14 Emerging Biotechnologies in Agriculture for Efficient Farming and Global Food Production

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Abstract

If the global population continues to grow, it will be difficult for agricultural productivity to keep pace without overtaxing essential environmental resources. To address global food security and place agriculture on a path to sustainability, a diverse and integrated approach will be needed. Modern biotechnology focuses on the enhanced application of genetically modified (GM) crops which represent an important range of resources that can promote sustainable agriculture and increased food security. This chapter deals with innovative research in the field of agricultural biotechnology by emphasizing novel and evolving techniques for efficient farming and global food production. This topic illustrates the importance of agriculture biotechnology for sustainable agronomy and improved food security which can further be used to encourage the production and adoption of beneficial GM crops.

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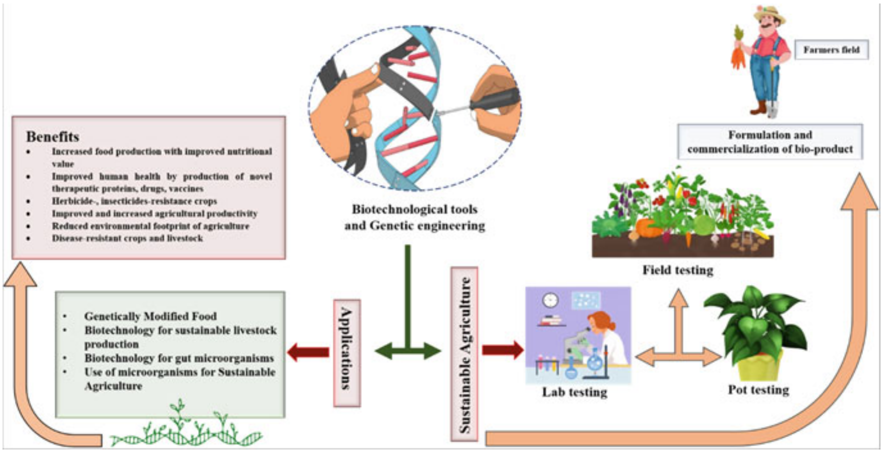
Graphical Abstract



Keywords

Food security · Sustainability · Agriculture biotechnology · Genetically modified crops · Plant growth regulators · Plant development

14.1 Introduction

The major goal of agricultural husbandary has been to produce sufficient feed, biofuel, fiber, and food to meet the requirements of the population and society. Sustainable agriculture aims to satisfy the aforementioned rudimentary common stipulations with a focus on reducing agricultural inputs, and quality perseverance of the soil, reducing the impact on the environment, and ensuring economic viability (Gilbert et al. 2010). It has been predicted that the world population can be reached to 9 billion within the next 30 years resulting in the escalating requirement for fiber, feed, biofuels, and food. This could be the exigent demand for the agronomy sector to run with the need (Gilbert et al. 2010). Agricultural production would be affected by pressure of growing population, and change in the climate and related severe conditions of weather along with the availability of the arable land and water availability for agricultural purpose. There is a requirement for more land to be converted to cultivated acres deprived of the crop production that can outperform current varieties, and more inputs will be required to meet growing societal demands. For example, the researcher estimated that if current agricultural patterns continue, an additional ~1 billion Ha (hectares) of cultivable land would be required by 2050 (Tilman et al. 2011). Without raising the carbon impact or carbon footprint, improving food safety in the face of these challenges would take a unified and varied perspective.

