

# **BIOTECHNOLOGY AND BIOFERTILIZATION: KEY TO SUSTAINABLE AGRICULTURE**

**BY**

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The population growth in the world is outstripping food supply and agricultural productivity. The world population is expected to reach 7 billion within 25 years and over 10 billion in the year 2050, while agricultural production is growing at slower rate of about 1.8 % annually. All human beings depend on agriculture that is required to produce food of the appropriate quality and in required quantities.

Domestication of plants and animals found in the wild, combined with gradual long-term changes in their qualitative traits, were the first attributes of agriculture. Domestication, followed by food storage, coincided with the growth of microorganisms. Thus was born classical food fermentation, the earliest known application of biotechnology for the generation of food products.

The “green revolution”, increased wheat production 10-fold in India, Pakistan and several countries in south East Asia , thereby feeding three times as many people. However this revolution has already been exploited to its limits, and alternative solutions are required to be embarked upon through integration of classical breeding and advanced techniques in crop production and biotechnology to create “evergreen revolution” on sustainable basis.

## **Current Status / Trends**

Current farming practices heavily rely on the use of chemical fertilizers with major emphasis on N and P fertilizers while K and micronutrients are generally not applied. Besides, almost all the crop residues are removed. This, coupled with planting of high yielding varieties, has led to decline in soil fertility and organic matter (< 0.5%) and crop production potential of soils. All the agricultural soils in Pakistan are deficient in nitrogen, 80-90% in phosphorus, and 30-40% in potassium. Among micronutrients, field scale deficiencies of economic significance prevail in zinc, boron, and iron. According to a recent survey (NFDC, 2003), 94% farmers used NPK fertilizers whereas 32.6% farmers use farmyard manure, 1.6% micronutrients, 2.7% crop residues and less than 1% use bio-fertilizers. On the whole, the fertilizer use in Pakistan is increasing day by day but soil fertility and organic matter levels are decreasing with the passage of time. Total consumption of nutrients has reached 3.8 million tons of which nitrogen accounts

for 77% and phosphorus 22%. This imbalanced nutrition is not only impacting crop productivity but it is leading to serious problem of soil degradation and environmental concerns as well. During the past 20 years, population has registered a growth of 2.4% per year, and fertilizer use has increased at 4.7% year. On the other hand, cropped area availability per capita has decreased from 0.21 to 0.14 hectares, and yields of major crops have increased by only 1.5-1.7% per year. During the same period, fertilizer efficiency (partial productivity factor) has decreased, for wheat for example, from over 20 to less than 12 kg of grain per kg of fertilizer used. Thus increase in fertilizer consumption is not fully translated in crop production. Crop yields continue to remain low which can be increased at least two-fold by adopting proper soil and water management practices, balanced crop nutrition involving the use of all possible sources of nutrients, improved crop production technology etc.

Under the situation, biofertilizers offer great potential for not only increasing improving soil fertility and organic matter levels but also provide for efficient use of various inputs (water and nutrients) and for increasing crop production on sustainable basis.

### **Biofertilizers/ Organic Wastes**

Biofertilizer is a material containing microorganism(s) added to a soil to directly or indirectly make certain essential elements available to plants for their nutrition. Various sources of biofertilizers include nitrogen fixers, phytostimulators, phosphate solubilizing bacteria, plant growth promoting rhizobacteria etc. Considerable progress has been made over the past two decades in evaluation of these technologies and development of application methods, yet we stand far away from adoption of these technologies. The simplest way of harnessing the benefits include planting of legumes which can fix atmospheric nitrogen to the extent of 250- 300 kg/ha/yr, besides improving soil fertility and added benefit to succeeding crops. Inclusion of legumes and green manure crops in the cropping systems can, therefore, substantially reduce nitrogen fertilizer requirements, increase fertilizer use efficiency and reduce production costs while improving soil quality and organic matter contents in an environment friendly manner. The discussion about quality and soil organic matter would be incomplete without discussing the positive contribution of organic wastes of crop, animal and industrial origin. Complete crop residue removal for fodder and fuel happens to be a norm in Pakistan, and application of animal manure and other organic wastes is also quite limited. Thus, depletion of soil organic matter stock from the root zone has adversely affected the soil productivity and environmental quality. In simple terms, poor farmers have passed on their suffering to the land through extractive processes. They cultivate marginal soils

with marginal inputs, produce marginal yields and perpetuate marginal living and poverty. The situation deserves concerted efforts and appropriate strategies and policy decisions to overcome the negative impact on crop production and food security environment.

