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RIS Discussion Papers

Biotechnology in South Asia: Issues, Concerns and Opportunities

Sachin Chaturvedi

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Biotechnology in South Asia: Issues, Concerns and Opportunities

Sachin Chaturvedi*

I Introduction

In the recent past, biotechnology is being seen as an instrument for addressing food security concerns and consequently as an important component in the poverty reduction strategy. The various achievements in biotechnology are encouraging, especially keeping in view the growing productivity stagnation in agriculture in last few years. The biotechnology is being seen as a major force for economic development in South Asia, despite of the fact that there is a strong limitation of funding, infrastructural facilities and experienced manpower. In the last decade or so all most all the countries in the region have initiated some activities in biotechnology. These programmes are largely designed keeping agriculture sector at the centre stage. Even within this sectoral choice national requirements and needs are effective in their own way. For instance, in Nepal food security is the stated objective of biotechnology policy while Bhutan is attaching more importance to the efficacious *ex-situ* conservation of biodiversity through Renewable Natural Resource Centres (RNRCs). Sri Lanka has very high emphasis on ethical aspects of biotechnology related research.

It seems that South Asian region faces a major challenge in terms of governance of biotechnology. The regulatory aspects of biotechnology need an urgent attention in the region. The biosafety regulations in some countries are not in place while others have to work further on the gaps between Cartegena Biosafety Protocol and their national legislations for effective management of biosafety. There are certain other major challenges which the region should

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address on priority such as the trade in GMOs. Though this is being addressed in various committees of WTO but it would be in the interest of the region to work out a common position as it concerns conservation of biodiversity in the sub-continent. The South Asian region also needs to consider issues like whether Convention of Biological Diversity (CBD) should prevail over WTO as has been proposed by several other developing countries. The trends in IPR regime within biotechnology also needs to be analyzed from the perspective of access to technology in the region. This paper identifies some of these key issues in South Asia in light of the national strategies adopted by various member countries and also attempts to identify the contribution of international agencies in advancement of biotechnology in South Asia.

II Trends and Status of Biotechnology

II.1 Bangladesh

In case of Bangladesh there is a clear policy emphasis on applying biotechnology in the agricultural sector, primarily to ensure, food and nutritional security and also for enhancing the export earnings by supporting industries like tissue culture and such other activities. In this context, a national guideline is being evolved to develop high yielding varieties of seeds with genetic modification at the indigenous research institutes. Bangladesh in 1993 appointed a National Committee on Biotechnology Product Development. The committee had the responsibility to identify key areas in which Bangladesh could commercialize agriculture related products. Recently, Bangladesh has also passed the "Biosafety Act 2001".

Bangladesh, being the party to the Convention on Biological Diversity (CBD) has undertaken an international commitment to prepare a National Biodiversity Action Plan. Several biodiversity-related programmes and projects are now at the implementation stage. Bangladesh is also targeting at achieving self-sufficiency of food grain through the introduction of biotechnology. The Government has established National Institute of Biotechnology under the Ministry of Science, Information Technology and Communication. This Ministry would take care of the research activities while the Ministry of Environment and Forest would look into the management aspects of biotechnology activities. In Bangladesh, Biodiversity and Community Knowledge Protection Act and Plant Diversity Act are also under review for possible enactment. Ministry of Environment and Forest is the notified national focal point for biosafety protocol also.

II.1.1 Institutional Infrastructure

The National Council for Science and Technology (NCST) is the key agency to work on development of technology in Bangladesh. On the recommendation of NCST Bangladesh government decided to establish a National Institute of Biotechnology. The institute would work as the central coordinating research centre under the Ministry of Science and Technology, Government of Bangladesh. The institute would have six major research laborateries on DNA technology, plant biotechnology, animal biotechnology, fish biotechnology, formation and bioprocessing, and bioenergy and fertilizers.[1] The institute would also be supporting and guiding biotechnology research across various research laboratories, universities and other institutions engaged in biotechnology.

There are several government supported research organizations engaged in biotechnology; for example, Bangladesh Atomic Energy Commission (BAEC), Bangladesh Rice Research Institute (BRRI) and few crop specific research institutes.[2] Apart from these institutes, there are 12 science universities and 30 private universities, which have some programmes of biotechnology. Some of the leading NGOs in agriculture plant biotechnology include Debtech and Proshika, which are working in the tissue culture sector.

In case of Bangladesh it is often felt that the duplication of research work may be avoided with improvement in the communication between the scientists of different research institutions and universities.[3] In this case mechanisms would have to create forums to be evolved to create forums to avoid such a situation. In this regard the Bangladesh Association for Plant Tissue Culture (BAPTC) has suggested to have a plant/crop specific national programme involving different agencies so that a comprehensive view may be taken on various initiatives. The outcome of such meetings will also ensure better coordination and fruitful collaboration between scientists belonging to different organizations.

II.1.2 Impact of biotechnology

In Bangladesh there is a strong movement for linking up tissue culture with wider activities of income generation. The BAPTC is regularly publishing a journal called "Plant Tissue Culture". The BAPTC also organizes biannual international meets to catch on with technology and international business. In the second international conference, a joint session of the scientists, journalists, investors, bankers, entrepreneurs was arranged with Professor Mohammad Yunus, the Founder Managing Director of 'Grameen Bank'. The objective of the session was to create an investment climate to set up tissue culture based industry in Bangladesh on the pattern of some leading Asian countries. The first two conferences created enough momentum for a few interested parties to consider seriously, setting up of a tissue culture based industry. Within two years as many as six companies were set up, BRAC (formerly, Bangladesh Rural Advancement Committee) laboratory being the largest. One lab was set up in Rajshahi focused mainly on commercial production of potato micro tubers. Now the Society is organizing the 5th International Conference in November, 2004.

Among the possible areas of application of biotechnology from the economic perspective include crops like rice and jute.[4] In Bangladesh rice production faces several problems. Major rice pests in Bangladesh include the Stem Borer and Brown Plant Hopper (BPH). Transformation of rice with the Bacillius toxin gene, Bt could be effective against the stem borer. BPH resistance is found in the wild rice variety. Two of the most important diseases of rice in Bangladesh are the Tungra viruse, Bacterial Leaf Blight and Blast. Resistance against viruses has been achieved in developed countries by inserting the coat protein gene of the effective virus in rice. Similarly, the major problem with lentil production is fungal infection causing great crop losses. Jute is one of the major cash crops which is the principle source of livelihood for several million people, including three million farmers. The major problem of jute is the pest and the fungus which adversely affect the crop. It is worth exploring if biotechnological approach like a systematic investigation by the bacteria bacillus thuringiensis in both the vegetative and the sporulation may help to identify suitable toxin effectiveness against the jute mite. Bangladesh Jute Research Institutes (BJRI) has over 2000 accessions of jute collected from South East Asia and Africa. Many have desirable properties like fungus resistance or flood tolerance. However, nothing is known about the jute genome. In this regard, research projects may be launched to identify useful markers with characteristics which could be identified by generating a suitable mapping or breeding population between commercial and otherwise useful cultivars. The process of DNA marking is a sufficiently advanced and sophisticated mechanism so may easily be undertaken.

The Food and Agriculture Organization (FAO) of UN has recently launched a technical cooperation programme on biofertilizers in Bangladesh. Under the Technical Cooperation Model Project, FAO is establishing a demonstration plant for the large scale production of Rhizobium biofertilizers in Bangladesh. It will also support extensive field trials to demonstrate to farmers the

effectiveness of biofertilizers in increasing the grain yields. Early field trials have already shown that the technology increases grain production by about 25 percent. Large scale adoption can thus save the country an estimated US$23 million per year in imported grains and some $6 million annually in imported chemical fertilizers.[5]

II.2 India

India is one of the first few countries to have recognized the importance of biotechnology as a tool to advance growth of agricultural and health sectors as early as in 1980s. India's Sixth Five Year Plan (1980-85) was the first policy document to cover biotechnology development in the country.[6] The plan document proposed to strengthen and develop capabilities in the areas such as immunology, genetics, communicable diseases, etc. In this context, referring to the Council of Scientific and Industrial Research (CSIR), the document suggested to ensure coordination on inter-institutional, inter-agency and on multi-disciplinary basis, full utilization of existing facilities and infrastructures in major areas including biotechnology. In India the programmes in the area of biotechnology include as mentioned in that document, application of tissue culture for medicinal and economic plants, fermentation technology and enzyme engineering for chemicals, antibiotics and other medical product development; agricultural and forest residues and slaughterhouse wastes utilization and genetic engineering and molecular biology.[7] Since then, the biotechnology sector, in India, has come a long way.