Food protection happens when "all individuals have physical and economical access to adequate, safe, and nutritious food at all times to satisfy their nutritional requirement and food preferences for an active and balanced life". Even though agricultural production is complex and depends on several political factors, infrastructure, and socioeconomic in a global context, the capacity of the agricultural sector optimizes the yield of crop output without abandonment of environmental resources. Agronomy has delivered tremendous prospect to boost sustainability in agricultural sector and safeguarding food security, but the functional and significant applications of agronomy are only beginning to be realized in the sense of food security and sustainability. The convention on biological diversity (CBD) describes biotechnology as "any technical application that creates or modifies processes or products for particular use using living organisms, biological systems, or derivatives thereof" (Secretariat of the Convention on Biological Diversity 2005). Within this comprehensive definition, for thousands of years, agriculture has been using biotechnology to improve germplasm, improve crop genetics, and select desired traits by selective breeding. Such biotechnology techniques help to promote the creation of pure genetic lines, compared to conventional breeding, and have improved the efficiency and speed of selecting desirable characteristics. In addition, transgenic plants are better known as genetically modified plants/crops that are fundamental to the area of contemporary agronomy developed using genetic and molecular tools. The espousal rate of GM plants/crops with biotechnological traits is expected to enhance continuously, especially in the developing countries. Much of the developments in GM crops to date are based on a variety of main row crops (such as corn, soybean, and cotton). Alternative approaches like promising resistance to various herbicides, and a range of stacked features offering tolerance to herbicides in combination with multiple insect resistance modes of action are also becoming readily available to farmers. In addition to the diversity of plants/crops being modified (like banana, wheat, cowpea, rice, and vegetable crops), further developments in the agriculture field are growing, but also the range of advanced genetic modifications (such as fungal, viral, and bacterial resistance, tolerance to abiotic stresses, improved nutrition, improved digestibility, and modified composition) (USDA-ERS, 2015).

A major global concern has been the effect of industrial agriculture on natural resources. Growth in the increased demand and population for agricultural products is increased day by day which leads to enhance pressure on land and water supplies. Low efficacy in the usage of resources, especially nitrogen, needs a major attention for many intensively controlled system related to agricultural having greater external inputs. Eventually, elevated usage leads to low performance outcomes in environmental issues such as eutrophication, ammonia and GHGs emissions, groundwater contamination, and soil erosion. Hence, the need is to turn existing agriculture toward highly productive, resource-efficient, ecologically sustainable, and socially acceptable. In order to improve the quality of a crop under suboptimal circumstances, the steady increase in global temperatures and the decline in freshwater supply pose crucial challenges for agricultural researchers. In the current scenario of developed agricultural practices, the key sources of contaminants that are highly harmful to animals and humans are the inefficient use of fertilizers and other chemicals in water, soil, and air. The twenty-first century's need is to move toward new farming techniques increasing the availability of feed and food, while at the same time mitigating the negative effects on agricultural productivity, such as the global warming.

Food availability in simple term can be explained as the physical presence of food. Food supply is a mix of domestic food stocks, commercial food exports and imports, and supplies of food along with the production of food at a national level. It is a fact that food could be grown and purchased at the household level from the local markets.

The growing necessities for nourishing, safe, and balanced food due to a growing population and the dedication to preserving biological diversity, climate change, and other sources are of a major concern for agriculture. Healthy and diverse foods can reduce diet-related diseases, largely based on plant-derived foods. Plant science investments will be required to develop a variety of cropping systems that balance efficiency, nutritional quality, and sustainability. Diversity of cultivars and nutrient composition are essential. To reduce degradation of soil, we need more diversed and nutritious cultivars by eliminating the application of hazardous chemical fertilizers and pesticides. To enhance the adaptability of crops toward the change in climate and resisting power to evolving pests, we need to collaborate with medical scientists and food materials, the food sector industries, breeders, and formers. The current global concerns of today are reduction in biodiversity, emission of greenhouse gases (GHGEs), climatic change, poverty, water scarcity, hunger, and malnutrition. Additional global issues are diet-related disorders like those associated with being overweight, obese, and diabetes. The provision of agricultural technologies such as genetic engineering and molecular technology often needs long-term plant science funding (Dwivedi et al. 2017).

A specially commission to direct sustainable food choices has shown that modest reduction in GHGE (<30%) is consistent with nutritional affordability and adequacy without adding substantial changes in the group of food in accordance with the guideline of the nutrition.

