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Adaption of temperate climate horticultural plants in tropical and subtropical developing countries *(Review Article)*

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I. Some aspects of the biology-based sustainable horticulture

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Plant physiology, as the theory of the horticulture in the XXth century

During the first few decades after its emergence, the leaders of the "old biotechnology", were engineers and technicians. They worked mainly in the specialized industrial plants associated with large scale production (breweries, wineries, tanneries, leather processing, canneries, sugar factories, and otherwise in the production of starch, yeast, alcohol, meat, milk and vegetable oil, etc.). From the beginning of the 20th century, in some centers of Europe and in the USA, specialized agricultural engineers started to organize the improvement of agricultural techniques. The mechanization of soil tillage, processes of cultivation, harvesting, transport and preservation, at the same time, use of chemical fertilizers, animal and plant breeding and many other new revolutionary technologies helped to replace the traditional agricultural production systems (livestock raising, cultivation of cereals, horticulture, etc.).

At the turn of the 19th and 20th centuries, among the first branches of agriculture, horticultural production was considered as a key area of applied science in the classics of botany. Thus the outstanding botanist, *Hans Molisch* entitled his popular book *"Plant physiology as the theory of horticulture"*. At the eve of the Austro-Hungarian empire, the Austrian *Goldscheid* and the Hungarian *Raoul H. Francé* founded the so-called psychobiological schools, which by independent means began to popularize their ideas about "biotécnics" in many parts of Europe. *Francé* was not just a neo-Lamarkian intellectual thinker. At the turn of the 20th century, he was a scientist of the Agricultural Academy of Magyaróvár in Hungary. Appropriately, the distinguished botanist *Gottlieb Haberlandt* had been born and lived nearby until his fifteenth year *and Friedrich Haberlandt*, his father had also been professor of botany there. *Francé* took out two patents for biohumus production of horticultural purpose and he set up a commercial biotechnical farm in Austria. In one of his famous books he affirms the following spiritual sentence: *"I felt clearly that I was facing one of the largest challenges of the mankind. Biotechniques will transform our whole civilization" (Francé,* 1943, cit. *Holló & Kralovánszky,* 2000).

Biotechnology as the practice of the horticulture in the XXIst century

After more than six decades of research, by the early 1960's several areas of the modern horticulture became leaders in the application of plant biotechnology (micropropagation of ornamental plants, vegetables, medicinal and aromatic plants, grape, fruit species, etc). Adapting *Molisch's* statement, it seems to be true that nowadays the "*biotechnology is one of the practices of horticulture*". The main areas of the horticultural biotechnology are *in vitro* cell and tissue culture (micropropagation, embryo culture, anther and microspore culture, etc.) and molecular genetics, e.g., genetic transformation and the use of molecular markers. Apart from commercial micropropagation, the real size of this small biological industry is not known exactly, however most of the procedures are firmly integrated into the production and development processes. The cultivated area of the first genetically modified vegetable species, the industrial tomato reached 60 000 ha, worldwide in 1998. Before the large scale commercial application of transgenic offspring of horticultural crops, they should be the subject of several rigorous phases of investigation (tomato, potato, Brassicas, eggplant, bell pepper, lettuce, melon, pea, bean, carrot, pumpkin, apple, apricot, plum, peach, strawberry, papaya, banana, etc.).

During the last two decades molecular biology has left the confines of the basic research laboratory and has been applied to the genetic improvement of plants used in commercial production in most of the industrialized countries. In several areas of Europe, USA and in some developing countries where horticulture is already well developed, horticultural biotechnology has already entered or elsewhere might enter an application phase. In there counties a relatively high investments will give a return to growers if the quality and/or the amount of products obtained through the new biotech methods enable higher profit and/or provide better positions for their goods on the market among the competitors. In these regions an intense development of new type of partnership-based information exchange can be observed among the public R & D centers, universities and the private sector. The horticultural biotech industry is also showing a strong tendency to increase its regional concentration. Many companies and universities have set up either together with others, or alone, biotech research units. This can be observed in most of the traditional horticultural production centers e.g. in Holland around Aalsmeer, Wageningen, in Belgium around Gent, in Israel around Rehovot, in France around Anger, Montfavet, in Italy around Bologna, Cesena in the USA in some places in California, among others.

The same tendencies can be observed to a smaller degree in some ex-communist countries, e.g. in Poland around Skierniewice, in Hungary around Budapest, and in the Czech Republic around Olomouc. In those countries, where the market based economy is not solid or it is in some phase of transition, the process is governed directly or indirectly by local traditions of R&D activity and state politics.

