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CROP BIOTECHNOLOGY AND SUSTAINABILITY: A CASE STUDY OF COLOMBIA

by

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Outline

I. Introduction

This document provides a description of Colombian agriculture at a glance, to then enter into a more analytical view of how macroeconomic policies have interacted with sectoral policies to contribute in shaping the activity into what it is today. The institutional framework of the biotechnology activity in the country is later exposed to lay the elements for an understanding of its potentials, weaknesses, opportunities and threats. Then, the document goes into a detailed description, by prioritized crop cases, of how biotechnology interacts with other processes, sometimes as an integral part of a research program, complementing other disciplines, and other times as just being an isolated component that pursues knowledge for its own sake. The section on diffusion of biotechnology products forms a synthesis of what was previously reviewed, while the last section, on future developments, tackles an essential objective of the study which is to make proposals regarding institutional and policy arrangements aimed at ensuring a more sustainable agriculture.

The essential objectives of these country studies are:

1.- To examine, within a broad socioeconomic and policy context, developments in crop biotechnology with respect, not only to research, but also to the mechanisms and structures (both at the micro and macro levels) that facilitate or impede the transition from research in the laboratory to a product in the field. Since the biotechnology product, by itself, is seldom identifiable, given that it is an intermediate input for the production of a more complex final product, which, in turn, is usually the result of an integrated solution to an usually complex technological challenge, this objective requires a birds' flight view of the conditions of agriculture in the country, including its agroecological reality, the macroeconomic and trade policies that set the framework for socioeconomic activities and the specific sectoral policies that intend to shape the relations at the core of agriculture. This general overview serves to set the institutional, agroecological and socioeconomic environment for crop related activities in Colombia. But, of course, there is a second level of equally basic importance to complete the picture of the sector: the microeconomic aspects, where specific products and processes obtain notoriety over and above the rest, because of their intrinsic advantages in contributing to fulfill the needs of society or because the broader socioeconomic and policy context confers them an artificial edge. The combination of the right set of policies, with the adequate products and the best processes should lead to viable outputs. But the mechanisms to decide which are the right policies, the adequate products and the best processes, within a democracy (although still not fully conformed) like the one that exists in Colombia, imply the existence of a set of rules and feedback procedures that should emerge from consensus agreements. The political economy of the process is complex and, as should be clear from this document, it is still being shaped by the different interested parties in the country. In the case of Colombia, the role of relatively old and well established producers' associations is a key component of this processes of political economics.

2.- A second objective is to determine whether the new biotechnology related products are more environmentally-friendly than alternative solutions, in the sense of being at least equally attractive and viable to the user and yet less dependent on agrochemicals and/or with a clear edge in contributing to a more sustainable development.

3.- Ultimately, the project is intended to make proposals regarding institutional arrangements and put policies and legislation in place aimed at ensuring that the contribution of biotechnology leads to a more sustainable agriculture in an efficient manner, particularly in the sense of reducing agrochemicals in production, while providing an alternative solution to the farmer in a first instance and to society in the final level of analysis. The profitability, and also the viability, of new technologies are strongly related to general macroeconomic and sectoral policy aspects, on one hand, and to the regulatory set of policies that foster and protect innovations. The existence of the new biotechnology related products with a clear environmental edge has to be examined in the context of private versus social costs. This implies also a willingness to intervene the markets to ensure that the analysis of mechanisms inducing to internalize certain externalities is viewed as a valid form of intervention in the light of internal laws, policies and international commitments. In many instances, this internalization of costs will be viewed as a subsidy rather than as an intentional effort to rationalize, towards the long run, the use of a scarce and valuable resource to achieve a more sustainable development. As a final consideration that is not explored in the paper, there must be a balance in the actions of the legislative and executive branches of Government with what the judiciary branch can enforce. Developing countries are overflowed with laws and regulations that nobody can effectively implement; on the contrary, they become a source of corruption, since the law is "informally" enforced.

II. Colombian Agriculture

This tropical country has a wealth of biological resources and agricultural possibilities, given the endowment of productive lands and the wide range of climates and agroecologies.

II.1.- Location. Colombia is located in the northwestern extreme of South America, with longitudes ranging from 66°50' and 84°46' west of Greenwich and latitudes ranging from 4°13' south and 17°50' north of the Equator. It has an area of 1,142,000 sq.Km.

II.2.- Ecosystems and Biodiversity. One third of the territory is formed by mountains and 67% is formed by tropical lowlands. Among the many major ecosystems, the most important ones are (i) the Andean hillsides (extending from south to north, with three main branches and occupying the western part of the country), (ii) the two interandean valleys formed by them, (iii) the Coastal lands (the Caribbean, in the north, and the Pacific, in the West), (iv) the Eastern plains and (v) the Amazonia (to the South). The latter two regions account for half of the territory but are virtually uninhabited (with 5% of the population). As a tropical country crossed by the Equator, it has all climates. The climate in the

Andean hillsides is very variable according to altitude and rainfall. The lowlands have warm weather with variable humidity: very humid in the Pacific and Amazons (mostly covered by rain forests), humid to sub-humid in the Orinoquia (with savanna vegetation and extensive grazing), and sub-humid to dry and even locally semiarid in the North Coast. As a result, one of the Colombia's most valuable assets is its wide expression in biodiversity of flora and fauna.

II.3.- Sustainable development. This term is used here in his broad meaning of development (growth, equity, efficiency and stability) in the framework of sustainable systems of production, which are defined as those "in which stable (and possibly increased) production is achieved without detrimental effects on the long-term potential capacity of natural resources" (DGIS, 1991). There is some connection between sustainability and natural resource use. But sustainability refers mainly to complex equity issues: (i) of the current generation with the future ones and (ii) among this generation, of the rich versus the poor. A deep concern with future generations is not convincing if it comes associated with lack of awareness about the actual levels of poverty in the planet (Solow, R.M., 1994). In this sense, sustainability implies to choose between consumption and investment. Since future generations do not participate in today's market, the issue cannot be left to be solved by those current forces. It is a well known fact that "poverty is a poor advisor in sustainability issues". A sound environmental management will be the outcome of the work of communities formed by persons with adequate resources, education and control of their own destinies.

The new constitution of Colombia (1991) explicitly formulated that the state has to foster the conditions to achieve a sustainable development in the country.

II.4.- Population. Colombia has some 35 million people, with 95% of that population located in and around the Andean hillsides and the North Coast. About 65% of them live in the urban sector. In 1951, only 39% of the population was urban. According to official statistics, 45% of the people are under the poverty line: their income is not enough to cover minimum daily nutritional requirements. Even worse, 23% are under the indigence line: even if they devote all their income to cover nutritional needs they cannot cover the minimum requirements. In recent years, there has been an improvement in the percent of people under the indigence line, but the percent of poverty remains the same (Perali, 1993). Population growth was around 2.0% in the period 1965-92, and has slowed down quite fast to about 1.7% per year in the 1990's. Urban population accounts for 73% of total.

The colombian history has been characterized by a continuous trace of blood linked to political and social unrest and commotion. "Perhaps we have been perverted by a system that incites us to live like rich when more than 40% of us can badly survive surrounded by misery. We always want a bit more than what we have..., and we get it, no matter how: even against the law. Aware that no government will abide by that anxiety, we have ended up being nonbelievers, abstentionists and ungovernable, in a solitary individualism

by virtue of which, we believe that one only depends on oneself" (García Márquez, 1994). On a positive side, the colombian literature novel prize winner adds that the two main characteristics of his people are its creativity and an utterly determination for personal improvement. This crude autocritical reflection led him to recommend that the base for social change must be an education system at the peak of priorities, reflexive and nonconformist, that will allow the children to discover their own roots in a society with higher love and esteem of itself. The dissociation between the people and their government, a feeling that goes back to the early days of the colonization, is still a basic problem for collaboration among public and private sectors.

II.5.- Agriculture, GDP and exports. The performance of the agricultural sector has been crucial to the development of the country. The sector contributed about a fourth of GDP and one-third of total employment in the economy in the 1960-85 period. By 1992, agricultural GDP represented 19.2% of total GDP. Agriculture's share in GDP is almost twice as high in Colombia as it is for Latin America and the Caribbean (LAC) as a whole. Its per capita GDP for 1,992 was US$1,243 (15th among 25 LAC countries and 62th in the World Bank tables among 130 countries).

Cultivated lands amount to 36.2 million has (32% of available lands). Crops account for 4.4 million has, and the rest is, mainly, under grazing (5.5 million has. of renovated pastures and 25 million has. of extensive natural pastures).

Agricultural exports accounted for more than 80% of export earnings (mainly coffee) in the 1960's, dropped to about two-thirds by 1986 and after 1987 they only represent one-third due to increases in the amount and value of oil and other mineral exports.

Presently, about 55% of gross agricultural output comes from crop activities and 45% from livestock. The latter increased its share from 37% in 1,970 due mainly to the strong dynamism of poultry and pork production. The agroindustrial sectors are growing more rapidly than primary agriculture. The ratio of value-added in agroprocessing to value added in crops and livestock increased from 54% in 1,970 to 70% in 1,983. The agroindustrial chain, incorporating primary, industrial and service related activities, account for more than a third of GDP and represents more than 40% of employment. It is accurate to affirm that agriculture, rather than having lost importance in the economy, has transformed its role, but continues to be an important engine for economic and social development.

In the livestock sector, there has been a strong growth of the poultry and egg industry in part at the expense of beef consumption. Relative price of chicken has decreased considerably with respect to the ones of pork and beef. Income elasticity and price elasticities for poultry were found to be significant and important in determining the rapid growth of its consumption. This growth brought high demand pressures to the feed industry and therefore to commercial feed inputs like maize, sorghum and oilseed cakes. Local production of these crops has been unable to meet the challenge as they do not

compete with subsidized grain imports in a highly distorted world market. The recent revaluation of the peso has meant higher costs in dollars, while imports become cheaper and more so when international prices were decreasing until 1993 Guterman, 1993).

II.6.- Small farmers. Of the 2 million farms in Colombia, 67.3% have less than 5 has. and 87% have less than 20 has. but represent 16% of the area, with an average farm size of 3.3 has. Of some 10 million people in the rural sector, 3.5 million are small farmers; this number grows at the slow pace of 0.4% annually (Ministerio de Agricultura-DNP, 1990). They have a predominance in the Pacific Coast (75%), the Amazonia (74%) and the Andean hillsides (65%) (Candelo, 1992). It has been estimated that small farmers produce 46% of total food in Colombia.

The research efforts of the past (like the Green Revolution) focused on improved varieties for the better lands, generally controlled by entrepreneurial farmers. It left out many of the small holders farming under marginal conditions who mostly apply technologies that require low level of cash outflows; the literature refers to that group as Low External Input Sustainable Agriculture (LEISA). (Bunders, JFG ed. 1990)

II.7.- Crop Priorities in Colombia. Under the current liberalization of the economy, there is a weak sectoral policy; however, it is in the process of being reinforced by the new agricultural law, approved by Congress in December, 1993, in a clear reversal of the disprotection that suffered this strategic sector. Macroeconomic and trade policies have traditionally discriminated against agriculture, setting a framework of instability where the state represents a substantial source of instability and risk for the sector. Therefore, there is not a clear consensus about strategic crops that constitute a national priority.

Tree (or permanent) crops represented 63% of agricultural value of production in 1992 while cash (or transitory) crops accounted for the other 37%. Coffee has been the dominant activity, with 20% of the value of agricultural production. It is found almost exclusively in the Andean hillsides. Sugar cane (both for sugar and for "panela" or raw brown sugar) shares with 18% of that value followed by plantains (7.6%). Among cash crops, flowers (7.2%), potatoes (5.7%), rice (5.6%) and maize (4.8%) are the most significant crops. Other crops are oil palm (4.5%), cotton (3.2%) and export bananas (3.2%) (Table 1).

To arrive at national priorities, a more comprehensive view of the agricultural activity is needed. It is assumed here that the policy objective is to achieve a sustainable development. An exercise conducted for the central coffee region (Sanint, 1993), prioritized the main crop activities according to the supply of technology and its demand. On the supply side, the exercise looks at four aspects of crop production that are necessary to achieve a sustainable development: economic growth, social equity for consumers and producers, conservation of natural resources and institutional factors. A total of 27 indicators, with different weights, were used to classify those activities. Then, the demand side was examined from the angle of development paths, i.e., the

endowments and socioeconomic characteristics of farmers in that region, using a GIS (geographic information system) available from the Coffee Federation.

In summary, the exercise shows that, for entrepreneurial farmers, the main crop activities are coffee, plantains, sugar cane, fruits (mainly citrus, pineapples, and passion fruit or maracuyá), tomatoes and onions. For small farmers, the group is composed of coffee, sugar cane (for panela or raw brown sugar), plantains, bananas, tomatoes, onions and staples like cassava, maize and beans.

In addition to that exercise, the collaborative biotechnology and development program of ICA-Corpoica and the DGIS mission in Colombia conducted a prioritization of small farmers' crops in the Coastal region. They found that, besides some crops common also to the Andean hillsides, like cassava, maize and beans, other crops like rice, yams, sesame and papaya are the most relevant for their development (ICA-Corpoica and Dutch Government, 1993).

To complete the picture of priorities, some entrepreneurial crops like cotton, oil palm, sorghum and soybeans which are not captured by the exercises mentioned, are quite relevant from the point of view of value of production, markets, export earnings, natural resource use and institutional aspects. They are important to commercial farmers in the lowlands of the Coast and the Eastern Plains (Llanos).

For the purposes of this case study, and based on the previous discussion, one dozen crops (or groups) were chosen: (1) coffee, (2) sugar cane, (3) musaceas (bananas and plantains), (4) flowers, (5) fruits (citrus, pineapples, passion fruit, others), (6) palm oil, (7) rice, (8) cassava, (9) beans, (10) potatoes, (11) cotton and (12) maize.

III. Macroeconomic Policy and Agriculture

This section focuses on the various economic aspects that have influenced resource allocation in Colombia, particularly between the agricultural sector and the rest of the economy (in a macro context) and within the agricultural sector during the past two decades. The analysis of the set of policies applied should contribute to the understanding of the role that the food and fiber sector have played in the development of the country, how that role has evolved and more importantly how it is likely to evolve in a near future.

III.1.- Economic Performance.- The Colombian economy has experienced a stable and rapid growth since the mid-1950s. Real GDP grew at an annual rate of 4.6% in the period 1961-91, while agricultural GDP expanded at 3.6% in that period. Colombia also has one of the lowest per capita public external debt of Latin America (US$500) as of 1,992, although debt service is close to one fourth of foreign exchange earnings. Several distinct periods can be identified.

Between 1961 and 1978, annual real GDP growth was 5.4%, while agriculture grew at 3.9%. In 1967, a crawling-peg devaluation of the peso was implemented (Decree 444) to promote exports while foreign exchange operations were controlled. The coffee boom (1977) marked a cornerstone in economic history; its aftershock coincided also the stagnation in the world economy.

After the 1977 coffee boom, the country witnessed a decrease in its rate of growth. The sharp increase in 1,980 of the international interest rates and the world recession that brought reductions in the prices of primary exports merged in Colombia with another adverse element: the aftermath of the coffee boom of the late seventies. Real GDP grew at a slower 2.8% per year with a sharper recession in agriculture which staggered at 1.8% per year in 1978-86. Compared with other Latin American countries, Colombia escaped the deep recession of the 1980's thanks, mostly, to more stable economic policies.