The execution of food system approach will help to evaluate, address, and recognize trade-off between social, nutritional, economic, and environmental priorities and limitation (Kumar et al. 2015). Agriculture practices, however, should fulfill the requirement of consumer food protection and quality, build successful value-chain linkages, and decrease ecological tension while increasing their sustainability. As shown in Fig. 14.1, three main features of a sustainable agriculture present in the food systems are depicted (Sukhdev et al. 2016).

Current agricultural strategies are mostly powered through features like predictability, high yield, quality, low cost, and nutritional values and not by taste (Kemp 2016). Instead of nutritional and functional characteristics, current agriculture programs have concentrated primarily on host plant resistance, low labor input, and edible yield (like driving herbicide-resistant cultivars). Therefore, the choice of cultivars according to nutritional value has received little attention (Leoncini et al. 2012).

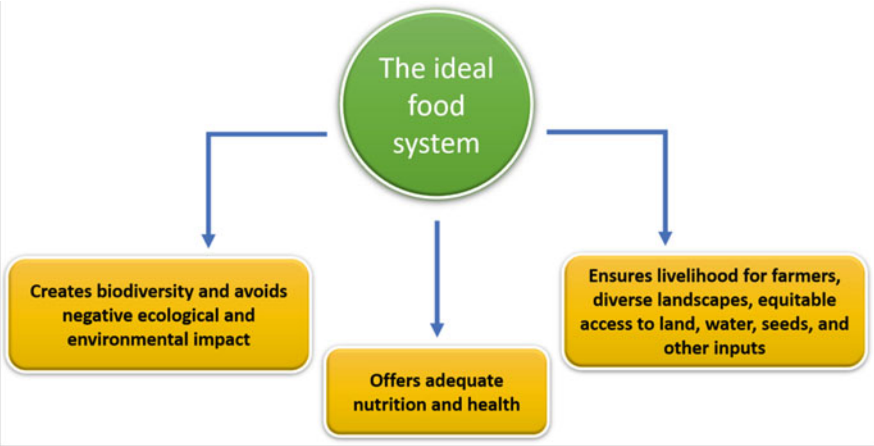


Fig. 14.1 Key attributes of a sustainable food system (adapted from Sukhdev et al. 2016)

Nowadays, 95% of the nation's energy comes through 30 crop species, however, as mentioned above, nearly half of the world's demand for calories, comes from three significant crops, notably wheat, maize, and rice. The study suggested that among the 30,000 only about 150 edible crop species were capable of growing. According to World Health Organization (2015) report, this lack of diversity alone was responsible for creating adverse effects on the health. The potential of biotechnology is to encourage and foster sustainable agriculture and rural development. Such innovations are beneficial for the environment, particularly given that renewable genetic outputs. In order to further promote rural and sustainable agriculture development, the potential of genotypes and genes, for example, species or varieties to replace renewable resources, is of great importance. It is critical to underline that biotechnology should not be viewed as a replacement for traditional crop improvement tools but rather as a means of integrating recombinant techniques in to traditional crop methods to boost agricultural research and development output (Singh and Mondal 2017). Biotechnology advances have typically led to the following accomplishments:

a. To get better understanding of the plant's roles and responses toward environment,
b. Molecular techniques for genetic resources elucidation, safety, and implementation,
c. Selection of objective that aim to improve the efficacy and yield of plants, crops, fish, farm animals, and food storage quality,
d. Make farm animals and fish immune to disease that is life-threatening,
e. Enhanced production of crops by rising disease resistance capacity,
f. Improved food quality by using high-proteinic GM crops with more suitable amino acid, nutrients, and starch levels,

g. Efficient molecular diagnostics for the identification and treatment of pathogens, parasites, and pests,
h. Healthier products—the longevity of products can be improved by genetic modification. Consumers can have more access to full foods of greater nutritional value through easier movement of fresher items. In addition, it will promote the prevention of injury, spoilage, and decreased nutritional value,
i. As genetic engineering lowers insecticides can remain in the diet, it can be a natural advantage. Therefore, the leaching of pesticides into groundwater will be decreased and the interaction of people working in the farm with toxic and lethal composites can be reduced,
j. Usage of molecular or genetic techniques (DNA) to provide understanding toward crop production.

