



## AGRICULTURAL BIOTECHNOLOGY AND THE DEVELOPING WORLD

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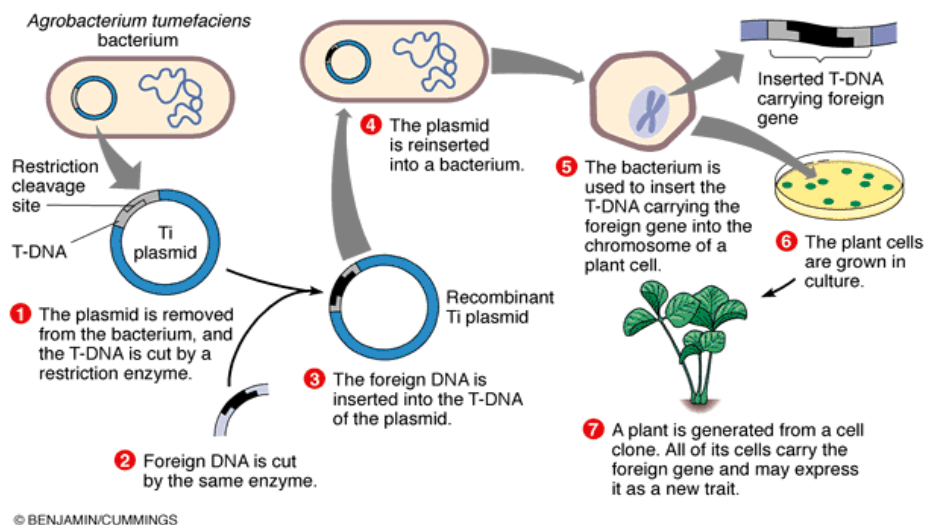
*The most critical areas in the world for bringing economic prosperity and stability are the developing countries. Agricultural productivity in these countries must advance more rapidly to meet growing food demands and raise incomes while protecting the environment for future generations. Agricultural biotechnology has the potential to play a large role toward this. Sadly, this opportunity remains a mirage for most developing nations because of numerous challenges that prevent them from benefiting from the technology. The use of agri biotechnology is controversial, and the subject of considerable debate. Advocates believe that use of the new technology enhances efficiencies in terms of higher yields, drought and salinity tolerance, pest and herbicide resistance, improved nutrition and even vaccines for many illnesses. Critics, however, raise the concern that genetic biotechnology could have adverse effects on human and animal health or result in potentially harmful migration of transgenes. They consider the technology a threat to safety, ethics, and welfare. In view of these divergent views, actual assessment of the impact of agricultural biotechnology is difficult. This article identifies the benefits and risks of agricultural biotechnology and concludes with recommendations on the appropriate use and application of the technology in to developing nations.*

*Key words: Agricultural biotechnology, developing nations*

### **Introduction**

Biotechnology and agriculture are both age-old fields by themselves that have come together for the betterment of mankind. Agricultural biotechnology allows the genetic code imparting a specific trait, for example resistance to a disease infection or drought resistance to be identified and isolated from a given organism. The great power of this technology lies in its ability to take genes from one organism and insert them into crop plants to impart novel characteristics. This capability is rooted in the biological reality that the genetic codes (genes) for all living organisms are organised in a similar manner and can, with minimal changes, be made to operate in a non-native genetic background. It is possible, therefore, to transfer genetic information from algae, bacteria, viruses or animals to plants or to move genes between sexually incompatible plants species. For example, crop plants can be engineered to produce their own pesticides, to have resistance to previously toxic chemicals or to have elevated nutritional qualities. Technical advances over the last five years have also demonstrated the ability to simultaneously transfer as many as 12 genes into a plant genome. This greatly enhances the potential to engineer complex disease and pest resistance pathways to produce more robust crop plants. Biosynthetic pathways can also be manipulated to produce high value pharmaceuticals and other polymers within the plant tissues. These are then available for direct consumption or for subsequent extraction on commercial scales. The ability to transfer beneficial agronomic traits cross species boundaries, within and out with the plant kingdom, opens a multitude of possibilities which are limited at this time only by our imaginations and by ethical and biosafety considerations. It is now widely considered, however, that if handled in a

responsible manner biotechnology represents a revolution with immense potential impact for the well-being of mankind. In plants, genetic modification is commonly conducted by the introduction of a vector, typically a virus or bacteria that can introduce new DNA to the plant genome (the set of chromosomes, containing all of the plant's genes and associated DNA ( Fig 1).



