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REVIEW ARTICLE **OPEN ACCESS**

Role of Biotechnology in Enhancing Farmer Prosperity: A Comprehensive review

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ABSTRACT
In the world, India has been emerging as one of the fastest growing economies. Almost 52% of the Indian population is involved in the agriculture and allied sector but unfortunately, most of the Indian farmers are still engaged in subsistence farming and their average annual income is below the poverty line. After the green revolution,though we have achieved self-sufficiency in food production, the situation of small and marginal farmers has remained the same. Climate changes, biotic and abiotic stresses, small land holdings, land degradation, the low market price of produces, and lack of low input-high output technologies are the major challenges which we have to deal with in order to increase farmer's income. Involvement of innovative technologies is one the best strategy for increasing crop production and income of the farmers. Biotechnology is one of the most attractive technologies for the crop improvement and is the fastest adopting technology across the globe. Plant tissue culture, molecular breeding, transgenic development, animal cloning are the important tools of biotechnology. It has been used to improve various traits like yield, resistance to biotic and abiotic stress, quality as well as introduction of novel traits like bioplastic production. Application of biotechnology in agriculture has significantly improved farmer's income and sustainability of crop production in the both developed and developing countries. Its application is not limited to the crop improvement but it has also been used in livestock improvement and fisheries. To improve the lifestyle of the farmers, status of Indian agriculture while maintaining the international standard of food quality and nutritional value it is critical to encourage the involvement of biotechnology in the agriculture and allied field.
***Keywords**: Biotechnology, Genetic modifications, Farmer's income, Yield, Agriculture.*

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INTRODUCTION

After the green revolution (1965-2015), India's food production has increased by 3.7 times while the Indian population has grown by 2.55 times. This increase in crop production has helped India not only to achieve self-sufficiency in food at the aggregate level but also made it reach a status of a net food exporting country [4]. It has been observed that increase in farm output resulted in farmers' income but it's not true always. The NSSO (national sample survey office) data on consumption expenditure survey for the year 2011-12 reveals that more than one-fifth of the rural households with self-employment in agriculture as their principal occupation were below poverty line.

The major sources of growth in output and income can be put into four categories 1. Development initiatives including infrastructure 2. Institutional mechanism 3. Policies 4. Technology. As Indian agriculture is dominated by small and marginal farmers, technological aspects play a very important role in increasing resource use efficacy and farm output [5]. Hence, development and introduction of novel technology in agriculture is need of the hour and use of biotechnology provides a way for it.

In broad sense, Biotechnology is the use of living systems and organisms to develop or make products, or "any technological application that uses biological systems, living organisms, or derivatives thereof, to make or modify products or processes for specific use" (UN Convention on Biological Diversity, Art. 2). Actually, this is combinational of various sciences, techniques and procedures in order to improve the biological potential of an organism. Improvement may be directional or holistic based on the requirements. Biotechnology has been in use since thousands of the years in the field of agriculture and

food production. It has been also a part of ancient medicine. If we look into ancient as well as the modern agriculture, farmers have unconsciously altered the genetic makeup of the crops through various breeding approaches like selection, hybridization and introduction into the new environment. The earliest farmers used to select and breed the best-suited crops having highest yields, in order to produce enough food to support a growing population. Hence, this was one of the first biotechnological methods practised in the field of agriculture.

Agricultural biotechnology:

Biotechnology has four major area of application at industrial scale. It includes healthcare sector (medical), agriculture and allied sectors, non-food (industrial) uses of crops and other products (e.g. biodegradable plastics, vegetable oil, biofuels)and environment-related applications. When biotechnology research is confined to agricultural processes, it is called as Green biotechnology . Tissue culture mediated selection, domestications and propagation are one of the aspects of biotechnology (Wenzel, 2006). Another field of agricultural biotechnology is the designing and development of transgenic plants using genetic engineering to give advanced and desirable traits to the host plant.

Application of plant biotechnology in the field of agriculture:

With the development of modern tools and improvement in the basic knowledge related to plant metabolism and its responses to various environmental conditions, biotechnology can easily be applied to improve plants and their behaviour. Biotechnology has potential to address all the problems related to agricultural production, defence to various stresses and post-harvest processing. It can not only improve the yield but can also enhance the quality and nutritional value of the crop produces. All this goal can be achieved alone by biotechnology but at the same time, it can also increase the scope and efficiency of plant breeding for crop improvement [18]. Biotechnology helps to raise and stabilize yields by improving resistance to pests, diseases and abiotic stresses such as drought and cold; and to enhance the nutritional content of foods [17, 9]. It is being used to develop low-cost, disease-free planting materials for crops such as cassava, banana and potato and is creating new tools for the diagnosis and treatment of plant and animal diseases and for the measurement and conservation of genetic resources. Biotechnology is being used not only to speed up breeding programmes for plants but also for livestock and fisheries [22, 27]. It has also been used to change the feed and feeding practices to improve animal nutrition and to reduce environmental waste. Biotechnology has also been applied in disease diagnostics and for the production of vaccines against animal diseases [34].