The aim of this chapter is to highlight advances in agronomy for sustainable agriculture and food security. The emphasis is on genetically modified plants/crops and, particularly, on biotechnology tools in sustainable agriculture, but it should be emphasized that GM crops are unable to replace other kinds of technologies needed to make system of production sustainable. In the future alternative, tactics need to be distinct. Yield enhances will remain key point, but it is essential to look for the ways of loosening the interdependence between yield and external use of input and making production systems more responsive to ecological stresses.

14.2 Potential Benefits and Effects of GM Crops

Genetically modified (GM) plants/crops have considerable potential to endanger the survival of sustainable agriculture and biodiversity. Centers of origins and megadiverse nations and/or crop species diversity are especially vulnerable areas of the world. Sustainable agriculture's future could be irreversibly jeopardized by the contamination of genetic resources retained in situ, threatening a strategic resource for global food protection. Since genetically modified plants/crops are genuinely scientific novelties, their deployment into the ecosystem expressed concern about both the uncertain evolutionary and ecological outcomes which may be expressed in the medium and long term by GM species/varieties itself and the associated fauna and flora. The widespread pollution of natural flora by GM traits and the depletion and deterioration of the widely owned genetic resources available today for agricultural production may be one of the implications of such processes. When release into atmosphere, GM crops/plants bearing industrial and pharmaceuticals characteristics can pose even more dangerous risks (Table 14.1).

The effect of commercialized GM crops on the benefits, use, and yield of chemical pesticides by farmers using micro-level data collected in different countries has been analyzed in a large number of studies (Qaim 2009; Carpenter 2010; Finger et al. 2011; Areal et al. 2013).

Table 14.1 Possible risks and benefits of genetically modified organisms (adapted from Lucht 2015)

Risks	Benefits
Religious, cultural, and ethical issues Issues related to health • Toxins and allergens • Stability of antibiotic Ecological and environmental issues • Insecticide resistance • Threat to biodiversity and to genetic diversity • Impacts on nontarget species	• Enhanced production of food with better-quality nutritious value • Human health improvement by production of innovative therapeutic drugs, proteins, and vaccines • Herbicide-resistant and insecticide-resistant crops • Improved and increased agricultural productivity • Reduced environmental footprint of agriculture • Resistance toward diseases

14.3 Application of Agricultural Biotechnology

14.3.1 Genetically Modified Food

Current revelations in molecular genetics and functional biology have shown that in the near future, the associated biotechnology products would be very practical. Improved crop diversities could therefore be tailored using GM technology for marginal agro-ecological regions, which were largely neglected by the green revolution. These all techniques offer the possibility of adding a beneficial trait from strongly related crops/plants without associated detrimental genes, or from related species that do not intersect promptly with crops of interest, or from entirely unrelated species, or from other taxonomic phylae. It creates the opportunity also for containment of pests/insects/diseases, food fortification in cereals with vital vitamins for example vitamin A, micronutrient like zinc, iron, and crucial amino acids such as lysine, and for the development of crops/plants that are resistant to drought or generally capable of growing well in harsh environments. The farmer approachability of GM techniques is a chief characteristic, as it is assembled in an efficient seed form. The key benefit of approaching same technique in agronomy is that it is possible to improve productivity by using new varieties with pest- and disease-resistant properties. The injury to the plants/crops is caused mostly by fungus and insect larvae, to some point by adult insects. There has been rapid progress in using GE for plant/crop enhancement in terms of pest-resistant, male sterility systems, and herbicide resistance due to improvements in gene expression and genetic transformation over the last decade. In 1987, the first transgenic plants were produced with *Bacillus thuringiensis* (Bt) genes. Bt cotton is a GM crop containing *B. thuringiensis*-isolated foreign gene. A novel technique based on the RNA interference mechanism (RNAi) has been introduced to avoid such problems. Using *Agrobacterium* as the carrier, the particular genes from the parasite are transmitted into the plant. The genes are inserted in a manner that generates both sense RNA (in insects) and antisense RNA (in plants). They form a double-stranded RNA, as these two RNAs are complementary. As a consequence, in the transgenic

