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Problems of Genetic Modification of Plants in Sustainable Agricultural Development

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Abstract. Genetic engineering has not only found medical applications, it has also led to the production of genetically modified agricultural crop varieties whose potential benefits and risks have provoked huge controversy. In the agricultural sector, contradictions arise from the nature of genetic engineering and the necessity of using its products. Currently, there are global concerns about sustainable development and improved relationships between human society and the natural environment. Therefore, investigating the effects and consequences of genetic engineering on agriculture and techniques that affect human health seems essential. As a result, identifying the role of genetically modified crops in providing the nutritional needs of human cannot be neglected. Meanwhile, there have been concerns about genetic engineering in four main areas of ethical issues, socioeconomic impacts, food security and human health, and biodiversity and environmental impacts.

Keywords: Development, genetically modified plants, promotion, sustainable agriculture, technology.

1. Introduction

Despite the advancements in agricultural production following the development of the Green Revolution technologies, the current production rates have failed to meet population needs and the world is facing food issues. Since the world, population has been estimated to reach eight billion in 2030, i.e. one billion more than the present population, improving the quality and quantity of food production is an inevitable necessity. Meanwhile, the limited available resources have compelled scientists and food industry stakeholders to seek a solution for providing the basic needs of this growing population. Accordingly, genetic engineering (introduced in the 1980's), has not only found medical applications, but has also lead to the production of genetically modified (GM) crop varieties. In fact, it has resolved several complex agricultural problems by facilitating deeper access to molecular structure of plants and its genetic content and transferring desirable genes between species.

In the new millennium, sustainable development and improved relationship between humans and the environment have attracted global attention. Thus, it is vital to investigate the immediate and future consequences of genetic engineering in agriculture and to identify methods that may not be consistent with the principles of sustainability. After reviewing the concepts of sustainable development and agriculture, the present study attempted to determine the advantages and disadvantages of producing GM plants based on the objectives and principles of sustainable agricultural development. It also sought to highlight the challenges faced by farmers and agricultural producers in GM products.

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2. Sustainable Development

The word "sustain", derived from the Latin sustinere (sus-, from below and tenere, to hold), implies long-term support or endurance. As it is debatable whether any change can remain permanent in today's world, sustainability cannot be accurately defined [1]. According to the World Commission on Environment and Development, sustainable development is any type of development that fulfills the current needs without compromising the resources of future generations. In other words, sustainable development signifies the conservation of natural resources and introduction of advances in technology and organizational structure to constantly satisfy present and future human needs. In agriculture and natural resources sectors, such a development aims to protect the land, water resources, genetic resources, and animals rather than producing the environment. It is thus technically suitable, economically valuable, and socially acceptable [2].

3. Dimensions and Objectives of Sustainable Development

The concept of sustainability has generally been considered to have three dimensions: ecological sustainability, economic sustainability and social sustainability.

3.1. Ecological Sustainability

This dimension involves the preservation of natural resources and enhancing the capacity, quality, and flexibility of the ecosystem. It is reinforced by reducing the use of energy reources, decreasing the amount of waste and pollution, recycling, and finding appropriate technologies.

3.2. Economic Sustainability

This dimension emphasizes on the preservation and improvement of economic conditions and higher return on investment. It can be assured through efficient allocation of resources and investment management.

3.3. Social Sustainability

It concerns fair distribution of resources, quality of life, access of all segments of the society to the benefits of development, and reduction of social tensions [2].