Of the available organic sources, farm yard manure is a potential source but almost 50% of it is not collected, and approximately half of that is used as fuel. So in essence only 25% of farm manure finds its way to the agriculture fields. Based on different assumptions, it is estimated that 1.5 million tons of nutrients are available from FYM, in addition to 0.185 million tons from poultry manure. The Pakistan sugar industry produces 1.2 million tons of filter cake every year which is a rich source of organic matter, and major and micronutrients. Application of these organic wastes and including biofertilizers in the farming systems can help maintain consistently high yields through improvements in water and nutrient use efficiencies and soil biotic activity and soil organic matter levels. An increase of 1 ton of soil organic carbon pool of degraded soils may increase crop yield by 20-40 kg/ha for wheat and similar increases for other crops, besides enhancing food security.

### **Organic Agriculture**

“Organic agriculture is a holistic production management system which promotes and enhances agro-ecosystem health, including biodiversity, biological cycles, and soil biological activity. It emphasises the use of management practices in preference to the use of off-farm inputs, taking into account that regional conditions and locally adapted systems. This is accomplished by using, where possible, agronomic, biological, and mechanical methods, as opposed to using synthetic materials, to fulfil any specific function within the system”. Organic agriculture is a system that relies on ecosystem management rather than external agricultural inputs. It is a system that begins to consider potential environmental and social impacts by eliminating the use of synthetic inputs, such as synthetic fertilizers and pesticides, veterinary drugs, genetically modified seeds and breeds, preservatives, additives and irradiation. These are replaced with site-specific management practices that maintain and increase long-term soil fertility and prevent pest and diseases.

There is increasing awareness among the farmers regarding the benefits of organisms in crop production and in improving soil health and nutrition status. Some farmers have already started converting their farms into organic agriculture where quality of the product and the environmental concerns stand a

priority. Production levels are often low under organic agriculture compared to conventional system based on agrochemicals but the farm produce from organic agriculture fetches better price as export commodity.

## **Biotechnology**

During the last two decades, the new biotechnologies have been adopted to agricultural practices which have opened new vistas for plant utilization for enhancement in agriculture productivity in a sustainable manner. This will continue and intensify in the next decade. Plant biotechnology – especially in-vitro regeneration and cell biology, DNA manipulation and genetic modification of biochemical pathways—is changing the plant scene in three major areas i.e., growth and development control (vegetative, generative and reproduction / propagation) , protecting plants against the ever-increasing threats of abiotic and biotic stress, and expanding the horizons by producing specialty foods , biochemicals and even bio-pharmaceuticals.

Achievements today in the biotechnology have already surprised all previous expectations, and the future is even more promising. The full realization of the agricultural biotechnology revolution depend on both continued successful and innovative research and development activities. Biotechnology should be fully integrated as an aid to classical breeding techniques, through bioengineering and molecular biology interventions techniques and by introduction and investment of engineering microorganisms into agricultural production systems.

It must be realized that only about 12% of the world's land surface is used to grow crops, and the agricultural areas required to support food production is going to drop to from – 0.44 ha / capita in 1961 to 0.15 ha / capita, in view of the population growth. The challenge for the agricultural sector during the next few decades is therefore clear, double the food production by 2025, on less per capita land, with less water, under increasingly challenging environmental conditions. The situation is further complicated by the fact that in spite of the heavy use of agrochemicals, modern agriculture still loses nearly 42% of crop productivity to competition with weeds and to pests and pathogens, and an additional 10-30% to post-harvest losses due to a variety of factors, especially in the developing countries where storage conditions are poor. During the 20<sup>th</sup> century traditional plant breeding has brought about enormous increases in crop productivity. However, plant improvement by hybridization is

slow and is restricted to a very small gene pool owing to natural barriers to crossability. Beginning in the early 1980s, advances in plant cell culture and genetic transformation have overcome these barriers by making it possible to transfer defined genes into all major food crops, including cereals, legumes, cassava, potato, and many vegetable fruits. The entire global gene pool whether it be plant, animal, bacterial or viral- is available for utilization. The first genes that have been integrated into crop species provide resistance to non-selective and environment friendly herbicides, and many pests and pathogens. Increasingly large acreages of transgenic maize, soybean, potato, tomato and cotton are being commercially grown for human use and consumption. Carefully planned introduction of such crops on a worldwide scale would greatly help in reducing or even elimination of the enormous crop losses attributed to weeds, pests and pathogens. The use of such crops will also have a beneficial effect on the environment by significantly reducing the use of agrochemicals. Other genes for improving crop productivity, and manipulating starch / protein / oil quality and quantity, resistance to environmental stresses such as temperature and drought are also being isolated and studied to produce second generation transgenic crops.

The biotechnology is required to be geared up and directed to develop biomaterials aimed at enhanced productivity to meet the food requirements of galloping population on sustainable basis in years to come. Two major categories of biomaterials could be direct improvement and modification of specialized constituents of plant origin, and manufacture in plants of non-plant compounds. Biotechniques, mostly based on the engineering of metabolic pathways, are now available to modify many plant constituents that are used in the food, chemical and energy industries to convert them into their bioforms. This includes many “primary” metabolites: carbohydrates (starch synthesis, yield and allocation, production of high-amylose or high-amylopectin starch, increased sucrose synthesis for sugar industry, enhanced production etc.), fructan production, proteins (improvements of amino acid composition and protein content), oils and fats (ratio of saturated to nonsaturated fatty acids, increased content of specific valuable fatty acids like uric acid, ricinoleic acid and others).