It has been found that agricultural biotechnology has the capability to increase crop production by seven to tenfolds as compared to the conventional agriculture in developing countries. In 2007, 12 million farmers in 23 countries, 12 developing and 11 industrialized – planted 252 million acres of biotech crops, primarily soybeans, corn, cotton and canola. Eleven millions of these were small or resource-poor farmers in developing countries. Farmers earn higher incomes in every country where biotech crops are grown. When farmers benefit, their communities benefit as well.

Disease Diagnosis: Advanced molecular tools can be used to detect disease and pathogen in a more accurate, rapid manner and at an early stage [24]. This approach helps in prevention of disease spread and contributes towards an increase in crop production and protection. Ultimately this is responsible for ensuring good health of crops, farm animals and fisheries.

Advanced vaccines and medicines: With the help of recombinant DNA technology, it is possible to develop advanced vaccines and drugs which can help prevention and curing of disease in livestock, poultry and fisheries [1, 15]. Now, there are some concepts of producing recombinant vaccines in fruit crops [23]. Commercialization of such crops may prove beneficial for farmers due to its higher industrial demand.

Tissue culture: Itis one of the most important and well established applications of plant biotechnology in crop improvement. Production of somaclone (e.g. Pusa Jaikisan, a mustard variety), disease-free planting material (e.g. Papaya and banana) through Micropropagation is one of the most commonly used methods of crop improvement [29]. Development of healthy and uniform planting material ensures not only higher production and increased income but it also reduces the expenses on chemical fertilizers and pesticides.

Molecular breeding and marker assisted selection (MAS): Development of molecular markers has played a crucial role in crop improvement through plant breeding. It has improved the speed and efficacy of plant breeding through identification and evaluation of suitable parent material as well as a selection of desirable traits in progenies [7].One of the most famous examples in India is the development of improved Pusa basmati 1 through marker-assisted backcrossing which is resistance against bacterial leaf blight disease [28]. Development of improved varieties like Pusa Basmati1 had made India a net exporter of Basmati rice to the different countries of the world, resulting in a gain of huge foreign currency and improved condition of farmers associated with the cultivation of this variety.

Genetic Modification (GM): It is a part of modern biotechnology which involves intentional manipulation of genetic material of any organism with the goal of developing desirable traits in the target organism. It involves addition, deletion or replacement of any target gene within the organism so as to develop some novel traits. The most contrasting difference between plant breeding and genetic engineering lies on the source of the gene and methods involved in the gene transfer. Genetic engineering involves the transfer of one or few specific gene in a highly regulated manner using biotechnological tools.It can transfer gene derived from any source to any target species like into plants, livestock, fish and tree species. One recent advancement in genetic modification is the use of genome editing tool which modified the target gene in high precision. Development and cultivation of Bt-cotton in India have not only increased the yield per unit area but also ensures the fibre quality, which has resulted in a higher market value of the produce [31].

Impact of Agri-biotechnology in relation to farmers agricultural productivity and Income:

1. Yield: Increase in yield is one of the important traits on which agri-biotechnological research in India is focused upon. Development of transgenic crops for enhanced photosynthetic efficiency, reduced height, higher harvest index and higher nutrient utilization efficiency will not only optimize the yield but also enhance the yield potential of the crop [14, 19]. Development of new genome technologies along with bioinformatics tools will further propel Indian agriculture into a new era where complex traits such as photosynthetic efficiency and crop yield can be greatly enhanced.

2. Resistance to biotic and abiotic stress: Reduction in arable land available for agricultural in India, improving the stress tolerance in field crop will permit productive farming on currently unproductive lands. According to an estimated 25% to 40% of world crop output is lost due to the attack of pests, weeds and diseases [8]. To control this problem, use of chemicals is the most commonly adopted method. Surprisingly, many crops even require 15-20 spray of highly toxic and expensive chemicals. Consequently, the indiscriminate use of pesticides is a major problem as it not only poses a health and environmental hazard but also increases the economic burden on the farmers [25, 26].On the other hand abiotic stresses like drought, salinity and waterlogging are major challenges for the present agriculture [13]. Unfortunately, there is not any foolproof strategy other than breeding for tolerance to abiotic stress. Development of molecular markers associated with given stress and its application in molecular breeding is a relatively slow process. Lack of suitable germplasm or cross-incompatibility leaves plant biotechnology as an only available option. Development of transgenic crops containing genes from different or related sources for various stress tolerance is a major aspect of biotechnology. Through the application of biotechnology, crops can be tailored to lower degrees of agricultural inputs (e.g. Fertilizers, pesticides, water), and to agricultural practices requiring less energy input (such as low tillage, perennial grains cultivation). This has proved true in the case of the adoption of genetically modified Bt cotton which has allowed cotton farmers, in both the developing and the developed countries, to reduce their pesticide sprayings significantly [16, 17, 2]. Herbicide-tolerant crops like biotech soybeans allowed farmers to almost completely eliminate ploughing on their fields, resulting in better soil health and conservation, improved water retention/ decreased soil erosion and decreased herbicide runoff. Introduction of the genetically modified crop has resulted up to six percent reduction in Global pesticide applications and has eliminated around 379 million pounds of pesticide applications. Biotech varieties have dramatically reduced farmers' dependence on the use of pesticides since 1997, the total consumption of pesticides on global biotech crop acreage has been condensed 8.8 percent. [2, 3]. Through biotechnology, more specialized and toxic herbicides have been replaced by a smaller number of low cost, safer, broad spectrum and efficient compounds with reduced environmental impacts. Hence, the use of biotechnology significantly contributes to the sustainability and farmers' prosperity.