II.2.1 Institutional Infrastructure

An apex official agency, viz. National Biotechnology Board (NBTB) was set up in 1982, to spearhead the development of biotechnology. The NBTB was chaired by Member (Science) of the Indian Planning Commission and had representation of almost all the S&T agencies in the country viz. Department of Science and Technology (DST), Council for Scientific and Industrial Research (CSIR), Indian Council of Agricultural Research (ICAR), Indian Council for Medical Research (ICMR), Department of Atomic Energy (DAE) and the University Grants Commission (UGC). In 1986, NBTB graduated to a full-fledged government department called Department of Biotechnology.

At present in India, there are six major agencies responsible for financing and supporting research in the realm of biotechnology apart from other sciences. They are Department of Science and Technology (DST), Department of Biotechnology (DBT), Council of Scientific and Industrial Research (CSIR), Indian Council of Medical Research (ICMR), Indian Council of Agriculture

Research (ICAR) and University Grants Commission (UGC), Department of Scientific and Industrial Research (DSIR). DST, DBT and DSIR are part of Ministry of Science and Technology while ICMR is with Ministry of Health, ICAR with Ministry of Agriculture and UGC with Ministry of Human Resource Development. DSIR is the funding agency for CSIR and both of them independently fund biotechnology related research programmes.

As Table 1 shows, the allocations for all of these agencies have gone up in the last decade. Out of this, DBT is the only agency completely devoted to R&D in biotechnology. It is very difficult to estimate the total allocations for this sector *per se* from other aforementioned agencies as in some cases the allocations are not separately marked as allocations for biotechnology. One faces this kind of constraint especially with those organisations, which are focusing on technological solutions and are not committed for X or Y nature of technology. Thus separately accounting for biotechnology becomes difficult. Table 1 gives a broad idea about total allocations by major Indian funding agencies to science and technology related projects and not necessarily to biotechnology alone. In case of UGC it gives a broad idea not only about S&T related projects but also about other research streams. The various programmes supported by UGC would be discussed in Section III while rest of the agencies are being discussed below.

II.2.2. Human Resource Development and Training

The National Biotechnology Board had launched an integrated short-term training programme way back in 1984, to cope up with growing demand for highly trained manpower. In the first phase (1984-85), 5 universities were selected for initiating M.Sc./M.Tech programme in this multi-disciplinary area. Subsequently, in 1985-86 and 1986-87, the DBT had added 8 universities/ institutions for M.Sc/M.Tech/Post-doctoral teaching programmes. Later DBT was entrusted with the responsibility of evolving curriculum for biotechnology courses and meet the demand for human resources in the field of biotechnology. In 1986-87 a model system of post-graduate/post-doctoral teaching in biotechnology in 7 universities/institutions was launched.[8] Some of the specialised M.Sc. courses in marine and agricultural biotechnology were launched in 1988-89 at 3 universities. In 1992-93, DBT supported a five year Integrated Programme in biochemical engineering and biotechnology in Indian Institute of Technology, Delhi and a post-doctoral programme at Indian Agricultural Research Institute, New Delhi.[9]

Table 1: Budgetary allocations of major funding agencies in India

(Rs. million)

	1990/91	**2000/01**	**2001/02**
Department of Scientific and Industrial Research (DSIR)	131.3	9704	3625
Department of Science and Technology (DST)	2588.9	7798	8240
Department of Biotechnology (DBT)	655	1361	1863
Indian Council of Agriculture Research (ICAR)	3236	13992	13837
Indian Council of Medical Research (ICMR)	396	1470	1673
Council of Scientific and Industrial Research (CSIR)	2351	9120	9322
University Grants Commission (UGC)	3495	14070	14908

Source: RIS based on budgetary papers of relevant years, Ministry of Finance, Government of India.

The DBT is supporting 20 M.Sc. courses in general biotechnology, 4 in agricultural biotechnology, one each in medical and marine biotechnology while couple of diploma courses in molecular and biochemical technology.[10] The total intake of students in the various post-graduate courses supported by the DBT in the country is around 550 per year. As part of restructuring of the post doctoral research and training programme, DBT has scraped the on going programme with different institutions and has given this responsibility to Indian Institute of Science (IISc), Bangalore. This is to ensure competitive attitude and quality output in the life sciences. It is being proposed that IISc would award up to 75 fellowships of two-year duration in different streams of biotechnology.

The DBT is also supporting overseas associateship and short-term training courses for at least 22-25 scientists in a particular year for exposing Indian scientists to newer trends in R&D. This helps working researchers and scientists to upgrade their knowledge and research areas of interest. In this context, services of Biotech Consortium India Limited (BCIL), New Delhi, a DBT supported organisation, is also being used to bridge the scientific knowledge of DBT supported associates and their industry requirements. The State Governments are also exploring various options to finance higher education in such advanced technologies. Recently Karnataka Government has established an Institute of Bioinformatics and Applied Biotechnology (IBAB), in collaboration with ICICI Ventures to offer a postgraduate course in bioinformatics on its International Technology Park campus.[11]

As part of a wider effort for capacity building in institutes of higher learning, full-fledged departments of biotechnology are being set up. The Indian Institute of Science, Bangalore, Indian Institute of Information Technology and Management, Gwalior; and select Regional Engineering Colleges are setting up departments of biotechnology. The All India Council for Technical Education (AICTE) has already approved B.Tech. programmes in biotechnology in eight engineering colleges and has since been advised to develop a model curriculum for undergraduate programmes. All the new departments will have undergraduate, post-graduate and doctoral programmes. Special funding will be provided for this purpose in the ongoing Tenth Five Year Plan. Apart from expanding teaching of biotechnology at higher educational institutions a separate module on biotechnology would also be integrated with the school curriculum. The Department of Biotechnology of Government of India has to provide the necessary outline of this module so that the National Council of Education Research and Training (NCERT) and the Boards of School Education are accordingly advised.[12]

Indian University Grants Commission has come out with a scheme to promote higher centres of learning at one place and assist them as much as possible. In this regard, Delhi based Jawaharlal Nehru University (JNU) has been identified by the UGC as centre of excellence in the areas of genomics, genetics and biotechnology.[13] The University has received funds to the tune of Rs 300 million and is planning to start a new integrated M.Sc./Ph.D programme in life sciences and biotechnology and is setting up a modern animal house for experiments. Efforts are also being made to upgrade equipment and library facilities. The new integrated programme in life sciences will reduce the time taken by a scholar to complete his Ph.D, by at least two years. Now the scholar will not be required to undergo a separate M.Phil programme. JNU is aiming at 10 seats for the integrated course and another 20-25 seats in the School of Life Sciences. The University has so far received 40 proposals for possible projects, which can be pursued by them in these fields in the future. Out of the funds that JNU has finally managed to get from the University Grants Commission on its selection as the University with potential for excellence, Rs. 100 million have been set aside for upgradation of facilities and equipments. The rest of the Rs. 200 million would help University to subscribe to some of the 8,000 online journals, both in the field of science and social sciences. Besides this, JNU also announced recruitment of more researchers. The tie-ups with industry are also likely to grow. For instance, researchers at the Center for Biotechnology (CBT) at JNU have been joined by industry to develop recombinant anthrax vaccine.

II.2.3 Private Sector Participation

In India, biotechnology industry has grown over the past few years at a very rapid pace to reach a sizeable scale in terms of turnover. According to the available estimates, the size of India's market for biotechnology products could be between US $ 1.5 to US $ 2.5 billion.[14] Of this the agriculture sector market is valued between US $ 450 to US $ 500 million and diagnostic/vaccines market at US $ 150 to US $ 420 million.

The companies in medical biotechnology in India can be divided into three broad categories. One is that of small startup companies that have indigenously developed biotech products, e.g., Shantha Biotech and Bharat Biotech. Then there are large companies, which have started responding to biotechnology and have in fact incorporated biotechnology in their work plan, for instance, Dr. Reddy's Laboratory (DRL), Ranbaxy Laboratories and Wockhardt Ltd. The third group has start-ups, which are all set to emerge as contract research organisations (CROs). Largely their work comes from TNCs.

Then there are companies like Biocon India which may not fit well in this kind of classification as they have an established presence in the industrial biotechnology (the fermentation sector) and a growing presence in the pharmaceutical sector, so eventually cover our first and second category. Biocon set its sights on biopharmaceuticals and using its capabilities in a wide range of fermentation technologies.[15] It is first Indian company to go public with an offer of Rs. 400 crores.[16]

Some of the private foundations such as M. S. Swaminathan Research Foundation (MSSRF), Chennai have taken important initiatives in terms of bridging gap between technology development, its commercialisation and its diffusion.[17] One of the important project MSSRF launched in early 1990s was the establishment of Biovillages in India and China. The Biovillage approach aims at covering principles of ecological sustainability and economic profitability with equity. This project actively promoted interaction between society, industry and R&D institutions. Some of the firms such as Indo-American Hybrid Seeds, Bangalore and R&D institution such as Tamil Nadu Agricultural University (TNAU) were the prominent partners. The Biovillage project helped in enhancing the demand for biofertilisers in the Southern Indian Villages.