Other methods of gene transfer technologies include: electroporation, where an electric current opens pores in cell membranes allowing insertion of foreign DNA; microparticle bombardment, where cell nuclei are penetrated by particles laden with new genetic material; and microinjection, where genetic material is directly injected into target cells. According to Glover (2001), recent scientific advances in genetics have opened up a range of potential new applications of modern biotechnology. In agriculture, these include the ability to: manipulate genetic material and transfer genes between organisms in order to promote desired traits and suppress unwanted ones, propagate disease-free planting material in the laboratory, and support traditional breeding techniques. The latest “big thing” in agricultural biotechnology are: genomics (mapping of complete organism genomics), and bioinformatics (computer processing of masses of genetic data).

### Biotech Applications

Plant tissue culture can help developing countries produce disease-free, high-quality planting material. In commercial applications, such as floriculture, it also generates much-needed employment, particularly for women.

DNA-based techniques include isolation, amplification, modification and recombination of DNA; genetic engineering to obtain Genetically Modified Organisms (GMOs); use of markers and probes in gene mapping and in functional and structural genomics; and unambiguous identification of genotypes through DNA fingerprinting.

Diagnostic kits based on the products of biotechnology (monoclonal antibodies, recombinant antigens) are very important modern agricultural applications for identification of plant and animal pathogens, with economic implications for pathogen monitoring and control programmes.

**Agro-industrial Applications** - There is untapped potential for increasing employment and adding value to agricultural products through agro-industry, diversification and alternative utilization of raw materials (e.g., use of vegetable oils as biofuels).

These gene modification technologies show considerable potential to enhance human health and well being. However, the practice of gene modification of food crops is controversial, and the subject of considerable debate. Opinions are divided on this issue. Advocates believe that use of GM technology enhances efficiencies in terms of higher yields, drought and salinity tolerance, pest and herbicide resistance, improved nutrition and even vaccines for many illnesses. Critics, however, raise the concern that genetic biotechnology could have adverse effects on human and animal health or result in potentially harmful migration of transgenes. They consider the technology a threat to safety, ethics, and welfare.

In view of these divergent views, actual assessment of the implications of agricultural biotechnology is difficult. Against this backdrop and in recognition of the vital contribution of biotech to global food, feed, and fibre security, it is imperative to examine its potential contributions. This article aims at finding the significance of agricultural biotech in sustaining food supplies, health and economic well-being of citizens in developing nations. The subsections of this paper are organised as follows: Section 2 outlines the need of biotechnology in developing nations. Section 3 presents a comparative statistics on area under biotech crops in different nations. Section 4 identifies the benefits and risks of agricultural biotechnology. The last section concludes with recommendations on the appropriate use and application of the technology in developing nations.

### **Agricultural Biotechnology and Developing Nations**

- Presently, 80% of the world's population live in Less Developed Countries (LDCs). Over the next fifty years the world's population is forecast to grow by 54 per cent, from 6.1 billion in 2000 to around 9.3 billion people by 2050. All of the increase in population is forecast to occur in developing countries, with population in developed countries forecast to decline slightly over this period (United Nations 2001). With increasing population pressure in developing countries it becomes paramount to find ways of increasing productivity on existing agricultural lands, if food security is to improve and environmental damage is to be minimised. Advances in agricultural biotechnology are widely considered to have a key role in fulfilling these objectives. The need for new technologies in agriculture is great in the developing nations on account of following reasons:
- Today, there are some 800 million people whose food intake is insufficient to meet basic energy requirements on a continuous basis.
- Malnutrition plays a significant role in half of the nearly 12 million deaths each year of

children under five in developing countries.