In 1985, a sharp devaluation was implemented. It was followed in the subsequent years by increased protection to agriculture, in what was known as the plan for selective supply: eight strategic crops received special attention from the Government. This actions were associated with a rate of growth of 4.0% in GDP between 1986 and 1990; in response, agricultural GDP expanded at 4.6% annually in that period while non-coffee agricultural exports grew at 5.5% per year and agricultural imports remained stagnant.

In the 1990's, an integral change of the state and of the economy, based on modernization of the institutions and liberalization of the economy was implemented by the incoming government. Since the 1960's, the economy had been increasingly isolated. Both exports and imports amounted to about 24% of GDP in the 1960's to decrease to around 15% in 1990 (Ocampo, 1993). The economic liberalization actions were implemented in a framework of reduced financial restrictions that were associated with money laundering and higher interest rates on the dollar (15% and higher) that induced a process of gradual and continued revaluation of the peso. The shift in resource allocation to nontradeables triggered by the revaluation of the peso coincided with lower international prices for foods and beverages and by two years of rain failures amidst elimination or sharp reductions of import tariffs, quotas and restraints.

The fight against inflation (which has been around 20% to 25% per year) was focused on reducing food prices to the urban consumer by increasing food imports sharply from 1.2 million tons in 1990 to about 3.0 million tons in 1993. The policies had a negative impact on the balance of trade of the country, which was positive by 1990 (with over US$1 billion) to become deficitary at about US$3.0 billion by 1993. In this fight against inflation, food imports boomed, agricultural profitability was shattered, its exports declined and area harvested decreased by more than 10% from 4.9 to 4.4 million has.

Temporary (or cash) crop area fell from 2.5 to 2.1 million has. The area under tree crops did not decrease much as it is quite inelastic in the short run; however, its productivity

declined sharply, particularly in coffee, where production fell by 50% (from 18 million 60 kg. bags in 1993 to 11 million in 1994).

Rural incomes decreased by 22.2% in the 1990-93 period while urban incomes increased by a similar amount; most of this fall (20%) is associated with the macroeconomic and trade policies (Lora, 1994). As a result, the gap in rural to urban incomes has increased and it is now at 33% of urban incomes, similar to what it was in the 1950's, after it had been considerably narrowed by 1990. The level of indigence in the rural sector increased from 26.7% in 1991 to 35% in 1993.

To sum up, it can be said that agriculture has been discriminated against. The slow down of agriculture is the result of a number of biases that affect agricultural production. At first glance, there was a policy of protection in effect for most agricultural products in Colombia since the 1960's until 1990. The internal price of most products has been higher than the international price; nominal protection indexes are positive (García and Montes, 1988). However, to be able to conclude that there was effective protection, one has to bring the overvaluation of the Peso into the picture. If the nominal protection is higher than the overvaluation, the product was protected. In this sense, only products like powder milk, oils and fats, and wheat would be truly importables, since they have been effectively protected even after making the adjustment for the overvaluation. Rice, coffee and cotton, for example, have been discriminated against in this sense for the past two decades (García and Montes, 1988). Rural unemployment has worsened, malnutrition is increasing, violence in the rural sector is high while food production has not responded adequately to the growing needs in demand.

By the mid-seventies, the country also saw the consolidation of a highly disturbing phenomenon of the Colombian economy and of its society: the prominence in the world supply of illegal drugs. It started with marihuana (Cannabis Sativa) but in the eighties the activity turned to the more profitable cocaine processing and distribution and in the nineties there has been an alarming shift to the agroecologically devastating cultivation of poppies in the Andean hillside and the production and commercialization of heroin. While many analysts, national and foreign, have minimized the effect of this activity on the economy, its impact has been deeper than many would like to admit. The country and its residents have had to pay an enormous daily bill for whatever foreign exchange the drugs have produced. Agriculture has been a major loser in the process as rural violence associated with the illegal activity and the destination of money laundering to speculate with farm land led land prices to values that are higher than in the developed countries, in many cases[1].

III.2.- Summary of policy environment. Colombia is heavily dependent in its agricultural sector as a significant source of growth, employment and foreign exchange. In broad

[1] A hectare of land in the Cauca Valley, for example, where mostly sugar cane is cultivated, sells for over US$20,000. Similar prices are found near Medellín, Bogotá and Ibagué, for example.

terms, Colombia has striven for food self-sufficiency in an economy that had been increasingly isolated. Out of 12 items that supply about two-thirds of the protein and calorie requirements of the population, 99% was produced internally (García, 1983). The country went from an import substituting to an export promotion policy in 1,967 (Decree 444). In 1978 came the coffee boom accompanied by revaluation. In 1985 there was a sharp devaluation and a strong sectoral policy for agriculture was in place. In 1990, the process of continued revaluation restarted as local interest rates and deregulation of foreign exchange stimulated large inflows of foreign capital. Agricultural production has been locked in a high cost scheme due to very high land prices, low levels of investment in rural infrastructure and research, and, more importantly, very high levels of violence and insecurity in the rural sector. When tariffs were abruptly eliminated, the sector was not prepared to compete with subsidized imports and, consequently, agricultural production fell sharply. Cultivated area today is at similar levels than in 1981 (4.4 million has). As one entrepreneur put it, "it is cheaper to bring grains from Kansas to our main cities than to transport it from our producing regions, due to the lack of adequate infrastructure" (Cano, 1994). Compensatory policies adopted to stimulate agricultural production were mostly directed at importables (grains and barley and wheat) while ignoring a vast agricultural sector; besides, these policies have lost effectiveness in recent years. Investment in the sector has been reduced. Lower unit costs are needed to increase production at profitable levels. The easing of import restraints (particularly for inputs) as well as the improvement in terms of trade are seen as a favorable developments in that sense. But yield improvements are a must in the mid-term.

From the viewpoint of Colombian producers, output prices are too low and yet they are not competitive in the world market (with the exception of coffee, bananas and a few minor export crops). The consensus is that the resulting biases from the other policies have been so strong that agriculture (mainly coffee) has had to pay more than half of the industrialization costs, with a loss of competitiveness that made necessary the implementation of compensatory policies. As those compensations disappeared and the economy allowed foreign subsidized foods (like grains, cereals, dairy and meats) to enter the country, in the context of lower international prices, internal crop failures resulting from a two-year drought (1991 and 1992) and increased violence in the rural sector, agriculture underwent one of the deepest crisis of this century. And finally, quantifying the adverse effects on agriculture of the easy foreign exchange obtained from illegal activities is, to say the least, difficult. But this is no excuse to ignore that it has had a devastating effect on society and, on the economic arena, agriculture has also been profoundly distressed.

III.3.- Agricultural Policy Instruments.

These have been designed as second best or compensatory policies. The targets have been, mainly, the commercial products.

III.3.1.- Prices and Commercialization. Four types of direct Government intervention have been mainly used in Colombia: (i) output price supports; (ii) price fixing in output and

input markets; (iii) agricultural export subsidies and taxes; and (iv) agricultural trade policies, including price bands, import tariffs and import/export licensing.

INA, created in 1,944 and later restructured under IDEMA, has been the organism responsible for administering the food policies of support and warranty prices, stocks, imports and exports, conduct studies and extend credit (Silva, 1,986). Support prices have been implemented for commercial products (rice, cotton, wheat, sorghum, corn, soybeans, sesame and barley) and for beans, the only traditional crop included in the list. These prices have served mainly as a price floor. Generally, support prices have been similar to market prices.

Closely related to this topic, is the program to build wholesale markets (Centrales de Abastos). There are 7 working: Bogotá, Medellín, Cali, Barranquilla, Bucaramanga, Pereira y Cúcuta. These facilities improve marketing, specially of perishables like fruits, roots and tubers, where losses constitute an economic problem of considerable magnitudes.

The main instruments of intervention in agricultural foreign trade had been tariffs, taxes, subsidies and quantitative restrictions on imports and exports.

The integration of the Andean countries has led to the elimination of most of the direct intervention forms and the establishment of common policy instruments, like price bands and the external common tariff.

III.3.2.- Credit.- The three main policy tools used are forced financing (Law 5), low and controlled interest rates and directed credit allocations. Two major institutions responsible for administering agricultural credit are Finagro (the former FFAP) and Caja Agraria. Most of the credit supplied by Finagro is directed to commercial agriculture. Of Colombia's 2 million farms, 1.7 million (or 87%) are classified as small farms (Ministerio de Agricultura-DNP, 1990). 80% of Caja Agraria credit goes to about 440,000 small farmers.

In terms of the type of commodities being financed, Finagro has concentrated its lending on a few commercial crops: irrigated rice, sorghum, soybeans and cotton. For these crops, it provides 90% or more of total credit granted. On the other hand, Caja has financed a wide spectrum of commodities that are characteristic of small farming systems. Producer associations and banks provide most of the credit for coffee and rice, the major credit recipients.

III.3.3.- Research and Extension.- Government expenditures in agriculture, although have been quite profitable (60% rate of return in 1,950-80) and have had a significant contribution to output growth (30% in that period according to Elías, 1985) were quite small. During the period 1980-88, the share of expenditures for science and technology went from 0.16% to 0.19% of GDP (represented in the budgets of ICA and Colciencias, mainly), compared with 2.8% in Japan and USA, 2.7% in Germany, 3% in Sweden or

0.5% in Chile. In the world, Colombia participates with 0.6% of the population, 0.3% of GDP, 0.1% of the production of capital goods but only with 0.02% of resources for research and 0.002% scientific authors (Trujillo, J.P., 1993).

The agricultural research institution, ICA, was created in 1,962 and had, as primary mission, until 1993, to generate and transfer improved production technologies for agriculture and to carry on activities of certification, health supervision, fiscalization, etc.. "Thirty years ago most agricultural research was carried out by ICA and Cenicafé. Today, more than 30 laboratories offer soil testing facilities, at least 25 institutions are involved in some form of plant biotechnology, 5 in embryo transfer and various producer or user groups are undertaking research for commodities such as sugar cane, barley, rice and oil palm. ICA's own mandate has become more complex and more development oriented" (Nestel, B., 1993).

ICA has operated within the framework of a decentralization policy which makes prioritization more complex and stresses technology transfer. In real terms, it received less funding in 1991 than at any time since 1984. (Nestel, 1993).

For many years, research contracting with the state was subject to the same rules that affected other types of public contracting: open public bidding and complex, tedious and lengthy bureaucratic procedures scared the private sector away from resorting to the state for research activities. Change in norms for research contracting with the state in 1991, by means of decrees 393 and 591, opened the possibility of a new system of contracting with the state for activities of research which are to be ruled according to the private norms, speeding and simplifying the unaccessible bureaucracy of the past, that scared the private sector away. This also apply to mixed capital ventures. In 1993 a new semi-private corporation was created (Corpoica, with 99% of its capital being public) to undertake the task of public research generation under the system of contract bidding, taking advantage of the new, faster system, and leave other tasks to ICA. Currently, the system is in a strenuous transition to the new model of research generation by Corpoica.

In the field of transfer of agricultural technologies, the country has a National System to Transfer Agricultural Technology (SINTAP) which executes the plans drawn by the National Program to Transfer Agricultural Technology (PRONATTA). The main objective is to coordinate efforts at the regional level of main actors in research and development, both from private and public institutions. The program has three functions: 1.- the direction and coordination is in charge of the Ministry of Agriculture; 2.- technology development is in charge of ICA; 3.- technical assistance and institutional development is in charge of the UMATAS (Municipal units for transfer of agricultural technologies), the Integrated Rural Development (DRI) Fund and the local secretaries of agriculture.

To complement the research effort with other production support services for the small farmers, such as credit, social services and marketing, the DRI program was created in 1,970, with emphasis being focused increasingly on food production targets. Potential

beneficiaries are 83,000 farmers or 8% of all tenants with less than 20 has. in Colombia. In 1994, a viceministry for peasant matters was created to better serve this important segment of agriculture.

Within agriculture, it seems that research and extension have had a strong bias in favor of commercial agriculture, supporting the emphasis of the overall agricultural policies enforced and widening the income gap between small and large farmers.

III.3.4.- Agricultural policies for inputs. The increasing degree of isolation of the colombian economy was also evident in the existence of import barriers for agricultural inputs. The degree of effective protection went from positive and significant in agrochemical pesticides, to moderate in machinery and low or even negative in fertilizers. Although there were few products under previous license or banned import regimes, tariffs were 30 per cent or higher and many inputs had to pay a value added tax of 10%. With the liberalization of the economy in 1990, tariffs are now classified into five categories: 0, 5, 10, 15, and 20 per cent and fewer inputs pay value added tax, which is now of 14%.

III.3.4.1- Pesticides. There are around 700 pesticides registered with ICA; they are based on some 250 active ingredients. Of these active ingredients, 20% correspond to categories 1"a" (extremely toxic) or 1"b" (highly toxic) of the World Health Organization (WHO). Also, 20% appear in the consolidated list of the United Nations, as products that have been either banned, or highly restricted, or removed from markets or not approved by Governments, and 35% appear as banned or restricted in the Americas, in the list published by the Panamerican Center of Health and Human Ecology. Of the active ingredients registered with ICA by December 1990, 7% of them, which represent 58 commercial formulations, appear in the PIC (Prior Informed Consent) list of FAO. Use of these products, accounted in Colombia for 10% of total sales in 1989 (Vergara, 1991). Since 1974, about 90 pesticides have lost their register, due to health and/or environmental reasons. Of them, 17 are registered in Colombia. The Environmental Protection Agency of the U.S. (EPA) has tested pesticides that are carcinogenics or can cause serious health problems. In Colombia, there are more than 60 of those products registered with ICA.

Use of insecticides dominated pesticide sales until the mid-seventies, with a share of 60% (Bellotti et al, 1990). In the 1980's, in terms of active ingredients (a.i.), insecticide sales remained constant at 3.5 million kgs., while fungicide use went from 4.3 million kgs to over 9.0 million kgs (up 110%) and herbicide sales went from 4.6 million kgs to 7.2 million kgs (up 56%). As a group, pesticide sales increased by 57%, from 12.5 million kgs of a.i. in 1980 to 19.8 million kgs of a.i. in 1989 (Table 2). In that decade, the maximum level of sales occurred in 1987 with 23.4 million kgs of a.i.. For that year, Nivia reports that sales of highly toxic pesticides reached some 2.6 million kgs. of a.i. or 11% of total sales. Main items sold in this category were methyl parathion, an insecticide, with 815,111 kgs of a.i., followed by paraquat, an herbicide, with 522,823 kgs of a.i. and by carbofuran, an insecticide, with 213,245 kgs. of a.i. (Nivia, 1989).

Although the toxicity of pesticides sold points to the existence of a serious problem in the country, the worst aspect refers to the inadequate handling and management of these poisons. The target area of those pesticides is around 1 million has, mainly of commercial farmers or one fourth of total cultivated area. These are the most densely populated areas of the country. Aerial sprays are common within urban boundaries. Human applicators seldom use the protective equipment because it is not furnished or, if provided, they do not like to wear it; they do not take baths after work; products are carelessly stored at the reach of children in corners of rooms that remain open, where tools and clothes are also kept; frequently, the applicators are not fully aware of the contents of the pesticides they are using; pesticides mixtures are stored in bottles of soft drinks or other edible products, etc. The worst accidents with these products occur in the rural areas and among women (Nivia, 1989).

The drop in insecticide use from the level of 1970's is mainly explained by a reduction in cotton applications against the bollworm (*Heliothis virensis*). The insect developed resistance and cotton was receiving from 22 to 28 applications of insecticides, mainly methyl parathion, per growing cycle, which made the activity unprofitable and its area was sharply reduced (Bellotti, et al, 1990). In 1984, the coffee rust appeared in Colombia, and use of fungicides doubled soon, from 5.9 million kgs of a.i. in 1984 to 12.9 million kgs of a.i. in 1987, and then decreased to 9.0 million kgs of a.i. by 1989 as the new rust resistant coffee variety ("Colombia") became more prevalent.