In the agriculture sector a large number of companies have taken up activities related to biotechnology. Leaving aside subsidiaries of TNCs in India, the agribiotech companies can be classified into three broad groups. One, the larger integrated seed companies which are expanding their R&D to cover biotechnology like Mahyco, Indo-American Hybrid Seed, etc. to develop their own transgenics. Second group is that of smaller companies which have not been active in research or product development but have started employing techniques such as tissue culture for their breeding programmes e.g. companies like Kastur Rangan and Adikeshevalu. The third group may cover highly specialized technology companies that undertake services for specified research, like contract research organisations. This is a relatively new concept in the agriculture R&D in India. Some of the companies like Avesthagen qualify in this group.

11.2.4 Role of Financial Institutions

In recent times, liberalisation has unleashed competition for garnering capital in the Indian market. This is more so for technology companies. Some of the major firms in IT and pharmaceutical sector have already achieved a listing at Nasdaq. The venture capital (VC) industry in India is also emerging as a vibrant

sector to support information technology, biotechnology, telecommunication and food processing related industries**.**

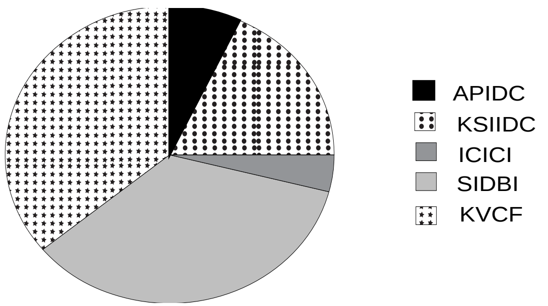
The venture capital industry in India has emerged after the Government of India, in 1988, announced guidelines for setting up venture capital funds (VCFs). These guidelines restricted the setting up of VCFs by banks or financial institutions only. Later, in September 1995, Government of India, issued guidelines for overseas venture capital investment in India whereas the Central Board of Direct Taxes (CBDT) issued guidelines for tax exemption purposes.[18] As part of its mandate to regulate and to develop the Indian capital markets, Securities and Exchange Board of India (SEBI) framed the SEBI (Venture Capital Funds) Regulations, 1996. While only 8 domestic VCFs were registered with SEBI during 1996-98, more than 30 additional funds have already been registered for 2000-01.

In the last Budget Proposals 2000-01, the Finance Minister announced SEBI as the single point nodal agency for registration and regulation of both domestic and overseas venture capital funds. Now, there are almost 70 VCFs with a focus on India.[19] Their cumulative assets under management would be somewhere close to $5 billion. The figures from the Indian Venture Capital Association (IVCA) reveal that, till 2000, around Rs. 22,000 million (US$ 500 million) had been committed by the domestic VCFs and offshore funds which are members of IVCA. The figures available from private sources indicate that overall funds committed are around US$ 1.3 billion.[20] It is being hoped that by 2005, India would have $10 billion invested through VCFs.

India witnessed the second highest disbursement of venture capital in the Asia-Pacific region during 2001 at $ 1.1 billion across 91 companies.[21] Japan received the highest disbursement in the region with $1.8 billion being invested in 39 companies. In contrast, China received only $393 million during the year across 11 companies, which placed it in sixth place among the 13 major markets, which constitute the region. While the total disbursement of $1.1 billion in 2001 was marginally lower than the previous year’s (2000) $11.3 billion. The situation is expected to change during the current calendar year (2002), with total disbursement projected to be in the region of $2 billion, according to the annual strategic review of the Indian IT industry by the National Association of Software and Services Companies (Nasscom). The pattern of VC disbursements last year indicates a preference for late-stage funding. According to the findings of the review, seed funding accounted for only 15 per cent of the total disbursement, while late-stage funding constituted 41 per cent. Deal sizes have also undergone a change. First round funding saw deal sizes in the range of $1-1.5 million, second round deal sizes were in the region of $3-5 million, third round deals ranged between $4-8 million and deals in the fourth round were in the region of $5-15 million.[22] The 70 VCs operating in India have $5.6 billion in assets under management. There has also been a significant shift to non-internet investments, with the share of non-internet investments increasing to 68 per cent in 2001 against 28 per cent in 2000. VCs have moved to longer gestation investments such as health, biotechnology, IT-enabled services and wireless applications. The consolidated VC pool in the Asia-Pacific region is estimated at $81.2 billion.

The biotechnology commitments by different VCFs amount to almost Rs. 3000 million (Figure 1). Out of this, Indian Credit and Investment Corporation of India (ICICI) and Small Industries Development Bank of India (SIDBI) have almost similar commitments for biotechnology while new entrants like Kerela Venture Capital Fund (KVCF) has committed Rs. 200 million, which is just 4 per cent of the total venture capital. SIDBI and ICICI have devoted Rs. 1000 million and Rs. 1700 million respectively. The two other southern states pro-actively supporting biotechnology through venture capital are Andhra Pradesh and Karnataka. Andhra Pradesh Industrial Development Corporation (APIDC) has devoted Rs. 500 million, which is 18 per cent of the total amount available at the national level while Karnataka State Industrial Infrastructure Development Corporation (KSIIDC) share 7 per cent with an allocation of Rs 100 million. APIDC Venture Capital is a joint venture between Dynam Venture East and

Figure 1: Biotechnology commitments of VCFs in India



Source: RIS data based on several sources.

Andhra Pradesh Industrial Development Corporation APIDC is in talks with Redmont Ventures of US for an investment of $20 million.[23] Some of the major biotechnology VCFs in India along with their specific initiatives are being discussed herewith.

ICICI

ICICI Venture currently manages/advises 11 funds, aggregating about US$ 400, milling it one of the large private equity investors in the country.[24] Consistent with its strategy of focussing on sectors where Indian companies have a global competitive advantage, all of the ICICI Venture funds make investments only in companies belonging to the IT, life sciences and services sectors. These industries have demonstrated a capability to leverage the intellectual capital in India to effectively address the global markets.

ICICI Venture is currently in the process of constituting a dedicated incubator fund for funding start-ups in the area of biotechnology and life sciences. As in the area of information technology, the ICICI Venture Incubator team would be extending support services to its incubatee companies, including basic research infrastructure in tie-up with ICICI-Knowledge Park Limited. The targeted fund size is Rs.1 billion. Recently ICICI Venture Funds and Global Trust Bank have invested $1.5 million in Avestha Gengraine Technologies Pvt. Ltd. (Avesthagen), a fully-integrated biotechnology and bioinformatics company based in International Tech Park Ltd (ITPL), Whitefield.[25] Avesthagen, operational since August 1999, would be going in for the second round of funding by April 2002 and expect a turnover of Rs 500 million in five years. The company currently employs 40 workers, out of which 34 are researchers. Focused on genomics and bioinformatics, with expertise in marker-aided selection, genome sequencing, gene discovery, plant transformation, database management, 3D structure-function analysis.

SIDBI

Small Industries Development Bank of India (SIDBI) and Department of biotechnology (DBT) have decided to initiate setting up of a Rs 1000 million Biotechnology Development Fund. This is to encourage public-private partnerships in the small-scale sector as well as to promote entrepreneurship in biotechnology. It is proposed that the DBT would put in Rs 200 million, while SIDBI would contribute the rest of the Rs. 800 million for the Fund. Earlier the proposal was of DBT-SIDBI for a Rs 500 million (Rs 250 million each) National Biotech Venture Fund but the Planning Commission of India did not agree with that proposal on the pretext that it would be better to leave it to the financial intermediaries (FIs) as it would entail nurturing and monitoring apart from financial management which FIs can do much better.[26] The finer details of the proposal are still to be worked out. The proposal is part of a larger industry orientation proposed by the DBT in its Tenth Plan Approach Paper. In collaboration with the Agriculture Ministry, a large number of decentralised production units (at least 1000 for biofertilisers and biopesticides) in the small scale sector are proposed to be established all over the country with new technology packages by the end of the Tenth Plan.

II.3 Pakistan

In Pakistan the government has taken an active interest in promotion of Biotechnology. A National Commission on Biotechnology was announced and nearly a sum of US$ 0.5 million was allotted to coordinate the national efforts in 2001. The NCB would have 10-11 members. This commission would sponsor research in the areas of agriculture, food, flowers and fruits and would also initiate programmes and publications to create mass awareness about biotechnology.