3. Quality improvement: Quality of the agricultural products is the major determinant of its market price. Use of inferior planting material, lack of nutrient, poor storage facilities and various biotic and abiotic stress severely affect the quality of produces. This ultimately leads to reduced income of the farmers. Biotechnology can play an important role in improving not only the quality in terms of appearance but it can also improve the nutritional value of the agricultural products. Genetic engineering and plant tissue culture has been used for improved shelf life and keeping qualities, enhancing the colours and aroma or improved nutritional status of the food crops [35, 20]. Similarly the prolonged 'vase life' of cut-flowers will help broaden the market for horticulturists, while reducing losses and minimising their dependency on expensive cold storage.

Research has shown [33] that one of the most efficient ways to reduce malnutrition of the poor is by enhancing the iron, zinc and vitamin A content of basic food grains. In some cases this can be done through conventional breeding, but for some micronutrients, such as Vitamin A and the case of Golden Rice [33], GM crops could be a part of the answer. Biofortification is another very important area of food crop improvement. Development of food crops with improved nutrient value will not only improve the

health of the country but more importantly it will prevent the cases of malnutrition and undernourishment in the poor families, mostly farming community. Hence, biotechnology can ensure the availability of high quality, nutritious food at affordable price. Golden rice is one of the most discussed miracles of plant biotechnology which contains significant amount of Vitamin A precursor and its improved versions are expected to provide Iron and vitamin E also [29, 30].Human and livestock health can be improved through crops with enhanced nutritional quality traits such as iron-rich rice and vitamin A-rich rapeseed oil, and through the production of edible vaccines and other pharmaceutical proteins.

The shelf life of fruits and vegetables can be improved to reduce losses due to food spoilage and expand the market view. There has been much human misery caused by hazardous antimetabolites and antinutritional compounds in many Indian food crops such as the presence of neurotoxic compounds in Khesar dal, cyanide compounds in cassava or tapioca, aflatoxins in groundnut and antimetabolites in chickpea, horsegram and sweet potato. Biotechnology has potential to 'silence' these undesirable and uneconomical traits. Hence, improvement of these traits will ensure higher greater consumer satisfaction and income of the farmers.

4. Production of crops having unconventional but important traits:

Developing countries can use agricultural biotechnology as a strategic base for environmentally friendly industrial growth where small-scale farming can potentially be made more profitable. The production of industrial (non-food/feed) products such as biofuels producing GM crops, starch producing crops, crops producing biodegradable plastics, oils and lubricants, detergents, enzymes, cosmetics, fragrances and flavours, pharmaceuticals, antibodies and vaccines, essential oils, flavours and fragrances can give a boost to the Indian economy and create jobs. These high value genetically modified crops can act as a better cash crops with high economic value and greater industrial applications. Trees that grow faster with fewer disease and pest problems can be developed with positive impact both on the rural economy and the environment.

CONCLUSIONS

If applied responsibly and carefully, the modern biotechnology can provide the Indian agriculture to address the present and future challenges in a more efficient and sustainable way despite its limited land, water and economic resources. With increasing population, climate change and the emergence of new pest species, India cannot lag behind in searching and utilize for best available technology to sustain its agriculture and farmers community. Biotechnology alone cannot solve the serious problems faced by farmers in developing countries and it should only be used when basic management or infrastructural requirements like biosafety laws, plant breeders' rights, seeds acts, IPRs are effectively in place. According to the IFPRI, the adoption of crops and traits improved through modern biotechnology significantly benefited small-scale farmers. Agri-biotechnology has a potential role in improving health, equity and poverty alleviation in relation to the adoption of crop genetics, effective breeding efforts and dissemination of more productive planting material and livestock remain as some of the most effective means by which farmers can be assisted. So the use of biotechnology in agriculture helps farmers to be more efficient in reducing land needed to grow food and farmers can use crop protection products more efficiently when using biotech crops. It has also been proven that biotech crops lower agricultural carbon footprint leading to a safer environment. Use of biotech crops boost income for smallholder farmers so that they can invest more in their farm, home, education and health.

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