- In addition to lack of food, deficiencies in micro-nutrients (especially vitamin A, iodine and iron) are widespread in developing nations.
- In developing countries about 650 million of the poorest people live in rural areas where the local production of food is the main economic activity. Without successful agriculture, these people will have neither employment nor the resources they need for a better life. Farming the land is the engine of progress in less developed countries.
- The rate of food production globally has dropped from 3 percent per annum in the 1970s to 1 percent per annum now. Burgeoning population, especially in the developing world, will soon outstrip food production.
- The ecologically acceptable expansion of arable land is no longer possible to support the ever growing population of people in developing nations. Unfortunately still, the production systems and practices in developing nations are not efficient to meet with demands. Growth rates in yields have been decreasing in most parts of developing nations and this declining trend is expected to continue if nothing urgent is done.
- Global climate change and alterations in land use will exacerbate the problems of regional production and demands for food. Climate change, which affects the frequency of extreme weather events, alters agricultural growing patterns as well as the distribution patterns of pests, weeds and diseases that threaten crops and livestock. Frequencies of natural disasters have increased in recent decades and global warming will likely lead to more natural disasters. The overall impacts of climate change on agriculture and food security are expected to be increasingly negative, especially in developing nations, which are already vulnerable to climate-related disasters and food insecurity.
- The world's population is projected to increase to over 9 billion people by the year 2050, and nearly all of this increase is forecast to occur in developing countries (UN Population Division, 2011). In addition, the ongoing migration from rural to urban areas is expected to continue, so that by 2050 about 70% of the world's population will be urban (compared to 50% today). Incomes are also expected to rise in the future in developing countries, resulting in dietary changes where the proportion of grains and other staple crops in diets will decline, while the proportion of vegetables, fruits, edible oil, meat, dairy and fish will increase. With this larger, more urban and, on average, richer population, it is estimated that the global demand for food in 2050 may be 70% higher than today (FAO, 2009a).

These statistics highlight a reality that has far reaching consequences, and in the opinion of many, constitutes the single most important challenge facing mankind for the coming decades. Sustaining food supplies, health and economic well-being for developing nation's citizens without destruction of the remaining forest and wilderness regions is a matter of great concern today. In view of above, increases in agricultural productivity through improvements in crop and livestock yields is urgently required. New scientific and technological advances therefore, remain the most probable option for sustainable

food and fibre production in developing countries. This is because the problem of food insecurity in most developing societies has remained intractable using the conventional traditional methods of food production. Meanwhile, research in recombinant genetics and biotechnology develops plant and animal species that provide reliable high yields at the same or lower costs by breeding-in qualities such as better product quality, resistance to diseases, pests, and stress factors, etc. Modern agricultural biotechnology has the potential to play a large role in more rapidly advancing agricultural productivity in developing countries while protecting the environment for future generations.

### **Global Area of Biotech Crops**

The global area under transgenic crops has risen dramatically, from 1.7 million hectares in 1996 to 90.7 million hectares in 2005. In 2005, four countries grew 99 per cent of global GM crops: the United States, which grew 49.8 million hectares (55 per cent of the world total), Argentina 17.1 million hectares (19 per cent), Canada 5.8 million hectares (6 per cent) and China 3.3 million hectares (4 per cent) (James 2002). These estimates may well understate the actual area of GM crops. Although it is illegal to grow GM crops in Brazil, many Brazilian farmers already grow them, using seed smuggled in from Argentina. It has been estimated that up to 30 per cent of Brazil's soybean crop, or over 4 million hectares, is produced from GM seed (Glover 2000). In contrast, the European Union — despite having strong public and private life-science capabilities — grew little commercial transgenic crops over the period. India's share in global area under transgenic crops amounts to a meagre 1.3 million hectares (1 per cent).

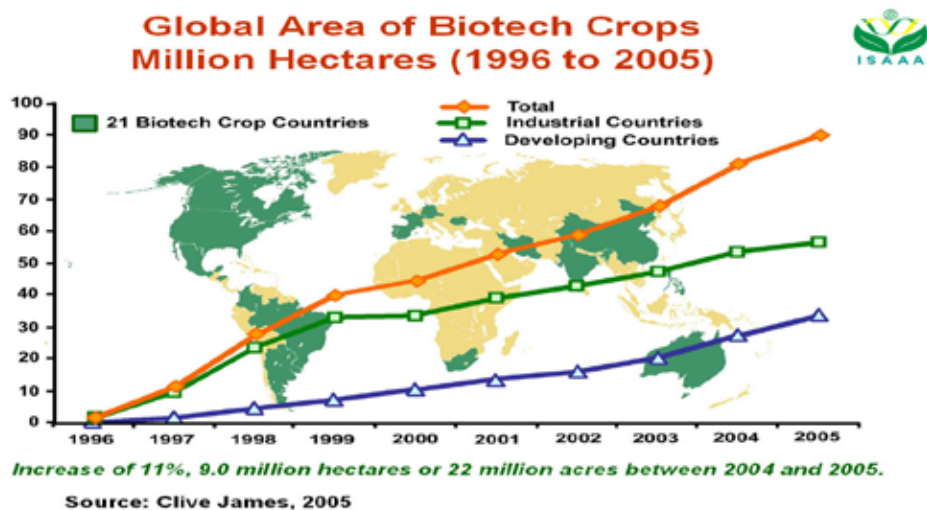
Data on the current global distribution of commercialized transgenic crops show how, with the exception of China and Argentina, there has been little impact in the developing societies as yet (Table 1 and Fig. 1)