Pakistan's Ministry of Science and Technology (MOST) has approved a project for the promotion of biotechnology research and preparation of a biotechnology action plan. The project will be implemented by the Pakistan Council for Science and Technology in a period of three years with a Rs. 38 million (around 634,000 US$) budget beginning from April 2003. Biotechnology is declared among the top priority areas in the third meeting of the National Commission for Science and Technology. The project was launched to improve the existing research facilities in the areas like agriculture, livestock and medical sectors at universities and R&D organizations.[27]

II.3.1 Institutional Infrastructure

The biotechnology programme actually started with the establishment of the National Institute for Biotechnology and Genetic Engineering (NIBGE) at Faisalabad in 1987 by the Pakistan Atomic Energy Commission (PAEC). This institute has emerged as an important linkage in the advancement of biotechnology in Pakistan. However the whole idea about the institute emerged in 1981 when a course on recombinant DNA technology was organized by the Nuclear Institute for agriculture and Biology (NIAB) at Faisalabad.[28] At that time NIAB was one of the three agricultural centres of the PAEC. The training workshop asked the government of Pakistan to develop a national centre of

biotechnology and genetic engineering. The Ministry of Education later approved the creation of a Centre of Excellence in Molecular Biology (CEMB), to be built on the campus of Punjab University. The National Institute for Bio-technology and Genetic Engineering (NIBGE) was approved in 1986. NIBGE was developed by Government of Pakistan with the investment of US$ 10.00 million.

Now the government is also supporting some other initiatives such as the Centre for Advanced Molecular Biology (CAMB) and the Institute of Biochemistry and Biotechnology (IBB). Recently, an Institute for Biotechnology has also been established at Karachi.

II.3.2 Impact of Biotechnology

The biotechnological interventions have contributed significantly towards sustaining the cotton production in the wake of an acute epidemic of cotton leaf curl virus.[29] In addition, development of virus-free potato seed, banana and micro-propagation of sugarcane through tissue culture are only some examples of biotechnology. Commercialization of biofertilizers for rice, wheat and legumes has also come about because of the biotechnology researches carried out at NIBGE and NARC. According to a study with the introduction of the Bt cotton in Pakistan could result in a 45-55 per cent reduction in insecticide use on cotton.[30] This would mean a benefit of about Rs. 4 to 5 million, apart from the favorable impact on the environment and increase in cotton yield. So far, transgenic plants have been produced in about 60 plant species. Cotton has received special attention of the biotechnological companies in the developed countries who were attracted by the profit motives associated with the high value added to the transgenic seeds.

NIBGE has become internationally a lead centre for research on cotton leaf curl virus by deciphering the virus genetic code and documenting the genetic diversity existing in the field.[31] A useful input from University of Arizona, Tuscon; John Imn Centre, Norwich, UK; Imperial College and Queen Mary College London resulted in accumulation of useful data, which is now being utilized for developing transgenic cotton resistant to CLCuV. Similarly establishment of a Plant Genomic Laboratory in collaboration with PARC (Pakistan Agricultural Research Council) is a step in right direction. The Institute has also excelled in the area of biofertilizers with support from IAEA and more recently from Islamic Development Bank through which Biofertilizer Resource Centre (BIRCEN) has been established at NIBGE. Commercialization

Table 2: Biopesticides programmes in Pakistan

Centre	Mechanism	Crops	Status
AEARC	Control of pests by parasitoids/ predators	Sugarcane/cotton	Small commercial venture
IIBC, Rawalpindi	Control of pests by parasitoids/ predators	Sugarcane/cotton	Small commercial venture
ITAR Karachi (PARC)	Neem-based formulation	Cotton	STADE/PCSIR Nimolene
CAMB, Lahore	Novel Bt biopesticide	Cotton/rice	Lab scale
CAMB, Lahore	Fungi-based pesticide	Cotton	Lab scale

Source: RIS, Based on Zafar (2001).

of biofertilizers under the trade name of BioPower is greatly helping in development of sustainable agriculture. Pakistan has an active programme supporting biopesticides (Table 2).

II.3.3 Private Sector Participation

In Pakistan, the first generation biotechnology is still to be commercialized at a large level. Almost all the plant tissue culture (PTC) laboratories are in public sector and universities. Despite noticeable contribution in basic research in PTC technology, commercial exploitation remains insignificant. Most of the research work conducted in universities or research institutions has not been developed beyond laboratory level achievements. Generally, research in Pakistan is based on public funds and the interest of research laboratories does not match with those of industry or the results are technically immature.[32] Thus no commercially viable plant tissue culture laboratory has been established in private sector, all over the country. However, Agriculture Biotechnologies Pakistan (Pvt) Ltd. is operating in the field of micro-propagation and seed production since 1995 to achieve the excellence in high technology agriculture.

Among the TNCs in the private sector, Monsanto Pakistan, is one of the active players. It acquired business of Pakistan Cargill Hybrid Seeds recently. Monsanto also acquired Dekalb Genetics and Asgrow business. Now Monsanto deals with proprietary Corn, Sunflower and Forage Sorghum

hybrid seeds. As part of a commitment, Monsanto is the only multinational producing and marketing genetically modified seeds. Monsanto has initiated some work on producing drought tolerant plants.[33] Although the research is in the initial stages, the results are encouraging. Scientists are working on the project by sequencing the genes in corn, soy, and rice genomes. Monsanto is confident of providing drought tolerant varieties, which will also improve the yield. Under severe water stress tests the productivity of these varieties increased at least two-fold.

NIBGE has also established a private commercial arm. This is called Pakistan Innovative Biotechnology service (PIBS). The mandate of PIBS is to expedite the commercialization of technologies applied in various sectors of the industry and agricultural fields, which might have a direct and indirect impact on economy.

II.3.4 International Collaborations

Pakistan has also initiated joint collaboration programme with neighbouring and other countries. Recently Pakistan has entered in an agreement with China for cooperation in the areas like agriculture, health and industrial biotechnology.[34] It has been decided to facilitate the exchange of microbial culture to enhance fermentation technology capability along with the exchange of visits of scientists. It has also been recommended that joint bilateral symposium should be regularized on annual basis. The action plan also include submission of joint research projects to be reviewed by scientific committees on both sides and their subsequent implementation. It has also been decided that students will be exchanged at graduate level and postdoctoral level. Exchange of eminent scientists as teaching faculty to participate in the academic activities of national universities and institutes will also take place. As of now 72 projects have been submitted to the Ministry of Science and Technology by various R&D organizations. They would be screened for undertaking joint research projects under Pak-China joint Research Fund.

Pakistan and the United States have also signed a joint operating arrangement (JOA) worth $10 million for scientists' cooperation in the field of natural sciences.[35] The arrangement has been designed for further cooperation among scientists of the two countries in the areas of significant mutual interest with a focus on collection, evaluation and exchange of germplasm, plant genomics, plant biotechnology, stress biology, bio-informatics, application of information technology in agriculture, identification and control of animal and plant diseases, dry land/sustainable agriculture production systems, biotechnology/microbiology and agribusiness development. Recently, Pakistan has also been benefited by the Asian Development Bank loan of $905,000 for the research and cultivation of iron-rich rice. The project would be from 2002 to 2005.

Pakistan is also member of Islamic Academy of Sciences (IAS). This institution organised a special session on biotechnology and genetic engineering.[36] In 2001, IAS adopted a Rabat Declaration, urging leaders and decision-makers of the OIC member countries to divert available resources to science education with a view to building a scientific and technological manpower-base capable of adapting and developing new technologies. OIC member states were also urged to re-define national developmental objectives in the area of science and technology, especially biotechnology and information technology, in view of globalization and free trade arrangements. The Rabat Declaration equally stressed the need for OIC countries to introduce biotechnology programmes at various stages of the educational process. Among the South Asian countries, apart from Pakistan, Bangladesh also signed this declaration.

II.4 Sri Lanka

Since 1990 Sri Lanka has strong research programme in biotechnology. In the initial years the focus was on plant biotechnology, but of late, the various research institutions, universities and government departments have entered in the areas of new biotechnology including in health and medical biotechnology. In Sri Lanka there is a growing sensitivity about the ethical aspects of biotechnology research. Earlier this year, the National Science and Technology Commission (NASTEC) had handed over a report to the Government on the medical ethics. At this stage, a 'Draft National Policy on Biomedical Ethics' related to 'New Genetic and Assisted Reproductive Technologies' is also being considered.

