

SCIENCE, AGRICULTURE AND PUBLIC POLICY: A STUDY OF GOVERNMENT-ACADEMIA-INDUSTRY NETWORKING IN INDIA

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DECLARATION

I hereby declare that the thesis entitled “**Science, Agriculture and Public Policy: A Study of Government-Academia-Industry Networking in India**” is the result of investigation carried out by me at the Department of Humanities and Social Sciences, Indian Institute of Technology Guwahati, under the supervision of Dr. Sambit Mallick. The work has not been submitted either in whole or in part to any other university/institution for a research degree.

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This is to certify that Ms. Madhulika Kumari has prepared the thesis entitled “**Science, Agriculture and Public Policy: A Study of Government-Academia-Industry Networking in India**” for the degree of Doctor of Philosophy at the Indian Institute of Technology Guwahati. The work was carried out under my supervision and in strict conformity with the rules laid down either in whole or in part to any other university/institution for the purpose. It is the result of her investigation and has not been submitted either in whole or in part to any other university/institution for a research degree.

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Abstract

Since the early 1990s, there has been an increasing trend towards commercialization of new and existing knowledge in science and technology. Now, new science does not depend on one discipline rather requires integrated expertise from diverse fields. Such situation calls for collaborative networking between the government, academia and private R&D institutions. The concept of triple helix is seen as a key analytical construct which synthesizes the dynamics of interaction, and functions as intersecting between the government, academia and industry. In this context, scientific collaboration is significant which not only increases the productivity of research but also aims at transferring knowledge from laboratory to the field.

Networking between government, academia and industry reflects upon the non-linear model of innovation which suggests that the process of networking is not characterized by over-simplistic method; rather, it undergoes a series of networking ties such as government-government, government-academia, academia-industry, government-academia-industry, and so on.

The present study critically examines the networking between government, academia and industry in terms of publications, patents, projects, laboratory facilities, personnel expertise, research and training, formal and/or informal research collaboration in both India and abroad in various research institutions, universities, MNCs, private industry, and so on. The present study critically analyzes the challenges faced by the scientists in forging such collaboration. The study suggests that the triple helix I form of knowledge production (where the government mediates the relationship between academia and industry) and triple helix II form of knowledge production (where the government has limited role with restricted relationship between the actors) is still more dominant as compared to triple helix III form of knowledge production (where the government, academia and industry play active role in the process of innovation) in agricultural biotechnology sector in India. The cases of Bt

cotton and Bt brinjal depict the politics underlying the triple helix model of innovation in developing countries such as India. The implementation of the agricultural innovation system in India depends on the quality of interaction between multiple actors in the triple helix model of innovation as well as civil society organizations, etc.

The study includes both primary and secondary data. The study is based on in-depth personal interviews with 81 scientists engaged in research in agricultural biotechnology across different institutional settings in India. The study elicits responses from the scientific community in India about the perceptions, attitudes, and the dynamics of such interaction. The study was conducted in public institutions such as universities (central, state and deemed universities), Indian Council of Agricultural Research-sponsored research institutions, mission-oriented research institutions, institutes of national importance, Council of Scientific and Industrial Research laboratories, international research institutions, private research foundation, industry such as Monsanto and CRIYAGEN. Scientists interviewed for the present study are specialized in the areas like genomics, genetic engineering, biotechnology, proteomic, seed science and technology, entomology, plant molecular biology, virology, biophysics, marker assisted selection breeding, plant pathology, transfer of technology and product development. Content analysis was deployed to analyse the interview material. The multidimensional approach has been adopted by looking into various aspects of research like scientists' institutional affiliation, intellectual antecedents, references, citations, etc. Such study has significant implications for controversial technologies in agriculture in India, which adds to the dynamics of interaction and communication between varied actors. The concept of triple helix model of innovation may be a useful tool to understand such transition in agricultural biotechnology in India.

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List of Abbreviations

ABLEAG	Association of Biotech Led Enterprise Agriculture Group
AIS	Agricultural Innovation System
ARI	Agharkar Research Institute
AU	Anna University
BCIL	Biotech Consortium India Limited
BIRAC	Biotechnology Industry Research Assistance Council
BIPP	Biotechnology Industry Partnership Programme
BI	Bose Institute
BIG	Biotechnology Ignition Grant
BRAI	Biotechnology Regulatory Authority of India
Bt	Bacillus Thuringiensis
CBD	Convention on Biological Diversity
C-CAMP	Centre for Cellular and Molecular Platforms
CCMB	Centre for Cellular and Molecular Biology
CIC	Cluster Innovation Centre
CICB	Cluster Innovation Centre in Biotechnology
CIMMYT	International Maize And Wheat Improvement System
CMIE	Centre for Monitoring Indian Economy Private Limited
CRS	Contract Research Scheme
CSIR	Council of Scientific and Industrial Research
CSOs	Civil Society Organizations
CU	Calcutta University
CV	Curriculum Vitae
DAE	Department of Atomic Energy
DBT	Department of Biotechnology
DNA	Deoxyribonucleic Acid
DRDO	Defence Research and Development Organisation
DST	Department of Science & Technology
FDA	Food and Drug Administration
FICCI	Federation of Indian Chambers of Commerce and Industry
FSB	Fruit and Shoot Borer
GATT	General Agreement on Tariffs and Trade
GDP	Gross Domestic Product
GE	Genetic Engineering
GEAC	Genetic Engineering Appraisal Committee
GEAC	Genetic Engineering Approval Committee
GERD	Gross Expenditure on Research and Development
GGSIPIU	Guru Gobind Singh Indraprastha University
GM	Genetically Modified
GMOs	Genetically Modified Organisms
HYV	High Yielding Varieties
IACS	Indian Association for the Cultivation of Science
IAS	Indian Academy of Science
IAASTD	International Assessment of Agricultural Knowledge, Science and Technology Development
ICAR	Indian Council of Agricultural Research
ICGEB	International Centre for Genetic Engineering and Biotechnology

ICT	Information and Communications Technology
ICRISAT	International Crops Research Institute for the Semi-Arid Tropics
IICB	Indian Institute of Chemical Biology
IISc	Indian Institute of Science
IIT	Indian Institute of Technology
IITM	Indian Institute of Technology Madras
IWBR	Indian Institute of Wheat and Barley Research
IIRR	Indian Institute of Rice Research
INAE	Indian National Academy of Engineering
INSA	Indian National Science Academy
IPM	Integrated Pest Management
IPRs	Intellectual Property Rights
ISAAA	International Service for the Acquisition of Agri-Biotech Applications
ISCB	International Society for Computational Biology
JNU	Jawaharlal Nehru University
LBR	Late Blight Resistance
LEIT	Low-External-Input Technology
MAHYCO	Maharashtra Hybrid Seed Company
MAS	Marker Assisted Selection
MIT	Massachusetts Institute of Technology
MMBL	Mahyco-Monsanto Biotech (India) Private Limited
MNCs	Multinational Corporations
MoEF	Ministry of Environment and Forests
MoU	Memorandum of Understanding
MSSRF	MS Swaminathan Research Foundation
NAAS	National Academy of Agricultural Sciences
NAMS	National Academy of Medical Sciences
NARS	National Agriculture Research System
NASI	National Academy of Sciences
NCBS	National Centre for Biological Sciences
NCL	National Chemical Laboratory
NCPGR	National Centre for Plant Genome Research
NGOs	Non-Governmental Organizations
NIS	National Innovation System
NITI Aayog	National Institution for Transformation India Aayog
NSTMIS	National Science & Technology Management Information System
OECD	Organisation for Economic Co-operation and Development
OU	Osmania University
PCT	Patent Cooperation Treaty
PPVFRA	Protection of Plant Varieties and Farmers' Rights Act
PPP	Public Private Partnership
R&D	Research and Development
RCGM	Review Committee on Genetic Manipulation
SAUs	State Agricultural Universities
SCI	Science Citation Index
SD	Standard Deviation
S&T	Science and Technology
SIBRI	Small Business Innovation Research Initiative
SINP	Saha Institute of Nuclear Physics
SIRO	Scientific & Industrial Research Organization

SPR	Scientific Policy Resolution
SST	Sociology of Science and Technology
TEC	Technical Expert Committee
TIFR	Tata Institute of Fundamental Research
TRIPS	Trade Related Aspects of Intellectual Property Rights
UAS	University of Agricultural Sciences
UGC	University Grant Commission
UIC	University Innovation Cluster
UNESCO	United Nations Educational, Scientific and Cultural Organization
UoD	University of Delhi
UoH	University of Hyderabad
UoM	University of Madras
UoP	University of Pune
USPTO	United States Patent and Trademark Office
WTO	World Trade Organization



CHAPTER I

INTRODUCTION

1.1 Introduction

Agriculture research in India faced a major paradigm shift in the 1990s in response to issues emanating from the Convention on Biological Diversity (CBD) and agreement under the World Trade Organization (WTO) (cited in Nair 2011). The provisions of the Trade Related Aspects of Intellectual Property Rights (TRIPS) agreement of the WTO established enforceable universal minimum standards of protection for all major forms of Intellectual Property Rights (IPR), of individual or institute, for new knowledge skills, technologies and products developed by them. Also, it extended the application of the IPR regime to living things and agricultural research. Article 27.3 of TRIPS (1995) allows protection of new plant varieties via patents or through an appropriate *sui generis* system of protection or a combination of both. These enforcements promote technological innovation as more plant breeders will be motivated to develop new plant varieties. Moreover, it will lead to commercialization of agriculture through the enforcement of IPR instruments such as patent, copyright, trademark, etc. (cited in Nair 2011). This leads to the commercialization of Indian agriculture. The changing nature of research in agricultural biotechnology in developing countries like India requires expertise from diverse fields such as genetics, physiology, pathology and entomology that has made collaboration among researchers from such diverse fields essential. In a developing economy like India, university-industry networking has remained low. In the 1960s, the High Yielding Varieties (HYV) of seeds were adopted to increase the volume and rate of agricultural production. The HYV seed was owned by the State and there was no ownership of the private sector over the seed. However, as the agricultural sector entered in the era of genetic modification, there was a transition in the

ownership of state to the multinational corporations (MNCs) over the production and use of the seed. Investments in such genotypic research cannot be fulfilled by the public sector alone and this calls for broader participation from private R&D (Mallick, Haribabu and Reddy 2011). Owing to the corporatization of invention in agricultural biotechnology, the private sector is now playing a key role (Singh and Pal 2015). In order to utilize the full benefit of research and innovations, it is important to understand the public-private networking aiming at concrete deliverables.

A new form of knowledge is created through the intersection of the interests of academia, industry and government (Ranga and Etzkowitz 2013). In this context, the thesis critically examines the networking between agricultural biotechnologists in various institutional settings, viz. government, academia and industry. The networking between academia and industry was legalized through the introduction of Bayh-Dole Act in 1980 in the USA, which allowed universities and public institutions to retain ownership of inventions. India is trying to evolve an indigenized model of Bayh-Dole Act to strengthen its R&D in public institutions which requires further articulation. Moreover, the concept of IPR was introduced to the research outcome coming out of public funded research institutes, a step in institutionalizing and legalizing research outcomes of public research institutions (Rhines 2005).

Scientific collaboration is more significant in the discipline where team work or expertise from diverse fields is required (Bennett and Gadlin 2012). One of the interesting features of scientific collaboration is that collaboration can take various forms. Scientific collaboration is a complex process and at times difficult to calculate the degree/amount of scientific expertise invested in the process.

In India, industry-academia collaboration has not fully evolved (Nangia and Pramanik 2011). Government policies and institutional mandates influence the individual

choice of research. Scientists may not be willing to work in controversial areas like transgenic technology as science and technology policies are intertwined with the public policies formulated by the government. There is more private-private collaboration in the case of proprietary non-food and food crops such as Bt Cotton and Bt Brinjal respectively. Debates on genetically modified (GM) crops are not just scientific or technological but also byproducts of the alliance between scientific, political and industrial elites. It is interesting to answer how biotechnology is shaped by the conflicting interests among varied stakeholders. Decisions on GM crops are not shaped solely by scientists as they are guided by the nature of the state and the making of public policy. The funding for the short term project may not contribute to national goals in the long run. It is in this context government in collaboration with industry should support the long-term holistic project funds.

1.2 Review of Literature

1.2.1 Historical Background to Agricultural Research in India

The development of agricultural technology in India was initiated through the green revolution in the 1960s where public sector played a dominant role. Since the 1990s, there has been a need of new agricultural technologies that can deal with complexities across diverse settings in India. Owing to the introduction of IPR in agriculture and growth in molecular biology and genetic engineering, the role of private sector has increased (Pingali and Raney 2005). Agriculture in developing countries including India not only involves a semi-skilled and unskilled workforce but also low technological intervention. Hence, any technology that would result in decrease in cost or improve the crop yield will be highly valuable.