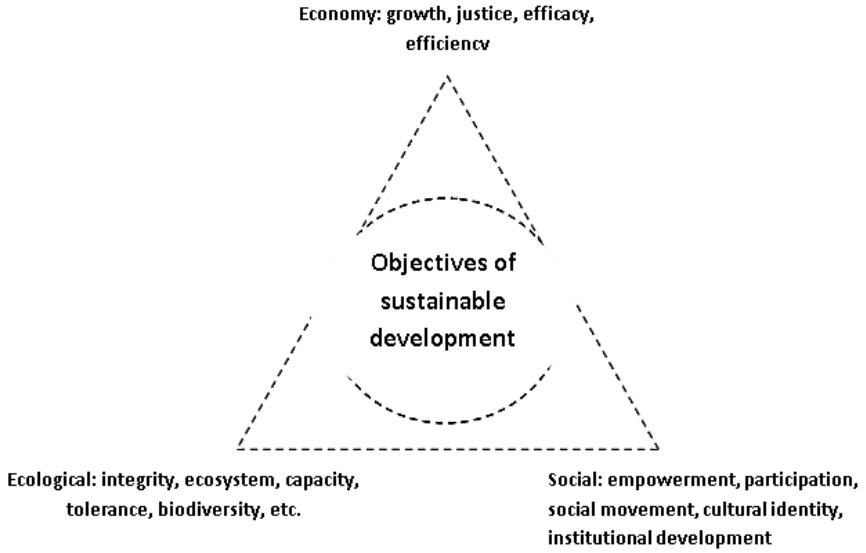

Fig. 1: Objectives of sustainable development

Other dimensions of sustainability, e.g. institutional, cultural, political, legal, and residential dimensions, can be somehow included in the above-mentioned dimensions [3]. Considering the economic (aiming at economic progress and efficiency), social (aiming at economical equity and reduced poverty), and ecological (aiming at empowerment of natural resources) dimensions of sustainable development, a number of objectives can be associated to the subject (Fig. 1).

4. Principles of Sustainable Development

4.1. Intergenerational Equity

Increased activity should not violate the future generations' rights to meet their needs.

4.2. Intergenerational Equity (Social Justice)

Underlining horizontal equity, this principle implies that all societies on the Earth shall equally use the available resources. Broad participation of societies is instrumental in achieving this principle [2].

4.3. The Polluter Pays Principle

It mainly focuses at assuming responsibility for creation of pollution and overexploitation of resources within national borders [4].

4.4. Appreciation and Protection of the Environment [2].

4.5. Considering Longer Time Horizons in Planning

It is based on the first principle and hence respects future generations as the center of sustainable development.

On the other hand, Turner declared the principles of sustainable development to include respecting and preserving the living community, quality of life improvement, protecting the vitality and biodiversity of the Earth, minimizing the use of non-renewable resources, and appreciating the environment and future systems [5].

5. Sustainable Agriculture

Global concerns have recently been raised about the adverse consequences of some agricultural activities on both the environment and the community. These concerns, which were particularly evident during the transition from traditional to industrial agriculture, have obliged enthusiastic agricultural experts and ecologists to provide recommendations on combating pests and diseases through biological methods and alternative farming practices. Some others, however, did not restrain themselves to recommendations and suggested the relatively novel concept of "sustainable agriculture" based on environmental considerations and interests of people from all social strata [6].

Sustainable agricultural technologies were widely accepted due to concerns about the environmental impacts of modern agriculture, dependence of agriculture on non-renewable resources, and long-term productivity of agricultural systems relying on huge external inputs [7]. Besides, destructive activities of conventional agriculture has led to a global consensus about protecting the environment and developing a type of agriculture to simultaneously prevent environmental damage and increase productivity [2].

The term "sustainable agriculture" encompasses novel agricultural methods to protect the environment, conserve natural resources, diminish the use of chemical compounds, and promote financial independence [8]. Sustainable agriculture is in fact an economical and environmental necessity in poorer countries where production technologies and systems in which waste constitutes a large proportion of production costs cannot be afforded. Consequently, development should be evaluated by a combination of qualitative and quantitative criteria and the effects of agricultural development on social, environmental, and health aspects as well as other fields should also be taken into account. Sustainable agricultural systems that are inseparable parts of rural development in many countries are actually environmentally flawless, financially and economically feasible, and socially acceptable. Although many factors are involved in the sustainability of agricultural systems, supportive institutional and infrastructural technologies have a significant role in this respect. In other words, sustainability and productivity are inescapable when seeking to protect the environment and reduce rural poverty [9].