At the turn of the 20th and 21st centuries, the competitiveness of R & D activities and the practical use of biological technology of horticultural crops vary considerably among developing countries. There are developing countries in the ten to fifteen biggest economies of the word, where this level reaches the level of developed countries and in some areas by some quantitative indexes even exceeds them. In China, as one of the pioneers of the horticulture of the human civilization for instance many protocols were already integrated at high level into practice, since about the mid 1980's (DH varieties of bell pepper, transgenic vegetables, etc.). In India, where the first protocol of anther culture was born almost forty years ago, the commercial micropropagation became a considerable factor of the international trade, due to favorable economical and local political coincidence, from the beginning of the 1990's. On the other side of the planet, in most of the countries of Latin America and the Caribbean, the horticultural biotechnology is beginning to strengthen and certainly will attain a quite considerable level in the first decade of the 21st century.

At the present time, according to the databank of the regional REDBIO/FAO biotech network 539 plant biotech laboratories in 23 countries are registered with approximately 1800 scientists (*Izquierdo and Riva, 2000*). In this area the application of micropropagation is more and more an indispensable factor and has already showed its advantage in the case of some economically important crops like banana, pineapple, garlic, table grapes and ornamental plants, etc. (Ecuador, Cuba, Chile, Colombia, Argentina, Brazil). Although micropropagation has had a very significant impact in some areas of these countries, the level of procedures is still less competitive and the quality of the final product is sometimes weak (lack of the indexing, low efficiency of plant protection, high level of somaclonal variations, etc.). In many countries of Asia, South America and Africa the level of the commercial production of horticultural plants is low and it is difficult to introduce modern technologies into the local market. In these regions the organization of well managed internationally added special packages of actions together with government decisions seem to be indispensable. If in these countries we could support the emergence of stronger horticultural regions and centers horticultural biotechnology could win space during the second decade of the 21st century.

The possible role of the horticultural plants in the new Green Revolutions

The concept of "Doubly Green Revolution" of *Conway (2000)* can be considered as one of the global models of food provisioning of the poor and marginalised populations. Biotechnology-based modern horticulture might have a very high impact in this context. The increase of the yield of horticultural species through more sustainable forms could be a crucial factor in all of the developing countries. The future of more resistant fruits and vegetables to diseases and pests, in combination with higher nutritional value, will have a larger impact in those areas, where the provisioning of iron, vitamin A and protein is still deficient in the diet, due to various reasons. This trend is more likely in those countries, where the human nutrition chain is poorly balanced (i.e. excessive consumption of grain cereals, as rice and corn).

The new "golden rice" obtained through genetic transformation (*Ye et al, 2000*) is a good example that is capable to produce iron and beta-carotene in the seeds and might be a very promising way of future development. It has to be pointed out here that the appropriate consumption of vegetable and fruits rich in these substances in "original form" (Brassicas, eggplant, bell pepper, papaya, etc.) represents another alternative. We have encountered impressive initiatives in some countries of Asia and South America, e.g. in China, Thailand and Brazil, where the government has encouraged this progress through strong administrative supports. However in these regions besides the genetic engineering, as well as the molecular mapping, the "traditional" tissue culture methods, micropropagation, embryo culture, anther culture, interspecific hybridization, are still less explored in the process of genetic improvement of local varieties.

On the other hand, the yield of the traditional varieties tends to be low. At the present time, one of the most typical problems in the tropical developing countries is the weak level of natural resistance/tolerance of the commercially available fruits and vegetable varieties to biotic and abiotic damages. Therefore, without appropriate application of the integrated pest management, these countries cannot supply their population with sufficient quantity of horticultural products. In Brazil for instance the industrial tomato grower uses about 40 kg of active ingredient per hectare of agrochemical compounds for plant protection per growing cycle for the control of pests, diseases and weeds. This amount exceeds by a factor of one hundred the level used on corn *(Table 1)*. It is known, that in some tropical, subtropical and semi-arid regions the production of table grapes is showing very convincing quantitative and qualitative increase (India, Northeast of Brazil, Chile, South Africa). In these places the integrated production based on perfect disease and pest management is one of the most crucial factors regarding the quality of the final products. Therefore without biotechnology among many other appropriate biological and chemical procedures, it is difficult to imagine how economies will survive against international competition (*A. Lakatos, 2000; J. V. Possingham, 1998, personal communications*). Taking into consideration these typical ecological circumstances given at the majority of tropical and subtropical developing countries, we think that the new biotechnological methods might be important. They

Table 1 Amount of active ingredients used for plant protection in tropical and subtropical regions of Brazil (in 1992[1] and 2000[2]).

