well demonstrated at the cellular level until efficient biotechnology techniques can be developed. Also, biotechnology is ready to use genetic diversity in nature. The development and understanding of technology acquired through the use of species like Arabidopsis has led to the discovery of alleles that are superior in plant species (Kumar et al., 2018; & Sawicka et al., 2019). In case of animal biotechnology, A major breakthrough has been introduced in form of precision breeding. This concept is allowing necessary changes to combat the issues of global food security along with environmental protection and animal welfare (R. Estimation of the global human population simulates the growth of humans to be touching the scale of 9 to 10 billion. This growth boom is expected in major developing countries and in the urban areas of the world. A rise in population is demanding on the resources and among them food is the major resource for survival this stress isn't only on the Planets resources but also on fellow species of the humans as more and more animal proteins are going to be needed (Montaldo, 2006). This stress scale shows a 70% demand more than what the demand stands today which seems unsustainable. More and more meat products are going to be needed to meet the protein needs of such a large population (Yadav et al., 2021). Concerns for the biotechnological advancement should aid health regulations, biosafety and not to be managed for benefit of corporations through concomitant sponsored research and therefore allowing exploratory trials on the public health and lives. Environmental protection, is an important factor in biotechnology progression directly via remediation procedures or indirectly preventative by replacements in the typical processes (Zhu et al., 2020).

CONCLUSION

World-wide biotechnology industry should rightly be thought of as a current tool to solve the issue of global hunger through enhancement of agriculture sector, solve health issues through properly understanding zoonotic diseases, save animal species from extinction through genetic manipulation and lot more. Lately, there has been a dramatic increase in biotechnology development linked with genetic engineering. Use of advanced techniques linked to biotechnology can do wonders in the fields of agriculture and zoology. Genetic engineering has enabled us to study and manipulate the genomes of plants and animals for the well-being of homo sapiens.

REFERENCES

Alemu, M. (2020). Trend of Biotechnology Applications in Pest Management: A Review. *International Journal of Applied Sciences and Biotechnology*, *8*(2), 108–131. https://doi.org/10.3126/ijasbt.v8i2.28326

Altman, A., & Hasegawa, P. M. (2012). Introduction to plant biotechnology 2011: Basic aspects and agricultural implications. In *Plant Biotechnology and Agriculture* (First Edit). Elsevier Inc. https://doi.org/10.1016/B978-0-12-381466-1.00050-X

Bielecki, S., & Tramper, J. (2000). S. Bielecki, J. Tramper and J. Polak (Editors) 9 2000 Elsevier Science B.V. All rights reserved. 307. *Food Biotechnology*, 307–310.

Deikman, J., Petracek, M., & Heard, J. E. (2012). Drought tolerance through biotechnology: Improving translation from the laboratory to farmers' fields. *Current Opinion in Biotechnology*, *23*(2), 243–250. https://doi.org/10.1016/j.copbio.2011.11.003

Farre, G., Twyman, R. M., Zhu, C., Capell, T., & Christou, P. (2011). Nutritionally enhanced crops and food security: Scientific achievements versus political expediency. *Current Opinion in Biotechnology*, *22*(2), 245–251. https://doi.org/10.1016/j.copbio.2010.11.002

Funahashi, H. (2020). Animal Biotechnology Roles in Livestock Production. *IOP Conference Series: Earth and Environmental Science*, *465*(1). https://doi.org/10.1088/1755-1315/465/1/012001

Ghosh, S. K., & Bera, T. (2021). Molecular mechanism of nano-fertilizer in plant growth and development: A recent account. In *Advances in Nano-Fertilizers and Nano-Pesticides in Agriculture* (pp. 535–560). Elsevier. https://doi.org/10.1016/b978-0-12-

820092-6.00022-7

Hefferon, K. L. (2016). Food Security of Genetically Modified Foods. In *Reference Module in Food Science*. Elsevier. https://doi.org/10.1016/b978-0-08-100596-5.03532-0

Hotz, C. (2009). The potential to improve zinc status through biofortification of staple food crops with zinc. *Food and Nutrition Bulletin*, *30*(1 SUPPL.), 172–178. https://doi.org/10.1177/15648265090301s109

Kumar, K., Karanwal, S., Meena, K., Singh, C.C., R., Meena, R.K., & Jaiswal, S. (2018). Role of biotechnology in crop and animal improvement for sustainable agriculture. *Journal of Pharmacognosy and Phytochemistry JPP*, *7*(71), 1120–1124. https://www.researchgate.net/profile/Kuldeep_Kumar55/publication/322959147_Role_of_biotechnology_in_crop_and_animal_improvement_for_sustainable_agriculture/links/5a79af7a45851541ce5d634b/Role-of-biotechnology-in-crop-and-animal-improvement-for-sustainable

Laurinčík, J. (2012). *Constantine the Philosopher University in Nitra Faculty of Natural Sciences Embryotechnology*.