While the reduced levels of protection were aimed at reducing costs of production, lower pesticide prices may encourage their indiscriminate use, particularly when integrated crop and pest management practices (ICM and IPM) are not yet well established for many crops. Economic, agricultural and demographic trends in Colombia point to increased use of pesticides. Several studies in Colombia have reported problems referring to human intoxication, water and air contamination, soil degradation as well as effects on wild animals, polinizers, natural enemies, secondary pests, resurgence and resistance (Vergara, 1991; Nivia, 1989).

IPM have contributed to decrease significantly the use of pesticides in crops like cotton, rice, sugar cane, tomatoes and snap beans, among others. However, a major emphasis on alternative control methods by national and international research institutions will be necessary (Bellotti et al, 1990). Biotechnology constitutes a promising complementary tool to this end.

With the liberalization of trade, both, active ingredients and raw materials not produced in the andean region are now exempt. Synthesized products using those products mentioned above are taxed with 5%. For pesticides produced in the region (active ingredients, raw material or finished products) the tariff is 10%. In many cases, this represented reductions from 15% to 25%. This reduction intends to lower production costs in an indiscriminate manner. There is ample evidence that the drop in the relative price of the pesticide to that of the crop stimulates a higher use of that input, since this kind of

application often obeys to a risk management principle, where the cost of spraying can be compared to the payment of a risk premium: the lower the premium, the higher the insurance purchased (Ramírez et al, 1993). Besides, quite often, sprays are cosmetic and unnecessary.

In terms of foreign trade, the trend in developed countries is to demand increasing amounts of organic, or at least not toxic, foods. If the reduction in import barriers intends to increase the competitiveness of a rapidly growing pesticide export market in Colombia, attention should be paid to the imbalance that this liberalization can also cause to potential food export markets in the future, at the expense of a relatively small export market for pesticides.

Therefore, given all these socioeconomic and environmental considerations, import and use policies should be more selective and strict, to avoid abuses, inefficiencies, as well as health and environmental problems and to foster the conditions for a truly sustainable development in Colombia.

III.3.4.2.- Fertilizers. During the 1980's, fertilizer use in Colombia more than doubled to surpass the 1 million tons per year by 1989. Nitrogen, the main form of fertilizer used, represents close to 300,000 kgs (Martínez and Sanint, 1989). In terms of kilograms per cultivated hectare, Colombia uses some 65 kgs, compared to a world average of 87 kgs or an average for developed countries of 121 kgs. (Gallón, 1988). These products have had very low tariffs, as most are imported. In Colombia, several universities have joined efforts with the private sector to do research on inoculum based on *Rhizobium*. The use of the inoculum should reduce costs and improve soil quality (Montoya and Buitrago, 1993). At the national level, on average, the main users of fertilizer are potatoes (550kg/ha), rice (220 kg/ha), coffee (120 kg/ha) and sugarcane (85 kg/ha). There is ample evidence that fertilizer applications are inefficient in terms of timing, form of application, doses, etc. Much remain to be done in agronomic research, before resorting to highly sophisticated techniques to improve fertilizer use and efficiency.

In the economic dispositions of 1990, tariffs were set as follows: for ingredients and salts synthesized in Colombia, 5%. and for finished products synthesized in Colombia, 10%.

III.3.4.3.- Machinery. In Colombia, a tractor costs twice as much as it does in the U.S. due to tariffs, taxes and commercialization margins. Sales of tractors have been stagnant since the early 1980's (Leguízamo, 1988) due to high costs of machinery, low profitability of the agricultural activity and high levels of instability, both social and economic. The amount of tractors in 1988 was similar to the one in 1972. The current park is old, overdimensioned and highly deteriorated, which attempts against an efficient cost structure of production.

In the economic dispositions of 1990, tariffs were set as follows: for tractors not produced in the country, irrigation equipment, plows, etc.: 10%; they do not pay the tax on value added, which now is 14%.

III.3.4.4.- Seeds. Use of certified seeds in Colombia is still very low. Of the 2.4 million has under cash crops in 1990, only 47% used certified seed. On the other hand, 92% of their sales corresponded to four crops: rice, sorghum, soybeans and cotton (Semillas, 1991). The industry is characterized by a large slack capacity. The seed producers' association, created in 1970, groups some 25 companies throughout the country. Products like maize, beans, barley, wheat, sesame, fruits and vegetables are barely covered, or are totally neglected, by this industry. Yet, sales of certified seeds have expanded in a significant manner in the past two decades. By 1970, sales amounted to 18,000 tons; by 1980, this amount grew to 62,384 tons; and by 1990, they reached 94,703 tons that are used in 1.2 million has of cash crops. The use of certified seed in forages has also expanded in the past decade, but there is no reliable data in this category.

The colombian research institution (ICA) has been in charge of seed certification (basic, registered, certified) and phitosanitary controls since 1968.

Seeds have been under the regime of free importation for many years. The tariff structure was reduced in 1990; all seeds feel in the 0% to 5% range, except in the case of potatoes, which were under the regime of previous licensing and were moved to the free category, but the tariff went up from 5% to 15%. All seeds have an additional duty of 13%. As a group, total duties went from more than 40% before the liberalization to around 18% currently. The recession in agriculture, the revaluation of the peso and the decreased protection have had a negative impact in the activity over this decade.

III.3.5.- Infrastructure. This is a priority area for the current administration. "Infrastructure represents, if not the engine, then the wheels of economic activity" (World Bank, 1994). The 1992-94 government plan has a ten year investment budget of US$1,06 billions for land systematization (irrigation, drainage and flood protection) with 50% subsidy to small holders covering an area of 535,000 has. which is more than twice the land ever adequated by the state. Currently, of some 6 million has that are apt for cultivation, only 11% (or 750,000 has) have been adequated. Of them, the state has contributed with 38% of the area (Cano, 1993). In the plans for the new Government (1994-98), there are important resources for agrarian reform (land acquisition and titling) for US$1 billion, small farmers' credit (US$900,000) and rural housing (US$400,000) (El País, 8/21/94). The discovery of important oil reserves in the country has led to the conviction that the country has to "plant the oil", i.e., it has to invest in rural infrastructure to foster agricultural production.

IV. Biotechnology in Colombia: institutional framework

The emphasis of this section is on the recent developments on modernization of the state and legislation.

IV.1.- Definition. Biotechnology can be defined as the integrated use of molecular genetics, biochemistry, microbiology and process technology employing microorganisms, parts of micro-organisms, or cells and tissues of higher organisms to supply goods and services (DGIS, 1989).

Biotechnology is one of many tools available in research and development activities. In crop production, for example, it already offers interesting opportunities for tackling several problems in developing countries. In the short term, the most prevalent applications are plant cell regeneration, meristem culture, tissue culture propagation, protoplast fusion (used to overcome crossing barriers), the transfer of parts of plant cells, improved biological nitrogen fixation, biological control agents, and improved diagnostics for plant and animal diseases. The major benefits to agriculture from other techniques of genetic engineering of plants are likely to be available after the year 2,010. (Bunders, JFG and J.E.W Broerse, editors, 1991)

IV.2.- Overview of biotechnology in Colombia. Agricultural biotechnology has had an important advance during the last five years. Among universities and the public sector, there are some 20 institutions with clearly defined programs and lines of research, development and/or extension of the technology. In the private sector, there are more than a dozen laboratories with important activities in research and commercial development of biotechnologies. All laboratories can apply basic techniques (tissue culture, meristems, micropropagation, embryo rescue) to a wide range of crops. There are also important developments in the area of virology, to obtain virus free materials, and do diagnosis and certification. With respect to molecular biology in search for markers, some labs are working with RFLP, RAPD and PCR. In the areas of biopesticides and biofertilizers, a few labs are working with a focus on isolation and purification, solid and liquid fermentation, rhizobiology and other nitrogen fixers, and mycorrizae. The industrial application refers mostly to biopesticides (Hodson, 1993). The use of biological procedures for decontamination and biodegradation is another promising area where a few labs are conducting research (Cenicafé and Bioplantas). There are other industrial research works to apply biotechnology tools in the area of fermentation, mainly with yeasts for the bread industry, with monosodic glutamate (MSG) as a food preserver and flavor enhancer, and with methionine and lysine for the feed industry (Montoya and Buitrago, 1993).

In general, it can be stated that Colombia has an adequate capacity for development and implementation of biotechnology tools for application to agricultural and forestry activities. The research staff includes some 25 PhDs and more than 30 with MSc degrees. Physical infrastructure does not appear to be a constraint. The main bottleneck is the lack of

trained personnel at several levels, mainly at the level of postgraduates (Hodson, 1993). Lack of concerted efforts and of clearly established priorities to avoid duplication of efforts and irrelevant work is also a constraint.

IV.3.- The market for new technologies and innovations. The technological question is at the heart of the production function and, consequently, of the cost of production and of the supply of goods and services. The type of technology applied by any given farmer depends, not only on the spectrum of available technologies (the supply side) but also on his resource endowment, that is, his availability of cash, credit, capital, skills, knowledge, as well as quality and amount of land, labor and water, among others, that enable him to formulate his needs in that market. The market for technologies is a typical market where the forces of supply and demand interact to define amounts, qualities and prices of the products. But it is certainly not a market of perfect competition. On the supply side, there are very few producers of the technology. Some of the potential products (like basic research activities) have a long term strategic nature for society but are not appreciated by the private sector, with its shorter time span for investments. On the demand side, the market is still very narrow and does not justify large investments, which implies operating at small scales and/or with very high fixed costs; furthermore, many potential consumers of the technology do not have any access to the market and, therefore, their needs are not expressed in it. Therefore, a presence of the public sector is well justified to ameliorate distortions.

Given the private and public nature of technology generation in Colombia, the definition of the type of technology to be produced is partially done by the private sector, with their own narrower interests that correspond to their identified demands, and by public institutions that are in charge of interpreting society's priorities and providing mechanisms to translate them into the decision making process, complementing the market mechanisms.

In that respect, the state has to intervene to define clear guidelines for both the private and public actions in that market and ensure that national interests are efficiently and effectively tackled with the scarce resources at hand. But this is easier said than done.

IV.4.- The national system of science and technology. The activities of S&T in Colombia have been somewhat isolated from other statements of society. In Colombia, "we continue to perceive our scientists in their hermetic state of medieval wizards" (García Márquez, 1994). The colombian individualism has also been obvious in the fragmentation of the S&T activities. The new S&T system is the result of this awareness and of the need to correct that fragmentation. It was created in 1991 (decree 585) with the purpose of integrating and structuring the research and development efforts of the state, researchers and the private sector and their participation in policy decisions and resource allocation. It also has the goal of integrating the local with the international scientific community in a more efficient manner. The system was the result of a series of efforts that culminated with the report of the mission on science and technology in 1990. (Colciencias, 1992). In

the first year of operations, there have been several important accomplishments. For example, the value of research proposals presented to Colciencias by private sector and researchers was tripled and the number of universities presenting research projects to the system went from 14 to 24.

The current precarious situation of the science and technology (S&T) system in Colombia can be summarized as follows (Trujillo, 1993):

a. A small S&T community with a slow rate of expansion. In the 1980's, Colombia had 40 scientists (1982) in the system compared with 183 in Malaysia or 4,853 in Japan (1987).

b. The programs in charge of generating or adapting knowledge or research, the doctorates and basic sciences are lagging.

c. The levels of expending in the S&T area, as percent of GDP are very low (0.19% in 1988).

d. Resources for S&T are basically of a public nature.

e. Low participation of the productive sector in S&T. In Colombia, the integration of Universities with state and private sectors is very poor, ad-hoc and informal.

The system is based on a National Council and on eleven Councils for an equal number of national programs of science and technology. Colciencias, government representatives, private sector, researchers and advisors form part of each Council. Biotechnology has its own Council. Two other programs are also closely related: agriculture and the environment. Currently, some regional councils are being formed to formulate policies based on elicited regional needs.

The objective of the national biotechnology program is "to create and strengthen the national scientific capacity in the domain and development of the new biotechnology, to promote its development in selected products or processes to reinforce the competitive advantage of the national production and promote biotechnology advances and applications in the pursue of increased welfare, proper management and use of natural resources and of the environment" (Colciencias, 1993).

In support to biotechnology activities, the program succeeded in creating fiscal incentives to investments in this field; they can be deducted from the net income for tax purposes. These incentives apply to all tax payers, without exception. Other countries, like Brazil, allow full deduction from taxes, which multiply the incentive by the inverse of the tax rate (at least by a factor of three assuming that the firm is around the 33% tax bracket).

A number of policy challenges emerge. Among others, some are clear current needs to ensure an efficient integration of the system:

a. Identify public and private sector responsibilities
b. Define a national policy toward intellectual property rights
c. Ensure appropriate biosafety policies
d. Set clear biodiversity guidelines
e. Establish appropriate skills training programs
f. Collaborate establishing priorities for biotechnology participation in agricultural research
g. Identify major limitations and weaknesses to formulate solutions
h. Facilitate collaborative schemes to avoid duplication of work and promote economies of scale in research

IV.5.- The Corporation for the Development of Biotechnology. The National Council for Economic and Social Policy recommended that, under investment projects for Science and Technology for 1994 (of March 1993), should be included this type of mixed Corporation, under the instance of Colciencias and the DNP (National Planning Department) and with shares from the private sector. It is in its last stages of its creation.

The main goal of the Corporation is to integrate the activities of biotechnology into a system of research. The corporation must react to certain general needs and to specific ones (CEGA, 1993).

IV.5.1.- General Needs. These are essential to configure an efficient system.

a. Information:
   - Human resources
   - Lab equipment and technical resources
   - Financial resources
   - Main research activity and projects under way
   - Bibliography and stock of technical knowledge
   - Publications

b. Protection of intellectual property rights

c. Scientific development (training, social aspects, etc.)

IV.5.2.- Specific Needs. Depend on the research entity and may constitute a burden for further expansion and development.

a. Industrial promotion

b. Scaling up of activities

IV.6.- Constraints to expand local biotechnology activities. This is a very new and unexploited field in the country. Much remains to be done in strengthening its capacities, through investments in human resources, equipment, inputs, networking, etc., and by inserting those efforts more efficiently into the national research and development efforts within a cohesive collaborative interinstitutional and multidisciplinary approach. A clear, comprehensive, and strategic framework of regulations and legislation is an important starting point to foster and warrant investments in this field within the concepts of intellectual property rights, biosafety and biodiversity.

Perhaps the main limitation to carry on more local activities in biotechnology is the lack of a critical mass of highly trained scientists in Colombia in the fields of biochemistry, molecular and cellular biology, and genetic engineering (Cadena, G., 1993). According to Torres (1993), the total amount of scientists working in agricultural biotechnology, including animal sciences, was 204 of which, 28 had PhD and 49 had MSc; about 50% of postgraduates belong to universities and public institutions.

In terms of the participation of highly trained researchers for the agricultural sector, the country has made substantial progress between 1980 and 1991. A relative strengthening of the private capacity as compared with the public sector can be seen in Table 3.