The involvement of private sector is particularly important especially with the involvement of the biotechnology sector and patent being granted under IPR. New biotechnology research is expensive and cannot be supported by the government institutions alone. So, there is a need for private sector funding in the areas of agriculture research and extension activities. Biotechnology is seen as an emerging industry in the countries like India. The relationship between private sector and the state is important to understand the politics of biotechnology policy processes in developing countries like India. The state often plays a crucial role by way of appropriate policy intervention to promote particular sector (Parthasarthy and Joseph 2002). In addition to the Indian Council of Agricultural Research (ICAR) and state agricultural universities, other state and central universities are engaged in agricultural research. However, in the wake of economic reforms in the 1990s and slash in public funding in the agricultural sector, the private institutions started playing an important role by investing increasingly in agricultural field especially in the area of biotechnology. The agricultural sector has undergone a transition from hybrid seeds (green revolution) to genetically modified seeds (gene revolution). Such transition requires inputs from various fields ranging from expertise, funding, networking to diffusion and commercialization of technology by involving varied actors. Owing to India's post-colonial developing country orientation, policymaking and policy research have been framed through the terms of development and planning (Mathur 2013). The future of Indian agriculture is bound to be affected by a number of emerging scenarios like shrinking land availability, lack of land reforms, absence of minimum support price, etc. In the field of agricultural biotechnology, university has become an active player in conducting basic research. Nevertheless, it has become categorically imperative to delve into more applicational aspects for greater public welfare.

With rapid development in plant genomics, biotechnology has profound implications in agricultural sciences and technologies. Innovative technology, improved technology or modified technology is often imperative for agricultural crop productivity enhancement. The effort of technology development is complete only when it is adopted by the end user as a product suitable for commercial application. It is thus crucial that academia/research organizations understand the needs of the industry and vice-versa or work in close collaboration with each other. University/research organizations are repositories of rich crop germplasm and skilled plant breeding that could offer unique solutions or provide a platform for modern improved technologies with effective pest and disease resistance traits (Mysore 2014). The present conditions of Indian agriculture demand the use of such germplasm for developing varieties with disease or pest resistance both by public and private sector research efforts. This does not simply mean a licensing between public and private sectors involving arbitrarily assigned value rather than active partnership by both sectors. About one-third of global private investments in agricultural R&D are directed towards agriculture chemicals, most significantly pesticides (Naseem et al. 2010). Private R&D tends to focus on cash crops such as tea, rubber, oil, vegetables etc. (Gerpacio 2003; Morris and Shin 1998). A useful indicator of private investment in agri-biotech is the number of field-trials approved by the government inspection agencies and conducted by private firms (Naseem et al. 2010). Nevertheless, more than 60 per cent of the field-trials are conducted by private firms in developed as well as developing countries (Naseem et al. 2010). It is important to note here that technology alone cannot help us achieve sustained higher growth rate in agriculture in India but technological thrust has to be backed by appropriate policy measures (Bhatia 1998).

1.2.2 Sociology of Science and Technology

Sociology of Science and Technology (SST) may be examined as a part of sociology that studies relationships between different idea systems and a variety of institutional and personality factors. It is a relatively new field in the sphere of science and technology studies, which has traditionally been dominated by philosophy and history of science. It deals with the social relativism of scientific research and its knowledge products. It informs that scientific research is a process, which involves social interests and the major social forces that prevail upon the working of a scientist. The SST is a speciality that examines the circumstances under which science is practised and technology is developed (Calhoun 2005). The sociology of science dates back to the late 1930s, where Robert K. Merton (1938) displaced the then existing Marxist perspective with a sociological approach to knowledge. In what come to be called the institutional approach to science, some of the important questions concerned the social organization of science and the 'institutional imperatives' or norms and values that sustained the scientific attitude from within the ethos of science, viz. universalism, communism, disinterestedness and organized skepticism (Merton 1968). The generation which followed turned its back on the functionalist mode of reasoning which is evident in these concerns and which Merton, like Parsons had adopted (Parsons 1968). It collectively moved away from the focus on social-structural and institutional processes characterizing scientific groups and organization, arguing that science cannot be understood if the cognitive content of science and technology, and the processes of knowledge and technology creation are not included in the analysis. This attitude was encouraged by the works of Kuhn (1970 [1962]) and Feyerabend (1975) who espoused a philosophy and historiography of science in which they traced the independence of cognitive and social factors in the history of physics and other disciplines. The outcome

of the collective change of mind was that the sociology of science and technology turned into sociology of knowledge.

Unlike Mannheim (1936) and Scheler (1924), who had proposed sociology of knowledge in the 1930s but excluded the natural sciences from it. The new generation insisted that natural science must be at the center of attention of social studies of science. Mannheim and Scheler's central thesis was that human thought was socially conditioned as was knowledge or economics, and more generally in the human sciences, but they assumed as most scholars did after them, that the natural sciences were exempted from such influence the common assumption explicitly endorsed by the earlier institutional school. Philosophers of science attempted to investigate the structure of scientific theories and the logic of discovery and justification. In contrast, what unfolded the new sociology of scientific knowledge guided by empirical sociological analysis in line with the principles of natural sciences and mathematics (Calhoun 2005).

The resulting studies (Pinch and Bijker 1984) show that the technical core of science could be studied empirically through methods of social sciences methods with greater advantage. Doing science and technology was a form of constructive action in collective contexts. Though the processes observed were intricate and complex, they were open to examination to no lesser degree than those in other areas of social life. This new sociology of social science was later expanded into a new sociology of technology (Pinch and Bijker 1984) and both proved tremendously successful, conceptually as well as empirically, yielding a number of new programmes and results. According to Merton (1968), "the social structure of modern science is highly dependent upon the social, economic and political organization of society and extremely sensitive to changes in this environment". Sociologists in the 1970s began advocating sociology of scientific knowledge that directly challenged the deeply held notion that science is unique among

social institutions in gaining access to natural and universal truths (see Barnes 1974; Mulkey 1979). Instead, researchers sought to demonstrate that scientific knowledge is social and particularistic and that the essential character of institutions and the cultural practice that support knowledge production in science is neither autonomous nor distinct (Frickel and Moore 2006). SST cuts across traditional boundaries and more of interdisciplinary in nature involving more networking, collaboration through publications, patents, research work, etc.

To sum up, on the one hand, the internalist characterization of science suggests that all knowledge *except* scientific knowledge is socially and culturally mediated (Mannheim 1936). On the other hand, the externalist characterization of science suggests that all knowledge *including* scientific knowledge is socially, historically and culturally conditioned (Bloor 1976; Kuhn 1970). However, the dichotomy between the internalist and externalist worlds of science is not rigid but porous. For example, Bourdieu (2003) points out that we have to go beyond the narrow confinements of the absolutist-idealist conception of science, on the one hand, and, historical relativism of those who consider science to be a purely social construct, on the other.

1.2.3 Contours of Public Policy

Science and agriculture are inherently politically and culturally conditioned. Science and agriculture are shaped through the policies of the state and various socio-political actors, viz. state-regulated institutions. Public policy is crucial to understand the changes that have taken place in science and agriculture.

Public policy is influenced by and influences several other fields of study and is highly interdisciplinary in nature. It is important to note that public policy is not just a government action, since non-action at times has deliberate consequences. As Jones

(1984: 27) states: “Public policy is a goal directed or purposive course of action followed by an actor or a set of actors in an attempt to deal with a particular problem”.

A policy process is fluid and varied; it changes over time and from policy to policy. Charles Jones (1984) describes five stages through which public policies usually pass. Let us discuss these in detail. First, citizens, interest groups, or policy makers must perceive and define a problem and thereby bring it to the public agenda. Second, policy makers formulate and debate possible solutions in Congress or the executive branch in the USA. Third, they adopt a set of solutions as law, an executive decision, or a regulation. In the fourth stage, bureaucrats study the programme and allocate resources to implement the policy. This task is often complicated by political pressures to delay or alter a programme. In the fifth stage, policy makers evaluate the outcome of the first four stages, but an assessment can be performed during any phase of the process and by any person, group, or institution. Finally, all the above mentioned stages rarely follow a proper chronological sequence, rather than subject to political maneuvering and bargaining. Thus, public policy has to be understood within the nature of an uneven structure of the society.

1.2.4 Models of the Policy Process

Let us discuss general models which have provided useful perspectives on policy process. One is the rational model, which assumes that policy makers have clear goals, the ability to assess many alternative courses of action, and the willingness to choose those policies that achieve their goals at the least cost (Herring 2007). This model emphasizes neutrality, objectivity, thoroughness, consistency, and the use of quantitative measures whenever possible having a close resemblance with the ideal scientific method. Other models emphasize the limitations of policy makers, as Barke (1985) argues that

policy makers take current policies as a starting point and make only incremental changes, thereby avoiding the need for clear definitions and searching analyses. In this model, policy makers lack time, ability, and resources to be thorough; instead, they try to adjust the old policies. The incremental policy model (Chaffee 1983) might be familiar to practicing scientists because it blends the spirit of the perfect scientific method with the real obstacles of being thorough. The incremental policy model lacks the capacity to accommodate unexpected changes which may alter the policy objectives. The third model is the garbage can model in which government is described as ‘organized anarchy’. Personal preferences are unclear, learning is by trial and error (therefore incomplete and not easily shared), and policy participants change easily due to personnel turnover or the reassignment of tasks (Barke 1985). Policy choices are similar to a “garbage can into which various kinds of problems and solutions are dumped by participants as they are generated” (Barke 1985: 128). Most importantly, policy outcomes depend on the coincidence of three major processes: problem recognition, policy formation and politics. The garbage can model describes a messy policy process that is difficult to predict. Just as the sciences occasionally undergo unexpected changes (‘paradigm shifts’ or ‘scientific revolutions’) due to inadequacies of earlier theories, delayed and limited responses to poorly understood problems characterize the policy process (Kuhn 1970).

Moreover, the formation of public policy is inherently political (Winner 1980) that requires both accumulation of facts and weighing of values. The fundamental task in policymaking is to move from what is to what someone believes should be. Yet public policies are formed from an aggregation of individual desires that may not be based on present reality. In general, policy process is pervaded by the tensions between scientific procedures to gather and analyse knowledge and the amorphous quid-pro-quo political

bargaining. Tensions also characterize science and technology policy: tensions between simplicity and reality, scientific understanding and social utility, public participation and professional competence, and short political time horizons and long scientific perspectives (Brooks 1982).

Thus, if the process of policymaking depends solely on political forces, the techniques and results of scientific inquiry would be ignored because objectivity will be irrelevant in this case or subverted to disguised subjectivity. In contrast, if policymaking depends solely on rationality and logic, scientific knowledge would be embraced and encouraged. But in practice, public policies usually fall somewhere between these extremes combining political necessities with scientific knowledge. Often 'objective' parts of the policymaking are nearly contaminated by the subjective values of interest groups, public opinion, or even the decision makers themselves (Mathur 2013). While comparing the costs and benefits of policies, conflicts between scientific facts and political values become crucial.

Government support includes funding for the education of science and technology, basic research and thus government regulation of science and technology can be both positive (when environmental regulation requires advances in antipollution technology) and negative (as when policies restrict the types of genetic research experiments that scientist can perform). In India, more than 75 per cent of total science and technology funding, including gross expenditure on research and development comes from the government (Krishna 2001). For this reason political attitudes and policies play a crucial role in the shaping of science and technology policies in India. Scientific methods and knowledge play a complex, yet crucial role in the process of technological innovation, and demand deliverable solution to the real-world problems.

1.2.5 Post-academic Science

Since the 1990s, there has been a transition from academic science to post-academic science (Ziman 2000), from being a curiosity-driven research to contract obligations. In other words, we witness a transition in the production of scientific knowledge from being a public resource to an intellectual property. According to Merton (1968), academic science, as discrete institutional order, differs from industry on the basis of academic values, norms and conventions. In this context, agriculture in India is often said to have remained largely outside the disciplines governing international trade (Bhagwati, Krishna and Panagariya 2014). But this view is partial in the legal sense, as the General Agreement on Tariffs and Trade (GATT) has been applied in full to agriculture (Nair 2011). The original GATT 1947 was applied to trade in agriculture, but it allowed various exceptions to the rules on non-tariff measures and subsidies, which led to several distortions in world of agricultural trade. For example, the GATT in 1947 allowed countries to use export subsidies on agricultural products whereas export subsidies on industrial products were prohibited. The GATT rules allowed countries to resort to import restrictions (e.g. import quotas) in the agricultural sector under certain conditions, notably when these restrictions were necessary to enforce measures to effectively limit domestic production. The result of all this was a proliferation of impediments to world agricultural trade. Including by means of import bans, quotas setting the maximum level of imports, minimum import prices, non-tariff measures maintained by state-trading enterprises, etc. The need of liberalization in the world trade in agriculture was felt due to extensive subsidization by the developed countries which led to the distortion in the prices of agricultural commodities (Braun, Gulati and Orden 2004). Till 1995, export subsidies came to dominate many areas of world agricultural trade, while the disciplines on import restrictions were often flouted. The 1986-1994

Uruguay Rounds went a long way towards changing all that. Agricultural trade is now firmly within the WTO multilateral trading system. The agricultural agreement, together with individual countries' commitments to reduce export subsidies, domestic support and import barriers on agricultural products were a significant first step towards reforming agricultural trade. Whether developing countries will be able to protect their plant genetic resources and the rights of local communities to control and enjoy the benefits of their traditional knowledge will be determined both by policies adopted by the WTO and by the domestic policies that nations implement within their respective interest (Plahe and Nyland 2003). Science is also the object of policy which is quite clear in biotechnology research where policy decisions regulate scientific practices. Sociologically speaking, there may be concerns or may be even overlap between the experts who inform and the scientists whose interests are affected by the policy decisions (DeMarchi 2003). Biotechnology experts are given central place in undertaking decisions regarding GM crops. Alvin Weinberg (1972) coined the term trans-scientific for questioning which can be asked of science and yet which can be answered by the scientists.