**Table 1: Global Area of Biotech Crops in 2005 (Million Hectares)**

Sl. No.	Country	Area	Crops
1.	USA	49.8 (55%)	Soybean, Maize, Cotton, Canola, Squash, Papaya
2.	Argentina	17.1 (19%)	Soybean, Maize, Cotton
3.	Brazil	9.4 (10%)	Soybean
4.	Canada	5.8 (6%)	Canola, Maize, Soybean
5.	China	3.3 (4%)	Cotton
6.	Paraguay	1.8 (2%)	Soybean
7.	India	1.3 (1%)	Cotton
8.	South Africa	0.5 (1%)	Maize, Cotton, Soybean
9.	Uruguay	0.3 (< 1%)	Maize, Soybean
10.	Australia	0.3 (< 1%)	Cotton

*Source: Clive James, 2005.*

**Fig. 1: Global Area of Biotech Crops in 2005 (Million Hectares)**



Over the past decade, agricultural production has been expanding in developed countries, largely through significant increases in yields. Use of biotechnology in agriculture has enabled commercial production on a large scale and pushed yields close to maximum attainable limits. Considerable increases in yield have also been realised in many middle income developing countries over the past decade, particularly for major grains such as rice and wheat. In comparison, agricultural production in low income developing countries has mainly come from smallholder subsistence production, where application of material inputs is quite low, reflecting their high cost relative to income levels, and agricultural operations, like weeding, are mostly carried out manually. Yields have remained well below those realised elsewhere, leaving large margins for potential increases with relatively smaller effort. Although, area under biotech crops in developing nations is insignificant compared to that in developed nations, the trend is encouraging. It also shows that there are wider scopes of GM technology in agriculture in these nations.

### Major Arguments in Favour of Using Biotechnology

Among the potential benefits of the technology are: an increase in the productivity of tropical commodities to meet future food needs, new opportunities for the use of marginal lands, and a reduction in the use of agrochemicals.

- The major potential benefits from the current generation of transgenic crops include increases in productivity from a combination of lower production costs and higher yields. Herbicide tolerant and insect resistant crops may lower chemical use in agricultural production that can have favorable impacts on human health and the environment.
- Genetically modified crops are expected to have positive effects on food safety, with lower chemical use in pest resistant crops resulting in lower incidents of chemical contamination of food production, particularly for fresh fruit and vegetables. Lower

pesticide use is also expected to result in less chemical contamination of local water resources, and will benefit both human health and the local environment.

- Reductions in chemical applications also benefit the environment in other ways. By reducing the need for conventional tillage necessary for weed control, herbicide tolerant GM crops could be grown with minimum or no tillage. This would result in reductions in farm fuel consumption. Besides lower costs to farmers, reductions in fuel use would generate environmental benefits in terms of reductions in greenhouse gas emissions.
- Succeeding generations of transgenic products (sometimes known as ‘second generation’ transgenic crops) are intended to improve productivity by increasing tolerance to other stresses such as frost, drought and salinity; by influencing rates of growth and maturity in plants and animals; and by introducing various quality improvements in products, such as modifications to increase oil or protein content, to make them more attractive to consumers (US Department of Agriculture 2001).
- In addition, research is progressing to genetically modify some crops to produce varieties with high value industrial properties and pharmaceutical qualities, such as incorporating vaccines for many common illnesses (‘third generation’ transgenic crops). For many poor communities in developing countries, it may be easier and cheaper to grow foods with medicinal properties than it is to pay for medicines that may be inaccessible because of high cost, poor supply lines or a lack of suitable storage facilities (Arakawa 1998).
- Of particular relevance to problems of hunger and malnutrition in developing countries is the potential for biotechnology to increase the nutritional value of food. Gene technology can enable the production of new crop varieties that produce essential vitamins and trace elements. This is especially important in regions where access to food is limited and balanced diets are difficult to achieve.
- Productivity increases afforded by biotechnology could make it possible to achieve the dual purpose of meeting current and future food demands for rapidly growing populations, particularly in developing countries, while reducing the need to encroach on lands supporting natural ecosystems.