IV.7.- Education in Colombia. Education appears to be the single most important determinant of inequality at any given time (Financial Times, 1994). The education levels of the population are relatively low. On average, a colombian has 6.5 years of academic formation. This number does not compare favorably with other countries: 0.64 that of Chile, 0.52 that of South Korea, 0.42 that of Taiwán and Japan and 0.39 that of the U.S. Countries like México, Venezuela, Korea, Taiwán and Portugal, which were below Colombia 40 years ago, today surpassed it and even duplicate it, like Taiwán and Korea (Trujillo, 1993). Coverage is quite deficient. Only 13% of preschoolers are covered, while in developed nations this figure is almost 100%. Coverage for urban children between 6 and 11 years old is 84%. There are problems with repetitions and advanced ages in primary level. The correlation of these figures with levels of poverty and malnutrition is not espureous. The public budget for education in Colombia represents less than 4.3% of GDP, which is the average for Latin America and the Caribbean.

The lack of critical mass of researchers is a limitation to expand biotechnologigy activities in the country. But this is not a problem exclusive of biotechnology. It is a generalized problem that demands a careful evaluation of other needs before committing too many resources to build up this capacity in an indiscriminate manner. Training of biotechnology scientists should be one of the last links to close in a research program. If the program is well equiped (like coffee research) this training will be an efficient investment in human capital. If the program is non-existent (like in fruits) it is better to invest in lower level scientists before reaching the high specializations.

IV.8.- Congruency between macroeconomic priorities and those of the S&T system. The main feature of the new S&T system is that it is still in formation and that its present reality is still far from the formulated theory of its plans and programs. The system has some weaknesses, stemming from the lack of clear priorities and signals from the macroeconomic sphere.

As it was seen before, agricultural policies in Colombia have been punctual and ad-hoc, without a strong, stable, well defined, long term sectoral policy. Besides, their timid objectives have been overwhelmed by macroeconomic and trade policies that discriminate against local agriculture. This partially explains the lack of dynamism in the sector and, consequently, creates an adverse climate for investment in related industries and activities like biotechnology.

In the absence of clear signals from the national plans of development, priorities are established and resources are allocated from the perspective of the science and technology councils, where a relatively long term horizon should prevail. Regardless of the validity of this process, one has to wonder about the reliability and social efficiency in resource use of those long term investments in activities affected by unstable and short term policies. This lack of congruency in policies and priorities has been prevalent among Latin American countries (Lynam et al, 1988). However, in 1993, as part of a general trend to modernization of the state that started in 1990, for the first time there is an agricultural law approved by congress. It is an important step to create a framework where clearly stated agricultural priorities can have a long term congruency with social, environmental and economic goals so that investment policies, including those for infrastructure and research, are all focused in the same objectives, minimizing resource waste and maximizing the returns on those investments.

There is another operational gap. The agricultural council establishes priorities in a separate council than the biotechnology council. This separation, in the absence of clear signals from outside of the S&T system may create incongruencies (although, out of ten members, they share one common representative from the government and two more from Colciencias). Besides, the participation of the private sector in those councils is narrow and is structured around individual prominent persons rather than representative members from producers' associations. The participation of the province in those councils is almost nonexistent. In this sense, the idea of creating regional councils may correct the problem at the risk of creating a huge bureaucratic apparatus. But this is a risk worth taking since proactive regional councils should be more an asset than a burden.

In the end, the system should be able to give clear signals as to where to allocate research funds, both among activities and among research tools. The technology generated must comply with the following attributes: (i) its relevance: the solution being sought is a priority for society; (ii) its feasibility: the problem can be solved, given the means employed, with a reasonable level of probability; (iii) its appropriateness: the

technology produced responds to the resource endowment of target farmers, environments or systems and fits within a context of sustainable development.

The tools employed to generate those technologies must also comply with certain attributes: (i) the tool must be efficient and effective; it produces the intended product with a low expected cost, i.e., it has a high probability of success, and/or it produces the desired result faster, and/or it has a lower cost; (ii) the tool has important complementarities with other tools and processes to achieve the desired products in the framework of a coordinated and harmonic effort; (iii) the tool has a comparative advantage over alternative tools; it makes more efficient use of abundant and cheaper resources in the country than alternative tools.

Biotechnology, in research and development, constitutes one alternative tool whose use should be evaluated in the context of efficiency, effectiveness, complementarities and comparative advantages to judge its superiority and desirability as a preferred tool.

In summary, there is a group of questions that should be asked before a decision to allocate resources in crops, themes and tools is taken:

1. What are the research priorities in terms of economic sectors, crops and themes that require investments in research and development, given the expected cost of the solution and the potential benefits that will result.

2.- What are the main development paths in the country. This refers to the resource endowment of farmers including their agroecological setting.

3.- What are the priorities that arise when main crops and themes are crossed with main development paths.

4. What are the major constraints/opportunities for the prioritized crop (or theme) in the country.

5. What are the potential contributions of biotechnology to offer solutions for them.

6. Under what conditions are certain biotechnology solutions:
   a) effective and efficient
   b) complementary to other tools
   c) comparatively advantageous

IV.9.- Intellectual property rights. The intellectual property system is crucial to the success of inventions in the medical and agricultural sectors, where the regulatory system takes a long time (Bartok, J. 1994). The system goes beyond national boundaries, as reciprocities and harmonization are a key element for legal negotiations. Some recent developments are worth mentioning.

IV.9.1- The Uruguay Round of GATT, 1992. It agreed on imposing a four year term for developed countries to develop and approve plant breeders rights; less developed countries have between nine and fourteen years to comply with this requisite that includes a law a regulation by the respective Congress.

IV.9.2.- The regime for industrial propriety in Colombia. The topic has been dealt within the Board of the Cartagena Agreement (or Andean Pact[2]). The agreement has been revived during this decade, not only as a trade union, but as a geopolitical block that should enhance the regional negotiating capacity in world forums. By December, 1995, the Andean Group should have completed the basic document to implement its own common agricultural policy, which includes, obviously, the adoption of common views and positions with respect to new aspects of agricultural legislation, like intellectual property rights. In the pursue of that goal, the Group already has made some progress. The decision 344 revises decision 313 and 85 previously in force. It (i) widens the coverage of patents to more items and from 5 to 20 years; (ii) states that the obligation to exploit the patent is not linked to local production: importation is a valid means; (iii) restricts compulsory licenses.

IV.9.3.- Protection of plant varieties in Colombia. This topic is also being handled within the Board of the Cartagena Agreement (or Andean Pact). Through decision 345 published in the official gazette of October 29, 1993, a regimen for plant breeders rights was approved, which was deeply influenced by the UPOV (Union pour la Protection des Obtentions Végétales). Protection to living forms, both animal and vegetal, had been previously excluded to facilitate the Uruguay Round talks of GATT, that were still taking place at that time. With respect to biotechnology inventions, decision 344 declares that animal species and races, and products essentially biological for their obtention are not patentable. Vegetable species are, then, susceptible of being patented (Bergel, 1994). These decisions need still to be refined and ratified by the respective legislature of the Andean Group countries.

While these decisions are being refined, many regional analysts believe that the spirit of 1978 UPOV treaty should form the basis for the design of the Andean Group legislation. In the 1978 UPOV treaty, it was stated that "the primary requirements for a variety's protection are stability and distinction from any other variety. Multiplication and sale of seeds is the privilege of the breeder's right's holder; genetic material remains free for breeding purposes (breeder's exemption) and the farmer may keep seed for on-farm use (farmer's privilege) (Bijloo, 1992). At the 1991 revision of the UPOV treaty, the double protection which regulated that a country had to choose for either legal protection under the plant breeder's rights or under patent law (utility patent USA), has been abolished.

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[2] The Cartagena Agreement set the norms for the creation of the Andean Pact, three decades ago. The Pact started mainly a trade union. It includes the andean countries, with the exception of Chile, i.e., Bolivia, Colombia, Ecuador, Perú and Venezuela. In recent years, trade among these countries has grown, but it still represents less than 10% of regional trade (Paz, 1993).

Also, the plant breeder's right has been opened to plant varieties, making patent protection for plants easier. The dependence of varieties upon each other has been strengthened, with the result that protected material is no longer freely available. Also, part of plants have been brought under the right. In some instances, breeding companies may set terms to the importation and exportation of harvested material and, in some cases, even of processed foods" (Bijloo, 1992).

The transitory third disposition of the Andean Group also states that member countries will approve before January 1995 a common regime for access to biogenetic resources and to protect the biosafety in the region, following the recommendations in the Treaty on Biological Diversity, adopted in Rio de Janeiro on June 5, 1992.

With respect to the double protection issue, "a number of experts think that breeders' rights are, through the certificates of protection, an efficient means of protection... without it being necessary to adopt the patent system... Furthermore, it does not seem necessary to make a distinction between the plant varieties bred through biotechnological means... and those which are the result of the current genetic breeding schemes". (Sasson, p. 287, 1988).

IV.9.4.- How far to go? During many centuries, farmers in developing countries have been improving local seeds and crops. The introduction of capital intensive biotechnology techniques caused an increased interest in developed countries in patenting new varieties. This patenting would enable developed countries plant breeders to acquire the exclusive rights on genetic material. "Berland and Lewontin (1986) see Plant Breeders' Rights (PBR) legislation as increasing the monopoly power and profits of breeders, while users (i.e. farmers) are inhibited from saving seed..." (Sasson, p. 289, 1988). Third world countries will end up paying for the use of their own genetic material. In this sense, it is crucial to maintain very flexible intellectual property rights in Colombia and contribute to a hemispheric policy to develop the concept of farmer's rights in an equitable system.

Furthermore, the patenting of genetically-engineered micro-organisms depends on the necessary deposits of the strain in a culture collection. This obligation is questioned by breeders if the same procedure were to be applied to new plant varieties.

Developing countries can implement several options within two extremes. One extreme is to deny any right of intellectual property and isolate itself. The other extreme position would be to accept all he imposed rules of the game which might lead the country to become merely a focus for the interest of multinational corporations.

In a pragmatic way, the UPOV convention of 1978 guarantees a right of compensation to the inventor, for the use of the invention, in addition to the ability to transfer it to anyone who would like to use the invention or to start commercial production. This is due to the fact that, in breeding a new plant variety, the innovative role largely belongs to nature. The right of compensation should avoid the oligopolistic system that prevails when

the patentee or inventor has an unlimited use right which can be exclusive or restricted to a certain area (Sasson, 1988).

In this area, there are certain questions that are not only of equity in nature but are also strategic within a broad concept of food independence. The treatment to agricultural products has to be selective, following national interests and priorities. At the level of producers and consumers, it also has to be clear who is more likely to win within and among those groups, both in the short and in the long term. A piece of legislation can put a multinational in a position of monopoly in the distribution of seed of a key staple commodity, for example. The multinational will be able to extract economic surpluses from the country. Large scale commercial producers with access to the technology can be winners, initially, while small farmers and consumers loose. In the longer run, however, the monopoly is likely to lead to stagnation in technological progress due to the reduced competition and even large producers end up as losers.

IV.10.- Biosecurity. Several regulations are needed to minimize the risks of biotechnology in the areas of:

a. Individual and public health issues (escape of harmful organisms, etc.).
b. Unforeseen or unexpected effects in the production of pathogenic genes.
c. Protection to ecosystems. Herbicide resistant crops are an example. They can induce widespread use of pesticides and even produce herbicide resistant weeds by natural crosses (rice with red rice, for example).

Colombia does not have norms and regulations for the protection regarding the use and commercialization of biotechnology products. There is not even a system for quality certification for disease free materials from tissue culture or for the efficiency of pathogens for biological control. The Andean pact has been making some progress in this area as well.

IV.11.- Biodiversity and the environment. Colombia has a history of regulations in the field of natural resources. It was one of the first countries to have its own code for natural resources and the environment in 1974, following the Stockholm conference. But the abundance of laws is not corresponded by the juridic instruments and the necessary institutions to enforce those laws. The country has 43 parks and 10 sanctuaries, comprising some 9 million has. Yet, they are in charge of 300 employees of the Institute for Natural Resources (Inderena).

Despite the regulations, Colombia ranked third in Latin America in deforested lands in the 1981-90 period with 300,000, sfter Brazil (3,4 million has.) and Venezela (550,000 has). The vast majority of that area is being used for grazing (85%); only 6% is under crops. Of some 2,5 million has. of forest in the hillsides in 1990, annual deforestation reached 40,000 has. (or 1.6% per year) (López and Ocaña, 1994). Poppy growing for the processing of heroin is an important factor in that deforestation.

The Constitution of 1991 stipulates the protection of the ecological biodiversity and the need to regulate the entry and exit of genetic material into the country. The law 99 of 1993 creates a new Ministry of the Environment, to coordinate actions among all entities dealing with the topic and create the appropriate mechanisms to enforce laws in this strategic field. It states that the budget for management of natural resources be increased from 0.3% to 0.55% of GDP, with resources coming from the oil royalties fund and fees for contamination and exploitation of resources (Isaza, 1993). This law consecrates the principles of the Rio earth conference of 1992: (i) conservation of biodiversity; (ii) sustainable use of the components; (iii) right to share the benefits that emerge from the use of genetic resources, recognizing the sovereignty of states, facilitating access to them and avoiding restrictions to the processes of R&D. The topics of biodiversity and biosecurity go beyond the national boundaries; they are being dealt by the community of andean countries.

IV.12.- The Universities and private enterprises. In Colombia, the collaboration of universities with the private sector is, to a large extent, informal. A recent study on this subject, revealed several aspects that are limiting a closer collaboration (Moreno, 1994)[3]: (i) loses in confidentiality and secrecy, since intellectual property rights are not clearly established; (ii) lack of identifiable responsibilities, also related to the informal contract; (iii) sluggishness and delays in deliverance, due to lack of control of the time of the researcher and of its use of lab facilities. The researcher participation with the private sector is not formally settled through a contract with the university, due to rigid formal bureaucratic procedures, deficient participation of the researcher in the benefits from research and poor negotiating capacity in the universities to share in the benefits of the process.

There is a need to configure an intermediary that provides the service of linkages, similar to what CIT does in México (Solleiro, 1994). The Universities must reduce red tape. There must be clear guidelines concerning intellectual property rights and sharing of research benefits from innovation between the private firm, the university and the researcher. The decrees 393 and 591 of 1991 that created a new system for contracting with the state for activities of research according to the private norms, speeded and simplified the unaccessible bureaucracy of the past and opened up new spaces for the universities to compete with other institutions, like Corpoica, for public research funds. This is a great opportunity to have universities truly involved in high quality research and where research and teaching go hand in hand.

IV.13.- The CGIAR and other international agencies. Colombia is the country host for CIAT; consequently, it has five seats in its Board of Directors. CIAT has had a strong

[3] The Colombian case is part of a broader study on relations between biotechnology firms and biotechnology research institutions. It also includes Argentina, Chile, Uruguay and Brazil. IDRC sponsored the study. The Colombian sample of private firms included Laverlam (vaccines, other), Meristemos (tissue culture), Instalab, Vecol (vaccines), Levapan (bakery), Alpina (dairy).

influence in Colombia's research through the commodity programs (tropical forages, beans, cassava and rice) as well as in the work of the support units (genetic resources, biotechnology, virology, agroecological studies, seeds) and, more recently, in CIAT's holistic approach to natural resources research within a matrix approach. Colombia has been a direct beneficiary of conferences, training (one out of four trainees has been colombian), methodology development in participatory research, variety development, etc. Other CGIAR centers, like CIP, CIMMYT, IPGRI and ISNAR have had close collaboration with local entities. Outside the CGIAR, institutions like IDRC, IICA, FAO, UNDP, IAAE (atomic energy agency) as well as many foreign universities and other institutions have been important collaborators. Yet, ICA has only devoted less than 5% of its budget in those interinstitutional endeavors.