1.2.6 Triple Helix Model of Innovation

The concept of the triple helix of university-government-industry relationships initiated in the 1990s by Etzkowitz and Leydesdorff (1995) which elucidates “the shift from a dominating industry-government dyad in the industrial society to a growing triadic relationship between academia, industry and government in knowledge society” (http://triplehelix.stanford.edu/3helix_concept, accessed on 28 January 2016). An evolutionary view of triple helix dwells upon the institutional perspective of private and public control at the level of academia, industry and government which enables various

degrees of selective mutual reconciliation (Leydesdorff and Etzkowitz 1998). In triple helix system, networking in formal and informal structures at regional, national and international levels is one of the major forms of interaction. The networking between government, academia and industry is necessary for the knowledge production in agricultural biotechnology processes. According to (Etzkowitz 2004), it is where most creative synergies emerge and set in motion a process of innovation in innovation, create new venues for networking and organizational formats as an individual and organizational actor not only perform their own role but also exchanges the role of the other.

The neo-evolutionary perspective suggests that academia, industry and government are co-evolving sub-sets of social systems that interact through an overlay of recursive network and organization that reshape their institutional arrangement through reflexive sub-dynamics such as markets and technological innovation (Leydesdorff 2008). Triple helix is significant in understanding the networking between different actors in agriculture innovation system which roughly relies on the traditional mode of knowledge diffusion (Hall et al. 2001). The triple helix model of innovation must cover the concerns of the citizens including the major stakeholders in agricultural biotechnology.

1.3 Research Gap

Triple helix model in the case of biotechnology is not fairly explored in the context of developing countries such as India. The present study is an attempt to understand the networking between government, academia and industry in formal and informal structures by directly investigating the motivation, interest and organizational mandates of different institutional settings. What are the challenges scientists face in the

course of forming such networking or collaboration? Triple helix model or government-academia-industry interaction is complex and its qualitative analysis is difficult in the case of developing countries like India. It extrapolates the functions, interaction and problem within triple helix. There is little information on informal collaboration between various actors. Hence, it is important to study the informal collaboration between varied actors, viz. government, academia and industry.

At the policy level, the Science, Technology and Innovation Policy (2013) of the Government of India promotes the Public-Private Partnership (PPP) model in the case of agricultural biotechnology in India (<http://www.icar.org.in/files/sti-policy-eng-07-01-2013.pdf>, accessed on 12 April 2016). What are the government policies responsible for transforming the National Innovation System (NIS) in India? What are the institutional mandates evolved to cope with the PPP model within the NIS framework?

Debating the controversies on GM and non-GM crops assumes greater significance in developing countries such as India. The present study does not attempt to make a demarcation between GM and non-GM crops and food. Rather, we attempt to understand the practices of the scientific community as 'mangled' (Pickering 1992) through the processes of resistance to and accommodation of new technological systems. It is interesting to examine how biotechnology is shaped by the conflicting interests among varied stakeholders. The present study is an attempt to examine the implications of proprietary technologies in agriculture in India where two genetically modified crops, namely Bt Cotton (non-food crop) and Bt Brinjal (food crop) are analyzed. It discusses debates and politics about biotechnology in general and Bt crops in particular. It critically examines how diverse actors involved in the process have their own interests and meanings. It also tries to study the networking between the government, academia and industry with a special focus on Bt Cotton and Bt Brinjal. It further argues how

increased networking and interaction between these three actors namely, government, academia and industry will have better adoption of agricultural biotechnology as well as it will lead to policy level changes required for GM crops.

1.4 Rationale for the Topic

The present study attempts to examine the networking between government, academia and industry in agricultural biotechnology in India. With the advancement of research, complexities of research have increased which require more collaboration among diverse disciplines and geographical locations. In India, though the public sector continues to support the major portion of R&D activities the funding for agricultural research is not adequate. This calls for enhancement of partnership especially from private sector's investment in agricultural R&D and non-R&D activities. The government is trying to promote PPP model in agricultural biotechnology by funding projects involving actors from government, academia and industry, incubation facilities, startups and so on (<http://www.icar.org.in/files/sti-policy-eng-07-01-2013.pdf>, accessed on 12 April 2016). In India, there is a constant effort to reach tri-lateral or triple helix model of innovation in agricultural biotechnology through networking and partnership (Sastry and Rao 2013). It also tries to study the status of GM crops in India against the backdrop of challenges posed by the different sections of the society. The challenge is to understand dynamics and debates and develop ways to deal with these challenges. The introduction of technologies is frequently marketed by governments, donor agencies and private businesses as 'safe and good' – even where the intrinsic contribution of such technological innovation to human safety remains under the scanner. In this context, it is significant to understand how India should position itself in relation to Bt seeds to suit the need of poor farmers.

1.5 Research Questions

The present study centres on the following research questions:

- (a) To what extent and in what ways the networking between the government, academia and industry promotes or otherwise proprietary technologies in agriculture? In other words, it is important to examine the interests and meanings associated with proprietary technologies in agriculture as well as various actors and institutions in India. It will be interesting to note how these debates and contested views on Bt crops can lead to policy suggestions which are critical for the appropriate utilization of new technologies in Indian agriculture.
- (b) What are the institutional mandates and policies outlined to enhance knowledge production in agricultural innovation system in India? Further, it tries to examine the factors which lead to innovation/knowledge production in agricultural innovation system in India.
- (c) What are the factors which lead to the hindrances to collaboration? What motivates the scientist to collaborate with industry or otherwise? It tries to examine networking between government, academia and industry by enquiring or capturing the views/understanding of scientists on research collaboration. Putting it succinctly, it tries to examine the status of triple helix model of innovation in agricultural biotechnology in India through patents, publications, projects, intellectual antecedents, informal networking ties, and so on.

1.6 Objectives of the Study

The objectives of the present study are to:

- (a) Understand the implications of the implementation of proprietary technologies in agriculture in India;
- (b) Examine the institutional mandates outlined to promote innovations in agricultural biotechnology research in India;
- (c) Examine the processes of government-academia-industry networking towards knowledge production in agricultural biotechnology in India.

1.7 Methodology

The present study, from sociology of science and technology perspective, attempts to understand the perspective of plant scientists on the current state of Bt seeds in agriculture in India, together with potential or actual applications, in order to address the social, economic, political, cultural, ethical, legal, institutional and ideological issues. It also tries to understand the networking between government, academia and industry on agricultural biotechnology in India and how this networking leads to the innovation/knowledge production in the agricultural biotechnology sector. The study was carried out through both primary and secondary data. The primary data include in-depth personal interviews with scientists engaged in research in plant biotechnology in the government, academic and private R&D institutions in India. Interview guide and questionnaire helped us ascertain the views of various stakeholders about Bt seeds in agriculture in India. Content analysis was deployed to analyze the interview material. Coding was done on the basis of themes and oft-repeated statements.

The multidimensional approach has been adopted by looking into various aspects of research like (affiliation, researchers' background, publications, citations, patents and instrumentalities). Triangulating information from interviews, publications, patents and

other complementary sources (i.e. CVs, personal and laboratory homepages) have been analyzed.

In-depth personal interviews with scientists of different institutional settings like government, industry and academia have been carried out. Scientists from government departments such as Indian Agriculture Research Institute, New Delhi; scientists from academic institutions such as University of Hyderabad, University of Delhi, Jawaharlal Nehru University; and scientists from industry such as Monsanto and CRYGEN are interviewed. Scientists interviewed for the present study are specialized in the areas like genomics, genetics and engineering, biotechnology, proteomic, seed science and technology, entomology, plant molecular biology, plant virology, biophysics, marker assisted selection breeding, plant pathology, transfer of technology and product development. The study was conducted in public institutions such as universities (central, state and deemed universities), ICAR-sponsored research institutions, mission-oriented research institution supported by the government, Institutes of National Importance, CSIR laboratories, international research institutions, the private research foundation and so on.

Among the means used for data collection was a questionnaire to elicit information related to employment, experience both teaching and research, institutional affiliation, research output such as publication and patent. Also, in-depth personal interviews with individual scientists were conducted in their laboratories and interestingly purely qualitative responses given in the interviews provided rich insights into the perceptions, attitudes, and the dynamics of interaction.

15	Bose Institute (BI), Kolkata	7
16	National Chemical Laboratory (NCL), Pune	4
17	Centre for Cellular and Molecular Biology (CCMB), Hyderabad	1
18	Indian Institute of Chemical Biology (IICB), Kolkata	2
19	Indian Agricultural Research Institute (IARI), New Delhi	4
20	Agharkar Research Institute (ARI), Pune	6
21	University of Agricultural Sciences (UAS), Bengaluru	14
22	Indian Institute of Rice Research (IIRR), Hyderabad	4
23	Saha Institute of Nuclear Physics (SINP), Kolkata	2
24	National Centre for Biological Sciences, Bengaluru	3
25	Indian Association for the Cultivation of Science (IACS), Kolkata	1
26	M.S. Swaminathan Research Foundation (MSSRF), Chennai	3
27	Criyagen, Bengaluru	2
28	Monsanto India Ltd.	1
	Total Number of Institutions: 28	81

Content analysis is a general term for a number of different strategies used to analyze text (Powers and Knapp 2006). It is a systematic coding and categorizing approaches used for exploring large amount of textual information unobtrusively to determine trends and patterns of words used, their frequencies, their relationships and the structures and discourses of communication (Mayring 2000). Qualitative Data Analysis (QDA) software has been used to analyze interview transcripts. QDA Miner helped in coding, annotating and retrieving and analyzing large number of interview transcripts. MS Excel and Minitab have been used to analyze questionnaire. The analysis focuses on Indian agricultural biotechnology research system. Performance levels of scientific collaboration between public and public institutions, public and private institutions, and private and private institutions are classified under three categories: low: 0-50%, moderate: 51-75% and high: above 75%. First we have to calculate mean and standard

deviation (SD) for all observant. These performance level, have been classified as low, medium and high categories. The formulae for calculating low, medium and high performance level are as follows:

Low: $< (\text{mean} - 1/2\text{SD})$

Medium: $\text{mean} - 1/2 \text{SD}$ to $\text{mean} + 1/2\text{SD}$

High: $> (\text{mean} + 1/2\text{SD})$

The secondary sources of data collection include books, journals, government reports and policies. The interview of the scientists was conducted from September 2014 to April 2015. Scientists interviewed for the present study belongs to the field of Genomic, Plant Molecular Biology, Genetic Engineering, Entomology, seed science and Technology, Plant Virology and Plant Pathology, IPR policy expert, Marker Assisted Selection breeding and so on.

1.7.1 Profile of the Respondents

Let us look at the profile of scientists interviewed for the present study. A majority of scientists interviewed are above the age of 50 out of which 66.7 per cent are senior scientists indicating that they are witness to pre- and post-WTO-regulated IPR regime. A scientist who is above the age of 50 and has research experience for more than 15 years is classified as the senior scientist. Senior scientists have more social capital, more publications, more research grants, and also work more prolifically with industrial collaborators. Also, 39.5 per cent of scientists interviewed completed their doctoral research in India, 6.2 per cent of scientists completed their doctoral research abroad. On the other hand, 11.1 per cent completed their doctoral and post-doctoral research in India, 43.2 per cent completed their doctoral studies in India and post-doctoral studies abroad.

49.4 per cent of scientists interviewed had international exposure at varying period of their research studies.