Table 14.2 Listed technologies for GM crops at the field trial level (adapted from Qaim 2016)

Crop	Trait	Countries
Apple	Reduced bruising/browning	Canada
Banana	Provitamin A content Bacterial resistance Insect/nematode resistance	Uganda
Bean	Virus resistance	Brazil
Cabbage	Insect resistance	India, China
Canola	Herbicide tolerance Omega-3 content	Australia, USA, Canada USA
Cassava	Virus resistance Provitamin A content	Kenya, Indonesia, Uganda Kenya, Nigeria, Uganda
Chickpea	Insect resistance	India
Cotton	Insect and herbicide resistance	India, USA, Pakistan, Ghana, Burkina Faso, Kenya, Cameroon
Cowpea	Insect resistance	Burkina Faso, Ghana, Nigeria
Eggplant	Insect resistance	India, Philippines
Groundnut	Virus/fungal resistance	India
Maize	High phytase (quality) Stacked insect and herbicide resistance	China India, Indonesia, Pakistan, South Africa, USA
Mustard	Male sterility	India
Orange	Bacterial resistance	USA
Pigeon-pea	Insect resistance	India
Potato	Fungal resistance	Bangladesh, India, Indonesia
Rice	Insect resistance Iron content, provitamin A content	China, India India, Philippines, Indonesia
Sunflower	High oleic acid	Australia, Argentina
Sorghum	Stacked provitamin A, iron, zinc	Kenya, Nigeria
Soybean	Multiple pest resistance, yield enhancement, and modified fatty acid	USA
Sugarcane	Insect resistance and herbicide tolerance, and drought tolerance	Australia, USA Brazil, Indonesia
Tomato	Fungal resistance and insect resistance	Argentina, India, Chile
Wheat	Drought tolerance Insect resistance Fungal resistance Virus resistance Herbicide tolerance Improved grain quality	Australia, Egypt UK China China USA Australia

host, the parasite does not line up and the transgenic plant is protected from the pest. In both developing and developed countries, transgenic crops/plants with desired genes will play a pivotal role in agriculture field. This will play a notable role in improving crop production, reducing insect-related losses, and improving the situation of poor people of rural areas. The production and deployment of transgenic crops/plants with pest management insecticidal characteristics would result in reduction of sprays for insecticides (Table 14.2) (Singh and Mondal 2017).

14.3.2 Biotechnological Approach for Sustainable Livestock Production

14.3.2.1 Embryonic Transfer and Superovulation

With the advent of artificial insemination (AI), the manipulation of reproduction in the domestic animals began in the 1930s. During the 1960s, AI organization stated to make regular use of freeze semen to make its application widespread, making better use of the cells of the egg by superovulation of the genetically superior animals. The transfer of embryos is a very effective technology to increase the productivity of an animal (Madan 2005). This technique has also made it possible to greatly promote imports and exports of valuable genetic materials, to establish new breeding principles, to conserve genes through freezing techniques, to produce twins, to introduce new genes into closely related herds, and to manipulate embryos and transgenic animals. The implementation of AI and the transfer of embryos has fully changed the bovine breeding scheme. A new dimension has been created by recent advances in the field of in vitro fertilization and oocyte maturation in farm animals.

14.3.2.2 Gene Transfer and Transgenic

The advancement of gene transfer techniques has created innovative new opportunities for modifying animal outputs (Hammer et al. 1985). Transfer of gene provides a strong perspective toward the development of animal growth and reproductive efficiency manipulation techniques.

14.3.2.3 Gene Knockout

A molecular technique that precisely silences a target gene is gene knockout or gene disruption. This technique can be useful to silence genes that have local or general (tissue-specific) function, including a feature that causes the entire body or particular tissue to grow slowly.

14.3.2.4 Gene Therapy

Another approach to bringing exogenous genes into animals is gene therapy. Originally, gene therapy was developed as a way of correcting human disorders based on genetics. This approach can also be used, however, to provide genes that can change the composition of the body and development.

