



BIOTECHNOLOGICAL ROLE OF FUNGAL MICROBES IN SUSTAINABLE AGRICULTURE

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Abstract

Over the past several decades, advances in biotechnology have been used as a tool to increase food production. Specifically, advances in genetic engineering have made possible the manipulation of crops to increase yield, guaranteeing food supplies for the increasing world population. The broad application of microbes in sustainable agriculture is due to the genetic dependency of plants on the beneficial functions provided by symbiotic cohabitants. Therefore, microbial biotechnology and its applications in sustainable development of agriculture and environmental health are getting better attention. Finally, a brief highlight has been given on the biotechnological role of mycobionts to sustain the agriculture sector.

Key words: Agriculture, biotechnology, microbes, sustainability

Introduction

The increase in human population worldwide has become a major threat to food security. The projected population indicates that India will be a first most populous country in the world and China will be second in 2050 (Population Reference Bureau, 2001). Population growth, particularly in countries with developing economies, will result in the need for a 70% increase in food production by the year 2050 (Delaney, 2015), making the significant enhancement of agricultural productivity in the next several decades a priority. So, more alarmingly population rise is a major concern of our country. This poses a great challenge to agricultural systems because Traditional farming equipment and practices are reaching their limits of effectiveness in increasing agricultural productivity. In this respect, efforts of biotechnology have been concentrated on creating technologies that can increase crop yields (Estrada *et al.* 2017).

The word “sustainable” has come for the word “sustain” that means to maintain or to support. Through sustainable agriculture people try to identify and solve

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the problems in the existing agricultural system in order to offer food and fiber for people over the long term. However, till date, a fully sustainable agriculture has not been developed, and for the predictable future much improvement can be done. There are three areas that must be addressed in order to be fully sustainable, these areas are as follows; agriculture, food, and natural resource systems. Through sustainable agriculture, a fair and reasonably secure living for the farm families can be achieved. And it also reduces the possible harm caused to the natural environment. It should also maintain basic natural resources such as clean water, clean air, and healthy soil (Das and Patra, 2017).

The 1990 Farm Bill defines sustainable agriculture as:

“An integrated system of plant and animal production practices having a site-specific application that will, over the long term:

- satisfy human food and fiber needs
- enhance environmental quality and the natural resource base upon which the agricultural economy depends

- make the most efficient use of nonrenewable resources and on-farm resources and integrate, where appropriate, natural biological cycles and controls
- sustain the economic viability of farm operations
- enhance the quality of life for farmers and society as a whole.”

Biotechnology is the branch of biological science, which deals with the manipulation through genetic engineering of living organisms or their components to produce useful products for various applications in biological sciences (Mosttafiz *et al.* 2012). Even though biotechnology applications can be traced to 6000 BC, it was in the 1970s when the expansion of genetic tools with cellular and tissue engineering gave the new momentum along with a range of possible novel applications to the arena of biotechnology (Awais *et al.* 2010).

Microbes are everywhere and often in very large numbers. One can think of microbes beyond the world in which we all live (*i.e.* from earth to space). Microbes are an integral part of biogeochemical cycles which are important for our sustenance. A large number of these microbes are beneficial to plants, animals and humans in one form or the other but some are harmful as well. Microbial world, a treasure in itself, if exploited judiciously, can contribute to the sustainable development. According to me there are three super challenges of the 21st century: (1) climate change, (2) food security, (3) dependence on imported petroleum, and I think microorganisms are efficient enough in meeting out these challenges (Abumhadi *et al.* 2012).

Microbes also play a significant role as the sustainable utilization in food agriculture and human health (Kuhad, 2012). Fungal Microbes are used as biofertilizers, natural fermentators, biopesticides, bioherbicides etc. for their sustainable utilization in agriculture (Mosttafiz *et al.* 2012). A lot of research has been undertaken for the favourable role of probiotics for developing novel food products and processes, for human health, rapid detection kits for GM foods, utilization of agricultural residues for obtaining value added products and low cost nutrient food supplements. Other areas of research where microbes contribute in producing healthy and nutritious foods are fungal protein such as some highly nutritional mushrooms like *Calocybe indica* (Milk mushroom), *Cordyceps sinensis* (Insect mushroom, Kirajali), *Lentinula edodes* (Shiitake) which are pharmaceutically important with many types of bioactive compounds of medicinal importance (Noble and Ruaysoongnern, 2010). Recently in our country a protocol has been developed for *L. edodes* cultivation using rice

straw as substrate (Kuhad, 2012).

Microbial Biotechnology and Sustainable Agriculture

Biotechnology has been contributing to sustainable agriculture through the following ways:

1. Increased resistance against biotic stresses (insect pests and diseases);
2. Increased resistance against abiotic stresses (drought, cold, flooding, and problem of soils);
3. Bioremediation of polluted soils and biotectors for monitoring pollution;
4. Increased productivity and quality;
5. Enhanced nitrogen fixation and increased nutrient uptake and use efficiency;
6. Improved fermentation technology;
7. Improved technologies for generating biomass-derived energy;
8. Generation of high nutrient levels in nutrient-deficient staple crops such as rice.

Microbial Biotechnology contributes to sustainable agriculture by reducing the dependence on agrochemicals, particularly pesticides, through the deployment of genes conferring tolerance or resistance to biotic and abiotic stresses. Carefully selected genes from related or unrelated genetic resources are integrated in otherwise desirable genotypes. Here is a broad explanation of the use of microbes in agriculture (Aruna and Sreekanth, 2015).