The study also suggests senior scientists are likely to attract more funding and plays a key role in decision making or policymaking regarding specific research areas as they have witnessed both pre and post liberalization period in India. They are working in partnership with industry and other research institutions at both national and international level. Each senior scientist individually is contributing to the knowledge production in agricultural biotechnology in India through a large number of publications, patents, projects, and networking. Seniority is often positively related to collaboration (Boardman 2008, 2009). More experienced researchers are likely to have a larger network, and thus more social capital, enabling them to find potential partners in the private sector (Haeussor and Colyvan 2011). Inter-individual collaboration seems to be more frequent than the other form of collaboration like inter-institutional, inter-department, international, inter-continental and so on.

Scientists for the present study are selected based on their research expertise, broadly in agricultural biotechnology, namely crop physiology, molecular biology, entomologists, plant breeders, genetic and plant breeding, life sciences, biochemistry, biophysics, and so on. Scientists are also selected from the leading industry like Monsanto and other private institutes like MS Swaminathan Research Foundation (MSSRF) and CRIYAGEN based on their expertise in agricultural biotechnology and genetic engineering. Scientists are also selected based on the reputation of their institutions, publications, patents, projects and their international and national collaboration.

Scientists included in the present study collaborate with public institutes, State Agricultural Universities and industry located in different places like Wageningen

University, Netherland, Department of Biotechnology (DBT), Department of Science Technology (DST), Council of Scientific and Industrial Research (CSIR), Indian Council of Agriculture Research (ICAR), International Crops Research Institute for the Semi-Arid Tropics (ICRISAT), Private Agencies, CSIRO Canberra, Plant Breeding Institute Sydney, Nottingham University, UK, Indian Institute of Wheat and Barley Research (IIWBR), Karnal, ITC Limited for demonstration of new wheat varieties, Dr. Balasaheb Sawant Konkan Krishi Vidyapeeth Ratnagiri, Maharashtra University, Weizmann Institute of Science, Israel, Plant Research international, the Netherland, CSIR-National Chemical Laboratory Catalyst Group, CSIR-National Chemical Laboratory Polymer Science group, Dabour, Bejoshetal, Ankur& Sri Biotech, National Institute of Plant Genome Research (NIPGR), NIT-Durgapur, Jamia Millia Islamia, University of Delhi, University of Calcutta, Ranchi University, Banasthali University, Kan-Biosys Pvt. Ltd. Pune, National Bureau of Plant Genetic Resource Germplasm, ICT, seed industry, Agharkar Research Institute Pune, National Chemical Laboratory Pune, Colorado State University, Punjab Agricultural University, CSIR labs/State Agricultural Universities, Persistent Systems Limited, Central Bee Research and training Institute Pune, University of Agricultural Sciences Dharwad, London Metropolitan University, UK, Montana State University, USA, Central Bee Research Training Institute, Pune University of Hyderabad, Iowa State University, Indian Institute of Rice Research & Centre for Cellular and molecular Biology (CCMB) Hyderabad, Tamil Nadu Agricultural University, Mahyco, Bioseeds, Cotton research Institute Pune, National Botanical Research Institute Lucknow, Indo-Swiss project, Department of Atomic Energy, University Grant Commission, AP-Netherlands Biotechnology Programme, Osmania University, Biotech, Genome diagnostics Pvt. Ltd, Guru Gobind Singh Indraprastha University (GGSIPU), Jawaharlal Nehru University (JNU), International Centre for

Genetic and Engineering Biotechnology (ICGEB), Central Research Institute for Dryland Agriculture (CRIDA), CSIR-Institute of Genomic & Integrative Biology (IGIB), University of Mumbai, Diagnostic Pharma, Ranbaxy, International Maize And Wheat Improvement System CIMMYT, All India Institute of Medical Sciences (AIIMS) and so on.

Table 1.3: Classification of Scientists by Age

Age Group (years)	Scientists (N=81)
	Number (Percentage)
30-40	9 (11.1)
40-50	28 (34.6)
50-above	44 (54.3)
Total	81 (100)

Table 1.4: Classification of Scientists by Designation

Designation	Scientists (N=81)
	Number (Percentage)
Scientist	27 (33.3)
Senior Scientist	54 (66.7)
Total	81 (100)

Table 1.5: Classification of Scientists by Research Experience

Research Experience	Scientists(N=81)
	Number (Percentage)
No	16 (19.7)
5-15 years	28 (34.6)
15-25 years	20 (24.7)
25-35 years	17 (21.0)
Total	81 (100)

Table 1.6: Classification of Scientists by Intellectual Antecedents

Intellectual Antecedents	Scientists (N=81)
	Number (Percentage)
PhD (India), PDF (Abroad)	35 (43.2)
PhD (India), PDF (India)	9 (11.1)
PhD (India)	32 (39.5)
PhD (Abroad)	5 (6.2)
Total	81 (100)

1.8 Chapter Scheme of the Thesis

The present study is divided into **six chapters**. The **first chapter** introduces various facets of the thesis: review of literature in the areas of sociology of science and technology, historical background of agriculture research in India, networking and collaboration, on networking expertise, public policy and its stages, models of the policy process, WTO, globalization and Indian agriculture, understanding IPR and agriculture and triple helix model of innovation, and then moves on to identify research gap, rationale, formulate research questions, set objectives and methodology, and chapter scheme of the thesis.

The **second chapter** discusses mode 1 and mode 2 forms of knowledge production, triple helix model of innovation, biotechnology innovation, agricultural innovation system, directed basic research, science and technology policies in India, agricultural policies in India, public-private partnerships, networking between government, academia and industry, international politics of genetically modified food, situating biotechnology debates in the context of triple helix model of innovation, biosafety, science of GMOs, risks associated with new technologies, cases of Bt Cotton and Bt Brinjal, technology input in agriculture, low-external-input technology (LEIT) and organic farming.

The **third chapter** examines the processes of government-academia-industry networking in agricultural biotechnology in India and how this networking results into knowledge production in agricultural biotechnology in India. It also discusses conflicting interests and shared meanings which guide and at times obstruct scientific collaboration among different stakeholders.

The **fourth chapter** captures debates on the politics of biotechnology in general and Bt crops in particular. This chapter also elucidates how diverse actors involved have

their own agendas. It also attempts to study the networking between government, academia and industry with the specific reference to Bt Cotton and Bt Brinjal.

The **fifth chapter** examines the institutional mandates outlined to promote innovations in agricultural innovation system in India. Further, it discusses how public policy and networking between varied actors lead to transition in traditional model of agricultural innovation system in India.

The **last chapter** summarizes the findings of the study, foregrounds the limitations of the study and explores scope for further research in the field.



CHAPTER II

TRANSITION IN AGRICULTURE RESEARCH SYSTEM IN INDIA: A HISTORICAL-SOCIOLOGICAL SURVEY

In the first chapter, we critically reviewed literature pertaining to science, agriculture and public policy and triple helix model of innovation in the Indian context. Having formulated the research questions and objectives of the study, the second chapter discusses mode 1 and mode 2 forms of knowledge production, triple helix model of innovation, agricultural innovation system, directed basic research, science and technology policies in India, agricultural policies in India, public-private partnerships, networking between government, academia and industry, international politics of genetically modified food, situating biotechnology debates in the context of triple helix model of innovation, biosafety, science of GMOs, risk, cases of Bt Cotton and Bt Brinjal, technology input in agriculture, low-external-input technology (LEIT), organic farming, and so forth.

As mentioned earlier, the future of Indian agriculture is bound to be affected by the number of emerging scenarios like shrinking land availability, adequate land reforms, but most importantly corporatization of agriculture research may have a bearing on future agriculture.

2.1 Historical-Sociological Background to Agriculture Research System in India

The state of agriculture science is under transition in India. During the 1950s-60s, there was an acute shortage of food grains. Before green revolution, we used to import food grains, import wheat under Public Law (PL-480) scheme. Previously, Indian agriculture was accompanied by dwarf varieties of wheat, without the use of advanced fertilizers. With the introduction of Green Revolution, yield was enhanced as harvest

index was involved in those varieties. An unexpected additional benefit from these genes has been an increase in grain yield through an improvement in the harvest index. But production was not increasing as per need and demand of growing population. Moreover demand gap was there and Green Revolution was not sufficient to fulfil the needs of growing population and it was dependent on heavy use of fertilizers, insecticides, water and pesticides (Bhatia 1998). These have adverse effects on the overall fertility of land, quality of food and environment. By the 1980s, private sector involvement increased and still India was largely regulated with limited/restricted entry and formation of large private domestic or foreign firms (Nair 2011). India liberalized the seed sector in the mid-1980s. It opened the doors to investment by large Indian firms and allowed foreign direct investment in the sector. This change, followed by continuing investment in public plant breeding and public-private partnerships, has continued to provide private firms with genetic materials for developing the proprietary hybrid. The increased interaction between government, academia and private industry will determine the future agriculture R&D paradigm. Also, the study suggests that protection on IPR will increase investment by private R&D.

Indian industry preferred to take up fully developed, scaled-up all tested ready to use technology rather than work with prototype and ideas (Raghuram 2005). With the willingness of foreign companies to transfer such technology, the primary preoccupation of the Indian industry was to look for collaboration and technology transfer from abroad. A large number of industries are collaborating with the national research laboratories on scientific and technical matters. The collaboration occurs at various levels e.g., representatives of industry participate through the executive councils of laboratories in programme formulation, and act as resource persons in special committees of the

laboratory. Similarly, laboratories often act as technical consultants to the industry and take up specific projects aiming at concrete deliverables.

New era of biotechnology, genomics, molecular biology, plant breeding, a new set of sciences came into the picture. Especially in the case of biotechnology sector, where R&D is mostly concentrated in the hands of multinational corporations, issues of protection of plant varieties and other life forms emerged. It is in this context, patent is significant in the agricultural sector. In the 1990s, genomics, GM technology was used to increase the volume and rate of production of agriculture, for example, Bt cotton. Earlier Bt cotton was imported to India but with the introduction of new technology, India has become one of the cotton exporter countries.

The International Service for the Acquisition of Agri-Biotech Applications (https://www.isaaa.org/resources/publications/annualreport/2014/pdf/ISAAA-Aannual_Report-2014.pdf, accessed on 12 April 2016) reports on GM crops suggest that adoption of GM crops is 52 per cent of global biotech crops as compared to 48 per cent in industrialized countries (James 2012).

India is currently the world's fourth largest producer of genetically modified crops (https://www.isaaa.org/resources/publications/annualreport/2014/pdf/ISAAA-Aannual_Report-2014.pdf, accessed on 12 April 2016). Unlike green revolution era, new gene revolution era is based on international private sector. Indian agriculture is changing fast and its mandate has changed from R&D orientation to innovation by involving varied actors from industry, startups, individual entrepreneurs, and so on. Policy debate is crucial for research and development in agricultural biotechnology in India. Agriculture needs to be viewed as a knowledge-based entrepreneurial activity.

2.1.1 Public Sector Investment in Agriculture in India

The public investment in biotechnology has increased during 2008-2009 (Ministry of Science and Technology) in India. Public investment in agricultural R&D is insufficient especially in developing countries. The public investment in agriculture increased substantially during 2010-2011 as compared to 2005-2006. Interestingly, there has been a substantial increase in the role of central government in increasing funding. Central government funding for agricultural research is largely channeled through the ICAR (95%). Now, ICAR funding pattern accrue highest allocation to agricultural education (31%) followed by crop science research (18%), natural resource management (11%), animal husbandry (9%), horticulture (7%), agricultural extension (7%), fisheries (5%), and agricultural engineering (2%). Another major investment by public sector in agriculture is the annual block grants from the states to their respective State Agricultural Universities (SAUs).

According to Singh and Pal (2015), increasing centralization of agricultural R&D spending in India is not reality as SAUs spending is two-third of national research expenditure while ICAR institutes spent only one-third. These two are major constituents of National Agriculture Research System (NARS) in India. With regard to research expertise, in terms of number of qualified scientists engaged in agricultural research, Indian National Agriculture Research System (NARS) employs the largest number of personnel.

2.1.2 Private Sector Investment in Agriculture in India

At both national and international levels, there is growing importance of private sector investment in agriculture sector. At present, private investment in agriculture is limited. As far as the private sector investment in agriculture is concerned, it plays a dominant role in providing farm inputs such as fertilize, seeds, pesticides etc. But

recently, its presence has been observed in product marketing and agriculture research. Private R&D in agriculture in India is increased due to the event of liberalization and entry of MNCs. Also, approval of Bt cotton in 2002 paved the way for private sector in agriculture in India. In this context, private sector investment in agriculture, especially in case of plant breeding is seen as a new source of funding.

The evidence on private R&D investment trends by studies reported more than ten-fold rise in private research expenditures from 23.9 million in 1999 to \$251.3 million in 2008-2009. The largest expenditure was for seed and plant biotech industry (\$88.6 million) in 2008-2009. The private sector investment in agriculture biotech sector is largest with the major concentration in Bt cotton. Thus, there is a need of private sector spending in other areas like biotic and abiotic stresses and self-pollinated crops. These areas can be enhanced judiciously by involving both private and public sector and other major stakeholders. In total, private sector invests 12% of total sales on research and development in 2011 (Singh and Pal 2015).