14.3.2.5 Somatotrophin in Milk Production

A possible technological method for increasing the production of milk in animals that are important for dairy industries is to inject growth hormones (GH) or bovine somatotrophin (BST). BST is a hormonal protein released by the anterior pituitary gland that occurs naturally and is widely used to increase milk production which has been made available by recent developments in recombinant DNA technology.

14.3.2.6 Vaccines and Diagnostics

Biotechnology has transformed vaccine production science, leading to new understandings in the field of biochemical processes of pathogenesis and infectious disease, and has unlocked the new approaches for recently developed vaccines such as recombinant DNA vaccines and peptide vaccines that have been chemically synthesized. Live and killed microorganisms are vaccines produced using traditional ways. There is a replicated agent in live vaccines, while the killed vaccine includes a non-infectious agent and an adjuvant.

14.3.3 Biotechnology for Gut Microorganisms

Biotechnology, which is very important for animal health and development, can be used to enhance the metabolism and behavior of gut microorganisms. Three main approaches are as follows:

1. Use of products that are produced biotechnologically for improvement of the gut ecosystem.
2. To promote the growth of advantageous bacteria for the preparation of prebiotics and probiotics.
3. Implementation of new strains or species of microorganisms into the gut.
4. Genetic manipulation of microorganism that is present naturally in the gut in order to boost their ability to perform defined functions or introduce new functions. Implementations of different genes have been investigated in gut microorganisms. GM microorganisms are capable of either digesting fibrous and forage lignin products, degrading contaminants, synthesizing essential amino acids, reducing the formation of methane, or tolerating acids.

Owing to technological challenges and public concerns, biotechnology for intestinal microorganisms is far from commercially applicable.

14.3.4 Use of Microorganisms for Sustainable Agriculture

Microorganisms play a crucial role in functioning of ecosystems and conservation of sustainable agriculture. This sustainable agriculture provides the ability to meet our present time agricultural requirements. The microorganisms associated with plants display a wide range of living habits whose saprophytic or symbiotic relationships with the plant may be beneficial. Most of these microorganisms reside in the rhizospheric zone, but some of them successfully penetrate and live within plant tissues, known as endophytes. For the purpose of sustainable and balanced crop production, many soil bacterial groups are utilized protecting the biosphere via improving plant nutrition, soil quality, and health, and these soil microorganisms play a significant role in agriculture (Lugtenberg 2015). In agriculture practices, the benefits of applying microbes include not only sustainable agriculture, but also other ecosystem-associated benefits. These include the regeneration of habitats, improving the resilience of plant species, the recovery of endangered flora, and adaptive management strategies for diversity (Barea et al. 2013). For this cause, many techniques are proposed to use the beneficial microbial community more effectively to assist sustainable environmental-friendly agrotechnological practices. For a continuous supply of essential nutrients for growth and plant defense, the main objective of using microbes is required. Because several biotic and abiotic factors and agronomic management influence the interactions between the microbial populations and plants, the impact of environmental stress factors must be overcome, mainly in the current global climate change scenario, as they severely harm the interactions between plants and microbes.

14.4 Food Security and Sustainable Agriculture

Food sustainability is one of the main problems with regard to climate change in the modern era. Unfavorable climate changes through heat stress and water affect cereal production, but are also correlated with frost logging and waterlogging, pest dynamics, and disease. As changes in unusual and uncertain weather conditions impact populations worldwide, climate change is a recurring force of change in livelihoods. Rising populations, shifting lifestyles, losing groundwater source, urbanization, and the additional demand for cereals like maize for fuel and fodder pose major challenges for production of cereal in the foreseeable future, even without any climate change (Hubert et al. 2010). Global demand for cereals is estimated to exceed 3 billion tons by 2050 (Alexandratos and Bruinsma 2012).