### **Major Arguments Against Using Biotechnology**

While agricultural biotechnology holds enormous promise for significantly increasing food production and relieving already strained land and water resources, it has become an emotional issue among some consumers, environmental groups and some societies. As the science continues to be developed it clearly presents numerous challenges which hinder its development throughout the food chain. These include:

- Altieri and Rosset (1999) and others have argued that the transmission of genetic material from GMOs could have adverse effects on the environment as well as on crop production. On the environmental risk, one of the major concerns is the possible transmission of transgenes to the wild relatives of the GM crop through crossbreeding. Of particular concern is the potential development of ‘superweeds’ as a result of wild

plants acquiring the genes that are responsible for herbicide resistance over time. This could result in these species outcompeting wild species and causing a reduction in biodiversity. Also, control of these 'superweeds' would come at a higher cost to the farmer and might have a negative impact on farm productivity.

- There are also concerns that pesticide resistant crops could have negative effects on non target insect species. For example, there have been claims that, in north America, windblown pollen from Bt corn fields landing on surrounding vegetation could kill the larvae of Monarch butterflies feeding on milkweed (Losey, Rayor and Carter 1999).
- Another environmental risk relates to animal species that have been modified to show novel or enhanced qualities. Following the recent development of a faster growing GM salmon for aquaculture farming, it is argued that the escape of such a fish to open waters might have a drastic effect on wild salmon populations. (
- Altieri and Rosset (1999) also raised the concern that genetic biotechnology could have adverse effects on human and animal health or result in potentially harmful migration of transgenes. A potential exists that genetic modification of foods for human consumption could lead to the development of allergens and toxins in the modified products. Regulatory authorities are generally aware of such concerns and this is seen by most authorities as a major reason for requiring stringent testing to be undertaken prior to genetically modified foods being approved for release.

### **Recommendations On The Appropriate Use And Application Of Agricultural Biotechnology In Developing Societies**

There is no doubt that modern biotechnology, like any new technology, has its associated benefits and risks. Assessment of the benefits and costs of individual applications of biotechnology is necessary in determining whether or not an application is beneficial. Individual countries need to identify their specific national priorities and preferences in food production, and harness the growing body of science and innovations in genetic engineering to address specific issues. Below are highlights of some recommendations:

**Setting Priorities** Biotechnology expertise should complement existing technologies and be output-driven. Since biotechnology is often more expensive than conventional research, it should be used only to solve specific problems where it has comparative advantage. In many developing countries, funding for research in agriculture is being reduced, and often research is being privatized, with the consequent risk that it could be aimed mainly at resource-rich farmers. In addition to technical considerations, priority setting should take into account national development policies, private sector interests and market possibilities. Different stakeholders should be involved in the formulation of national biotechnology strategies, policies and plans.

**Infrastructure and Capacity** For research to be truly productive, there must be a critical mass of expertise, knowledge and facilities. Biotechnology is no exception. Biotechnology research requires skilled staff, backed up by well-equipped laboratories with proper working conditions, a constant supply of good quality water, a reliable electricity supply, and



organized institutional support . A minimal technology base is needed to adapt technology tried and tested elsewhere to local ecological and production conditions. Biotechnology research needs strong and organized outreach services and suitable institutions and infrastructures to facilitate its application.

**Intellectual Property Rights (IPRs)** Under the World Trade Organization's Agreement on Trade Related Aspects of Intellectual Property Rights (TRIPS), most processes and many products of biotechnology research are patentable. Since most biotechnology research is conducted in industrialized countries, very often by private companies, developing countries may have to pay to use a new procedure or product. IPRs are critical for growth of the biotechnology industry, and lack of patent protection in a country can limit access to the results of biotechnology originating elsewhere. The issues are complex, with implications for trade, technical investment and access to biotechnology outputs. Countries need to evaluate carefully their positions and, as appropriate, introduce legislation foreseen in the WTO Agreement. In particular, they will need to evaluate the most appropriate form of protection for plant varieties.