The agri-biotech receives the most attention in terms of private investment. Since, the commercialization of Bt cotton in 2002, private sector govern the market of transgenic in the country. According to GMO research information system, field trials data indicates that selected characteristics like insect resistance and herbicide tolerance, cash crops and hybrid received priority in research agenda of the private sector. So, private sector invests in the areas of profitability. Moreover, private firms both national and multinational are depended largely on public sector gene bank and pre-breeding material for the development of their hybrids. According to Singh and Pal (2015), it is difficult to gather information on private investment in various hybrid crops and tissue culture industry but private R&D investment is prominent in cotton, rice, flowers, banana, maize, and ornamental (tissue culture) shares the major portion.

Table 2.1: National Expenditure on Research and Development by Sector

(Rs. in Crores)

Sector	Central Sector	State Sector	Private Sector	Higher Education Sector	Total
1990-91	3058.27	365.92	549.98		3974.17
1995-96	5199.79	657.02	1627.07		7483.88
2001-02	11536.33	1494.33	3292.69	714.8	17038.15
2004-05	15079.95	1941.53	6038.96	1050.8	24117.24
2005-06	17872.02	2334.6	8471.95	1254.01	29932.58
2006-07	19551.8	2757.79	10485.58	1443.21	34238.39
2007-08	21898.88	2951.8	12926.14	1660.96	39437.77
2008-09	27513.88	3562.54	14365.4	1911.56	47353.38
2009-10	31670.54	3865.24	15305.55	2199.97	53041.3
2010-11	36737.25	4435.91	18332.88	2547.43	62053.47
2011-12	42614.53	5090.84	21965.31	2949.76	72620.44

Source: Department of Science and Technology, Government of India (2013-14)**Note:**

1. Central sector data includes 117 R&D units of public sector/Joint sector companies.
2. State sector includes R&D expenditure of State Agricultural universities and other state departments/organization.
3. Private sector industries data for the year 2003-04 onwards comprised of R&D units/firms recognized by DSIR and industries/multi-national companies from CMIE database not registered with DSIR.
4. Higher education sector includes data from 106 universities and 27 PG colleges doing R&D but excludes R&D expenditure of State Agricultural Universities & extramural project funding of central funding agency.

Table 2.2: Expenditure on Research and Development by Objective (Agricultural Production and Technology) (2005-06 to 2009-10)

(Rs. in Crores)

Sector	Central Government	State Government	Public Sector	Private Sector
2005-06	1917.09	2182.5	9.75	414.42
2006-07	2206.76	2582.04	5.05	468.44
2007-08	2205.78	2727.31	4.62	667.34
2008-09	2900.13	3350.56	6.33	771.47
2009-10	3239	3590.57	7.22	913.14

Source: Department of Science and Technology, Government of India (2013-14)**Note:**

1. Central government includes higher education.
2. Private sector includes Scientific & Industrial Research Organization (SIRO).

- Objectives are standardized as per United Nations Educational, Scientific and Cultural Organization (UNESCO) classification.

Table 2.3: Science and Technology Expenditure by Type of Work by Central and State Governments

(Rs. Crores)

Year	Basic Research	Applied Research	Experimental or Developmental	Other Related S&T Activities
1996-97	1167.17	2684.25	2218.71	675.96
1997-98	1419.03	3202.53	2650.75	845.69
1998-99	1671.09	3920.59	3188.02	625.50
1999-00	1965.78	4627.92	3764.83	745.57
2000-01	2228.17	5273.99	4279.47	856.47
2001-02	2331.06	5470.68	4461.56	857.99
2002-03	3530.98	4874.91	4355.36	847.94
2003-04	3706.38	5213.33	4713.72	886.59
2004-05	4515.81	5972.29	5275.50	1043.46
2005-06	4723.93	6773.73	7421.76	1519.23
2006-07	5332.24	7470.24	8041.71	1746.01
2007-08	5875.53	8239.99	8857.91	1978.66
2008-09	7443.46	10432.19	10743.76	2425.30
2009-10	8462.39	11820.59	12438.24	2706.88

Source: Department of Science and Technology, Government of India (2013-14)

Note:

- It is to be noted that such a classification for expenditure by the type of work is not available for the industrial sector.
- Experimental or developmental research connotes oriented / directed basic research.

2.2 Mode 1 and Mode 2 Forms of Knowledge Production

The transition in research and knowledge pattern can be understood by the work of Gibbons, et al. (1994). Mode 2 form of knowledge production was coined by Gibbons and his colleagues in 1994 in *The New Production of Knowledge: The Dynamics of Science and Research in Contemporary Societies* (Gibbons et al 1994). Mode 1 form of knowledge production is characterized by the hegemony of disciplinary sciences with no focus on the applicability of their findings (Nowotny, Scott and Gibbons 2003). According to this concept, universities were considered the place of conducting teaching and disciplinary research. Mode 2 form of knowledge production is seen as the new

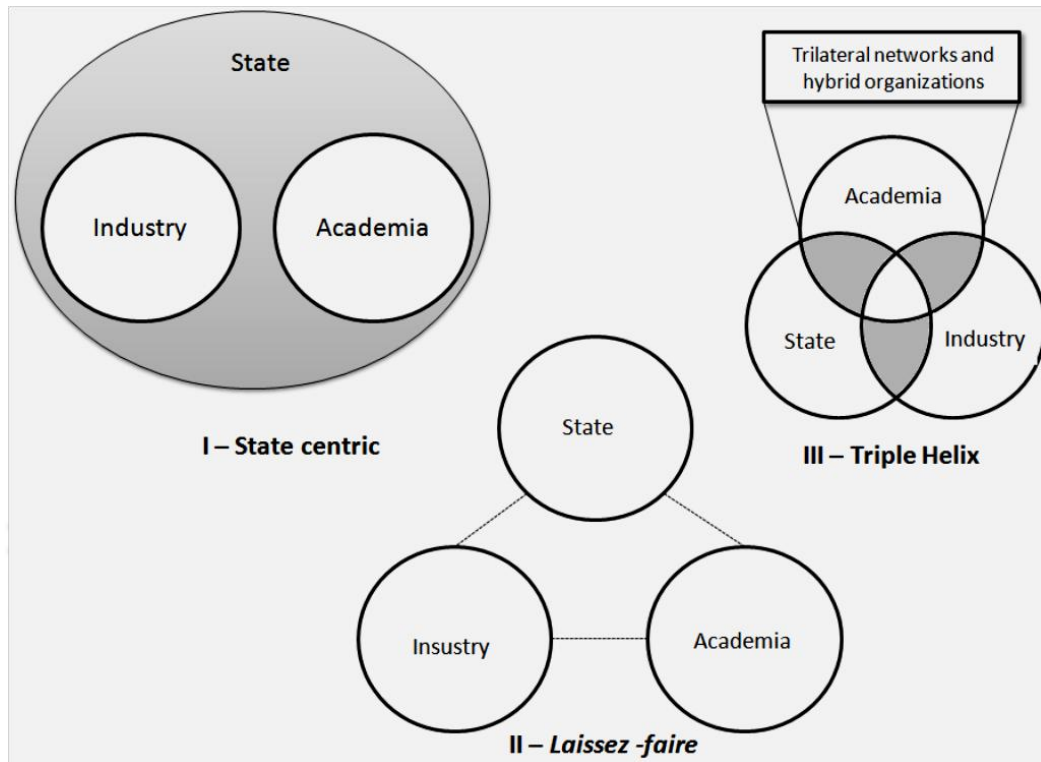
paradigm shift of knowledge production which is application-oriented and subject to multiple objectives of the modern society. This made science accountable by situating science in the context of social, economic and cultural spaces. On the one hand, in mode 1 form of knowledge production, universities were engaged in basic research and industries were engaged in applied research. On the other, in mode 2 form of knowledge production, universities and industries tried to understand the need or role of the other and undertook research in both basic and applied sciences (Martin and Etzkowitz 2000). Mode 2 enters the realm of academic research through Mode 1. Mode 2 form of knowledge production derives the concept of applicability with the commercialization of research for social distribution of knowledge. In Mode 1, commercialization is seen as a threat to the relative autonomy of disciplinary sciences. For example, it might affect the quality of pure research, while in mode 2 a synergy is maintained between academic research and its applicability. Mode 2 form of knowledge is based on the practical applicability of science which gives importance to material base of science. The transition from mode 1 to mode 2 production of knowledge adds to new dynamics to innovation studies (Etzkowitz and Leydesdorff 2000). Mode 2 form of knowledge production for practical purposes involves accountability leading to more accountable science benefiting society as a whole (Jasanoff 2005).

2.3 Triple Helix Model of Innovation

The triple helix model initiated by Etzkowitz and Leydesdorff (2000) suggested three ways by which dynamics of interaction between government, academia and industry can be examined. In triple helix I, the government directs the relationship between academia and industry. In triple helix II, the government has a limited role where both academia and industry perform their functions with limited interaction with the other spheres. The third sphere is triple helix III where there is networking between

these three actors namely academia, government and industry where one takes the role of the other leading to the hybrid organization. Triple Helix III is balanced configuration and most favourable situation for any country and most of the countries are trying to reach this balanced configuration.

Figure 2.1: Statist Configuration to laissez-faire Configuration and Triple Helix Model



Source: Etzkowitz and Leydesdorff (2000: 111)

Ranga and Etzkowitz (2013) recently introduced an analytical framework that synthesizes the key features of triple helix interaction into an innovation format, broadly as a set of components, relationships and functions. Components of triple helix System made a distinction between (i) R&D and non-R&D innovators (ii) “single sphere” and “multi-sphere” institutions (iii) individual and institutional innovators. The main functions of triple helix system are generation, diffusion and utilization of knowledge and innovation. Thus, the objective of triple helix III is to create more favourable

conditions at the intersection of varied actors cutting across geographical boundaries and technologies. These functions are retained not only in techno-economic competencies but also within entrepreneurial, societal, and cultural and policy competencies that are embedded in 'triple helix spaces': the knowledge, innovation and consensus spaces (Etzkowitz and Leydesdorff 1995). The responsibilities of the government are to provide incentives to create institutions and enhance public and private sector partnership. Collaborative networking has significant impact on the policy studies. Since the 1990s, collaborations in scientific research have increased (Powell, et al. 1996). Leydesdorff (2005) argues that historically one notices a transition from single helix to triple helix model of innovation through double helix that facilitates the collapse of barriers between university and industry. In a triple helix, the first step usually involves collaboration among university, industry and government in a project to enhance a local cluster or create a technopole. To address the gap between the needs of industry and the capabilities of academia, each partner in the triple helix model assumes the role of the other and learns to take the view of the other. This also increases the role of trust while undertaking any collaboration especially in the case of collaboration between private and public institutions.

2.4 Networking between Government, Academia and Industry

Modern science requires a new form of collaboration and broader sharing of knowledge and resources. New knowledge and technology have been created as a result of collaboration between government, academia and industry but how diffusion of this knowledge should be made is still a challenge. Scientific collaboration is a complex phenomenon which has been studied systematically since the 1960s (see Clark 1964, 1967; Price and Beaver 1966; Smith 1958).

What role collaborative and other networks of experts played in terms of influence, visibility, credibility, consensus and weight of argument in the case of GM technology / agricultural research in India? The social construal of expertise in science and technology has been a matter of concern in science studies (Collins and Evans 2002).

Statements of scientific experts appear to be more valuable and credible when there is a consensus among them. On the contrary, controversies arise when there is an element of disagreement among the experts (Thomas 2009) and dissenting voices from the civil society. In complex socio-scientific controversies, it is often difficult to determine what kind of experts are usually seen as relevant experts for the issue at stake, as well as who should decide who the relevant experts are (Jasanoff 2003).

From the SST perspective, the idea that there is clear distinction between expert and non-expert view is clearly abandoned and criticized (Irwin and Wynne 1996). Often ordinary citizen accrues knowledge that is crucial to apply abstract scientific knowledge in particular contexts and cases. It is also valuable and significant in reaching decisions regarding public policy (Fischer 2003; Corburn 2005).

Universities and public research institutions play a central role in innovation system by providing new knowledge, especially in the areas in which economic consideration is less or less immediate. In addition, universities contribute to skill formation and may inspire talented young people to enter research careers or innovation-related occupations. The coverage of public research polices has been extended from knowledge production to technology transfer. The engagement of universities and research institutions with industry is increasing rapidly for the transfer of science from the laboratory to the field.

In order to utilize the public research support more appropriately, government has revised its approach to IPR protection and sharing such as by providing license free of

charge, proposing preferential access to “sleeping” patents requiring publication in digital format, and providing open data repositories (OECD 2014). Collaborative research projects are definitely needed to make more agricultural productivity.