CROP PLANTS		ACTIVE INGREDIENTS	
		Kg/ha	Index (Corn = 1)
Horticultural plants	Table grapes	59–68[2]	147–170
	Tomato	39.5	98.7
	Potato	21.8	54.5
	Orange	12.2	30.5
Industrial plants	Cotton	2.4	6.0
	Sugar-cane	1.6	4.0
	Soybean	0.9	2.2
Corn		0.4	1.0

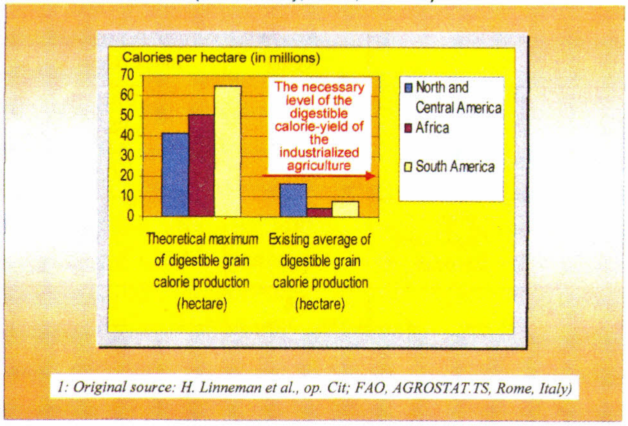
1: Campanhola et al., 1998. In: Racionalizacion del uso de pesticidas en el Cono Sur, Subprograma recursos naturales y sostenibilidad agricola, IICA – PROCISUR, Montevideo, Uruguay, p. 43–49. (modified);
2: A. Lakatos, 2000, personal communication)

could guarantee higher yield in stable level, improve the quality, reduce the cost, and increase the aggregated value of the product without damaging the nature.

One of the newest alternatives could be the so called "transplastomic technology" invented by the Hungarian *Pál Maliga* in the USA (*Hayes et al., 1996*). Through such environment saving techniques of molecular genetics in the future we could imagine the application of GMO horticultural plants near the areas of their genetic origin, without any harmful side effects as for example to enhance the genetic pollution of the nature. However we think that the traditions of these countries also have to be considered. In poor countries of the developing world, where the flavors of "international style" do not dominate, in other words, where the consumers eat their own traditional palates of the site, we have to protect this valuable tradition with the largest possible efficiency through inter-institutional cooperation. For example more productive better varieties through integration of the associations of local growers, etc. have to be developed. This practice could assure the best form of preservation of the genetic resources of the given horticultural species (China, India, Mexico, South America, Africa, etc.). To reach this objective it would be necessary to introduce better national and international common measures (*Borlaug, 1997*). In such areas and under the sponsorship of international and national institutions, we think the organization of *"Unit of Applied Biotechnology Missions"*(UABM) might be a viable alternative. A group of trained "adopted" foreign scientists together with local partners could accomplish temporary services of 4 to 5 years (elaboration of projects, leading R&D works, conduct education, organize a training course, etc.). We already met some successes of this type in Africa and in Latin America. One of them is the agricultural scientific exchange program established between the Brazilian and Hungarian Governments that has already lasted almost twenty years. This partnership has incorporated the biotechnology of horticultural plants since 1990.

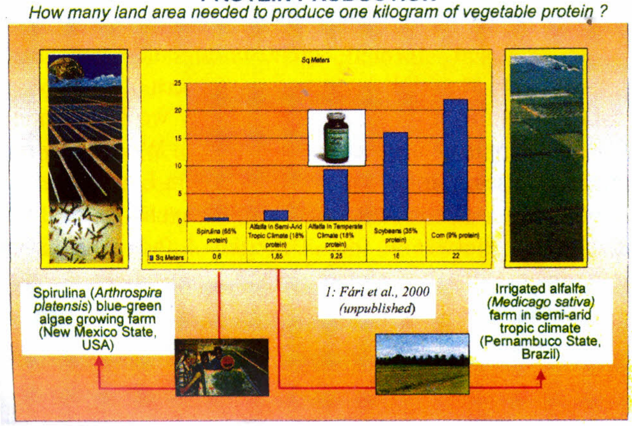
A UABM program was implanted in the heart of the Semi-Arid region of Northeast Brazil through the integration