**Biosafety, Food Safety and the Environment :** Potential environmental hazards from new products of biotechnology, mainly involving genetically modified organisms (GMOs), have raised concerns that companies may use developing countries as "test sites" for their products. Some of the potential environmental risks concern plant pests, while gene escape from GMOs could result in increased weediness in sexually compatible wild species. The inclusion of novel genes for herbicide resistance in plants may increase the occurrence of weeds with resistance to certain agrochemicals. Another worry about GMOs is the possible inadvertent production of toxins and allergens. FAO says developing countries need assistance in developing appropriate legislation and setting up regulatory bodies for all aspects of biosafety. National legislation must be consistent with international instruments and reflect national positions.

**Biodiversity Issues** Biotechnology can contribute to the conservation, characterization and utilization of biodiversity, thus increasing its usefulness. Some techniques such as in vitro culture are very useful in maintaining ex situ germplasm collections of plant species that have asexual propagation (e.g. bananas, onions, garlic) and species that are hard to keep as seeds or in field gene banks. Related techniques are also important for the preservation of animal biodiversity through cryopreservation of semen and embryos, coupled with embryo transfer and artificial insemination. At the same time, however, biotechnology may reduce genetic diversity indirectly by displacing landraces and their inherent diversity as farmers adopt genetically uniform varieties of plants and other organisms.

**Export Substitution** Some products with a high export value for some developing countries, could be substituted by products with similar properties (e.g. copra-quality oil from rapeseed) obtained by genetic modification of other crops or through in vitro techniques. Such products could alter the competitive position of traditional crops, affecting existing trade patterns and consequently the food security of many developing countries that rely on agricultural export revenues.

**Ethical Aspects** Biotechnology is more than just a scientific issue - it is seen by some as "interfering with the workings of nature and creation". In priority setting, all concerns must be clearly balanced, respecting ethical aspects but recognizing biotechnology's potential for increasing food supplies and alleviating hunger. Many ethical issues are now being debated in the context of IPR legislation but others remain unresolved. Since such issues are largely related to cultural background and levels of public perception and awareness, decisions on the use of specific technologies should respect socio-economic realities.

**Public Debate** Public debate is essential for new agricultural biotechnology products and processes to grow. Public confidence in modern agricultural biotechnology is one of the factors that will greatly influence the extent to which countries of developing societies invest in and benefit from genetic engineering to increase food production.

**Human Resource Development and Training** Training in risk management and assessment procedures will be crucial to the building of national capacity for agricultural biotechnology Research and Development. Mobilizing the basic scientific skills usually found in universities to solve agricultural problems will require new policy and institutional arrangements and more financial resources.

**Public-private Sector Collaboration** Public- private sector collaboration is necessary for the funding of agricultural research. This will require: continued public sector investments from domestic and external resources, public-private sector partnership, innovative funding mechanisms on the part of international development agencies, and involvement of both local private sector companies and transnational companies.

**Marketing:** Biotechnology is increasingly market and demand driven, and most of its products result from research and development investments by the private sector in developed countries. There is little point in developing a new technology if there is no market for the product. The same is valid for new varieties of plants and new breeds of animals, new vaccines and diagnostic kits. Market studies are fundamental in defining which ventures should be undertaken. Given that commercial considerations may not necessarily reflect social concerns and needs, there remains a pivotal role for public-sector research.

## **Conclusion**

Agricultural biotechnology has a vital role to play in addressing the world's present and future agricultural requirements. It can be an important factor in achieving improved standards of health and economic security for the entire world's people. Countries should establish broadbased platforms to mobilize the public and scientific communities to build confidence in the technological advances associated with GE. Individual countries need to identify their specific national priorities and preferences in food production, and harness the growing body of science and innovations in genetic engineering to address specific issues. Biotechnology should be considered as an important tool that can be used, provided the ecological risks are investigated and deemed acceptable, in conjunction with a host of other approaches to move agriculture towards sustainability.

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