Although CIAT's participation in the biotechnology council has been informal, it seems convenient that its participation within the science and technology system be more active. On the other hand, Colombia's participation in CIAT's Board should also be more proactive, to influence the Center's agenda towards truly relevant research for the country's needs and priorities.

V. Crop biotechnology in Colombia: some specific cases

In this section, the main crops in colombian agriculture are reviewed (see section II.7 above), analyzing their current situation in terms of research needs and accomplishments. The approach is positivistic: what has research done or is doing to solve major constraints with the help of biotechnology and how it fits according to its efficiency, complementarity and comparative advantage. In that sense, there are efforts in many other crops that are not included here.

V.1.- Coffee. It is the main agricultural activity in Colombia, occupying 1.15 million has, cultivated by 350,000 farmers that, in 1992, produced some 18 million 60kg. bags of green coffee or about 5 million tons in terms of coffee cherries. Coffee exports represent about a third of agricultural exports and 20% of total exports. (Ministerio de Agricultura, 1993). The productivity of coffee in Colombia is among the highest in the world. Coffee is hand picked, selecting only the ripe grains, which are then peeled, washed and dried. Coffee constitutes more than a crop, a whole culture around which some 4 million people earn a living in Colombia. The Federation of coffee growers was founded in 1927. It serves the needs of producers and also takes activities of research (since the 1930's), commercialization and even infrastructure (schools, roads, aqueducts, playing fields, electrification, etc.). The standards of living in the coffee areas of the country are higher than in the rest of the country to a great extent thanks to the actions of the Federation. Its funds come, from 1940, from a set of taxes to producers that is handled by the coffee fund. These taxes are variable in nature, as they are designed to isolate the internal price from sharp external fluctuations. In times of high international prices, the tax may be as high as 80% (like in 1977, for example). In times of low international prices, the internal price may be above it, as it happened in 1993. The Fund is private but it is handled by

a committee with private and public participation ("parafiscality"). Besides being a form of price stabilization, the fund is used to keep the producers association running, to pay for coffee research and extension and to pay for infrastructure investments in the coffee region. The participation of the government in the committee that controls the fund has also implied that the fund is used for investments that are not high priority for coffee growers. The new constitution explicitly allows the existence of these funds and many other crops have followed the example (rice, cereals, cocoa, poultry, oil palm, panela or raw brown sugar).

V.1.1.- Coffee research in Colombia. The national center for coffee research, Cenicafé, conducts activities, almost exclusively, since the 1930's in the areas of genetics, phytopathology, entomology, physiology, ecology, cultural practices, soil conservation and socioeconomic. It also does some work in other crops of interest for coffee growers as they form part of activities that help them to diversify income within the farm (like plantains, citrus, macadamia, sour sop, pastures...).

The biotechnology work was initiated in the Laboratory for research in the chemistry of coffee (LIQC) in 1976 and three years later was also initiated at Cenicafé. The two centers belong to the Federation of coffee growers and have common objectives and goals to work in close collaboration with foreign universities and institutions.

The objective of biotechnology research in coffee is to develop techniques and apply them to coffee breeding and crop management aspects in those cases where conventional technic are not applicable. It has to serve as support for other basic disciplines in the development of strategies to solve, in the medium and long term, the main constraints of coffee cultivation in Colombia (Cadena, 1994).

The LIQC has, as one of three programs, one on biochemistry. It has, as main objectives:

a. Conduct studies on the chemistry of coffee.
b. Select, adapt, generate, and apply techniques on tissue culture and genetic engineering that are most relevant to solve certain problems in coffee research that cannot be solved efficiently by conventional methods.
c. Select microorganisms and develop systems of protection for them to increase the efficiency of biological control under field conditions.
d. Study chemical signals that intervene in the behavior of insect pests to coffee to improve their control.

The program has three basic ongoing projects:

a. Genetic transformation and molecular biology of coffee.
b. Biochemical studies and biological control.
c. Production of haploids for breeding purposes.

Since the beginning, the program has been developing methodologies and procedures for in-vitro cultivation of cells and tissue as a first step to support research in several fields. Routine activities are somatic embryogenesis, culture of cells in suspension, anther culture, embryo rescue for interespecific hybrids in distant materials, isolation and culture of protoplasts (de Peña, 1991). In collaboration with CIAT, the genome library of coffee is being characterized.

V.1.2.- Main coffee pest and disease problems. Colombia had been relatively free of major pests until 1983, when the rust (*Hemileia vastatrix*) was found in the main coffee growing region. In the late 1980's, the coffee borer (broca, *Hypothenemus hampei*) entered the country through the border with Ecuador and in three years (by 1991) it had reached the main coffee region at the heart of the andean region.

Breeding for resistance against the rust started around 1960, twentyfive years before it appeared in the country, by Cenicafé, using Tymor's hybrid, a source of resistance to the disease. A resistant pool of varieties (Var. Colombia) was already available at that time and its adoption was quite fast. Many other complementary crop management practices based on fertilization, selective fungicide applications, shadow management, etc. were also developed as alternatives methods to fight the disease (Cenicafé, Comité Departamental de Cafeteros de Caldas; Federación Nacional de Cafeteros, 1988). It was estimated that biotechnology does not have a comparative advantage in this program.

It is estimated that there are some 300,000 has affected by the coffee berry borer (*Hypothenemus hampei*), mostly with low percentages of infestation. Of the 1.15 million has in coffee in 1993, about one fourth are in marginal lands. There are no known sources of resistant against this insect. The research strategy to fight this serious pest has activities to control the insect (crop management, pesticide use and biological control) and to generate a source of resistance in coffee. This field constitutes the top priority in coffee research, currently.

A fungus, *Beauveria bassiana*, for biological control of the borer is now being sold by commercial companies (Hoechst, the coffee federation, Laverlam). Cenicafé has now 80 isolates of the fungus and has a project to work on protoplasts of the fungus. The most virulent isolates are also being characterized to reproduce them at a commercial scale. The fungus is being sold at relatively low prices. While 1.5 to 2.0 lts/ha of insecticide for one application, like thiodan (endolsulphan), actelic (piriniphosmethyl) or sumition (fenitotrion) costs some US$15 per hectare, the recommended doses of the fungus (1.0 kg/ha) for a similar application costs half of it. Under favorable ecologies and agroclimatic conditions (like ranges in day and night temperatures, luminosity, elevation above sea level, rainfall patterns, humidity) the fungus can be quickly established and offers an effective control. The pest management strategy requires complementary application of pesticides, but on a sporadic fashion and by patches, rather than generalized, frequent applications. A technical use of the fungus should imply a reduction from a typical situation of about four applications of pesticide per year to less than one. Of the 1.1

million has of coffee in Colombia, about one fourth does not comply with the favorable agroclimatic conditions for the fungus and, most likely, will have to move to other alternative crops. *Beauveria bassiana* has also been effective parasiting *Diatrea sacharallis*, the sugar cane borer, and *Anthonomus*, or picudo, a pest that attacks pineapples.

Additional work is being conducted with 50 isolates of *Metarhizium anisopliae* for the same purpose of biological control of the insect. In addition, the IPM strategy is also using wasps (*Cephalonomia stephanoderis, Prorops nasuta*, already in the country, and *Phymasticus sp*., which will be introduced in the future) that parasites the insect. This alternative has a bottleneck in the slow multiplication of the wasp and, consequently, its high cost. Management practices for control of coffee borer, including recollection of dried berries in the trees and on the ground, could represent between 10% and 15% of crop management costs. More work is still being done in this subject. There has been active collaboration with ODA, NRI and IIBC of England under an agreement of Cenicafé with the British Goverment for the development of an Integrated Pest Manangement for the coffee berry borer.

V.1.3.- From researcher to farmers. The coffee federation has an extension system based on the activities of the coffee departmental committees (or state committees) spread throughout all productions regions of the country. Therefore, technology transfer is almost immediate and is available to small as well a to large farmers. The use of Beauveria has expanded fast but its effectiveness depends, as mentioned earlier, on favorable agroclimatic conditions for the fungus.

This simple biotechnology tool for biological control has a clear flow from researchers to farmers; its low cost makes it available to small farmers; it has an obvious environmental impact, as it substitutes for the use of dangerous and harmful pesticides eliminating adverse effects on human health, water streams and elimination of beneficial insects.

Since there is not an official certification of the product being sold, as it is the case for chemical products that are certified by ICA, some companies are selling iniquitous powders that have undermined the credibility of the strategy of biological control. It is important to have a credible system that regulates this product.

V.1.4.- Transformation of the coffee plant. There are collaborative projects with the universities of Cornell and Purdue. At Cornell, work is being conducted on coffee plants sent to them from Colombia in-vitro. Transformation is done using *Agrobacterium tumefasciens* and the gene gun, developed originally at Cornell. There are two professionals from Cenicafé collaborating in those projects and being trained in their Ph.D. At Cenicafé, work on artificial diets for the insect permits researchers in Cornell to multiply the insect and advance work on gene markers to identify genes to be used in the transformation of the coffee plant. Cenicafé entomologists were also trained at Cornell in

the technic of bioessays with inhibitors that will eventually be used in genetic engineering work.

With Purdue, another person is working in the Ph.D. thesis in developing a protocol for genetic transformation by means of protoplasts to obtain a plant with resistance to the borer.

V.1.5.- Postharvest activities.- One preoccupying aspect of the coffee activity is the disposal of the waters used in the peeling and washing of the coffee berry, to obtain the dried green coffee grains, a process that takes place in most coffee growing farms in Colombia, where the model of centralized processing plants is the exception. This style of individual processing creates a problem of contamination in a myriad of water streams throughout the coffee region; the water carries phenols, tanines and other toxic elements that increase the biochemical demand for oxygen. Cenicafé has been tackling the problem by working in the design of a system that will use little or no water in the process, as a drastic solution to the problem. But some research has been taking place also with bacteria that can be used to detoxify the waters, when incorporated in the fermentation tanks or afterwards, in special treatment tanks. Here, biotechnology, acts as a complementary, and second best solution, to a key and growing environmental problem in the region.

V.1.6.- In summary. The coffee federation has a well focused, efficient and well integrated research program where priorities are clearly established. Biotechnology is done in two centers (Cenicafé and LIQC) as part of one program with common objectives and goals. Its use is restricted to areas where it has comparative advantage. Most of the work is collaborative to better use facilities abroad and to increase the critical mass of researchers required to advance biotechnology in Colombia. The products of biotechnology find an expedite way to reach farmers. So far, the only visible product at the farm level is the *Beauveria bassiana*, which forms part of an integrated package to fight the coffee berry borer. Its low cost makes this technology available to small farmers, who are even trained by extension workers to use homemade techniques to reproduce the inoculum. The environmental impact is enormous as the fungus substitutes for the use of dangerous insecticides helping to preserve beneficiary insects, avoiding health threats to humans and keeping the water and the air cleaner.

Main research institutions involved: LIQC, Cenicafé, Cornell, Purdue, IIBC, NRI, ODA, CIRAD/FLHOR, CIAT.

V.2.- Sugar cane. This crop occupies some 340,000 has. divided in cane for "panela" (or raw brown sugar) with 190,000 has. and cane for sugar, with 150,000 has. They represented 17.9% of the value of agricultural production in 1992. Sugar exports have been recovering fast since 1987 when they plunged from US$200 million in 1980 to US$30 million to steadily rebound to US$130 million by 1992. Compared with other crops, they occupy the fourth place, after coffee, flowers and bananas (Ministerio de Agricultura,

1993). Panela is virtually all consumed internally. In absolute terms, Colombia is the third producer of panela in the world, after India and Pakistán. In per capita terms, it is the first consumer in the world with some 40 kilos per capita. Although it is the same crop, both products (sugar and panela) are very well separated in their final market as well as in their production technologies and type of producers. Cane for sugar has a very solid organization of both processors and producers.

V.2.1.- Sugar cane research in Colombia. With private funds, sugar cane producers have been financing their own research center (Cenicaña) since the late 1970's, when they undertook the activities that were being carried by ICA, the state research institution. Panela producers also have a research fund that comes from a parafiscal retention on panela sales (similar to the coffee fund); their research mostly focusses on processing technologies. Cenicaña conducts research in the areas of breeding, crop management, processing and fermentation.

V.2.2.- Biotechnology activities in sugar cane. They are relatively new and are perceived as support for the breeding program, mainly.

Since 1990, Cenicaña has been working in tissue culture for cleaning the material from pathogens (mosaic virus, rust, carbón), speeding up the breeding activities and maintain germplasm (Larrahondo, 1991). Meristems are also used to analyze mericlonal variation.

Biological control of *Diatrea Sacharallis* has been effective with the use of tachomid and braconid natural enemies (Bellotti et al, 1990); recently, it seems that the use of the fungus *Beauveria bassiana* has a potential for control of the borer; in this sense, sugar cane can benefit for the work in coffee; experiments are just being conducted.

The work on molecular biology has several angles. With CIAT, work has been done with molecular markers, fingerprinting, and molecular biochemistry for genes responsible for sugar accumulation. In a very efficient scheme of international collaboration, Cenicaña joined a consortium with participation of institutions from several countries (USA, Australia, South Africa, Brazil, and others) to contract biotechnology research from U.S. universities like BYU, Cornell, Texas A&M, California Institute of Research. There are works in the genome mapping, quantitative trait loci and development of methodologies for transformation. Currently, consortium contracts amount to about US$1 million per year.

Meristemos S.A., a company founded in 1990 and exclusively dedicated to vegetal biotechnology, acquired an accelerated technology from DINAP (New Jersey) to propagate sugar cane. Field trials are being conducted to assess the cost efficiency of the plantules when compared with the traditional method of vegetative seed. Data from Hawaii, shows that this plantules can yield up to 15% more due to absence of pathogens, better stem quality and lower lodging. According to a company manager, half of the sugar cane area in Louisiana and Florida has been seeded with material from Crop Genetics

(a company from Maryland) and at that large scale, it also shows yield increases of some 15%.

An important work in fermentation has been conducted with ORSTOM (of France) to produce unicellular protein from sugar cane byproducts (Montoya and Buitrago, 1993; Torres, 1993).

V.2.3.- Summary. The biotechnology activity at Cenicaña is still relatively modest. The center contracts most of the work they need through the international consortium or with local entities. The in-house work is focussed on characterization of material, in preparation to intellectual property rights, and in tissue culture to support breeding activities. The research in that area is strategic in nature. Currently, there is not an identifiable finished product that has reached farmers. There are a few spill-overs from cane research for sugar production and the one for "panela" as varieties and practices are usually different (although closely related) in each form of exploitation. With the new producers' fund, panela research should be expanded to include some biotechnology to support more efficient breeding.

Main institutions involved: Cenicaña, Meristemos, CIAT, Texas A&M, Cornell, BYU, California Institute of Research, ORSTOM.

V.3.- Musaceas. Both bananas and plantains are very important crops in Colombia. Together, they represent 10.6% of the value of agricultural production. Bananas occupy an area of 43,000 has. They are a major agricultural export crop, with US$425 million in 1991, the second after coffee (Ministerio de Agricultura, 1993). Colombia is the third world producer of plantains after Uganda. Per capita consumption is around 70 kilos, which shows its importance as a staple of the population.

V.3.2.- Research. For bananas, research is mainly done by the transnationals, like Del Monte and Dole; it is usually confidential. The association of banana producers also have their own research institution, Cenibanano. In the case of plantains, ICA-Corpoica, the Coffee Federation, several universities and other public institutions have important research programs. Collaborative work among those institutions, as well as with INIBAP and CIRAD/FLHOR is frequent. A prevalent characteristic of plantains research has been the poor coordination of efforts, with frequent duplication and contradictory messages through a great number of demonstration plots. Sigatoka (both black and yellow) is a major problem throughout the country (Belalcázar, 1991).