6. Dimensions of Sustainable Agriculture

Despite various definitions of sustainable agriculture, there is a general agreement about the presence of all three main dimensions of sustainability (ecological, economic, and social dimensions). Hence, sustainable agriculture has social acceptability (self-reliance, equity, and improved quality of life), ecological suitability (protection and improvement of the environment), and economic durability (maintaining performance and crop productivity) [10].

7. Objectives of Sustainable Agriculture

Permanence and coherence of natural activities, reducing the use of external non-renewable resources, increasing production through the application of native knowledge and national experiences, enhancing profitability and efficiency, and meeting the present and future needs are among the most important objectives of sustainable agriculture. Given the three dimensions of sustainable agriculture, its objectives can be categorized as:

7.1. Ecological Objectives

Increasing production while maintaining and promoting the production capacity of resources

7.2. Social Objectives

Fair access to food, agricultural job opportunities, adequate income

7.3. Economic Objectives

Raising long-term productivity and profitability

8. Importance of Biotechnology in Agriculture

The question may arise that why would biotechnology be necessary when dramatic advances in the food chain have been achieved through the traditional breeding improvement of species? The answer is that the world population will double by 2050 and thus food security will turn into a critical challenge of the new millennium. Obviously, food production should be doubled or tripled to meet the needs of 11 billion people who will mostly (90%) reside in the developing parts of the world. The importance and dimensions of this challenge become more evident knowing that the significant population growth coincides with reduced availability of resources. Therefore, in order to preserve forested areas and the environment in general, food production has to be promoted in the existing wastelands or marginal soils [11].

Over 800 million people throughout the world are currently suffering from hunger. Moreover, global population growth within the next 50 years will mostly be observed in developing countries where malnutrition is already common. As about half of the prevailing agricultural lands have experienced severe erosion and the mentioned goals cannot be achieved merely via conventional or breeding improvement of species, biotechnology can be a food production strategy along other methods [12].

9. Benefits of Genetic Technology to Agriculture

Being introduced in the early 1980s, genetic engineering of crops provided the opportunity for the transfer of one or two genes between species while traditional breeding involved random insertion of tens of thousands of genes in another plant. Thus, genetic engineering is a more transparent method to improve plants and can accelerate the progress, i.e. though it used to take about 10-15 years to introduce a new variety of a plant, the duration of the process has been at least halved by means of genetic engineering [12].

The benefits of gene technology to agriculture have essentially been material. The innovations of this technology have generally led to the following achievements:

- Better understanding of plants' functions and reactions to the environment
- Purposeful objective selection in programs to improve the performance and productivity of crops, trees, farm animals, fish, and quality of food storage

- Application of molecular markers (DNA) in creating intelligence and the capability to choose main features and limit the variety of choices in a farm
- Molecular tools for description, protection, and application of genetic resources
- Powerful molecular diagnoses to help detect and manage parasites, pests, and pathogens
- Making domestic animals and fish resistant to life-threatening diseases [13]

The benefits of applying genetic modification techniques in biotechnology include:

- Increased crop productivity: Biotechnology can enhance crop productivity through increasing resistance to diseases and draught
- Increased crop safety: Farmers use crop protection technologies as an affordable solution to pest problems since otherwise their crops will be irreparably damaged. Genetic engineering has produced a kind of protein in crops such as maze, cotton, and potato that kills pests while they feed on the plant. In some cases, effective technologies for transgenic protection can control pests better and cheaper than existing technologies.
- Improved food processing: The first officially approved GM organism in food industry (an enzyme called chymosin) was introduced in 1990. Chymosin has replaced calf rennet and is used in 60% of all cheese productions. The advantages of this method are increased purity, stable supply, a 50% reduction in costs, and high efficiency.
- Improved nutritional value: With raised interest in greater nutritional value, taste, and nutritional composition of food products, high-protein GM products with more desirable nutrients, amino acids, and starch levels have been developed for people with inappropriate diets.
- Better flavor: Promoting the enzymatic activity of plants will perfect their flavor.
- Fresher products: Genetic modification can augment the durability of products. By easier transfer of fresher products, consumers will have more access to complete foods with higher nutritional value. In addition, preventing spoilage, damage, and reduced nutritional value will be facilitated.
- Natural benefits: Since genetic engineering decreases the dependence on insecticides, lower levels of insecticide will remain in food. The leaching of insecticides into groundwater will hence be reduced and farm workers' contact with hazardous and deadly compounds will be minimized.