Collaboration between central institutions and local/regional institutions can prioritize an important locale of innovation. Collaboration is not only effective in selecting projects with effective/appropriate business or technical risk but also a source of social capital which is believed to play a key role in regional development. A new configuration/networking is emerging between university, government and academia which are opening new vistas of firms/industry creating innovation that can contribute to regional and national development (Leydesdorff 2005).

Science and technology policies in India require collaboration between regional/small business/industrial firms, university and business research institutions (<http://www.icar.org.in/files/sti-policy-eng-07-01-2013.pdf>, accessed on 12 April 2016). Together they can contribute to most comprehensive technology policy, supporting innovation, development and diffusion of technology at national, regional and local levels. Networking is good but it needs to be augmented and further strengthened. In triple helix system, universities are considered the most important element as it is where knowledge is created. In triple helix system creation of knowledge is given supreme importance (Etzkowitz and Leydesdorff 1995).

As the university takes a new role in promoting innovation, its educational and research mission is also transformed. As the university expands its role in the economy, from a provider of human resources to a generator of economic activity, its relationship to university and government is enhanced. University with its role transformation and changes in its activity is expected to influence, with academic autonomy increased in some instance and reduced in other. Transformation in the functions of university,

government and industry takes place as each institution assumes the role of the other. University often takes the role of industry, transforming the technology to influence the existing firm with new life and helping from new firms in incubating facilities. The government takes the role of industry, helping to support this development through funding programme and changes the regulatory environment. Industry takes the role of the university in developing training and research, often at the same high level as academic institutions. Along with educational and research purpose, economic and social development mission/target/objective is enhanced.

Assuming this new role and responsibility, the university became one of the important actors in the triple helix model of innovation. The transformation of university-industry linkage from a linear to an interactive innovation model can especially be seen in the evolution of university, business incubator from a linear to a non-linear model and transforming from an isolated to an interactive entity. In addition to mentoring university originated firms, the incubator brings in firms from outside the university allowing both types of firms to interact with and learn from each other. Moreover, links among incubator allow joint development and transfer of technology. As the university becomes closely involved in the transfer of technology and founding of new firms, it attains a new entrepreneurial identity (Etzkowitz 2001).

The business expertise that was formerly localized within the university is now being expanded to achieve higher growth goals based upon capital that can be created from academic research as well as other sources. Within academic departments and centres, faculty members and other technical personnel are assigned special responsibility to assess the commercial aspects of research findings and encourage interaction with external partners. Hybrid entities, such as the universities at Albany, incubator facility combine academic research groups, government laboratories, and

existing firms to gain critical mass in a research field and economic potential. Industry and government are also developing intermediary capabilities. Companies collaborate on research projects as they realize that they cannot always do all the work needed for the development of the new product by themselves (Nonaka and Takeuchi 1995).

The rules of interaction between academia and industry are understood and negotiated in the WTO-regulated IPR framework. University selects industry projects that will both solve a practical problem and lead to a fundamental advancement in knowledge.

A system of university-industry relationship has emerged since the early twentieth century based upon models for academic consultation; patenting and firm formation originated at Massachusetts Institute of Technology (MIT). The research corporation introduced the principle of utilizing income generated by patents to fund new research. As university enlarges its role of innovation, controversies arise on the basis of transformation of the role of university as service provider to the university-industry collaboration as the capitalization of knowledge. The emergence of such controversies indicates changes in the normative framework of the triple helix model (Etzkowitz 2001).

Funding has been the focus of attention in explaining recent changes in the university and its role in society. Definitely, increase or decrease in funding certainly has an effect on academic and other institutions, such trends can just as easily rigidify existing structure, expanding or contracting them along existing lines as well as including their reform (Etzkowitz 2001).

The transformation is also observed when there is a shift of mission from narrow to broad, say for example from economic to social development. Also, instead of focusing on individual patent, university focuses on the development of regional

organizations. Traditionally incubator was not seen as a part of educational facilities of the university where its role shifts from educating an individual to the group (Etzkowitz 2001). Automatically university's educational role requires generation and development of new organizations under its incubator facilities and sending them out to society and this activity occurs outside the classroom. There are a few bottlenecks of university incubator facilities outlined below:

Universities not only train students but also organizations. This incubation facility combines an expert from different fields, say one is a specialist in molecular biology and the other is an expert from software. Further incubation facilities from the single university should be networked with incubation facilities of other universities. In developing countries where universities provide incubator facilities to firms typically lack the ability to assist their firms to reach partners and market in other countries. As far as university incubator facilities are concerned worldwide, university incubator facilities are more in Brazil and the USA. Incubation facilities are also increasing in China and in other Asian countries (Etzkowitz 2001).

Bell (1973) argues that knowledge has displaced property as the central preoccupation in the postindustrial society. Soon role of science and technology for regional development increases and with this growth the number of players/actors to get involved also increases. Traditionally universities were not much involved in applied research but recently they are becoming more applied research-oriented and often receive funds from the state and local governments as they realize the importance of technology and research.

2.5 Basic and Applied Research

Historically, basic agricultural research uncovers some fundamental scientific principles, whereas applied research aims to produce specific technologies, while

developmental research concerns the adaptation of applied research directly to real-world scenarios (Muller and Pursell 2012). In other words, basic research may have little market orientation and may expand its focus towards the development of public goods such as public health and safety, environmental protection, etc. These areas require attention of public research investment.

Let us look at the changing conceptions of relations between basic (pure or academic) research and applied (industrial) research and the resulting implications for agricultural biotechnology in general. Let us discuss the historical roots of differentiation between basic and applied science. Traditionally, the relationship between basic science and applied science has been conceptualized in terms of hierarchical relations.

Basic research was considered the act of knowing (episteme) and hence superior. Applied research was considered an act of doing or manipulation (techne), hence inferior (Haribabu 2000). The distinction between basic and applied sciences is historically constructed in the sense that today's basic science will be tomorrow's applied science. According to (Ziman 1996), "Academic science has been undergoing a cultural revolution. It is giving way to 'post-academic' science, which may be different sociologically and philosophically that it will produce a new type of knowledge." Public knowledge is being transformed into 'intellectual property' (Haribabu 2000). Basic research network includes several research groups with direct industrial interests. As the distinction between science and technology is getting blurred, the distinction between basic and applied science has become opaque. Scientific research is 'applied' to the extent that it has the capacity to generate immediate useful results. According to Maienschein (1993), it is impossible to operationally define a distinction between basic and applied research as one is output and the other is the process. Generally speaking, if we want to make a distinction between basic and applied research basic research may be

called original as an advancement of knowledge which does not have specific commercial objectives, whereas applied research is directed towards practical application of knowledge and has the specific commercial objective with regard to its product or processes though a clear distinction between the two cannot be made by the respondents included in the present study. State and industry are the principal sources of funding for scientific research. The new form of biotechnology has been encouraged for their apparent potential for reducing chemical connection to modern, industrial agriculture (Kloppenborg, Jr. 1988).

The utilitarian considerations have begun to influence basic research in molecular biology. Strategic research aims to generate knowledge about, and solutions to, current problems of crucial importance. Such research necessarily questions the boundary between basic and applied science. Strategic research may be organized into two different ways. The purpose can be to achieve either a supply-push model or a demand-pull model of technology. Frame and Carpenter (1979) contend that rise in international institutional collaboration has been influenced by the growth of basic research – more international in nature than applied research - and relative scientific capacity - scientist in developing countries look abroad for collaboration and funding opportunities. In developing countries, where research capacity lags behind the developed countries, international inter-institutional collaborative networking is seen as an opportunity (Mallick 2016).

Since the 1990s, biotechnology has developed under the auspices of private corporate enterprises most of which are multinational or transnational corporations. It may be characterized as supply-push technology (Singh and Pal 2015). But what is needed on the other hand is a demand-pull model of technology development, one that basically involves client driven research and development. Interaction between

technology developers and end-users is important as this will educate and inform, for example farmers about the precautionary and safety measures to be taken while using a particular technology, for example Bt cotton. Many farmers do not know the precautionary and safety measures which should be taken while growing Bt cotton, which often produced adverse results (Singh and Pal 2015).

This is in contrast to traditional linear models that tend to assume that interests and world views are shared in common by technology developers and end-users. Knowledge acquired on the basis of interdisciplinary exchange would help us understand the interconnections between complex problems and evolving solutions (Guston 2001). Efforts should be made to ensure accountability and improve efficiency. Competitive funding mechanisms achieve synergy through collaboration and networking, and help strengthen other institutional reforms.

2.6 Agricultural Innovation System

The concept of innovation systems was introduced in the 1980s where institutions and learning processes are of central importance (Freeman and Lundvall 1988). Lundvall (1992) see National Innovation System (NIS) as the starting point which defines the process of innovation. With the introduction of NIS (OECD 1999), the role of the government in building innovative cultures, enhancing technology diffusion, promoting networking and clusters, leverage research and development across sectors, responses to economic reforms and attracting foreign direct investment increased. This concept was defined as “a set of innovation actors (firms, universities, government, regulatory bodies and so on), their activities and their inter-linkages at the aggregate level”. According to World Bank (2006), “An innovation system comprises the organizations, enterprises and individuals that demand and supply knowledge and technologies, and the policies, rules

and mechanisms which affect the way different agents interact to share, access, exchange and use knowledge” (www.merit.unu.edu/publications/wppdf/2007/wp2007-038.pdf, accessed on 16 January 2016). According to Metcalfe (1995: 409), the NIS is “... that set of distinct institutions which jointly and individually contribute to the development and diffusion of new technology and which provides the framework within which government form and implement policies to influence the innovation process. As such it is a system of interconnected institutions to create, store and transfer the knowledge, skills and artefacts which define new technology.” According to Nelson (1993: 4-5), the NIS is “a set of institutions whose interactions determine the innovative performance ... of national firms.”

Innovation requires a large number of interactions between varied actors. If we want to promote innovations in agriculture it is necessary to understand the roles of each sector and pattern of their interaction. University takes on a more central/independent role through its contribution to innovation in societies. The role of university has expanded from being engaged in teaching and research to being a contributor to broader social and economic development. Knowledge producing institutions are essential to innovation as knowledge plays a key role in product development. This expansion of the concept of innovation makes government and university significant actors in the process of innovation, both collaborative and individual. Public sector research institution may need to expand their management and policy functions within national agriculture research system to promote effectiveness and transparency to achieve development goals. One of the objectives is to create the paradigm of connectivity between government, academia, industry and non-profit organisations dedicated to quality innovation. Innovation comes out of the activities of the diverse actors such as multinational firms, businesses, startups, universities and research institutions (OECD

Science, Technology and Innovation Outlook 2014). Meeting with these challenges requires the technological breakthrough, rapid deployment of existing or new technological solutions and systemic changes (in policies, regulation, behaviour etc.).

India has an extensive National Agricultural Research System comprising a rich network of ICAR (Indian Council of Agricultural Research), central universities, state universities, CSIR institutes funded by Department of Biotechnology (DBT), Department of Science and Technology (DST), Department of Atomic Energy (DAE), private institutions and voluntary research and development organizations. State agricultural universities such as IARI, ARI, UAS and IIRR have several areas of research dealing with specific crops and agro-ecological zones. These universities have developed a useful technology which has been extensively adopted. Participation of private research institutes in agricultural R&D has increased recently (Hall 2006). Previously private sector investment was in fertilizers, machinery, pesticides and seeds but recently private investment in plant breeding and biotechnology has increased (Hall 2006). Civil society involvement is increasing and many of them are working with poor farmers and help them access new technology, knowledge and information.

2.7 Science and Technology Policies in Post-colonial India

Debates on science and technology policies in India should be located in the context of decolonization and the alliance between scientific, political and industrial elites of the country which cultivated in the Scientific Policy Resolution (1958). The relationship between the 'expert' and the 'citizen' has changed and new forms of knowledge have to be considered.

However, the SPR (1958) failed to develop strong indigenous technological base and improve the quality of life of a large number of people (Krishna 2001). The draft

National Innovation Act (2001) promotes public-private partnership for innovation. Government plays a crucial role in developing a science and technology policy as 75 per cent of the funding for research comes from the government institutions (Mandal et al. 2008). Technological solutions failed because policymakers did not go deeper into the problem in instituting the required mechanisms. It is important to note that problem is not just economical or technological rather social and political.