V.3.3.- Biotechnology in Musaceas. "In-vitro" propagation by local companies is now a wide spread technique at the commercial level (Meristemos, Agrevo/Hoechst-Schering, Bioplantas, U. de Caldas, U. de Oriente, U. Javeriana, U. del Valle, MG). Biochemical characterization and mutations have also been done. Isrex, an irrigation company from Israel, sells also plantules as part of the whole package of land adequation and crop

management; their price is substantially higher than the one local companies charge (US$1.20 versus US$0.80 per local plantules).

Colombia and Costa Rica have been pioneers in the use of the "in-vitro" propagation of plantules. Work started at the Agronomy Faculty of the Universidad Nacional in collaboration with its Biology department and the University of New York in 1983. Today, there is a big national annual supply of over 4 million plantules of bananas and plantains of many kinds, that compete very favorably in price with imported material from Israel (US$1.20 per imported plantule -vs- US$0.80 to US$1.00 for the national material). In these crops, in-vitro plants have many advantages associated with the technique: clean material, vigor, lodging resistance, earliness, more productivity, low percentages of somaclonal variation, etc. But there is a logistic advantage as well: the speed of multiplication. Increasing areas by use of sprouts is very slow, particularly with new or scarce varieties. Most of the multiplication takes place with bananas Cavendish (Gran Enano, dwarf), Gros Michel and baby banana (exotic) and with plantains dominico-hartón.

The Universidad Nacional, in collaboration with INIBAP and the Agency of Atomic Energy (IAAE, Austria), obtained two mutant cultivars by irradiating in-vitro plants with Cobalt. Hoechst has done research on biochemical characterization of cultivars to guarantee the genetic stability of their plantules. AUGURA (the private association of banana exporters) contracted with the Universidad Nacional (Biology department) a project for evaluation of mutagenically treated bananas and other for evaluation to tolerance and resistance to Sigatoka Negra. Corpoica is doing a biochemical characterization of banana mutants to establish ranges where they can appear (González, et al. 1994).

V.3.3.3.- Summary. The widespread use of plantules in banana and plantains has an important impact on the use of nematicides and insecticides. The system of propagation also increases the economic efficiency of the crop. By avoiding the removal of sprouts for reproduction, loss of soil is also drastically reduced. But the plantules imply a cash outflow, which represents a limitation for small farmers when adopting this technique, even when it is economically profitable, since liquidity is usually a major constraint and their access to credit is limited by their inadequate levels of collateral.

Main institutions involved: Meristemos, Agrevo/Hoechst-Schering, Bioplantas, U. de Caldas, U. Católica de Oriente, U. Javeriana, U. del Valle, MG, INIBAP, IAAE, CIRAD/FLHOR, AUGURA, Corpoica..

V.4.- Flowers. The export promotion policies of the 1970's found a significant response in this item. Export value amounted to some US$350 million in 1993, making it the second source of foreign exchange in agriculture, after coffee. Colombia is the second largest exporter in the world after Holland. The U.S. is its main buyer, with 80% of the market, followed by the EEC with 14%. By items, the share in value shows carnations (with 35%), roses (28%) chrysanthemums (pompons) (12%), minicarnations (10%), as the main types of flowers. Currently, flowers represent 7.1% of the value of production

(Ministerio de Agricultura,1993). They are characterized by being a very intensive capital activity, with operating capital representing close to US$100,000/ha. The big firms have tissue culture to produce for the internal needs of the company only. These companies are all local firms.

V.4.1.- Crop management problems. The introduction of materials from several countries resulted in the entrance to the country of a number of pests due to imperfections in the quarantine services. The limited research on these new plants, the reduced availability of biological control methods and the large investments, result in massive applications of toxic pesticides that have polluted the water and the air and cause health problems to careless workers. The current use of clean materials from tissue culture does not eliminate the need for applications but it certainly contributes to reduce the entrance of foreign contaminated materials and the increase of pathogens and pests (Angarita, 1991).

V.4.2.- Biotechnology in flowers. Commercial firms in this area work under the system of patents with foreign firms. Varieties with more than 15 years do not pay royalties. There is not a public system of certification; this is done by the same company that sells the plantules, which apply advanced techniques of screening (serologic methods, molecular hybridization) against some viruses and pathogens. Universidad Nacional produces a diagnostic kit for the spot virus of carnation at a cost of US$240; the imported from Aetgia cost US$350. Sales are already around US$10,000 and there is a potential market of about US$20,000 per year for some 5 different viruses.

The lack of clear laws on intellectual property limits the collaboration to reproduce materials from foreign companies, which are skeptical about the payment of royalties for release of their materials in the country and their use in further research for breeding to local conditions. Yet, Meristemos S.A., the largest supplier of roses, has already a contract to sell plantules from Rosen Tantau of Germany for US$1.20, which includes a royalty of US$0.60 for each plantule.

V.4.3.- Summary. The boom of the flower industry was accompanied by an introduction of a wide range of pathogens and pests. Research is needed to find sources of resistance to ameliorate pesticide use which is currently at unbearable levels. Since some flowers are protected by patents, there is a limitation on the research that can be done. Tissue culture contributes to propagation of clean material that can be transported freely within the country and also competes favorably with imported plantules and stalks, reducing the importation of foreign plants and, therefore, the risk of introducing new pests and diseases. This is a very intensive capital using industry where some companies produce their own tissue culture materials. Biotechnology in this activity is mainly concentrated in the private sector, where an efficient combination of traditional breeding and biotechnology takes place, which translates into a highly competitive sector in the world market (Montoya and Aramendis, 1991).

Main institutions involved: Universidad Nacional (Facultad de Medicina), Universidad Católica de Oriente, Universidad Javeriana, Meristemos, Propagar, Floramérica, Hanna-Ichi, Jardínes de los Andes, Orquídeas Eva, Vivero Sol Rojo, Exportaciones Bochica, MG, Flores Esmeralda, Michigan State University.

V.5.- Fruits (excluding bananas). The tropical condition of the country gives Colombia access to production of a wide variety of fruits. With the exception of bananas, the country is not a major exporter in any of them. All fruits (without bananas) account for 4.5% of the value of agricultural production (Ministerio de Agricultura, 1993). At the household level, fruits represent only 7% of food expenditures. After bananas, the main consumption goes to citrus. Per capita consumption of citrus juice in Colombia is 0.6 liters per year, compared to over 30 liters in Germany or in the U.S.

V.5.1.- Crop management problems. The wide spectrum of fruits is accompanied by a similar amount of problems that go from lack of improved varieties to rudimentary technologies for production, marketing and processing. In the case of citrus, for example, there are problems with viruses, all sorts of pathogens and lack of clear crop management guidelines in terms of planting distances, fertilization, prunings, etc. There are many family orchards characterized by all sorts of pathological problems that, being uncontrolled, constitute loci of infestations to spread the problems quickly.

V.5.2.- Research. The main characteristic of the research program is lack of funds and poor focus. Too many scattered research activities in isolated centers result in lack of depth and of relevance to farmers needs. An exercise to prioritize fruits and research themes is urgently needed at the national level, with active participation from producers. As a result, funds should flow to priority activities in the context of collaborative research programs avoiding the current isolation and duplication of efforts.

V.5.2.1.- Biotechnology activities in citrus. The main efforts are found at universities. By the economic implications, the most relevant work started six years ago on the CTV (citrus tristeza virus) in the Universidad Nacional, department of medicine. The work, sponsored by Colciencias and the PNUD, explored a representative sample of orchards throughout the country and found that more than 95% of the samples were affected by the virus. There are some 25 virus strains in the country. The virus is transmitted by an aphid. They have found in the northern part of the country, a weak strain that seems to be conferring resistances to the stronger ones. Most nurseries are in the center of the country, reproducing infected plants. The danger is that those plants will be transported to the relatively virus-free zones in the north. Therefore, there is an urgent need to formulate a phitosanitary program for citrus. This valuable information is not integrated into sound plant and crop management improvement programs. The program has support from the University of Florida, where the CTV is not a problem yet but the aphid has been reported now in Guatemala and continues to move north.

V.5.2.2.- Biotechnology in other fruits. Universidad Javeriana has an important effort in passifloras. The emphasis is more on the development of methodologies. In passion fruit, a Ph.D. thesis is looking into methods of transformation for resistance against the potivirus with protoplasts and agrobacterium. The work is in collaboration with the Universities of Florida and Nottingham and with support from Grajales, the largest private group of processors and exporters of this fruit in Colombia. Passion fruit went through a rapid expansion of areas in 1990 as a response to stimulus from the government and the coffee growers federation to diversify coffee activities. Colombia became the second world exporter of the juice, after Brazil. However, the lack of research in adapted material and in crop management problems were coupled with low international prices and with the sharp revaluation of the peso. The activity went through a crisis that resulted in exit of most farmers after incurring in severe economic loss. At Universidad Javeriana, a thesis on Mycorrizae for passion fruit is also being sponsored by Grajales. The work intends to isolate, maintain and cultivate the mycorrizae to produce a viable biological fertilizer.

In the case of berries (*Rubus*), there is an important effort to characterize germplasm and conserve it both in-situ and ex-situ. Pineapples, strawberries, pitahaya and sour sop are other fruits where tissue culture is being made to obtain high quality material for further propagation.

V.5.3.- Summary. Fruit research programs in fruits are rather weak in Colombia, despite the great potential and varieties cultivated in Colombia. In that context, biotechnology research does not complement breeding and crop management programs and, in most cases, becomes a fancy work that does not reach farmers. The first step is to prioritize fruit crops and focus research within a broad program that has to include phitosanitary regulations. A close collaboration with the private sector has to be the basis for the research program, to ensure the relevance of studies and channel funds from potential users of the technologies.

Main institutions involved: Universidad Nacional, Universidad Javeriana, Universidad del Valle, Universidad de Caldas, LIQC, Meristemos, MG, Florida State University, University of Nottingham, Bioplantas, Corporación Andina de Fomento.

V.6.- Oil palm. It represents 4.5% of the value of agricultural production and occupies 115,000 has. There has been a continued expansion in areas particularly from 1988, when there were 63,000 has. (Ministerio de Agricultura, 1993).

V.6.1.- Research in oil palm. Cenipalma was created in the past decade to conduct relevant research in the areas of crop management and breeding. The national federation of oil palm producers has now their own parafiscal fund, which will increase the amount of funds available for research and extension.

V.6.2.- Biotechnology in oil palm. Cenipalma has an agreement with Corpoica to conduct research on the diagnostic of the red ring (*Rhadinaphelencus Cocophilus*) isolating the

enzymes that cause biochemical changes in the plant caused by the presence of the nematode and producing antibodies that react with those enzymes (González, et al. 1994). Propagation of clean plantules for their breeding program is also an objective of this collaboration. A PhD student is working on the subject at Cornell.

Main institutions involved: Corpoica, Cenipalma, Cornell.

V.7.- Rice. This is one of the most basic staple foods in Colombia, as it is the main source of calories and proteins among the low income quintile of the population. It accounts for 5.6% of the value of production and its area harvested was 425,000 has in 1992 (Ministerio de Agricultura, 1993). Yields are among the highest in Latin America, thanks to the widespread adoption of the new semidwarf cultivars of the Green Revolution that were released from the 1970's. The Federation of rice growers has more than 50 years of creation. The national rice fund, of a parafiscal nature, constitutes the basis for rice research at Fedearroz and Corpoica.

V.7.1.- Research agenda. In Colombia, the triangle formed by Fedearroz with ICA and CIAT has had a very strong research program in the framework of a collaborative effort of public and private sectors as well as of national and international institutions. Variety release has been very active (16 varieties since 1972). Crop management has been a priority too. A study of economic efficiency conducted between Fedearroz and CIAT (Ramírez et al, 1993) found that, on average, this index is of 72%; a totally efficient farmer would get an index of 100%. Perhaps, the most important result of this research is the fact that the gap among farmers is quite large. The cuartile with lowest efficiency have an efficiency index of 45% while the one with highest efficiency has an index of more than 95%. The rice technology has been generated but it is not widely applied, due to restrictions of capital, lack of knowledge and uncertainty about certain practices that have not been thoroughly tested under diverse agroecological conditions. In terms of priorities, adaptive research on crop management alternatives must be stressed, given the high expected returns that can be obtained with low levels of investment.

V.7.2.- Biotechnology in rice. CIAT has been very active in this area since the 1980's with important spillovers for Colombia. There have been collaborative efforts with Corpica and some Universities.

As part of the support to breeding programs in Latin America, this research has generated the theory of lineages that groups isolates of *Pyricularia Grisae* by genetic families and virulence. Gene tagging and fingerprinting are the main techniques applied. One thesis at Universidad de los Andes was supported.

For Hoja Blanca Virus (HBV) and Rhizoctonia, molecular transformation techniques (protoplasts and immature embryos) are being applied. There are no known sources of resistance for Rhizoctonia. CIAT took one gene (RIP from Maxplant) that has shown

efficiency in tobacco, to clone it and produce a transgenic plant with resistance to the pathogen. There is one M.Sc. thesis student working on this subject as well.

In the field of anther culture, extensive research was done on developing protocols and media for several types of rice (indica, japonica and intermediate cultivars). This work has been important in speeding up breeding and reducing its costs (Sanint et al, 1994); it also has other advantages, as a tool for other biotechnology activities and for hybridization of rice. Corpoica has trained two scientists in this technique.

CIAT has been characterizing the rice base of Latin America which, of course, includes Colombian varieties.

V.7.3.- Summary. Crop management research needs to be strengthened, possibly at the expense of breeding in Colombia, given the wide gaps in economic efficiency that exist among farmers. Colombia has maintained a very close collaboration with CIAT in rice research, which explains in part why the country has yields that are among the highest of Latin America.

Main institutions involved: Corpoica, Fedearroz, CIAT, Universidad de los Andes, Purdue, Cornell, IRRI.

V.8.- Cassava. This is an important crop, particularly for small farmers. It represents 2.6% in the value of agricultural production. Cassava occupied 180,000 has. in 1992 (Ministerio de Agricultura, 1993). Dry cassava production started at a commercial scale in the late 1980's based in small farmers cooperatives; currently, the country produces 50,000 MT and it is proving that is quite profitable to the farmers involved. In terms of Domestic Resource Cost, it is more effective than growing sorghum (Sanint, 1987). There is a high and growing demand for fresh cassava but unless marketing constraints are reduced, marketing margins will remain high and market access will be quite restricted.

V.8.1.- Cassava constraints. This is a highly perishable crop; consequently, marketing margins are high due to crop losses in transportation and commercialization. Dry cassava can substitute grains in feed diets. It is also a source of starch, but it does not compete well with other starch sources. The plant is not propagated by sexual seeds but by stalks. Somaclonal variation is high and difficult to assess until harvest time.

V.8.2.- Cassava research: a case of incongruent policies. Being a small farmer's crop, many institutions have paid attention to this crop. CIAT has a program on cassava since the 1970's and so does ICA. In the 1980's, the integrated pilot projects for dried cassava plants were implemented by those two institutions, together with DRI and other local institutions. The program contemplated breeding and crop management systems, technology for drying cassava and was based in farmers' cooperatives for producing and commercializing the dried cassava. The integrated approach was quite successful and drying plants proliferated. However, as a result of the opening up of the economy, large

imports were allowed from Thailand in 1992, threatening the survival of those cooperatives. This case illustrates how important it is to have congruent policies a t the macro level and in Research and Development. A careful effort of more than ten years can be lost by one careless decision. Given its ability to grow on marginal lands, its intensive use of labor and its vastly unexploited yield potential, cassava appears as a strong candidate to contribute to the welfare of small farmers throughout Colombia and should be a permanent priority in agricultural policies.