In Sri Lanka there is a National Genetics Commission and the National Assisted Reproductive Technologies Commission are to be set up soon. The National Assisted Reproductive Technologies Commission set up by an Act of Parliament should be the apex body overseeing the introduction and practice of assisted reproductive technologies both in research and in clinical settings in Sri Lanka.[37]

II.4.1 Institutional Infrastructure

The Ministry for Economic Reform, Science and Technology (MOST) provides a framework for the strategic economic development and growth of the country. In Sri Lanka the National Science and Technology Commission (NASTEC) plays the key role in terms of working as a key apex policy formulating and advisory body to the Government of Sri Lanka on Science and Technology matters. This was established in 1998. It works in consultation with National Science Foundation (NSF).

NASTEC fulfills a need that has been highlighted for a long time by the scientific community. This works as the policy making apex body in the area of science and technology. Its responsibility includes prioritization of areas of national importance of Science and Technology, and in advising the Government as regards the rational allocation of funds for research and development among the national Science and Technology institutions. NASTEC also works closely with the Council for Agricultural Research Policy (CARP) and the National Health Research Council (NHRC) and professional bodies such as Sri Lanka Association for the Advancement of Science (SLAAS), Institute of Chemistry, Institute of Physics, Institute of Engineers and Institute of Biology.

The Plant Genetic Resource Centre (PGRC) is the key institute in Sri Lanka to collect, characterize, conserve and multiply germplasms of crops and other plants. This institute was established with the liberal grant from Japan in 1987. It has more than 2000 accessions. The PGRC is under Ministry of Agriculture. Under the same ministry is the Horticultural Crop Research and Development Institute (HORDI). This has also started exploring the first generation biotechnology options in their various research pursuits

The Council for Agricultural Research Policy (CARP) also of Ministry of Agriculture has identified biotechnology as a thrust area for agricultural research and a key area for development on a national scale.[38] In view of this, the CARP committee of specialists in biotechnology and plant breeding in the national agricultural research system (NARS) was required to identify constrains confronted with research relating to biotechnology and to suggest possible ways as to how CARP can play a role in developing biotechnology to benefit agricultural development of Sri Lanka.

II.4.2 Strong Emphasis on Ethical Aspects

The guidelines for the Proposed National Genetics Commission and the National Assisted Reproductive Technologies Commission have been worked out by an expert group appointed by the NASTEC. The group has also drawn guidelines on how researchers should liaise with the media. It suggests that the preliminary findings of seemingly promising research should be reported because such research may require substantial validation through future studies or as such projects may require further research and a considerable passage of time before it could be translated into human use although it may seem that human application is round the corner. It is also important to safeguard against inaccurate reporting and to ensure that privacy and confidentiality of subjects is not compromised especially in publishing family histories and in publishing or presenting photographs, slides, videos of subject(s), prior consent to do so should be obtained.

The guidelines also suggest that the international collaborative research projects should, in addition to ethical clearance in Sri Lanka, receive clearance from the ethical review committee(s) of the collaborating institution(s) abroad and be subject to other guidelines for international collaboration as may be recommended by the proposed Genetics Technologies Commission and/or the proposed National Assisted Reproductive Technologies Commission.

The guidelines to be drawn up by the proposed commissions shall in addition to other factors, take into account the need to ensure transfer of technology to Sri Lanka so that such projects result in the development of research capacity within the country and not merely the transfer of biological material to other countries. The export/import of biological material from/to Sri Lanka should be banned at all times except where it is justified by established medico-legal practices.

II.4.3 The Economic Challenges

The strong institutional linkages in Sri Lanka have created a system where by science and technology is being used to overcome the economic challenges. In this regard, the CARP has identified some of the important areas for the potential application of biotechnology. In Sri Lanka rice is the staple food and is one of the important food crops of the country. It is estimated that Sri Lanka should produce atleast 3.4 million tones rice to cope up with the demand by 2005. The major constrain comes from the pests of rice that cause reduction in yield. They are thrips, gall midge, stem borers, leaf folders, brown plant hopper and paddy bug, while the main diseases are blast, leaf blight and sheath blight. High cost was incurred for use of pesticides and fertilizer and chemicals for disease control. Moreover, yield losses due to weed competition alone exceed losses caused by

other biotic constraints. The use of herbicides is the most common technique used by farmers to control weeds in rice fields.

The major plantation crops of Sri Lanka are tea, rubber and coconut constitute. The production and export of these crops as given below show a gradual increase in tea and coconut and a decline in rubber. The cost of production has increased dramatically in all the three crops.[39] Tea improvements require expansion of the existing narrow genetic base, improvement of assessment of germplasm, and production and use of new genotypes such as polyploids. Rubber requires improvement of technical properties of the natural rubber, shortening of the immature period, improvement of timber and assessment of merit of the accessions. Coconut improvement requires development of vegetative propagation methods, broadening the germplasm and reducing the time and cost of breeding new varieties.

Sri Lanka has right from the beginning focused on the need of trained manpower in this skills intensive sector. The national science foundation data indicate that trained manpower even in advanced biotechnology is indigenously available (Table 2). The major challenge is to encourage private sector participation in development of biotechnology. The private sector as of now is largely engaged in tissue culture and biopesticide related activities. Among the private sector firms Genetech is one of the leading and probably only firm in Sri Lanka engaged in DNA typing and finger printing.

The initiative by various universities and research institutes of making available high skilled manpower in areas other than plant biotechnology is likely to encourage private sector participation. Table 3 provides the distribution of skilled manpower in biotechnology in Sri Lanka. The universities have developed curricula to include modern trends in biotechnology research and development. In this regard the Asian Development Bank has also provided $ 20,000 as part of the loan for expanding science and technology personnel development in 1987. As a result University of Peradeniya has established under graduate and post graduate course in biotechnology. ADB has also helped in improving the infrastructure at the University of Colombo.

II.4.4 International Cooperation

The research cooperation between Sri Lanka and the Swedish International Development Cooperation Agency (SIDA) has been in operation since 1982.[40] National Science Foundation (NSF) of Sri Lanka has been functioning as the

Table 3: Distribution of technical skills in Sri Lanka (2001)

R&D Activities	Distribution of Personnel (in Per cent)
Genetic engineering and DNA markers	
In crop breeding	18
DNA/Immuno diagnostics	63
Vaccines	03
Gene therapy	00
Environmental biotechnology	05
Industrial biotechnology	04
Food biotechnology	04

Source: National Science Foundation, 2001.

coordinating agency for many projects under the agreement signed by the governments of Sri Lanka and Sweden. SIDA and NSF have launched a two year project to establish bioassay techniques to identify insecticidal and other bioactive extracts, fractions and compounds. The programme including training of bioassay technicians and other technical personnel. This project would help in protecting major export crops such as tea and other crops from pest attack. Conventional methods of pest control involve the use of synthetic pesticides and unmonitored use of which has led to an accumulation of toxic residues and development of resistance to pesticides by pests. This project also aims at developing strategies for environmentally acceptable methods of control of seven Sri Lankan pests; the shot-hole borer beetle, the live-wood termite, the root-lesion and burrowing nematodes of tea, the groundnut aphid, the diamond-back moth and the cowpea beetle.

Another major area of cooperation with Sweden includes the establishment of a molecular biology and gene technology department in the Faculty of Medicine at the University of Colombo. Two areas were identified as of primary importance: training of manpower resources at the M.Sc. and Ph.D. level and research and development in this field as applied to the study of filariasis. Research collaboration and training has been undertaken with the Department of Medical Genetics, Biomedical Centre, Uppsala University, Sweden.

Recently during the US visit of the Sri Lankan Prime Minister a number of agreements to further business opportunities in the knowledge economy sectors such as biotechnology and Information and Communication Technology (ICT) were signed. A Memorandum of Understanding between the Government of Sri Lanka and the US Trade and Development Agency (USTDA) enables funding for technical assistance, feasibility studies, training, orientation visits and business workshops with particular attention to biotechnology was signed.[41] It is decided to constitute a group to study the development of the biotechnology sector in Sri Lanka and a Memorandum of Understanding with the Microsoft Corporation to provide support for the E-Sri Lanka initiative. The MOU will provide a multi million dollar investment from Microsoft in technology trading, educational assistance and infrastructure support over a five year period. Microsoft will also be setting up a subsidiary in Sri Lanka for strengthening the bioinformatics programme.

Sri Lanka also has four on-going research projects with India. Both the countries have serious economic interests in aquaculture. In a joint project at College of Fisheries, Mangalore, efforts have been made to develop cell lines for marine fish Sillago which is commonly available in the region. In other projects at National Environment Engineering Research Institute (NEERI), Nagpur, projects has been launched to study and evaluate biotechnological processes for treatment of waste water.