Reduced seed set, decreased grain size, pollen sterility, quality, shriveled seed, and stigma drying (in wheat), poor anther dehiscence, nonviable pollen, poor pollen development, early embryo abortion (in rice), pollen deposition on stigma, tassel blast, leaf firing, pollen sterility, accelerated senescence, barren plants, and decreased seed set are various qualitative indicators of heat stress. Wheat early flowering and poor grain filling are some of the qualitative indicators for drought stress, poor panicle emergence (in rice), decrease in leaf expansion, early senescence, inferior grain set, and decreased grain weight, leaf senescence (in maize), increase in anthesis-silking interval, barren plants, decreased gran set, and poor ear tip filling (in pearl millet).

Food security was described according to the UN (1975), as the “availability at all times of adequate world food supplies of basic foodstuffs to support a steady expansion of food consumption and to offset production and price fluctuations.”

14.5 Current and Future Trends

Growing the worldwide population, shifts in the nature and size of per capita demand, improving photosynthesis, defeating exotic diseases, climate change, reducing environmental change, leveraging genome advances, competition for key resources and changes, understanding diet and health in consumer values, and ethical roles are important factors affecting the food system. Maintaining future agriculture consumption, increasing effciency with existing/new science and technology tools and processes, resolving unknown risks, and minimizing waste are priorities. It is also necessary to resolve the danger of future instability in the food system, to end hunger and reducing GHGEs. It is important to enforce strategic policies to conserve the environment and biodiversity for sustainable food production. Promoting sustainable agriculture is also important to safeguard the economic viability of farmers. Sustainable agriculture is indeed a collection of agriculture practices which can, in the long-term, wish to maintain efficiency, profitability, and farm productivity without degrading natural resources and the environment. It may be of significant response to promote the implementation of native skills, less dependency on external inputs, major prominence on the diversity of crop, rotation of the crops and development based on needs, and easy marketability to ensure the survival of small farmers.

Global food prices have decreased dramatically over the twentieth century due to the massive upsurges in the production of agricultural products due to the significant advancement in the various technologies. The long-term adverse inflation rate made many assume that with economic growth, food prices will always decline. The price spike in year 2007–2008 and subsequent years has shown that food shortage is not just a problem (FAO 2011). Farmers who sell crops/plants are content with increasing wages and earnings, while customers who buy food cannot afford high expenses. Many poor and food-insecure households in the world purchase greater amount of food than they sell, that is why suffering from increased costs. Therefore, price rises aim to worsen global poverty and food in security (Ecker and Qaim 2011).

Although rate of population increasing is no longer as high as they used to be in the past, with over 70 million new people added to the planet each year, the global population continues to rise more. Furthermore, the agronomy-based products are used more precisely for non-food uses, like biofuels, which have just augmented dramatically in value. According to the report, the total need for agronomical products like feed and food has gained by an average of 1.8–2.0% per year over the past 15 years (Qaim and Klümper 2013). Other developments will have to produce more productivity gains, particularly improvement in agronomy. However, advancement in breeding is constrained by the genetic variation that is or can be created in the species of interest. Traditional methods alone would not be enough to maintain past rates of breeding success on a sustainable basis. GE provides tremendous potential to increase the genetic diversity that breeders will use to cope with the challenges ahead (Tester and Langridge 2010).

Over the next few decades, growth in agricultural production will continue to be substantial leading to a further rise in the global population, rising profits, and the increasing use of plant-based goods and substances for energy and other industrial processes (Godfray et al. 2010; Hertel 2015). Rising natural resources scarcity, including water and land, environmental concerns like soil depletion and extinction of biodiversity, and changing weather patterns pose major encounters which need to be tackled by improved technology. It is often suggested that current priority should be given to by decreasing post-harvesting losses, surplus, and restricting food intake rather than rising production. Undoubtedly, decreasing waste and losses are concern objective and reduction in food consumption would also be beneficial, particularly in rich nations. Such improvements, however, are not easy to achieve and alone will not be sufficient to alter global supply and demand patterns (Qaim and Klümper 2013). Therefore, different policies need to be followed concurrently, and one of them needs to be sustainable increase in agricultural production. Despite forecasts and concerns to the breeders, farmers, contrary, and agronomists/scientists have developed and implemented agricultural technologies that maintain that growth in food production is sufficient to meet the growing demand for food. There is no reason to assume, from a mere technical viewpoint, that this will not be feasible in the future as well. Combined with other promising innovations, genetic engineering and modern biotechnology may play a significant part in boosting production and product quality, while decreasing the use of limited resources and agricultural chemicals. But nowadays, the prices and direction of farming techniques are importantly dependent on public tendencies. Emerging innovations need to be used cautiously, but we cannot afford to rule out promising fields of research solely on the basis of bias, given the challenges ahead.