V.8.3.- Cassava biotechnology. There are a number of projects at CIAT related to the plant and its uses.

Colciencias and the CIF (Centro Internacional de Física, Universidad Nacional de Colombia) are sponsoring research on the genome of cassava. Their interest is in the methodology more than in the crop. There is a M.Sc. student being supported.

The method for cryoconservation of cassava is being improved to have duplicates of the world collection of cassava in a safe, efficient manner.

There is also work on the mechanisms of C-O2 fixation to better understand the C3 and C4 debate around cassava photosynthesis process.

In post harvest research, a key activity in cassava given its high degree of perishability, there are two projects on starch production and one on post harvest deterioration of cassava. One starch project is on methodology development for transformation leading to manipulation of starch by cloning the genes of branching enzymes to, subsequently, transfer them. Additional work is being done on the characterization of amylolytic acid bacterias from cassava sour starch fermentation (CIAT, 1993). The project on post harvest deterioration of cassava is just on the pipeline. The high perishability is a major limitation of fresh cassava commercialization and, therefore, to its consumption.

Meristem culture is now a routine activity, helpful to germplasm interchange and cleaning material.

V.8.4.- Summary. Several of the biotechnology activities in this crop are not ready for farmer's use yet. Meristem culture does not compete commercially with the use of properly disinfected stalks, given the substantially higher costs of the plantules, when compared to the low cost of stalks and of the fungicides used to disinfect them through a simple process of immersion before planting. The research program in this crop appears well balanced from the plant to its production, its processing and its commercialization. The collaboration of CIAT with local organizations constitutes an example of interinstitutional work of national with international agencies. Biotechnology appears as a good complement in breeding, biological control and post harvest research.

Main institutions involved: CIAT, Universidad Nacional, ICA, DRI, PNR, Universidad del Valle (Microbiology), SAR/CIRAD, ORSTOM.

V.9.- Beans. Another small farmer's crop, accounted for 1.7% of value of production in 1992 when annual cultivated area was 127,000 has. (Ministerio de Agricultura, 1993). The crop is found in the andean hillsides, often being intercropped with maize, cassava or coffee. It is an important source of vegetal protein for the population. Its short cycle of production and small cash requirements makes it very attractive to mix with tree crops as well.

V.9.1.- Crop constraints. There are several types of beans according to the tastes and preferences of each region. Beans are very susceptible to all kinds of diseases and pests.

V.9.2.- Bean research. Both ICA (and now Corpoica) and Cenicafé have had close collaborative projects with the bean program at CIAT. Several varieties have been released. Producers' associations are small and do not have the capacity to finance major research activities.

V.9.3.- Bean biotechnology. As in the case of cassava and rice, this activities are conducted at CIAT but have participation from universities, for training, and ICA-Corpoica for research.

Polyanthers of common beans and embryo rescue of interespecific crosses are being done by Corpoica-Rionegro.

Germplasm characterization is done with Corpoica. Development of markers for mapping is done with Universidad del Valle.

Identification of a resistant factor against bruchids (*acantocelides*) at the molecular level to tag gene of resistance as a complement to the breeding work done on this subject is also an important complementary activity.

One of the first works done at U. Nacional was on bean rugous mosaic virus. At CIAT, there has been intensive work in gene tagging for the golden mosaic virus and for anthracnosis.

V.9.4.- Summary. Bean research has still to deliver a clearly superior variety to dynamize its stagnant production. After years of traditional breeding disappointments, biotechnology may offer some helpful hints and tools to make the breakthrough. In that sense, biotechnology will not produce finished products by itself, but intermediate methods to strengthen research programs.

Main institutions involved: Corpoica, Universidad Nacional, CIAT, Universidad del Valle.

V.10.- Potatoes. This is a crop that has increased yields substantially in the past years, thanks to new technologies and cultivars. In 1992, there were 150,000 cultivated has. that accounted for 5.7% of the value of production. (Ministerio de Agricultura, 1993). Potatoes are produced in high altitudes, mainly by small farmers.

V.10.1.- Research. CIP has had close collaboration with ICA and Corpoica. The breeding program has released several varieties and crop management aspects have also been researched. One important constraint in potatoes is the presence of viruses that handicap its ability to yield well.

V.10.2.- Biotechnology. Several institutions have been very active in the production of disease free potato seed (U. Nacional in Bogotá and Medellín, U. Católica de Oriente, ICA-Corpoica, Meristemos S.A.). The seminal work started at the Universidad Nacional when, in 1990, they brought 4 certified varieties from CIP and micropropagated them. With funds from PNUD, the PBX virus was isolated, purified and antibodies were produced, establishing the ELISA technique. The purpose now is to produce transgenic potato plants to introduce the virus that codes for the PBX, PBY and PBS viruses. There is still an unfulfilled demand for high quality clean seed from the private sector due to the low capacity in the country to scale up the clean material for commercial sales. Recent interest has also focused on "papa criolla" (*Solanum phureja*). Several companies are interested in financing activities related to clean seed (Papas Margarita, Distriaves, as well as Fedepapa and individual growers). IBUN (Instituto de Biotecnología de la U. Nacional) has been a crucial institution in the advancement of these activities. The creation of the Corporation for the Development of Biotechnology, sponsored by IBUN, intends to eliminate these bottle necks by undertaking these commercially oriented activities at market scale.

V.10.3.- Summary. The disease free seed is a visible product that is reaching farmers at costs that are comparable with the cost of certified seed ($600-800/kg or US$0.75-$1.00/kg). The impact on potato production is significant, with yields up 30% or more from regular infected material. A certification system is still needed to guarantee top quality seed.

Main institutions involved: Corpoica, CIP, Universidad Nacional (IBUN and Medellín), Meristemos, Fedepapa, Universidad Católica de Oriente, University of Gembloux.

V.11.- Cotton. This has been an important export crop that was decimated by recent government policies. In 1992, there were 210,000 cultivated has. that accounted for 3.2% of the value of agricultural production. (Ministerio de Agricultura, 1993). This crop is cultivated in the interandean valleys (long fiber) by capital intensive methods and in the coast mainly by small farmers.

V.11.1.- Research issues. A main problem of cotton production is the high cost of pesticide application for insect control. In Colombia, there is a system that bans cropping

in one semester in each of the two major producing areas, alternating to cut pest cycles. Pesticide use got out of control in the late 1970's and costs of production soared out of control.

V.11.2.- Biotechnology in cotton. IBUN (Instituto de Biotecnología de la U. Nacional) and CIB (Corporación para las Investigaciones Biológicas, a private company from Medellín) have a collaborative project on the use of *Bacillus Thuringiensis*. CIB wants it for human applications while IBUN is interested in control of lepidopterus. IBUN is stronger in molecular biology while CIB's advantage is in biological trials. With the National Federation of Cotton Growers, FEDERALGODON, several comparisons of imported bioinsecticides with those produced at IBUN were made with outstanding results for the IBUN material. With Vecol (a semiprivate lab that is being privatized), the strains classified by CIB will be scaled up for industrial commercialization. There is close collaboration with the Instituto de Biotecnología of UNAM (México) in this subject, where a colombian Ph.D. student is currently doing research. The bacillus project has many spill overs for potatoes, tomatoes, tobacco, etc.

V.11.3.- Summary. Biological pest control is a cheap and clean way to fight harmful insects while protecting beneficiaries. The work on Bacillus Turigiensis is very relevant, given the spill-overs it has for control of many insects that have alkaline ph factor, which is what triggers the toxin in the Bacillus.

Main institutions involved: Universidad Nacional (IBUN), UNAM (México), CIB, Federalgodón.

V.12.- Maize. This is an important crop for small farmers that has had strong competition from subsidized grains abroad. In 1992, there were 700,000 cultivated has. that represented 4.8% of the value of agricultural production. (Ministerio de Agricultura, 1993). Technified maize represent only 93,000 has. with an average yield of 2.8 tons/ha. The rest (about 600,000 has.) correspond to traditional farmers.

V.12.1.- Research issues in maize. There are two types of maize farmers: the entrepreneurial and the small subsistence ones. They demand different technologies and use different varieties. Large farmers have access to hybrids and packages that are intensive in input use, including irrigation, to obtain relatively high yields. For the small farmers there is lack of improved varieties and available seed is scarce and of low quality. Spodoptera is a manageable pest.

V.12.2.- Biotechnology in maize. Little has been done in Colombia with this important crop. Perhaps, FENALCE should pay more attention to research. CIMMYT, which has headquarters in México and outposted scientists in Palmira, at CIAT, has done work in the areas of:

- molecular transformation

- haploids
- tissue culture
- germplasm characterization
- genome

V.12.3.- Summary. There is lack of support for maize research, a crop dominated by small, traditional peasants. The crop has been also hit by recent liberalization policies as commercial farmers find it difficult to compete, under the present circumstances of abandonment, with subsidized foreign imports which, by 1993, amounted to 500,000 MT.

VI. Diffusion of biotechnology products

Diffusion depends both on supply-pushed and demand-pulled factors. The interest, both by the direct users (farmers) as well as by the end users (society) of the new biotechnology-related input, constitutes the basis for the demand. The supply of the new invention depends on the incentives to develop the results of research, the risk involved in the operation, the capital needed for the implementation and the competitive edge that the new alternative offers to the farmer. The interest in the application of the biotechnology by the user is enhanced by the existence of a mechanism that links farmers to researchers, by the relevance of the research line to the user, and by the profitability and the viability that the use of the new input or technique can generate.

When judging sustainable alternatives, the supply and demand signals must reflect the long terms objectives of society as a whole. This is an interesting twist from pure market mechanisms, where the user would be the farmer and the supplier would also be the private sector, and their preferences and costs are the ones that dictate what is marketed. The existence of this intermediate decision-maker implies that, when needed to "make the market work to satisfy common needs", the state must intervene in the supply of the technology, the demand or both ends of it.

Adoption of a new technology goes beyond its diffusion, since adoption implies a somewhat permanent use of an appropriate technology. To ensure this permanence, the product or practice has to go through a series of validations and field tests, within a comprehensive crop management effort. The issue of appropriate technology involves the identification of target farmers and ecosystems. Therefore, it is quite clear that the diffusion of biotechnology products with a sustainability goal implies a complexity that is beyond the scope of a single institution and requires collaborative work.

Colombia has a tradition of strong producer associations; several of them now have their own research center or program (coffee, sugar, rice, oil palm, panela, bananas). This is a strength of the system that has to be pursued further to consolidate better research programs. Research supported by producers' associations have a high probability of adoption, given the direct involvement of farmers in setting up the research agenda and the existence of the continuum from researcher to extensionist to farmer. The private

sector has increasingly recognized the benefits from supporting research. In Colombia, this has been an efficient vehicle for research and, towards the future, the model of research by producers' associations is gaining importance. Therefore, the state should put priority in the design of mechanisms leading to influence their research agendas by means of clear incentives (fiscal deductions, pay-back mechanisms, etc.) for research on strategic issues of social interest, conducted by the private sector. This private action must be inserted in a system of concertation, to conform a mechanism where all beneficiaries of the technologies (producers and consumers) not only decide what should be produced but where they also jointly pay for their research and development. The producers are paying by using resources from the parafiscal funds. Consumers can pay, through the goverment collaboration in those schemes and by giving subsidies to the associations that work on strategic issues. The process of privatization of research in Colombia needs to be closely checked by the public sector, to arrive at sets of domain on both sectors that keep a balance of private and public interests, both in the short and long term, according to the advantages of each one.

Private profitability is a prerequisite for adoption. Here, also, the state can subsidize certain sustainable biotechnology products and/or tax the alternative pesticide-based practices to promote adoption. In this sense, the recent, indiscriminate tariff reduction on pesticides is not a move in the right direction; there are more creative alternatives to increase the efficiency, competitiveness and profitability of agricultural activities. The viability refers to the investment requirements: even if a new alternative is profitable, it may require a capital investment that is beyond the ability or preference of the farmer. Although the individual producer makes the ultimate decision for use, society as a whole must be involved in the process, to ensure that private interests do not prevail over the public welfare.

As mentioned earlier, the 1991 science and technology system in Colombia is still at incipient stages of implementation; it has many gaps in the process of establishing agricultural research priorities that are congruent with the national interests, since the latter are not clearly and explicitly stated. At a different level, to establish priorities on processes, there is a major obstacle, since many research programs are rather weak; in that case, it is difficult to establish the need for biotechnology within a given program, or its efficiency, complementarity and comparative advantage when compared with other processes. At the operational level, there is not a system of research in biotechnology; there are, in most cases, insular activities (CEGA, 1993).

The participation of universities in the process deserves a particularly important mention. In biotechnology, these institutions received a significant share of the physical infrastructure as well as the human capital to carry out this research activity (Torres, 1993). Yet, as Moreno points out, the relations between the university and the private sector are characterized by their informality and the lack of a strong and solid interaction, that has, at its root, the obsolete and inadequate legislation and the underdeveloped capacity of the universities to negotiate with the private sector (Moreno, 1994). The

debate around the convenience to create in Colombia a similar entity to CIT-UNAM (the intermediary that exists in Mexico to foster these linkages) or even to modify one already in existence to include this activity in its mandate, should be a priority issue.

VI.1.- Market and non-market mechanisms. In some instances, biotechnology products are clearly attractive to farmers as they are supplied and a market develops naturally around them. Products like flowers, bananas and plantains do not need much advertizing, since the market already generated an awareness for the advantages of using clean plantules. In Colombia, private companies supply mainly tissue culture products that are competitive with foreign suppliers (like in the case of bananas, plantains and flowers) and biopesticides that have some internal competition. Unfortunately, in those newly developed markets, the processes of certification are informal and depend on the seller, which constitutes a big risk for the consumer and for the credibility of the system, when unscrupulous suppliers enter the market.

Producers' associations have also other channels to diffuse the products as a service to the producer who, through many years of having received these services, has developed a high degree of confidence in their services. This is the case of the use of *Beauveria Bassiana* in coffee, a biopesticide that is recommended and taken directly to farmers' fields by extension agents from the Coffee Growers Federation. The same applies to *Bacillus Thuringiensis* with the Federation of Cotton Growers or the use of clean potato seed with Fedepapa.

There are a number of works at the public sector that do not find a way to the farmer; many thesis on tissue culture of a great number of crops die at the stands of the libraries because they were not known or were not relevant. This should not be repeated, but depends on whether or not the universities can develop better interinstitutional arrangements with agricultural research institutions and private firms, since the key to useful research is its relevance and universities, by themselves, are not well positioned to detect priorities.

A case that is somewhat puzzling is the research on the CTV (citrus tristeza virus) done at the Universidad Nacional; it is relevant, has an enormous potential payoff in the medium term, is strategic in nature and, yet, no one seems to care, except the citrus growers from the US, a country where the virus has not arrived. Obviously, there is no such a thing as a program for citrus research in Colombia. It is the responsibility of producers and researchers to repair this problem. The marginal pay-off of such effort would be enormous.