Sri Lankan biotechnology programme is also being benefited by the programmes supported by the sub regional grouping such as by the BIMST-EC. This regional grouping was established in 1997 and comprises of Bangladesh, India, Myanmar, Sri Lanka and Thailand. The purpose of this regional grouping is to provide trade and technological co-operation among the BIMST -EC countries in the areas of trade, investment, tourism, transport, commerce, technology, energy and fisheries. National Science and Technology Commission is the focal point from Sri Lanka for science and technology cooperation. The second Expert Group Meeting was held in Sri Lanka in October 2002. The focus of this Expert Group Meeting was Agricultural Technology, Biotechnology, Food Technology, Herbal Drugs and Aromatic Plants, Post-Harvest Technology and Information and Communication Technology. These areas were chosen because of the common agricultural background of the BIMST-EC countries and the ever-growing importance of ICT. The identified areas for R&D collaboration between Sri Lanka, India and Thailand include the following:

1. Establishment of a Database on Medicinal Plants, Bioactive Natural Products and Mushrooms
2. Establishment of a Database on Traditional Knowledge
3. Bio-Fertilizer and Bio-Pesticides
4. Methods of Identification of Functional Foods
5. Policy Formulation and Development of Identification Protocols and Validation on GM Foods

Basing on the identification of these areas seven joint projects have been launched as part of BIMT-EC initiative for technology cooperation.

II.5. Nepal

Recently, Nepal has attached a high priority to biotechnology. The Ministry of Science and Technology has placed its vision for biotechnology in Nepal to enhance the quality of life of the Nepalese people in terms of agriculture, forestry, health, safety, environment, social and economic development. The Ministry plans to do this by utilizing the benefits of biotechnology for the betterment of community, industry and environment. The newly drafted biotechnology policy for Nepal with its main focus on poverty alleviation was recently released.[42]

In Nepal a strategy for development of biotechnology is being worked out largely in the agriculture sector. The stated objective is to provide easy and affordable excess to biotechnology products and appropriate inputs such as biofertilisers etc to agriculturists especially small and marginal farmers. The areas of priority for research and development include mass production of virus-free pre-basic seeds of potato by tissue culture; mass production of disease-free banana and citrus saplings by tissue culture and grafting; production of virus-free cardamom plantlets; biotechnological development of poor man's food crop – millet, barley, buckwheat etc; development of yield – increasing rice varieties by combination of conventional breeding, marker assisted breeding, anther culture and genetic transformation; mass production of biofertilizers and biopesticides.[43] Nepal has also actively started organizing major conferences and seminars on biotechnology and biodiversity. One such major conference with almost 265 scientists from twenty five different countries was organized in Katmandu recently.[44] This gave an opportunity to local industry and academicians to interact with external experts and entrepreneurs in the field.

II.5.1 Institutional Infrastructure

Nepal is one of the few LDCs which has strong institutional infrastructure in government as well as in non-government sector. The non-government sector is largely in the domain of private sector with limited financial support from community based development programmes. Some of the major initiatives in non-government sector include Botanical Enterprise Private Limited, Godavari; Nepal Biotech Nursery, Bhainsepati; Research Laboratory for Agriculture Biotechnology and Bidiversity (RLABB) Balkhu and Microplants, Taukhel.

In the government research centers, there are three major institutes which support biotechnology. They are Department of Plant Resources (DPR), Nepal Agriculture Research Council (NARC) and Royal Nepal Academy of Science and Technology (RONAST). The DPR is largely working on mass propagation of tissue culture disease- free plants of banana and citrus. The DPR has already come out with their biotechnology action plant. The NARC has an active programme on developing virus free seeds of potato. The agriculture botany division of NARC is working on anther culture of rice and wheat and is also all set to establish germplasm conservation and diagnostic facilities using PCR technology.[45] The NARC is also planning to initiate some work on biofertilisers. It has established regional linkages with Nepal by establishing laboratory in different parts of the countries.

The RONAST has initiated work on molecular studies on genetic variation of rhizobium and *in vitro* grafting of citrus for disease elimination.[46] RONAST has screened more than 80 isolates of rhizobium for enhancing productivity of grain legumes.

II.5.2 Central Coordination and Other Developments in Biotechnology

Since the Eight Five Year Plan (1995), planning in biotechnology has come a long way in Nepal. This was the first plan in which importance of biotechnology and biodiversity was acknowledged. The National Council for Science and Technology, however, has been active in terms of developing and supporting various facets of biotechnology. At this point, Nepal has to work towards further strengthening the institutional coordination and also establish the inter linkages in the biotechnology research in the country. There are several studies which indicate that there is an urgent need of a central coordinating agency in Nepal like Department of Biotechnology (DBT) in India or Biotechnology Commission in Pakistan.[47] This may help in coordinating allocations for various programmes in biotechnology for instance Panta and Aryal (2000) mention that such funding is needed for a strong programme at the advanced research institutes like Tribhuvan University. The Central Department of Botany (CDB) in Tribhuvan University has been planning for initiation of biotechnology programme but due to lack of proper funds the programme could not be started. In this regard the proposal for Biotechnology Development Council (BDC) or Biotechnology Coordination Committee (BCC) is an important idea to begin with.

Nepal also has an acute shortage of trained manpower in this advanced technology. The recently concluded, National Biotechnology Policy Conference (NBPC) also discussed this issue. It was suggested that one of the two committees BDC or BCC would have to take some steps in this directions. Some of the earlier studies by Yami (1997) and Tuladhar (1994) indicate that there were only 72 graduates out of which 57 per cent had masters degrees and 32 per cent had doctoral degrees. Most of them have specialized in either agriculture or in botany but not in biotechnology. The proposed biotechnology coordination committee is being identified as the agency for developing manpower required for this sector and raise public awareness about biotechnology.

II.6 Bhutan

Bhutan has shown a keen interest in biodiversity conservation related international activities. It was in 1992 itself that Bhutan became signatory to CBD. The recently concluded 9th Five Year Plan of Bhutan strengthened the various measures taken up in the light of the commitment towards CBD. In this regard the National Environment Strategy was announced in 1999. The Ministry of Agriculture has also established a National Biodiversity Centre (NBC) in the year 2000. This Centre has initiated some work on inventorisation of biodiversity in different parts of Bhutan. The National Environment Commission (NEC), established with support from UNEP and Global Environment Facility (GEF), is one of the important initiative, to evolve a national focal point for environment and biosafety management.

In Bhutan some initiatives have been taken to strengthen the institutional infrastructure for first generation biotechnology.[48] The Royal Government of Bhutan has established two tissue culture laboratories for commercial propagation of agronomically important plants. Recently four Renewable Natural Resources Centres (RNRCs) have been established to work on the rich biodiversity available. However, the private sector participation is yet to come

forward in this area. Nevertheless the international cooperation has helped Bhutan in launching several important initiatives. It is with the assistance of the Dutch government that a National Gene Bank has been established. Under this project the Dutch government is also providing assistance for training technical staff. It was in 1985 that Bhutan had taken the membership of the Centre for Science and Technology of the NAM countries and signed the agreement for becoming a member of the International Centre for Genetic Engineering and Biotechnology.

III International Institutions in the Region

Advancement of biotechnology in the region is also facilitated by the presence of advanced research institutes. In South Asia, there are two major international institutes which have developed strong regional linkages. The International Centre for Genetic Engineering and Biotechnology (ICGEB), New Delhi and The International Crops Research Institute for the Semi-Arid Tropics (ICRISAT), Hyderabad. They have established close ties with the farmers and industrial sector for the transfer of innovative technologies and/or products of potential interests. These institutions have also played a key role in human resource development in the region.

ICRISAT has launched several initiatives in South Asian and some of them are financially supported by multilateral financial agencies for instance, ICRISAT and ADB were partners in two bilateral projects, one with Pakistan and the other with Sri Lanka.[49] The project on strengthening chickpea research in Pakistan worked towards stabilizing yield of the crop, and successfully developing a variety of chickpea which is resistant to the damaging fungus *aschochyta blight*. The project attempted this over the different phases till late nineties. In case of Sri Lanka the initiative covered the production of pigeonpea and diversification to other crops. The project developed a *maruca* resistant variety which is a short duration pigeonpea, and also designed and developed a processing machine for small farmers. The establishment of a plant biotechnology research and training unit at ICRISAT and its state-of-the-art applied genomics facility has further strengthened the biotechnology infrastructure in South Asia.

The facility helps train NARS scientists in tissue culture, transformation, molecular marker technology and in virus diagnostics. Recently the ICRISAT genebank was augmented, training in genetic resources was provided, and 22 germplasm collection missions in 13 countries resulted in the addition of 10,955 accessions to the ICRISAT genebank.

The Regional Technical Assistance (RETA) grants from ADB under cooperation programme with ICRISAT has also strengthened the grain legume research in South Asia and also strengthened the regional collaboration in cereals and legumes in Asia (1995-99). This worked towards assisting NARS in Asia to improve productivity of grain legumes and coarse cereals. Legume-based technologies for rice and wheat production systems in south and southeast Asia (1997-Apr 2001) is an ongoing project designed to quantify the scope for greater inclusion of legumes in rice and wheat cropping systems, evaluate improved technologies, assess adoption, and quantify the impact of improved legume-based technologies.