Mar, N. (2014). *Molecular Approaches to Zoology Molecular Zoology: Advances, Strategies, and Protocols by Joan D. Ferraris; Stephen R. Palumbi Review by: Maureen K. Krause topics, but still unfortunately, there is far too little emphasis on the inter-*. *47*(3), 194–196.

Marrone, P. (2020). The Role of Industrial Biotechnology in Sustainable Agriculture. *Industrial Biotechnology*, *16*(4), 211–212. https://doi.org/10.1089/ind.2020.29221.pma

Mastroeni, M., Mittra, J., & Tait, J. (2019). Political influences on biotechnology-based innovation for European agriculture: risk-assessment and risk management. *Technology Analysis and Strategic Management*, *0*(0), 1–12. https://doi.org/10.1080/09537325.2019.1573983

Montaldo, H. H. (2006). Genetic engineering applications in animal breeding. *Electronic Journal of Biotechnology*, *9*(2), 157–170. https://doi.org/10.2225/vol9-issue2-fulltext-7

Nath, A., Singh, Y. J., Asghar, A., Neelam, R., & Editors, Y. (n.d.). *Sustainable Development and Biodiversity 25 Plant Microbiomes for Sustainable Agriculture*. http://www.springer.com/series/11920

Niemann, H., & Wrenzycki, C. (2018). Animal biotechnology 1: Reproductive biotechnologies. *Animal Biotechnology 1: Reproductive Biotechnologies*, 1–304. https://doi.org/10.1007/978-3-319-92327-7

Rischer, H., Szilvay, G. R., & Oksman-Caldentey, K. M. (2020). Cellular agriculture — industrial biotechnology for food and materials. *Current Opinion in Biotechnology*, *61*, 128–134. https://doi.org/10.1016/j.copbio.2019.12.003

Russian, I. (2020). *ANIMAL* 55(2).

Said, S., Agung, P. P., Putra, W. P. B., & Kaiin, E. M. (2020). The role of biotechnology in animal production. *IOP Conference Series: Earth and Environmental Science*, *492*(1). https://doi.org/10.1088/1755-1315/492/1/012035

Saravanan, K. A., Kumar, H., Mayank, D., Virbhai, K., Tyagi, S. K., Rajawat, D., Kaisa, K., Bhushan, B., Panigrahi, M., & Preethi, A. L. (2020). Advances in genome editing technology and its applications in poultry breeding. ~ *1416 ~ Journal of Entomology and Zoology Studies*, *8*(2), 1416–1423.

http://www.entomoljournal.com

Sawicka, B., Umachandran, K., Skiba, D., & Ziarati, P. (2019). Plant biotechnology in food security. In *Natural Remedies for Pest, Disease and Weed Control*. Elsevier Inc. https://doi.org/10.1016/B978-0-12-819304-4.00014-2

Verma, A. (2013). Animal Tissue Culture: Principles and Applications. In *Animal Biotechnology: Models in Discovery and Translation*. Elsevier. https://doi.org/10.1016/B978-0-12-416002-6.00012-2

Wu, Y., Zhou, N., Ni, X., Okoye, C. O., Wang, Y., Li, X., Gao, L., Zhou, G., & Jiang, J. (2021). Developing a long-term and powerful in vitro culture and Agrobacterium-mediated transformation system for Miscanthus sinensis (Poaceae). *Industrial Crops and Products*, *161*, 113190. https://doi.org/10.1016/j.indcrop.2020.113190

Yadav, A. N., Singh, J., Singh, C., & Yadav, N. (2021). *Current Trends in Microbial Biotechnology for Sustainable Agriculture*.

Zhu, H., Li, C., & Gao, C. (2020). Applications of CRISPR–Cas in agriculture and plant biotechnology. *Nature Reviews Molecular Cell Biology*, *21*(11), 661–677. https://doi.org/10.1038/s41580-020-00288-9