14.6 Strategies and Approaches of Sustainable Agriculture

Social justice, environmental security, and economic development are the golden triangle of sustainable agriculture. The techniques are aimed at minimizing degradation of soil and erosion, preserving the quality of the soil, saving water, use of chemical fertilizers, generating large amount of nutritious food at low cost, fewer pollutant-causing pesticides, addressing food protection, and maintaining biodiversity, ensuring customer access to quality and quantity of food. Strategies should be systematic in their existence, including social and policy decisions, agricultural input control, creative farming methods, and genetic modification.

14.7 Discussion

The major global concern has been effect of industrial agriculture on natural resources. Growth in the population and increased demand for agricultural products are continuously increasing the pressure on land and water supplies. The overall amount of arable land available for agriculture is small and may be of low quality for intensive agricultural production in some regions of the world. Sustainable agriculture is fundamental to responsible management of mental resources in the environment, such as renewable and non-renewable energy, soil, water, and nutrient inputs. For crop varieties with improved characteristics (like improved nutrition, increased yield, and improved stress tolerance), conventional breeding has been used in the past to pick. The advent of modern biotechnology and the production of GM crops, however, have enhanced the toolbox of the breeder and enabled agriculture to move much faster on a path to sustainability. Such innovations have a wide and established track record of improving yield and prosperity, benefiting more from smallholder farmers in developing regions than in developed regions (Klümper and Qaim 2014).

The technologies addressed here are only a few examples of what can be done to improve food protection and environmental stewardship. While these new developments are highly promising, it is important to note that agricultural biotechnology represents only one set of instruments to improve the sustainability of agriculture and food security. In order to improve sustainability and manage the environmental burden of agriculture, an integrated approach including precision farming for input applications, cover cropping conservation tillage, increased crop diversity, and other best management practices would all be necessary (National Research Council 2010). Every concept seems to have a diverse focus and a separate collection of analytical questions. It remains a theoretical and conceptual hurdle to overcome incompatibilities between these approaches and among the objectives of sustainable agriculture in general. The analysis and understanding of sustainable agriculture presented here, however, offer a basis for evaluating agriculture's sustainability.

14.8 Conclusion

Agriculture productivity can also be understood via an economic, ecological, and social viewpoint and should be analyzed in relation to all three dimensions of agriculture. Sustainable agriculture can also be presented on various time scales as a set of interacting structures. In thinking about and practicing sustainable agriculture, conceptual diversity occurs. Limiting the effect on the environment of agriculture and enhancing the quality of food nutrition would involve innovative food production approaches and, thus, innovative plant breeding practices. To address nutritional and food protection and achieve environmental sustainability, there is no single solution. Nutrition, agricultural productivity, and health are multidimensional, interconnected, and complex. An assessment is adopted where together with enhanced nutritional value, management of integrated natural resources, and resource-efficient plants/crops will mitigate the adverse impact of climate change on agriculture. Dietary trends and crop diversity that reduce the effects on the environment and improve health need to be recognized and adopted. Based on the use of heterogeneous cultivars, processing systems contribute to the diversity of diets and thus to better well-being and human health. Since nourishment is a complex function, we recommend a comprehensive perspective to seizure nutrition's complexity in relation to human health. In addition to recognizing dietary trends with lower environmental effects, coupled with the promotion of more active lifestyles, policies that promote the adoption of healthier diets are a positive strategy to improve public health.

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