International Centre for Genetic Engineering and Biotechnology (ICGEB) is another international organisation, dedicated to the research and training in the field of biotechnology and genetic engineering. There are two components of this organisation. One is in Trieste (Italy) and other in New Delhi (India). The main mandate of the centre is to impart research and training in the field of biotechnology. ICGEB also helps in developing cost effective technologies in the field of human health and plant biotechnology. As Table 4 shows in the region Sri Lanka and India have been benefited at the industry level by getting access to the technologies developed by ICGEB. Pakistan, Bangladesh, Bhutan and Nepal are also members of ICGEB. The centre has conducted more then 100 training progrmmes and transferred number of technologies to the member countries. In the New Delhi component, scientists and students from SAARC countries participate in training programme and the centre has transferred technologies to various SAARC countries. Some of them are listed in Table 4.

V Biodiversity Conservation and CBD

In the South Asian region there is a growing concern about rapid degradation of major ecosystems and their biological components. Developing and establishing adequate conservation measures and mechanisms for sustainable utilization of bioresources pose multidimensional challenges. These issues have been negotiated extensively under the aegis of the United Nations. Consequently, the international treaties such as the Convention on Biological Diversity (CBD), 1992; Trade Related Intellectual Property Rights (TRIPS) agreement under World Trade Organization (WTO), 1995; the Cartagena Biosafety Protocol, 2000 have been finalized (see Table 5). The Contracting Parties of these

Table 4: Agreements entered into by ICGEB for transfers of technology to the industrial sector

Product	Country	Year
HIV 1-2 Diagnostic Kit	India Nigeria	1997 1992
Hepatitis C Diagnostic Kit	India Sri Lanka India	1997 1999 2001
Hepatitis B Vaccine(option)(under negotiation)	India Egypt Sri Lanka Brazil Italy/Iran	1998 1999 1999 2002 2002
Recombinant Insulin	Argentina Sri Lanka	1998 1999
EPO - Erythropoietin(option)(option)	Italy India Egypt Sri Lanka Venezuela Italy/Iran Brazil	1996 1998 1999 1999 2001 2001 2002
Alpha Interferon 2b	India Sri Lanka	1998 1999
Alpha Interferon 2a	India	2002
Gamma Interferon	India Sri Lanka	1998 1999
HGH - Human Growth Hormone	Italy India	1996 1999
G-CSF - Granulocyte Colony Stimulating Factor	India Sri Lanka	1998 1999
Vegetable Brassica expressing BT Toxin	India	1999
Development of a Malaria Vaccine	India	2001
Development of Recombinant RHBV-BAC	India	2001
Patent "Plastid transformation"	India	2002

instruments are actively engaged in evolving mechanisms to effectively implement the provisions contained therein.

Significantly, these developments have also reflected some contradictory trends, which need to be closely examined at, in order that, we succeed in safeguarding livelihoods of local communities dependent on biological resources and in ensuring full realization of potential of new emerging technologies for the benefit of coming generations. It is being increasingly accepted that the task of reconciliation cannot be discharged by any single country and that regional co-operation and global responsibilities need to be formalized and gives an institutional mechanism.

In Pakistan the Plant Variety Protection (PVP) Act has been finalized after detailed deliberations. Pakistan has strengthened the mechanism for approval of any plant variety for commercial cultivation. All the varieties of major crops are now screened and tested for any possible disease, for their tolerance and their possible implications for environments . The environment ministry has issued the guidelines for complying with before PVP protection is granted. The various ministries are also working towards the necessary legislation concerning access to genetic resources required under the Convention on Biological Diversity (CBD).

Biodiversity in Sri Lanka has been a major policy concern. This country is one of the 25 biodiversity hotspots of the world.[50] The South Western region of Sri Lanka is extremely rich with biodiversity. The Convention on Biological Diversity was signed and ratified by Sri Lanka in July 1992 and March 1994 respectively. The Ministry responsible for the subject is the Ministry of Environment and Forest has the duty to ensure that the provisions of the Convention are adhered to.

As part of India's commitment at TRIPs under WTO India had to enact a legislation protecting plant varieties. In the year 1999 Government introduced a bill to this effect in the Parliament which was later referred to a Joint Parliamentary Committee (JPC) so as to ensure protection of farmers' interests. After getting recommendations from this committee Government has enacted the Plant Variety Protection Act, 2001.

The PVPA attempts to ensure the delicate balance between the interests of plant breeders and farmers. The farmers now can raise crops of a protected

Table 5: Status of the convention on biological diversity

Countries	CBD		Contribution to Trust Fund for CBD (in US$)
	Signatories	Ratification	
Bangladesh	05-06-1992	13-05-1994	955
Bhutan	11-06-1992	25-08-1995	92
India	05-06-1992	18-02-1994	31,534
Nepal	12-06-1992	23-11-1993	370
Pakistan	05-06-1992	26-07-1994	5,641
Sri Lanka	10-06-1992	23-03-1994	1480

Source: RIS based on various report & CBD.

variety every year from their saved seeds. Under this legislation the plant breeders can make profit from the first time sale of self-perpetuating plant species. The Act has taken care of farmers' interests by putting a clause (Article 17), requiring a plant breeder to provide an affidavit that the newly bred variety does not contain the terminator gene.[51] The Act has a strong provision for compulsory license to undertake production, distribution and sale of the seed/planting material of a particular variety, if the same is not available on reasonable price or in adequate amount. However in the region biopiracy is still a challenge to be dealt with Bio-prospecting the search for new genes or chemicals of value in pharmaceutical, biotechnology, or agriculture industries is a rapidly growing endeavour, and one which can have immense economic benefits.

Several transnational corporations and other firms have used the rich biodiversity of developing countries in various products without any payment for the same. The argument has been that bioprospecting is justified as in most developing countries there is no technological capacity for complete product development. In order to avoid this, the Convention on Biological Diversity (CBD) and in particular its Articles 15 and 16 proposed to allow access to genetic resources with the condition that the developing countries should be benefited by the transfer of technology.

Despite of the fact that Bhutan signed CBD in 1992 and ratified it in 1995 things have not changed much. Bhutan, as is a well know fact, is rich in biodiversity. It has an estimated 300 species of plants and animals which are of immense value for medicinal purposes in forming nearly 200 different traditional medicines but is still struggling for strengthening technologically advanced facility for *ex-citu* conservation. This is when Bhutan has been contributing to the global gene pool quite liberally. An International Plant Genetic Resources Institute (IPGRI) mission to Bhutan in 1981 collected 483 samples of food plants, legumes and vegetables. The mission noted serious threat to indigenous wheat and rice varieties.[52] In 1983, an IRRI mission collected 184 traditional rice varieties from high and medium altitude rice growing areas, but most remote areas were not visited. Recently, 154 samples of cultivated rice from 68 villages have been collected. This germplasm has special value as it has been collected from a very high altitude areas and traversing about three quarters of the country's rice growing regions.[53] Moreover now studies are raising apprehensions about the sustainability of agriculture in Bhutan. Here specialized forms of crop production have evolved as a result of its geography and climate.

The narrowness of the genetic base could pose greater risk of crop failure as occurred in other parts of the world. Many local crop and landraces are being replaced by these HYV's, and in extreme cases, traditional germplasms are so rare that they are in danger of extinction. So far, limited formal germplasm collection has been undertaken in Bhutan.

The country has no medium to long-term storage facility for ex situ collections yet. There is concern that loss due to inaction could become expensive; and no time should be wasted in collecting germplasm of major food crops before farming communities succumb to the pressure of population growth, migration to urban areas and a shift toward consumerism. The National Biodiversity Centre has been established in 2000 but it has very moderate facilities. The Herbarium Project funded by Danida, and Agro-biodiversity Project by the Dutch have started some form of *ex-situ* conservation of floral diversity in the country.

VI Biosafety Management and Regulatory Issues

In the recent years almost all the South Asian countries have promoted development and diffusion of biotechnology in a major way. The inter-linkages between different sectors have been strengthened and institutional structures have been developed for commercialization of various biotechnology products. However, there is some apprehension about adverse implications of biotechnology. The status of regulatory system in the South Asian countries is summarized in Table 6.