10. Challenges to Promotion of Gm Plants in Sustainable Agricultural Development

Some consumers and environmentalists point out the risks (e.g. long-term effects) associated with the application of genetic engineering and want the development and research about GM crops to be ceased. People's panic and fear reflects their concerns when dealing with contradictory and obscure statements about GM crops and their supply. This fear may be caused by lack of sufficient or correct information. Such concerns of about the ecological health and welfare of the planet should indeed be taken into account. Challenges to promoting GM crops which relate to sustainable agricultural development are summarized in three sub-dimensions:

10.1. Agricultural Biotechnology, Food Security, and Human Health

Modern agricultural biotechnology, especially the development of GM food products and other living modified organisms (LMOs), is the subject of public debate on food security, efficacy of new products, and the ethical and socioeconomic issues related to their use and development.

10.2. Health-Related Issues

10.2.1. Allergens and Toxins

Specific proteins that induce unusual immune responses in food allergic individuals are called allergens. Food allergies are seen in roughly 2% of all age groups and are usually limited to one several products. Therefore, there is a major concern regarding genetic engineering involves the risk of transferring toxins and allergens to other plant species.

10.2.2. Antibiotic Stability

Opponents of genetic engineering argue that it may create a specific type of resistant bacteria and increase antibiotic-resistant diseases.

10.2.3. Labeling of GM Products

Some consumer groups contend that GM food products should have special labels. Such an idea does not is not a mere concern about food security. In fact, the manufacture of some GM products is not in accordance with religious views and beliefs. However, arguments for and against the labeling of these products often focus on food security and the right to choose. Currently, some countries have obligated the labeling of products which are nutritionally different from their traditional counterparts [14].

On the other hand, consumers are mostly eager to be able to identify the allergens and harmful substances in GM products. People with allergies or low resistance to specific foods need to avoid these products. Some may even stay away from these products because of religious beliefs or ethical reasons. Hence, labels should convey information about the ingredients of special products and provide the consumers with the chance to choose after knowing their potential benefits and risks. Meanwhile, owing to genetic modifications, labeling of GM products is compulsory. Nevertheless, such labels would only show the use of modern molecular plants or other genetic production technologies and do not contain information about their nutritional content or safety.

10.2.4. Food Safety Standards

As more people worry about the safety of GM products, they require higher standards of safety than traditional agricultural or organic products. On the other hand, with increasing global concern about food safety, all countries should pass regulations regarding food safety and human and infrastructural capacity and also create and apply food safety standards that ensure the quality of food in the manufacturing country and achievement of export standards determined by the importing countries. Developing international safety standards for GM products and the absence of tariffs on trade are challenges faced by the international community.

10.3. Agricultural Biotechnology, Biodiversity, and the Environment

Concerns about the risks and advantages of LMOs are based on the assumption that a number of gene-containing organisms which enter the environment through unnatural methods may threaten the environment [15].

10.3.1. Ecological and Environmental Issues

According to the opponents of genetic engineering, new GM products may have cross-fertilization with weeds, resulting in difficult-to-control, resistant weeds (this might not occur too often, but it is still not too farfetched). Some others are worried about creating and spreading wild species and the consequent ecological imbalance.

Both direct and indirect environmental effects of LMOs have to be examined. Among their direct effects, there is a dispute over the potential effects of these products on biodiversity and non-target species. Indirect effects may refer to changes in agricultural management practices made or intensified due to the use of these products. The positive impacts of GM products on the environment can be revealed by comparing agricultural activities with other technological choices [16].