It is now generally realized that the enhanced agriculture productivity could only be attained through the practice of better plant breeding which will continue to move forward as progress is being made in advanced techniques through biotechnology endeavours and its consequent limitations associated with use of synthetic chemical fertilizers as well as insecticides and pesticides. Scientists in the future will not only be forced to hone their traditional skills but will also have to integrate them with knowledge and

experience to coincide with recent advancement and technologies derived from cellular and molecular concept and approaches. For worldwide crops such as potato, rice, maize and in the future wheat, as well as for high value vegetable crops, the future of agriculture and scientists is associated with the use of combination of practices involving traditional breeding, genetic engineering and tissue culture techniques. In addition to increasing reliance on breeding, agriculture will also depend on biocontrol to complement and make possible the use of chemicals that are compatible with intelligent management of the natural resources essential for a sustainable yet highly productive agriculture. Plant tissue culture technique an aspect of agriculture, not only provides essential way for the clonal propagation of many agriculturally important crops such as woody ornamentals and vegetable plants but they are also the basis for the production of transgenic plants and are at the forefront of the recent studies in biotechnology and plant physiology, developmental biology and biochemistry. Spectacular progress in our knowledge of plant sciences, relevant to agriculture and breeding, can be expected from the integration of more traditional sciences with molecular and cellular concept and techniques.

Sustainability, however, would never be achieved as long as our agriculture practices continue beyond the carrying capacity of the ecosystem through indiscriminate use and abuse of agricultural chemicals. The rapid growth of agriculture productivity in chemical farming systems in the wake of intensive farming and population growth needs a serious rethinking due to continued soil degradation, loss of fertility and environmental pollution. Environmental concerns from agricultural activities jeopardize agriculture growth in several countries of Asia, Africa and subsaharan region. Problems associated with the agriculture production in the developed world and underproduction in developing countries therefore, necessitates an assessment of the present status of agriculture. It is time to develop new farming systems committed to environment friendly and sustainable approaches, producing healthy food free of agrochemical residues. Ecologically oriented farming routines including biofertilization techniques need to be developed and embarked upon within the framework of recent achievements in environmental biotechnology, the most important of which is the clean farming system which is increasingly acknowledged as a potential solution to copious problems of present world agriculture. It is a farming system, which aims at evading the routine use of agricultural chemicals and reducing their rates of application. Clean farming system is associated with four environmental biotechnologies, i.e., recycling of composted organic waste, fortifying the rhizosphere soil with biofertilizers, encouraging the use of biopesticides in agricultural practices and bioremediation of polluted agro-ecosystems.

Increasing realization of the ill effects of long sustained, exclusive use of chemical fertilizers, and consistent growing demand from the consumers for quality, coupled with unsustainable productivity of crops, fruits and vegetables have fostered experimentation with some alternative cultural practices. Organic culture is claimed to be the most benign alternative. Use of organic materials such as farmyard manure, cakes of plant origin, vermicompost, and microbial bio-fertilizers on one hand, and exploiting the synergism between fruit-vesicular arbuscular mycorrhizal fungus on the other hand, are important components of the bio-organic concept of fruit / crop cultivation. Mycorrhizae were observed to be highly effective in low fertility, coarse texture soils. Mycorrhizal-treated trees had better plant growth and uptake of nutrients like P, Ca, Zn, Cu, and Fe compared to non-mycorrhizal trees. Inoculation of soil with mycorrhizae also helps in regulating the water relations and carbohydrate metabolism of fruit trees / vegetables. Phosphorus nutrition of mycorrhizae also helps in regulating the water relations and carbohydrates metabolism of crops. Phosphorus nutrition of mycorrhizal-treated fruit tree was best improved by using biofertilization techniques and by adopting alternative farming systems through organic agriculture practices.

Over the years the PGPR (plant growth promoting rhizobacteria) have gained worldwide importance and acceptance for agricultural benefits. These microorganisms are the potential tools for sustainable agriculture and the trend for the future. Scientific researchers involve multidisciplinary approaches to understand adaptation of PGPR to the rhizosphere, mechanisms of root colonization, effects of plant physiology and growth, biofertilization, induced systemic resistance, biocontrol of plant pathogens, production of determinants etc. Biodiversity of PGPR and mechanisms of action for the different groups: diazotrophs, bacilli, pseudomonads, and rhizobia are shown. Effects of physical, chemical and biological factors on root colonization and the proteomics perspective on biocontrol and plant defence have also shown positive results. Visualization of interactions of pathogens and biocontrol agents on plant roots using autofluorescent protein makers has provided more understanding of biocontrol processes with overall positive consequences.