Amount of Digestible Grain Calorie-Yield in Three Continents of the World
(after Conway, 2000[1], modified)



of foreign horticultural biotech scientists. Since 1993 they have been participating in the R & D efforts of the local tropical fruit and vegetable species (micropropagation of tropical fruits like bananas, virus-free table & wine grapes, nursery, cell and tissue culture and genetic transformation of vegetable crops i.e. eggplant, industrial tomato, bell peppers, production of double haploids by anther culture, embryo rescue, etc.). In this region, the total horticulture surface comprises one hundred thousand km^2. Among its nine big irrigation plateaus, the size of the agribusiness around the cities of Petrolina and Juazeiro already reached 2 billion USD in 1998 and in this year the table grape export to Europe was 1.2 million boxes. In the past the Brazilian Northeast was only known as a place of poverty and hunger. Today the irrigated orchards bring wealth, prosperity and employment for the former poor and excluded rural population and are attracting more and more foreign and national capital investments. Among other factors of this success, biotechnology could be a powerful means to guarantee the continuity of this prosperity. The consultants of UABM have indispensable tasks exactly at this phase. According to the former experiences obtained in this semi-arid tropical climate, the use of virus-free nursery material for table grape growing is one of the factors of key importance. There are many farms where that superior material was planted. Here in combination with appropriate plant treatments the productivity (cv. Italy) can reach about 80 to 90 t/ha in a year (two harvests per year) and 70% of it are exported to European markets. Those farmers, who planted traditional, not indexed and not virus-free propagation materials, never produce above 50 tons a year (in two yields/year) and the quality is also inferior. It is well known that Thai, Colombian, Indian ornamentals, orchids, cut flowers are transported to the international market by air. This is already a reality for the Brazilian seedless table grape growers of the São Francisco river valley. On the basis of these positive examples, we are strongly convinced that it could improve the quality of life of the excluded people of the developing world through correct measures. Therefore, in the success of a true type "Doubly Green Revolution" the biotechnology of horticultural plants will have an essential impact.

INTENSITY OF THE INDUSTRIAL-SCALE VEGETABLE PROTEIN PRODUCTION
How many land area needed to produce one kilogram of vegetable protein ?



Poor country, rich in biodiversity – rich country, poor in biodiversity: BIOAMAZONIA

It is known that the larger biodiversity, as well as the most vulnerable ecosystems of the planet, concentrate in the territories of the tropical and subtropical developing countries. In some places the current tendencies are irreversible deforestation. The illegal international trade of wild plant and animal species, uncontrolled extraction of natural products, etc, are very worrying not only for the governments, environmentalists, green movement activists, but for all of us. However a more "silent" form of the exploration of the wealth of the tropical forests is the "bio-piracy", that means the commercialization of products obtained from the basis of substances developed by the nature during thousands of years. The application of "molecular ecology", might be a powerful biotechnological tool in the preservation of the biosphere, also could have a very promising future in the hand of the developing countries. It has been calculated that almost one fourth of the medicines and other natural pharmaceutical products have their origin in those forests. Among others, the tropical rain forests are the main sources of these substances. The size of the world market of the biotech pharmaceutical products is around 500 billion dollars. The PROBEM project (Brazilian Program of Molecular Ecology) of the Brazilian Government is accomplishing the implantation of a biotechnological center in the heart of the largest biological reserve of the planet, in the Amazonian basin at Manaus (*Cardoso, 1998*). According to this plan, a new project called "Bioamazőnia" will take place on 12 000 m^2 area, where 24 top laboratories for specialized research teams led by internationally recognized scientists will be established. Under broad spectrum of national and international partnership, the Brazilian ABC – Amazonian Biotechnology Center will have the primary goal to explore the natural wealth of this area without devastating forests, not to disturb the living systems. They will look for and they will just extract bioactive molecules, useful for the medicine, like lifestyle drugs, for agriculture, like bio-pesticides and for many other purposes (body care products, fragrances, and cosmetics). It is also expected that the industrialization of this national wealth of nature will give considerable support to the economy, but also to the preservation of the environment. We think that such ambitious projects of great size based on molecular biology might be a good model for other tropical areas to explore their natural wealth in a correct, ecological and biotechnological way.

Conclusion

In the final years of the 19^{th} century and the first decades of the next, researches at the interface of biology, industrial technology and philosophy progressed considerably. It seemed to scientific and industrial entrepreneurs that sciences dealing with the biological processes of living organisms such as biochemistry, physiology and later molecular biology, were ready to be exploited technologically. After more than six decades of research, by the early 1960's, several areas of the modern horticulture became leaders in the application of plant biotechnology. Taking into consideration those typical ecological and economical circumstances given at the majority of tropical and subtropical developing countries, we think that the new biotechnological methods might be important. In such countries, under the sponsorship of international and national institutions, we think the organization of *"Units of Applied Biotechnology Missions"* (UABM) might be a viable alternative. On the basis of our experiences, we are strongly convinced that it could improve the quality of life of the excluded people of the developing world through correct measures.

Therefore, in the success of a true type "Doubly Green Revolution", the biotechnology of horticultural plants will have an essential impact. We are convinced that the conscious application of modern procedures of horticultural biotechnology will guarantee higher yield on a stable level, improve the quality, reduce the cost and increase the accumulated value of the product, without damaging the nature.

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