Fungal-Bioinsecticides

Fungi cause diseases in some 200 different insects and this disease producing traits of fungi is being used as bio-insecticides.

Fermentation technology is used to mass production of fungi. Spores are harvested and packaged so these are applied to insect-ridden fields. When the spores are applied, they use enzymes to break through the outer surface of the insects' bodies. Once inside, they begin to grow and eventually cause death (Parkash and Saikia, 2015).

Fungal agents are recommended by some researchers as having the best potential for long-term insect control. This is because these bio-insecticides attack in a variety of ways at once, making it very difficult for insects to develop resistance.

Fungal-Biofertilizers

It has been observed that some microorganisms, including fungi, have shown biofertilizer-like activities in

the agricultural sector (Mahanty *et al.* 2016). The utilization of microbes as biofertilizers is currently being considered, to some extent, as an alternative to chemical fertilizers to enhance crop production.

The addition of biofertilizers to soil can improve the retention of nutrients in plants and may encourage soil richness and increased harvest yields. Phosphate and nitrogen are important for the growth of plants. These compounds exist naturally in the environment but plants have a limited ability to extract them. Phosphate plays an important role in crop stress tolerance, maturity, quality and directly or indirectly, in nitrogen fixation. A fungus, *Penicillium bilaii* helps to unlock phosphate from the soil. It makes an organic acid, which dissolves the phosphate in the soil so that the roots can use it. Biofertilizer made from this organism is applied by either coating seeds with the fungus as inoculation, or putting it directly into the ground.

Crop productivity in fields can increase up to 300% after the addition of *Trichoderma hamatum* or *T. koningii* as biofertilizer. According to Chang *et al.* (1986) improved germination, a fast rate of blooming and increased height and weight of specific plants, namely pepper and chrysanthemums, were observed when soil was treated with conidial suspensions of *T. harzianum*. Shivanna *et al.* (1994, 1996) recorded increased development of wheat and soybean under nursery conditions when treated with *Penicillium* and *Trichoderma*. They further expressed that the reaction varied when the same was attempted in field conditions yet increases in yield were perceived at times. *T. harzianum* strain T-203 enters the roots and acts like a mycorrhizal growth, advancing development (Kleifield and Chet 1992). *Trichoderma* spp. are known to control minor pathogens such as *Pythium* sp. (Ahmad & Baker 1988, Harman *et al.* 2004) and in this roundabout way advance development.

Transgenic Food

Transgenic foods, also known as genetically modified or engineered foods, are defined as those that are produced and/or are processed from organisms that have had changes introduced into their DNA using the methods of genetic engineering (Fernández-Suárez, 2009; Herrera-Díaz and Gómez-Solis, 2011; PALT, 2014).

Transgenic foods can include the following:

- a) Crops that can be directly used as food and that have been genetically modified, e.g., corn crops that are pest resistant.
- b) Food that contains an ingredient or an additive derived from a GMO.

- c) Foods that uses an auxiliary product for their production derived from a GMO, e.g., cheese made from recombinant chymosin obtained from a strain of the fungus *Aspergillus niger* that has been genetically manipulated to produce the bovine enzyme.

Improving Animal Feed

The agricultural products alone cannot meet the food demand; therefore the research on the animal productivity holds equal importance (Godfray and Garnett, 2014). Microbes can really contribute in improving the animal feed for ruminants and non-ruminants. The white rot fungal fermentation of wheat straw has improved its protein content and digestibility. Lignocellulose Biotechnology Laboratory, University of Delhi South Campus in collaboration with IIT, Delhi and Ayurved Pvt. Ltd., Delhi has achieved success in developing animal feed. Some groups in India have been working on the application of xylanases and phytases in improving the grains and converting keratin substrate with keratinases into feed for poultry and piggery. The work in these areas needs more efforts and government support to transform the R and D into commercial viable technology (Kuhad, 2012).

Conclusion

Beneficial fungi contribute to plant growth and productivity. This chapter condenses the beneficial fungal characteristics that are utilized to promote biotechnological advantages for plants to sustain the agriculture sector. Arbuscular mycorrhizal fungi and biocontrol agents such as *Trichoderma* and *Gliocladium* spp. summarize just a few of the beneficial fungal characteristics that improve plant cultivation. Creating a sustainable economy and protecting our environment are, more than ever before, dominant topics in our everyday life. Increasing demands on our agricultural industry due to increasing population and energy crop production demands more efficient crop management. Positively, the focus is shifting to sustainable organic farming. This shift will require more from biocontrol agents and plant growth promoters in plant protection and as biofertilizers. Continuous research in this topic will aid innovation and advancements in biotechnologically beneficial fungi in relation to plant production.

The prospects for a future development of agricultural microbiology may involve the construction of novel multipartite endo- and ecto-symbiotic communities based on extended genetic and molecular (metagenomic) analyses. The primary approach for such construction is to create composite inoculants, which simulate the natural plant associated microbial communities. For balancing

the host plant metabolism, a combination of N- and P-providing symbionts would appear promising, including the endosymbiotic rhizobia + VAM-fungi. At last it can be said that, the use of biotechnological tools and microbiological techniques has opened up new vistas in the field of sustainable development particularly in the areas of medicine, agriculture, silviculture, horticulture, environment and other important issues.

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