In the late 1970s and early 1980s, a significant change took place in the agricultural scenario of the country (Indian Patents Act 1970 and New Seed Policy in 1988). This change is marked by the dramatic increase in the number of input suppliers such as seeds, fertilizers, pesticides, etc. The university provided the trained human skills required for the industry. In the case of India, attainment of technological self-reliance is required which will improve the condition of the economically marginalized sections of society as well as help in the speedy development of backward regions. Technology must suit the local condition of the specific country and it should be cost effective. Two important things mentioned in the Technology Policy Statement (1983) were: first, use of obsolete technology should be resisted; importance was also given to basic research. Secondly, policies which do not focus on the requirement or the need for Indian conditions should be discarded (www.ispepune.org.in/PDF%20ISSUE/.../Technology-Policy-Statement-January.pdf, accessed on 16 January 2016). Choice of technology must be clearly defined taking into account economic, social and cultural factors along with technological considerations. The main objective of Technology Policy Statement (1983) was to develop indigenous technology and efficient absorption and advancement of imported technology. The main objective can be further broken into various parts like reducing vulnerability in critical and strategic areas, maximum gains to the weaker sections of the society. Identification of obsolescence of technology in use and

modernization of both technology and equipment in use are important to reduce demand for energy particularly from non-renewable sources of energy. The Technology Policy Statement (1983) also gave importance in strengthening of technology base in newly emerging and frontier areas like biotechnology. The major thrusts were the call for substantial financial investment and strengthening of the linkages between various sectors such as educational, R&D establishments, industry and government machinery.

It is important to provide the incentive to inventors and direct their skills to the areas of urgency (www.ispepune.org.in/PDF%20ISSUE/.../Technology-Policy-Statement-January.pdf, accessed on 16 January 2016). The Technology Policy Statement (1983) gave importance to the development of indigenous technology and its use. Interaction between academia and industry is required to translate know-how into technology, thereby promoting effective transfer of technology and share of knowledge. This policy statement also encouraged setting up of R&D units in industry. A well-defined collaborative arrangement in research and development can help to acquire advantages of technological developments elsewhere. Technology can grow out of the study of science and its applications. With technological advancement, the gap between developed and developing countries has increased creating digital divide across the continents. Focus was also given to enhance in-house research and development in industry.

The Science and Technology Policy (2003) follows the footsteps of Scientific Policy Resolution (1958) and Technology Policy Statement (1983). The main objective of the Science and Technology Policy (2003) is to cultivate scientific temper and fully integrate science and technology in national activities. It further emphasizes on strengthening of the IPR regime to commercialise domestic inventions at the earliest. One of its key points is to provide full autonomy and flexibility leading to de-

bureaucratization of the university and institutions. This will fasten the collaborative networking among research institutions, universities, private R&D, etc. But, at present, a long-term reform is required to de-bureaucratize the institutions and universities in India. Further, it emphasizes on increasing the investment by industry in R&D to make the contribution by private sectors adequate. Optimum utilization of infrastructure through networking is emphasized. The Science and Technology Policy (2003) suggests that a new mechanism for funding would be adopted to strengthen basic research in institutions. Further, it tries to strengthen the synergy between academia and industry by establishing technology transfer offices in academia to facilitate the transfer of technological know-how generated to industry. It also emphasizes on generation and management of intellectual property, protection of traditional knowledge, public awareness of science and technology, increase interaction between science and social sciences, facilitating increased international collaboration through various programmes and so on. The essence of any policy is its effective implementation.

According to the Science, Technology and Innovation Policy (2013), innovation occurs when science and technology-led solutions are successfully deployed in economy or society. Government expenditure on R&D should be increased many fold and this is impossible to achieve unless Indian industry take the lead to share at least 80 per cent of total R&D expenditure of the country which moves around 15-25 per cent since independence (Mandal et al. 2008). One of the important strategies envisaged in science and technology policy is to increase investments in gross R&D expenditure, currently which is 0.8% of its Gross Domestic Product (Government of India 2013a). This policy also emphasizes that this increase in R&D expenditure should come from industry as they have witnessed a significant increase in their sales turnover especially from 2006-10 (Government of India 2013a). New innovation policy uses the traditional approach to the

innovative development of the country, which includes a set of traditional measures: (a) increase spending on R&D; (b) promoting excellence and relevance in R&D; (c) participation in global R&D infrastructure.

Now, India can create its own technologies with extensive input of scientific origin. The share of world's knowledge is often reflected by means like publications, patents, etc. (Dahlman and Utz 2005). This policy states that India's strength in basic research is recognized internationally. This policy also states that scientific collaboration is becoming a multi-disciplinary and multi-institutional practice since 2000. Basic research requires large equipment, expertise and human resources. Science and technology have become a source of economic dependence on the developed countries, which has led to the increased restrictions on sharing of knowledge, compliance with the international intellectual property rights regime and dictates of multinational corporations. The complex issues of paradigms of development since 2000 include the perceptions about GM crops by the scientific and farming communities. In this regard, the Science, Technology and Innovation Policy (2013) observed that S&T systems must undergo a paradigm shift from the current input-driven model to output-driven development strategy/model. An analysis indicates that the approach at the level of selection of policy instruments is limited to supporting "structural innovation" policy that only strengthen the importance of improving innovation capabilities of the firm and the institutional changes to strengthening them. It means other important sectors are ignored by the Science, Technology and Innovation Policy (2013). Focus was stressed on policies to strengthen innovation policies that will generate new technology and knowledge. The policy rationale perspective is limited to: (a) facilitating the private sector investment in R&D; (b) treating multi-stakeholder participation in the Indian R&D system; (c) treating R&D in the private sector at par with public institutions depending

upon the availability of funds; (d) benchmarking of R&D funding mechanism and patterns globally; (e) modifying the intellectual property rights policy to provide for space for rights of social goods when supported by public funds and co-sharing of IPR generated under public-private partnerships; (f) provide incentive for commercialization of innovation (Government of India 2013b).

2.8 New Agriculture Policy (2000)

The New Agriculture Policy (NAP 2000) of the Government of India was enshrined such objectives as: (a) over 4 per cent annual growth rate aimed over next two decades; (b) greater private sector participation through contract farming; (c) price protection for farmers; (d) national agricultural insurance scheme to be launched; (e) dismantling of restrictions on movement of agricultural commodities throughout the country; (f) rational utilisation of country's water resources for optimum use of irrigation potential; (g) high priority to development of animal husbandry, poultry, dairy and aquaculture; (h) capital inflow and assured markets for crop production; (i) exemption from payment of capital gains tax on compulsory acquisition of agricultural land; (j) minimise fluctuations in commodity prices; (k) continuous monitoring of international prices; (l) plant varieties to be protected through a legislation; (m) adequate and timely supply of quality inputs to farmers; (n) high priority to rural electrification; (o) setting up of agro-processing units and creation of off-farm employment in rural areas (<http://rrtd.nic.in/agriculture.html>, accessed on 28 January 2016).

The first generation Bt seed was called obsolete due to the following reasons: firstly, to keep the patent evergreen and secondly to maintain a profit margin (Shiva 2006). Resistance developed by the first generation bollworms poses a serious problem to R&D, regulation, ethics and environment. So, NAP (2000) should be examined

urgently to make it compatible with the changed scenario. The second generation Bt seeds was introduced by the industry to develop resistance against bollworms but no independent test was performed by the regulatory bodies on the authenticity or safety of second generation Bt seeds.

2.9 Public-Private Partnerships in Agriculture

Public-Private Partnership (PPP) in science, technology and innovation can help make research and innovation policy more responsive to the changing nature of innovation. Partnership can take many forms ranging from partnership between single industry and a single company on a research project with specific short term goals for the creation of physical research centres with specific vision and long term mandates to large infrastructure projects with a longer term horizon and broad networks. According to the Organisation for Economic Cooperation and Economic Development (OECD 2004), PPP is “any formal relationship or arrangement over fixed-term/indefinite period of time between private and public actors, where both sides interact in decision-making process, and co-invest scarce resources such as money, facility, personnel, information in order to achieve specific objectives in the area of science, technology and innovation”. The PPP can have combination of goals such as specific targets or goals and combination of soft and hard elements such as it may act as a provider of training or creation of joint research centre. The fundamental purpose of most of the PPPs in research and innovation are as follows (OECD 2004):

- a) improving the leverage of public support to business R&D by sharing cost and risk
- b) securing higher-quality contributions from the private sector to government mission-oriented R&D and increasing opportunities for commercial spillovers from the public research

- c) fostering the commercialization of research from public research institutions
- d) and upgrading knowledge infrastructure

Subsidies have been removed by the more adaptive tools like PPPs especially in the areas where nature of R&D and innovation is changing. The need to connect science to innovation to meet the challenges of agriculture is increasingly pressing. PPP is an important policy tool in the demand side of innovation policy such as taxation policy, financing via matching grants, etc. Mutual cooperation, collaboration and networking are important for the development of science and technology innovations. Private sector analyses its interest keeping in mind the benefit of resource-poor farmers in perspective. Partnership with private sector is highly encouraged. Promotion of partnership is successful on the following grounds (Ayyappan et al. 2007):

- a) Adequate emphasis on the conduct of research
- b) Involvement of private sector in the governance of funds
- c) A transparent mechanism for benefit sharing

If improvement is made by funding agency in India in this direction, it can contribute to the overall development of Indian agriculture research system in India. How can the effectiveness and sustainability of financing in India be improved? Most of the funds aim to improve the effectiveness of research through better targets such as increasing accountability, effective institutional reforms, visible socioeconomic impact and close participation of private sector in terms of management of funds.

2.10 The International Politics of Genetically Modified Food

Controversies over the adoption of GM crops have created hostility towards the development of biotechnology. Many countries lack even minimum regulatory

framework for GM crops. Agribiotech sector is growing fast in contrast with the incomplete and fragmented framework of biotechnology regulation. The global area of GM crop production such as maize, soybean, corn and cotton is estimated to have grown 1.7 million hectares in 1996 to 39.9 million hectares in 1999, with an increase of 44 per cent between 1998 and 1999 alone. The sales volume of GM crops has increased approximately 30 fold in the period 1995-99, and the global market prices for GM crops has reached \$25 million in 2000 (Falkner 2007). The cultivation of GM crops is undertaken by 14 million farmers, including small and resource-poor farmers, planted 134 million hectare of GM crops in 2009, across 25 countries during fourteenth year [1997] of commercialization of GM crops (Government of India 2012).

Most countries in Asia, Africa and Latin America lacked the necessary scientific or regulatory capacities in the field of biotechnology, and therefore placed their hopes for international legal, financial and technological support in an international biosafety agreement (Falkner 2007). Developing countries are often presented as victims of unscrupulous multinational corporations seeking to exploit their economic vulnerability. Developing countries are more strongly influenced by international political and economic pressures that constrain and enable particular policy options and processes than is the case for many northern countries (Falkner 2007). Also, it is difficult for the developing countries to prioritize food security and poverty reduction over the imperative of attracting capital.

Developing countries find themselves torn between WTO pressures to open their markets to agricultural imports and resistance from farmers' groups whose livelihoods may suffer from sudden exposure to global markets. They find that their ability to act upon concerns regarding the socioeconomic impacts of GMOs on incomes, livelihoods and food security are constrained by international instruments which only deal with the

environmental implications of the technology. They find that global rules on IPR sit uneasily with indigenous traditions of innovation and ethical concerns regarding the patenting of living organisms (Falkner 2007). Policies and measures that may be popularly desirable, such as labeling, comprehensive and precautionary forms of risk assessment, forms of trade protection for the poor, restrictions on investment in domestic seed markets or even moratoriums on the trade in GMOs, are increasingly difficult to enforce on the basis that they are incompatible with global trade accords.

Since the 1990s, biotech companies have been willing to make inflated claims about the technology's ability to tackle problems of poverty and food insecurity. Claims which prompted a backlash from the NGO community and skeptical publics, more recent discourses have emphasised 'farmer's choice' (Kuruganti 2006). In India, for example, there is widespread evidence that whichever edicts emerge from the deliberations of regulatory committees the reality 'on the ground' is that farmers are seeking access to GM seeds largely through black markets. Biotech firms, taking this as a threat to their profits, have presented this as evidence that the farmers have already preferred the new technology. This is an extreme version of democracy as market choice and citizen as consumer and is not what advocates of democratizing biotechnology had in mind in calling for policy more responsive to the needs of poorer groups (Newell 2006). Threats to withdraw investment have been repeatedly made to countries such as China, seen to be doing little to prevent illegal use of biotechnology products, and even against such stridently pro-GM nations as Argentina, for failing to protect firm's intellectual property.

2.11 GMOs: Risk and Precautionary Measures

The North American position on the safety of GM crops is that there is minimal risk attached to them, and because of this a precautionary approach in their adoption is

not warranted (Clapp 2005). In both the United States and Canada, regulatory procedures for GMOs are premised on the logic that if the developer of a GM crop or food can demonstrate that it is 'substantially equivalent' to a conventional counterpart, the GM crop or food does not require an extensive risk assessment prior to its approval (Prakash and Kollman 2003).