10.3.2. Impacts on Non-Target Species

Some environmentalists believe that products which have been genetically modified once will spread in the environment and induce unpredictable, adverse effects.

10.3.3. Resistance to Insecticides

Broad acceptance of GM products is also prohibited by the belief that they may increase the resistance of pests and thus make pest control harder.

10.3.4. Reduced Biodiversity

Many environmentalists and farmers are agonized about the loss of biodiversity and wild species in the environment. Such anxiety has led to extensive efforts like collection and storage of seeds of all existing varieties [14].

11.Biodiversity, Intellectual Property Rights, and Private Sector

In 1996, the global market of biotechnology products was less than 500 million dollars. The dramatic increase of its revenue in the past decade has encouraged private sector investment in biotechnology. According to a report by Food and Agriculture Organization (FAO), private sector agricultural research in the members of the Organization for Economic Co-operation and Development (OECD), i.e. half of the countries that have invested in the field, exceeds 7 billion dollars.

Research has shown that few small agricultural biotechnology companies are currently in business. Because of antitrust policies for consumer protection in some countries and commercial reasons, wealthy farmers are probably the biggest target of the market and receive the greatest proportion of public sector budget. As a result, national and international support is warranted to boost the production and development of raw materials that are not for export.

Intellectual property rights promote private sector investment in research. Replacement or modification of incentives (e.g. restrictions on exclusive licenses) is highly appropriate for public research institutions. Both public and private companies are demanding intellectual property rights for agricultural biotechnology products.

12.Potentials of Biotechnology in Sustainable Agriculture

Agricultural biotechnology has the potential to facilitate and promote sustainable agriculture and rural development. Furthermore, these technologies have environmental benefits, especially considering the fact that renewable genetic inputs are efficient alternatives to dependence on external agro-chemical inputs. The potential of genes or genotypes (e.g. varieties or species) to replace renewable resources is highly important in further promotion of sustainable agriculture and rural development.

However, the power of modern biotechnology to create useful genotypes has not yet been dominated by poorer farmers. On the other hand, the extent to which biotechnology can help the achievement of food security is debatable. Science alone cannot provide a comprehensive solution to rural development problems. Several processes, factors, and socioeconomic structures such as inaccessibility of land and other production resources, low purchasing power, lack of political power, environmental vulnerability, and distance from the market contribute to poverty in rural areas. Although agricultural research can influence on rural poverty, it cannot guarantee sustainable agriculture and rural development.

Various organizations have performed comparative reviews on the state of agricultural biotechnology in developing countries. Their findings have indicated that most developing countries have limited access to the required tools and resources for the application of biotechnology at national level [7].

Moreover, biotechnology research does not closely correlate with problems and constraints faced by low-income farmers in agriculture sector of developing countries. While biotechnology must focus on important local issues related to sustainable agriculture and rural development, this necessity has not historically been considered.

Governments, scientists, non-governmental organizations (NGOs), supporters, and the Consultative Group on International Agricultural Research (CGIAR) have to promote the innovative mechanisms for transfer of biotechnology knowledge to developing agriculture. Besides, long-term public funds have to be allocated based on the interests of deprived farmers.

By considering the needs of deprived farmers, the long-term application of some biotechnological approaches to improve agriculture will undoubtedly have socioeconomic and environmental benefits. Despite the high possibility of advancements in a wide range of biotechnological methods in the near future, it seems unlikely for poorer farmers to be able to afford the technology without government interventions.

Involvement of deprived farmers and other stakeholders in sustainable agriculture and rural development has been the main issue of the 21st century. Importance of impact of public funds in sustainable agricultural biotechnology and rural development may be achievable by involvement of farmers in decisions concerning objectives of sustainable agriculture and rural development. Due to lack of appropriate dialogue between public sector biotechnology researchers and farm researchers and farmers, participatory problem transfer provides a suitable structure to discuss the need for research.