Table 6: Leading biotechnology institutions and status of biosafety in South Asian countries

Country	Responsible Agency	Protocol Signed	Protocol Ratified	Field Testing
		Status of regulatory system		
India	• Ministry of Science and Technology (Department of Biotechnology) • Ministry of Environment and Forests (Genetic Engineering Approval Committee) • Centre for Cellular and Molecular Biology • Center for DNA Fingerprinting & Diagnostics	√	√	√
Pakistan	• Establishment of Centre of Excellence on Molecular Biology (CEMB) • National Institute for Biotechnology and Genetic Engineering (NIBGE) • Centre of Chemistry and Biotechnology, Agricultural Biotechnology • Institute of Biochemistry and Biotechnology	√	X	√
Sri Lanka	• National Science and Technology Commission (NASTEC) • National Genetic Commission • National Assisted Reproductive Technologies Commission • National Science and Technology Commission • Plant Genetic Resource Centre	√	X	√
Nepal	• National Agriculture Research Council (NARC) • Royal Nepal Academy of Science and Technology (RONAST) • Biotechnology Development Council • Biotechnology Coordination Committee	√	X	X
Bhutan	• National Biodiversity Center • National Environment Commission • Renewable Natural Resources Centres	√	√	X

In Pakistan, in order to overcome the biosafety concerns, NIBGE proposed a voluntary code of conduct for release of GMOs way back in 1994. This has now been updated by the Ministry of Environment, as bio-safety guidelines, in consultation with all the stakeholders, which hopefully will soon be approved. This will provide an impetus to the indigenous biotechnologyR&D activities. A National Biosafety Committee has also been formed. Draft proposal on Biosafety Regulation was prepared and is at the approval stage by the Federal Government.

The biosafety debate in South Asia came under a sharp focus when Sri Lanka banned completely the imports of GM food in May 2001.[54] The Sri Lankan gazette notification on the ban stated that, "it affects any food or food additives that have been subjected to genetic modification". It mentioned that "genetically engineered food" means, "food that contains or was produced with a genetically modified material". There are materials derived from any part of genetically engineered organism. One of the reasons given for the ban was that Sri Lanka did not have the expertise to judge whether imported GM foods were good or bad. This got Sri Lankan authorities at the centre of storm. The ban was subsequently suspended. However the ban had made environmentalist and conservative happy. They all had praised the ban, but some members of the scientific community completely dismissed the idea. At this point Sri Lanka is working with the UNEP-Biosafety project to evolve national guidelines and strengthening the risk assessment and management system for effective biosafety mechanisms. As part of the project, the database is also been established to put together information about GMOs and LMOs. Sri Lanka has also signed the Biosafety Protocol on 24 May 2000 and is all set to establish domestic legal measures and build capacity in the area of biosafety before final ratification comes. The Ministry of Environment is the National Focal Point and is obliged to implement the articles of the protocol.

In Bangladesh the priority at this point is in setting up of a National Committee on Biosafety of Bangladesh (NCBB) as has also been proposed in the Biosafety guidelines. The committee is to oversee research on transgenic and hazardous organisms in the research institutes handling such material, monitor release of such organisms into the environment and also to ensure food safety, if such organisms are detected in food. The committee will also oversee the import of such organisms into the country. The NCBB has to be headed by a full Secretary and a member-secretary on a full time basis as explained in the guidelines. [55]

In India, the debate on biosafety guidelines has come a full circle as Indian Ministry of Environment and Forest (MOEF) reported sowing of unapproved genetically modified (GM) cotton seeds in several hundred hectares of land. The report has stirred the ongoing debate on GM crops in India, as had happened way back in 1997 when, unapproved GM eggplant was found in an agricultural research institute without sufficient safeguards.[56] This has once again brought the implementation-related aspects of biosafety protocol at the centre-stage and has raised several issues concerning the very ability in many developing countries to handle sensitive technologies in such vital sector as agriculture. Though India established the bio safety guidelines way back in 1989, till now no commercial trials of GM crops have been allowed except the one permission granted last month (March 2002). India's Biosafety and Recombinant DNA Guidelines (1990) fall under the Environment (Protection) Act of 1986. In 1994, after India signed the Convention on Biodiversity, the DBT revised its earlier guidelines to accommodate the safe handling of GMOs in research, application and technology transfer. This includes the large-scale production and deliberate release of GM plants, animals and products into the environment. The guidelines are also provided for the shipment and importation of GMOs for laboratory research.

VII Summing Up

Biotechnology has emerged as one of the important links in the regional cooperation programme in the Asian context. BIMST-EC, the Asian Cooperation Dialogue (ACD) and the Indian Ocean Rim Cooperation (IORC) are some of the groupings in which different South Asian countries are participating and there biotechnology has been identified as a priority area for cooperation. In the framework of SAARC also several activities are being conducted.

The first meeting of the Technical Committee on Science and Technology under the reconstituted SAARC Integrated Programme of action identified biotechnology as an important area for joint activity in Delhi 2001.[57] The committee emphasized on the need of building a talent pool, available in the SAARC countries. The meeting also called for acknowledging the availability of a vast reservoir of natural resources in the region. The Special Session on Biotechnology also reviewed progress on activities undertaken, such as plant tissue culture, medicinal and aromatic plants, vaccines and diagnostics for human health, aquaculture and human resource development. However, there are certain areas enlisted below which should be addressed on priority for regional cooperation:

Research Priority for Food and Nutritional Security

In terms of ensuring nutritional security in the region it is important that research plans address issues like increasing vitamin A, iron and other nutrient in the edible portion of various plants and crops. It is desirable that South Asian countries come together to address these constraints and economize on selection and application of various techniques in biotechnology. Regional cooperation may even strengthened national approaches in integrated nutrient management and development of biofertilizers and biopesticides. The post-Green Revolution period with soil fertility, environment, biological stresses should be share to evolve an effective strategy towards sustainable agriculture.

It is important to link up various research project funded at the bilateral and multilateral level to converge so as to yield regional gains. There are some major challenges which modern biotechnology may help in overcoming together with traditional plant improvement methods in making available better agro economic practices. In many paths of south Asia salinity and drought resistance are some of the traits which have to be addressed on priority.

Harmonization of Biosafety Regulations

In the region Biosafety Protocol has yet to be ratified by some of the member countries. This puts South Asia on an uneven ground in terms of implementation of a regulatory regime for governance of biotechnology in the region. The biosafety and protocols from all member states except two were exchanged. Follow up action is being taken by respective member states. It may be agreed that that all countries would exchange their existing biosafety procedures and protocols. Depending on the outcome of on-going WTO discussion on labeling and segregation of GMOs, it is important that regional approach is developed in this important area. In this regard, international support by various agencies should be explored so as to overcome the scientific uncertainity and methods for traceability.

Lesson should be learnt from OECD countries where debate on monitoring of GMOs after release into the natural environment has further intensified. Some scientist argued that monitoring should be continued so more insights are available for risk management while others feel that the high cost of monitoring are not justified when transgenics have successfully passed the hurdles of safety assessment and risk management.

Cooperation in Human Resource Development

It is important to realize that some of the South Asian countries are facing constraints on the front of trained manpower in the first generation biotechnology. At present, there are not enough capable scientist with adequate exposure to advance biotechnology. As agriculture and forestry are key sectors where even preliminary biotechnology can help in a major way and as is clear some other members like India and Sri Lank are moving towards the new biotechnologies from the first generation biotechnology. Thus these complementarities should be tapped for expanding the regional technological frontier. In this regard the financial support from SAARC-Japan Special Fund may be tapped to strengthen the manpower skill up gradation programme. Human resource development is also important for facilitating technology transfer and adaptation when it comes to international collaboration.

Data Bases and Networking

The South Asian countries may also consider the pooling of resources for ensuring online search for scientific literature through internet and help scientific institutions overcome the high costs of purchase of scientific journals. In order to access such facilities at the regional level through the intranet, availability of broad band will minimize internet expenses to a considerable extent.

Some countries are gaining experience in field testing, while others have not yet completed biosafety guidelines. Information of socioeconomic and scientific development in biotechnology and biosafety can be accessed from a number of information sources, including the Biosafety Clearing House mechanism to be provided under the terms of the Cartegena Biosafety Protocol.

Developments in Biotechnology are largely driven by multinational cooperation the world over. It is important that small national companies get regional support in terms of access to technology and resources. In this regard, firms working in the area of biotechnology in South Asian region should become more active at a joint forum to provide their inputs for policy formulation and for working toward joint stands in international negotiations.

At regional level efforts should be made to establish a Regional Biodiversity Conservation Fund (RBCF). The RBCF would be meeting a long felt need of a financial mechanism required for the conservation and management of biodiversity. The SAARC member countries may consider various instruments to tap resources for this fund. The fund may be used for supporting collective initiative such as inventorising the germplasm collected for SAARC gene bank;

for setting up of crisis management group for any kind of biohazard and collective monitoring of biosafety protocol for checking transboundry movement of genetically modified organism.

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