VI.2.- Comparative advantage of biotechnology products versus other options: costs and acceptability. In the case of flowers and musaceas, the costs are not an impediment to widespread acceptance of the plantules. They compete well with imported materials. The use of the traditional, contaminated sprouts is clearly non-competitive in the mid-term, when diseases handicap the performance of the new plant. The same could be said

about the use of virus-free potato seed, although it is early to tell, since the market share is still very low due to slow expansion in the multiplication and scaling up of the technology. In the case of *Beauveria Bassiana* against the coffee borer, acceptance is good but there are problems of uncertainty, as the practice has a high degree of dependence on climatic conditions; the farmer has to determine optimal humidity and temperature conditions suitable for establishment of the fungus. The coffee research program aims at an integrated crop management alternative, involving planting densities, shading, fertilization, pruning, intercropping, use of pesticides, etc. There have been complaints about the presence in the market of certain brands with very low aggressiveness. The state action here should be in the certification of the products and in providing incentives to novel users of the technology, by subsidizing the fungus; taxing the pesticides can also help to foster the use of the fungus against the use of the pesticide as the relative prices of both options is biased in favor of the new, sustainable alternative.

VI.3.- Equity aspects of the research: small farmers acceptability and need. Among selected crops, there is a bias in favor of research on high value crops for large and capital intensive farmers (bananas, sugar cane, flowers, fruits). Relevant work already available to small farmers has been done in coffee, potatoes, bananas and plantains. Of those, only the fungus to control the coffee borer is cheap or can even be homemade. Plantules of musaceas and clean potato seed are relatively expensive and imply a cash outflow. Liquidity is usually a major constraint to small farmers; as has been long established, special subsidized credit lines have never been very effective, since credit is highly fungible (money is money no matter where it came from) and subsidies usually induce the presence of black markets that end up favoring farmers outside the target group (Adams, 1971). Specially targeted diagnoses, like the one conducted by ICA-Corpoica and the DGIS for the Colombian Coast, constitute a rational way of identifying how biotechnology products can efficiently solve real problems among small farming communities.

But the main equity issue arises at a higher level. Typical questions of what, how, by whom, for whom, when, where and how much should not be left to the dictamen of a fragmented system. What should be the balance between private and public sectors in the research bill? How much to invest in biotechnology when applied research, and even research programs, are almost nonexistent or are poorly articulated? How much should society invest in training sophisticated scientists when education indicators for the bulk of the population are so poor? How much should be invested in capital intensive crops that apply increasing amounts of pesticides and pollute air and water, at the expense of research in food staples that can be produced in a more sustainable manner? How to reward a scientist working in routine, applied research issues of national priority versus the one that concentrates on fancy, sophisticated and glamorous techniques of their own private interest? It also requires a clear awareness of the current state of all links in the long chain of research, extension and training. Overemphasizing research in biotechnology is like having a shining gold cupula on top of a 20 stories wreck. There is

a question of balance, graduality and selectivity in the process of strengthening the research capacity of the country. The answer requires that the national science and technology system has a clear mission, with explicit objectives and goals, that are the product of a broad concertation and that respond to long term sectoral priorities based on the overall objective of a sustainable development.

The establishment of priority crops must consult both aspects of technology development: the supply and the demand side. On the supply side, technology design must conform to the requisites of sustainable development. But the end user's characteristics must also be incorporated (see point II.7 above). This needs a thorough analysis of the resource endowment of farmers, including their agroecological characteristics, i.e. of the different development paths. The crossing of both exercises yields priority crops or themes for priority types of farmers. Then comes the issue of prioritizing among processes, research tools and the role of biotechnology within it.

These are just but a few of the questions concerning the most efficient way in which biotechnology can serve as support of a national research program. Research priorities must be the subject of society as a whole. Research and development of the technologies cannot be left in the hands of the private sector exclusively because there will be a bias in favor of their own interests. On the other hand, it cannot be left out in the hands of the public sector alone because it does not have the mechanisms to efficiently identify priorities and the system will lack accountability.

In summary, there is an acceptable diffusion of several biotechnology products that found a substantial market almost instantly, as is the case of clean plantules of flowers, bananas, plantains and, to a lesser degree, potatoes. Biological control products have been more dependent on non-market mechanisms, like the decided action of producers' associations to disseminate the technologies. There is a clear need for official certification of these products. Products that lack a sound research program are unable to fully incorporate biotechnology innovations, as efforts remain fragmented and products can not follow all the necessary steps required to make of a new discovery an adopted practice at the farm level.

Although the issue of sustainability is mentioned by policy makers, there does not seem to exist the explicit effort to promote the substitution of harmful pesticides by biological products. The recent indiscriminate reduction of tariffs for pesticides is not a step in the right direction, since market signals here do not necessarily reflect the best interest of society nor lead to a sustainable development. There is need for a more decisive support from the state to research that seeks to reduce pesticide use, like the IPM programs and the biotechnology activities that support them. The use of Beauveria in the potential one million hectares of coffee should not be viewed as profitable to farmers only: it is the best investment this country can do in its hillsides. Society as a whole, and not only the coffee growers, should be willing to pay for it.

The issue of biotechnology at the reach of small farmers is also relevant to the objective of sustainable development. Again, poverty is a poor advisor on issues of natural resource use. Biotechnology products, if left to the market forces alone, may lead to a widening of disparity in the rural sector, something that is clearly not sustainable in many ways. The interinstitutional and multidisciplinary approach must be supported by a clear political will to encourage prosperity along this crucial development path.

VII. Future developments

The integral implementation of the new S&T system should follow a gradual, selective and clear sequence, starting with a revision of research programs for priority activities; the research centers with producers' support represent an obvious starting point. The decentralization of a system that remains centrally coordinated, with the creation of the regional councils, is also an important step in the right direction. S&T has to be a topic of interest for everyone, everywhere.

The proposed Corporation for the Development of Biotechnology (see IV.5 above) has a clear role to play in integrating the system and increasing the flow of products and information in biotechnology. The whole system of science and technology is still more theory than practice. It is important to guarantee a broader participation of producer associations in the councils. It is better to have fewer but relevant people than too many and too unique that do not represent democratic interests.

Given the nature and high value of equipments for biotechnology, it is important to concentrate activities at a regional or subregional level and avoid the atomization of labs and equipment. The Regional Program for Biotechnology in Latin America, originally sponsored by PNUD/DRLAC is one good initiative that should be strengthened to create an apparatus for joint discussion of common needs, execute collaborative projects, have joint training teams, communication networking and interchange of scientific personnel. To have a truly useful instrument, the program should be financed entirely by participating countries, to ensure control of the agenda, continuity and sense of belonging.

The international centers in the CGIAR can fill a vacuum of leadership in the region, by reemphasizing activities related to germplasm, breeding and biotechnology. They should become "centers of excellence" in these fields, by taking advantage of their credibility, capacity to obtain economies of scale, avoid duplication of efforts and exploit their internationality by fostering links with researchers from countries within the region and from outside. These centers should house an advanced equipment and a highly specialized group of scientists. Their core resources should be directed to key, priority processes, while they should be in a position to execute research on contract and serve as training camps, as well. Given the scarce resources for development in the region, this model allows countries to execute high level research as a complement to their research programs without having to pay the whole price of expensive laboratories and highly

specialized personnel, while achieving important cost savings by sharing responsibilities in costs and management.

On the other hand, Colombia benefits most by pooling research resources from producers associations and governments of neighboring countries to tackle common subregional research needs. The maturity that the country has in the collaborative research efforts between private and public sectors can be an asset to lead these processes to a sure reality.

Among the case studies reviewed in this document, the commodities that have a solid producers' association backing up their research and extension programs are the ones that have stable and well focused activities; they are using biotechnology as a complementary tool in the research process.

There are three commodities that have been most effectively taking advantage of international facilities: coffee, sugar cane and rice. Coffee presents the most sophisticated model, reflecting the importance of the crop and the maturity of its producer organization in the country. Biotechnology is used to complement their breeding efforts and also where the other disciplines are not an effective tool to tackle the problems at hand. As they already have a solid research apparatus, they are now building up their human capacity to consolidate a stronger biotechnology program. In doing so, they are creating bonds with major research institutions in the U.S. Given the nature of coffee research in the world, characterized by secrecy and little collaboration, this strategy seems rather sound. Sugar cane has a different, but effective, approach. Instead of building their own big biotechnology capacity, they have a modest activity to back up their breeding. The more ambitious activities in biotechnology are undertaken jointly, through an international network, where several partners contract works with research institutions in the developed countries. Rice also has a strong research program, that contracts activities with Corpoica. But FEDEARROZ has also had strong ties to CIAT's rice program, which gives them direct and first hand access to the biotechnology activities of the international center, rather than attempting to create their own biotechnology program. Recently, and given the reduction of CIAT's efforts in irrigated rice, FEDEARROZ became part of an initiative leading to create a consortium of Latin American countries that should form their own regional research program with the participation of CIAT and IRRI. The regional consortium will control the agenda and the execution of the research programs. Support of current CIAT biotechnology activities appear as a priority to the group.

There is an intermediate group of crops that have producer-based research programs, like oil palm, bananas and flowers. They are using the national biotechnology capacity in universities, public research institutions and private firms in a relatively effective way. Cotton belongs to this group as well, but the recent economic stagnation of the activity in Colombia has deteriorated their research capacity in a significant manner. The articulation of the universities to the process must be more proactive. With those commodities, the state has to provide mechanisms to warrant the efficiency of their own

research and should influence the agenda towards national (rather than purely private) objectives, by contributing resources for certain activities that are not a top priority for producers but are high on the list of the country's interest.

Then, there are a group of commodities that do not have strong producers' associations supporting their research. The instability and relative isolation of the public institutions in charge of their research has led to rather weak programs at best. In many cases, there are just a few fragmented activities that do not conform a well focused program. The lack of continuity in sectoral programs have also affected those crops. These are mainly food crops (potatoes, cassava, maize, beans) that are important to the diets and also to the economy of small farmers throughout the country.

Fruits can be classified in a final group, where much has been said about their future potential, both as a source of foreign revenue and in the internal markets. Yet, there is little producer support to research and the public activities lack focus and resources.

In this last group of commodities, it is imperative for the country to take a hard look at the priority that those crops should have and, if they are important, foster producer organizations and strengthen their public research programs.

Finally, Colombia is going through a period of deep transformation of the state and its economy. It is early to tell how efficient the new system can be but there is an iterative, more open and participatory process. The basis is laid for increased coherence but there are some obvious gaps in the establishment of priorities and in overcoming the isolation and individualism of key actors in the S&T system that merit all the attention from society as a whole. The attention on the biotechnology issues is coming from the executive and the legislative branch of the Government; currently, the other branch, the judiciary, is rather weak and has overwhelming priorities; it does not have the capacity and the time to tackle intellectual property issues of a highly complex and specialized nature. In the case of biodiversity and the environment, for example, the problem is not the lack of laws, but the lack of a capacity to enforce them and the little awareness of the public to help in the process.

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List of Acronyms

ACOSEMILLAS	Asociación Colombiana de Productores de Semillas
Andean Group	Economic union integrated by the andean countries
AUGURA	Asociation of private banana exporters of Urabá
BYU	Bringham Young University
CEGA	Centro de Estudios Ganaderos y Agrícolas
CENIBANANO	Centro Nacional de Investigaciones del Banano
CENICAÑA	Centro Nacional de Investigaciones de la Caña de Azúcar
CENICAFE	Centro Nacional de Investigaciones del Café
CENIPALMA	Centro Nacional de Investigaciones de la Palma de Aceite
CIAT	Centro Internacional de Agricultura Tropical
CIB	Corporación para Investigaciones Biológicas
CIF	Centro Internacional de Física, Universidad Nacional de Colombia
CIMMYT	Centro Internacional de Mejoramiento de Maíz y Trigo
CIP	Centro Internacional de la Papa
CIRAD	Centre de Cooperation Internationale en Recherche Agronomique pour le Development
CIT	Centro de Innovación Tecnológica, UNAM
CTV	Citrus Tristeza Virus
DNA	Deoxyribonucleic Acid
EEC	European Economic Community
FEDEARROZ	Federación Nacional de Arroceros de Colombia
FEDECAFE	Federación Nacional de Cafeteros de Colombia
FEDEPAPA	Federación de Productores de Papa
FEDEPALMA	Federación Nacional de Productores de Palma de Aceite
FEDERALGODON	Federacion Nacional de Algodoneros
FENALCE	Federación Nacional de Cerealeros
GATT	General Agreement on Trade and Tariffs
HBV	Hoja Blanca Virus
IAAE	International Agency for Atomic Eenrg
IBUN	Instituto de Biotecnología, Universidad Nacional de Colombia
IDRC	International Development and Research Centre
IIBC	International Institute of Biologic Control
IICA	Instituto Interamericano de Cooperación para la Agricultura
INIBAP	International Network for Improvement of Bananas and Plantains
IPGRI	International Plant Genetic Resources Institute
IRRI	International Rice Research Institute
ISNAR	International Service for National Agricultural Research
LIQC	Laboratorio de Investigaciones Químicas del Café
M.Sc.	Master of Science
NRI	National Research Institute
ODA	Overseas Development Administration, England
ORSTOM	Organization de la Recherche Scientifique des Territories d'Outre Mer
PBR	Plant Breeders' Rights
PCR	Polimerase Chain Reaction
PhD	Philosophy Doctor
PNUD (UNDP)	United Nations Development Program
RAPD	Random Amplified Polimorphism of DNA
RFLP	Restriction-Fragment Lenght Polimorfism
R&D	Research and Development
S&T	Science and Technology
UNAM	Universidad Nacional Autónoma de México
UPOV	Union pour la Protection des Obtentions Végétales

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Table 1. Percent share of selected crops in agricultural value of production, Colombia, 1982 and 1992.

Crop	**1982**	**1992**
Coffee	20.9	20.2
Sugar Cane	17.4	17.9
Bananas, plantains	10.7	11.6
Flowers	3.0	7.1
Fruits	1.6	4.5
Oil Palm	1.8	4.5
Rice	8.9	5.6
Cassava	3.3	2.6
Beans	1.4	1.7
Potatoes	7.4	5.7
Cotton	2.2	3.2
Maize	5.6	4.8
Subtotal 12 crops	84.2	89.4
Total all crops	100.0	100.0

Source: Ministerio de Agricultura, Anuario Estadístico 1982-92.

Table 2. Percent variation of internal sales of insecticides, fungicides and herbicides in Colombia, in terms of active ingredients (tons.), 1980-1989.

Year	Insecticides		Fungicides		Herbicides		Active Ing. total	
	Ton.	%	Ton.	%	Ton.	%	Ton.	%
1980	3641	100	4310	100	4321	100	12572	100
1981	3159	87	4453	103	4599	100	12211	97
1982	2836	78	4814	112	5203	113	12853	102
1983	3237	89	5445	126	5672	123	14354	114
1984	3523	97	5936	138	6001	130	15460	123
1985	3912	107	7021	163	6113	132	17046	136
1986	3671	101	6301	146	6257	135	16229	129
1987	3912	107	12937	300	6530	141	23379	186
1988	4538	125	10682	248	6096	132	21316	170
1989	3478	96	9067	210	7205	156	19751	157

Source: Vergara, 1991.

Table 3. Participation of highly trained researchers for the agricultural sector: private capacity as compared with the public sector in Colombia.

Year	PhD Publ.	PhD Priv.	MSc Publ.	MSc Priv.	Prof. Publ.	Prof. Priv.	Tot. Publ.	Tot. Priv.	%ICA Publ.
1980	35	3	142	23	203	41	280	67	100%
1985	55	11	182	38	240	85	477	134	95%
1991	105	24	301	64	75	196	493	284	90%

Publ=Public; Priv=Private; M.Sc.=Master of Science; Prof= Professors; Tot=Total; %ICA= share in ICA.

Source: Falconi, César. 1993. May, pag. 12.