The 21st century agenda of "on-farm research" is in line with the development of alternative non-chemical materials through pest-replacement. Biotechnology can reduce chemicals by creating pest-resistant species or pathogens via the insertion of resistant genes. The review of available literature revealed that all the desirable biotechnological goals of the 21st century cannot be achieved. In fact, creating technology does not ensure its widespread application, especially for poorer social groups as no examples of poverty-oriented agricultural biotechnology exist. Utilization of farms in required scales seems efficient in influencing rural poverty and assessing the effects of biotechnology on health and the environment.

13.Conclusion

Despite the achievements of genetic technology in agriculture, contradictions regarding the nature and necessity of application of GM products have been raised. Overcoming such oppositions, especially in the third world countries, requires a holistic approach and designing a set of strategies according to the advantages and disadvantages of these technologies, their local suitability, and conditions of their consumers. Today, public and private promotion systems which deal with biotechnology through any type of approach must consider the interactions between these technologies and principles of sustainable agricultural development. They should thus adapt strategic plans and find mechanisms to face and overcome the challenges ahead.

The belief that research without the practical application of its results on farms is worthless necessitates a proper context for activists to systemically and systematically consider all aspects of the transition process and technology management and move toward the objectives and principles of sustainable agricultural development (which is a requirement and the only method of providing the human race with food security).

Activists of this system, especially the promoters and introducers of such technologies to both the producers and consumers, are compelled to consider the upcoming challenges based on the dimensions of sustainable agriculture. This is particularly important in the third world countries where many prerequisites of sustainable agriculture are not available and using the simplest technologies can threaten the principles of sustainable development.

In spite of the substantial role of GM plants in satisfying the primary needs of humans, they have provoked various challenges when dealing with the objectives and principles of sustainable development. These challenges are less obvious in the economic dimension of sustainable agriculture since the high capacity of such technologies leads to higher production with less direct and indirect costs. As the problem of food security has also been somewhat resolved, by meeting the needs of the community in other respects, GM products will well fit into this dimension of sustainable agricultural development and observe intergenerational equity which will in turn lead to improved performance and productivity.

The uncertainty of genetic engineers about the ecological dimension of sustainable development and issues such as growing number of new diseases and the global tendency to use organic products questions the consistency of such technologies with the objectives and principles of sustainable agricultural development. These issues are crucial since most critics focus on ecological problems associated with the use of GM products. That kind of alertness is rational because making up for economical loss is much easier than compensating long-term ecological imbalance, disturbed biodiversity, or environmental instability.

The application of GM plants has raised the greatest concerns in the social dimension of sustainable agricultural development. In fact, the economic and ecological dimensions exist to pave the way for sustainability in social dimension and reducing inequities in human community. Consequently, instability in this dimension will in some cases be irreparable. Owners of technology usually perceive management of technology as a means of gaining superiority over others. Such a belief is more apparent in case of

biotechnology. While compliance with principles like self-reliance, equality, and improved quality of life in a competitive economic atmosphere among countries with unequal and non-homogeneous backgrounds is extremely hard, if not impossible, introduction of issues like intellectual property rights and facilitating the activity of private sector in producing GM plants can reduce social instabilities.

Given the nature of such technologies, they are accessible to particular individuals and institutions. This prepares the ground for greater social and economic differences between countries and challenges the social application of these technologies in agricultural communities. Generally, a major need is felt for a holistic outlook and improved communication between various social, scientific, industrial, and environmental sectors. Great innovations in science and technology, especially successive discoveries in genetic technology, can lead to sustainable development, if:

- It aims for the defined objectives which influence poverty alleviation, food security, environmental protection, and business competitions.
- It is consistent with political interests, supportive national policies, and public and private investments in science, technology, and development and distribution of products.
- It has a clear regulatory and support framework that can attract public trust, ensure safe and ethical applications of new bioproducts, preserve human health, agriculture and the environment.

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