In the USA, risks associated with GMOs do not automatically invoke a precautionary approach. In other words, agricultural biotechnology products are assumed to be innocent until proven guilty. It is further argued that the benefits of GM crops, in terms of higher yields and easier management of weeds, far outweigh the (known) risks associated with them (Paarlberg 2001). The United States and Canada view their approach to the regulation of agricultural biotechnology as being firmly grounded in 'sound science' (Falkner 2007).

The EU and many developing countries such as Brazil, India, Pakistan and South Africa are of the view that before GM products are approved, they must be subject to a rigorous scientific risk assessment (Qaim 2005). Many developing countries lack a regulatory structure to approve agricultural biotechnology products, and for this reason they have tended to favour the EU approach that applies precaution in the face of scientific uncertainty. There are disagreements about the use of GM products in the EU and many developing countries.

The politics of biotechnology in developing countries is played through food aid, whereas many developing countries like Zimbabwe, Kenya and Zambia in Africa, etc. have rejected the aid. For example, Zambian President Levy Mwanawasa expressed his concern that GM food aid was 'poison,' stating 'If it is safe, then we will give it to our people. But if it is not, then we would rather starve than get something toxic' (see Falkner 2007: 96 quoted in Dynes 2002).

Legal protection in developing countries is relatively weak and has not been the principal barrier to replication. Seed from hybrid crops cannot be used without major yield reduction in future generations. Hybrid seeds, therefore, provided a mechanism for private technology, suppliers to appropriate a significant share of the gains from higher yields (Ramaswami 2002).

Many developing countries such as Brazil, Russia, India and China are withholding approval for the release of GM crops as it involves questions of health, environment, ethics and safety parameters. One of the drawbacks of GM crop technologies created by private companies is that it restricts technology transfer to poor farmers because of the privately held property rights. As far as cotton cultivation in India is concerned, it has been plagued with rising costs of cultivation, ineffective pesticides, and adulterated seeds leading to consecutive crop failures and heavy indebtedness which have led to farmers' suicides in India (Shiva 2006).

The Technical Expert Committee (TEC) of the Genetic Engineering Approval Committee (GEAC) pointed out that the safety of Bt transgenics with regard to chronic toxicity had not been established that requires adequate field tests before it can be considered safe (Cultivation of Genetically Modified Crops: Prospects and Effects 2012). In this regard, the largest deployment of transgenics worldwide is in soybean, corn, cotton, and canola, all of which are used primarily for oil or feed. Nowhere has Bt transgenics brought about widely consumed in large amounts for any major food crop that is directly used for human consumption. The TEC found no compelling reason for India to be the first to do so (Ramakrishnan 2013).

2.12 Issues of GM Crops and Biosafety

Contamination of Indian cotton with illegal Bt cotton was made in Gujarat in 2001 which shows serious regulatory failure in the country on account of Bt cotton. Biosafety is an important consideration with transgenic crops since they have known environmental and health hazards and once released into the environment are irreversible and are 'living' (Prakash and Kollman 2003). India is the centre of origin of brinjal and any gene transfer/contamination from the transgenic plant could prove to be disastrous for the crop itself. Kuruganti (2006) states that due to civil society investigation that the cotton fiber of Bt cotton was known to be causing a lot of allergies. She also states that non-chemical Integrated Pest Management (IPM) methods have yielded equal or better results than the ones being claimed by the Bt brinjal promotion. Further, she states that there are thousands of practising organic farmers in the country who know how to take up pest management in brinjal without causing environmental and health problems for themselves and others. This often does not get adequate attention by the state. Considering the present scenario of agrarian distress, it is necessary to have broad based democratic processes of eliciting views and expert opinions. Increased use of biotechnology in sectors such as agriculture and medicine has been accompanied by conflict over the ecological, socioeconomic, political and ethical implications of such use (Gottweis 1998; Shiva 1993). Debates over agricultural biotechnology have been over risks and benefits associated with this technology. Biosafety remains characterized by scientific uncertainties and conflicts. It is mainly due to a lack of building consensus to address scientific uncertainties and conflicting interests.

Proper testing is important for GM technologies in every new environment. Biosafety procedures have been highly politicized in many countries. Biosafety approval is usually necessary as it is the last step prior to commercialization. As far as India is

concerned, critiques to uncritical introduction tools attempt to convince the authorities that a social impact assessment should be the part of biosafety clearance (Herring 2014).

If we look at global acceptance of GM crops, then in the US it has benefitted the US farmers, reported by US Academy of Sciences (James 2002). Similarly in China, they have permitted Bt rice and also promoted aggressively public sector based GM crops (Purkayastha 2010). But what is important in the case of India is that it should look at how to handle GM crop technology and the risks associated with it. Technological advances have always come with potential risks. Risks associated with those technologies should be analyzed before the introduction of those technologies. Before analyzing the risks associated with new technologies, it is important to note that it is not possible to know in advance the full risk of these technologies. Politics and policy towards agricultural biotechnology in India for the future will be conditioned by the success or failure of Bt cotton. The charge that “Bt cotton has failed” originates from a loose coalition of non-governmental organizations (NGOs), often connected to transnational advocacy networks. Their narrative explicitly claims: “(a) Bt technology lowers rather than raises on-farm yields, and (b) Bt adoption drives farmers into debt because of high seed price and agronomic failure, often resulting in catastrophe: sale of body parts and suicides” (Herring 2006).

Proponents of transgenic cotton argue that evidence from the field shows the same success in India that is apparent in China and other countries (James 2002). India has far more small-holder adopters of GM crops than any other country (Stone 2012). Coalition for GM-free India urges the central government to take the report seriously and act on it in the interest of food safety, security and sovereignty as well as protection of the environment and livelihood. In contrast, the Association of Biotech Led Enterprise Agriculture Group (ABLEAG) that represents the industry has termed the document

though an improvement over the interim report that called for a ten-year moratorium on field trials of Bt transgenic in all food crops.

The committee further observed that the Bill did not accord the Genetic Engineering Appraisal Committee (GEAC) any role in policy matters relating to the research and development of GM crops, food security, pricing of GM seeds, commercialization of GM crops and labeling for consumer awareness. The committee's report stated that 93 per cent of cultivated land the world over supported conventional cropping, and only a few countries carried out concentrated cultivation of GM crops. It is interesting to note that the International Assessment of Agricultural Knowledge, Science and Technology for Development (2008) observed that as privatization fuels a transfer of knowledge away from the commons, there is a contradiction in both crop diversity and numbers of local breeding specialists (<http://food-security.wikispaces.com/Bill+Dyer>, accessed on 14 January 2016). In many parts of the world women play this role and thus a risk exists that privatization may lead to women losing economic resources and social standing as their plant breeding knowledge gets appropriated. At the same time, entire communities run the risk of losing control of their food security. Whether it was the introduction of Bt brinjal in 2010, the continued cultivation of Bt cotton in spite of widespread national and international opinion against it, or contract farming for profit, the latest trend in farming, issues of regulation have never been of great importance to policymakers.

Parsai (2013) argues that the Biotechnology Regulatory Authority of India (BRAI) Bill (2013) promotes harmful and unwanted biotechnology which shows a move to corporatize agriculture. "There is a concerted effort to shape Indian Agriculture on the American model, without appreciating the fact that American farming is inefficient and needs massive support in various ways and without appreciating inherent strength of

Indian agriculture” (Kuriganti 2006). It is interesting to mention that existing legislation in India seems hardly adequate to address the challenges posed by the opening up of agriculture and technology, and emerging framework of agriculture is quite outside the domain of any regulation (Parsai 2013; Rajalakshmi 2013).

2.13 Cases of Bt Cotton and Bt Brinjal

The multinational seed companies like Monsanto are allowed to trade in India, while India’s Plant Varieties Act still awaits approval by the Parliament. Commercial use of Bt Brinjal seed is still not approved by the Genetic Engineering Appraisal Committee (GEAC) which is the final hurdle in the process of commercialization of Bt seeds. The Bt brinjal is the first in a list of other Bt food crops in the pipeline. That is one of the reasons why the Bt brinjal case has assumed importance. However, if the technology remains hostage to transnational agribusiness, the cost of seeds would remain high. Under such circumstances, the farmers would not only buy high-value seeds but may also use a higher level of pesticides to protect their high-cost crop. This is the reason that while in China, Bt cotton saw a drop in the use of pesticides (Huang et al. 2003), Indian Bt cotton did not – Indian farmers intended to use even a higher amount of pesticides than with non-Bt cotton. Therefore, one of the benefits of Bt brinjal – the lower use of pesticides – may not materialize in India.

There is a possibility of setting up regulatory board for approvals and making the GEAC as only an advisory body concerning safety measures. This could be a useful modification, since safety is only one aspect of introduction of a new crop. In China, the costs are only slightly higher for Bt seed, since China also has an indigenous Bt technology that is not sponsored by any MNC. Bt cotton has helped increase agricultural productivity in India and raised up to 90 per cent but most of the profit is transferred to

Monsanto by Indian farmers (James 2012). The problem is that gene revolution is under the control of a few global corporations unlike green revolution which was sponsored and owned by the state. The increasing corporatisation of inputs, as exemplified by the Monsanto-driven Bt crops, exacerbates this squeeze further, and is an issue of concern.

It is important to discuss the conflicts over whether to approve a genetically modified variety of widely consumed vegetable, viz. eggplant (brinjal). GEAC, in October 2009, approved Bt Brinjal, the first genetically modified food crop to receive commercial clearance in India. Bt Brinjal variety is also developed by the same private-private collaboration between the Maharashtra Hybrid Seed Company (MAHYCO) the Indian seed company, and Monsanto, its American counterpart, which developed and marketed the first transgenic crop called Bt cotton in India (Qaim 2005). There were huge protests by public on commercial release of Bt brinjal in India and as a result a moratorium on Bt brinjal was passed (Herring 2015a).

The proponents argue that the extensive tests had shown that Bt brinjal was safe for human consumption on the ground that it represented much needed technological solution which would provide protection against pest damage and also it would be economically beneficial to the small brinjal farmers and poor consumers (Herring 2015b). It is also important to note the claim made by the opponents which includes health risks of consuming Bt Brinjal to the threat of foreign control over Indian seed market (Murali 2016). Also, brinjal is widely consumed so there is a threat posed to indigenous brinjal varieties from transgenic varieties. It is also found that there is a lack of liability regime to compensate farmers in the case of loss due to damage, lack of national segregation and labeling laws or capacity to guarantee a consumer right to choose about whether to consume Bt brinjal (Herring 2015b). It is important to

determine whether there is a need of transgenic brinjal or not given locally appropriate alternative technological and other solutions to the problem of pest (Gupta 2011).

What is challenging is that advancement in technology in developing countries is accompanied by private sector and these new trends in regime seem to foreclose the entry of public sector in this domain. The Convention on Biological Diversity (CBD) in Rio de Janeiro, in 1992, defined biotechnology as, any technological application that uses biological systems, living organisms or derivatives thereof, to make or modify products or processes for specific uses (cited in Chaturvedi 2002).

Agriculture in developing countries is going through many challenges like stagnation in primary agricultural crops after green revolution, large scale malnutrition and declining R&D allocations (Leach et al. 2005). Right to food has major implications for the ways in which technology is developed and accessed. It can also try to protect the crops of the poor from unintended introgression from GM crops. Danger with GM crops is that over-enthusiastic repackaging of genetic information renders the planting material indecipherable to the low-input user faced with highly uncertain conditions. Stone (2012) argues that a major problem with GM cotton for peasant producers in India is that they do not know how to modify planting strategies for these new seeds in times of drought or rainfall.

2.14 Technology Input in Agriculture/Low-External-Input Technology (LEIT)

Agricultural development can be achieved by improving the green revolution technology or on the promises of biotechnology which are often met by simpler technologies, more attended to farmers' traditional practices and more compatible with environmental sustainability, are a more appropriate alternative. Owing to diminishing returns from conventional technologies and natural resource degradation, agricultural

productivity has slowed down in many irrigated and favourable rain-fed areas. This adds to the promotion of alternative agricultural technologies among poor, small-scale and marginal farmers. The LEIT is an alternative agricultural technology and has contributed in improving productivity and conserving natural resources but there is no evidence that they are particularly suited for resource-poor farmers (Reijntjes et al. 1992).

The LEIT approaches involve limiting the use of external inputs such as inorganic fertilizers and pesticides and use a wide range of local and naturally available resources and a combination of traditional and improved methods to manage soil fertility, water, pests and other agronomic needs. The particular methods used include a wide range of technologies, such as water harvesting, soil and water conservation measures, minimum or zero tillage, the application of manure and compost, the incorporation of crop residues, the transfer of biomass and mulching, the use of leguminous cover crops, shrubs, or trees in improved fallows or intercropping systems, the use of crop rotation to manage soil fertility and pests, and integrated pest management (Tripp 2006). The ecological principles underlying these technologies involve favourable soil conditions for plant growth by managing soil organic matter and enhancing soil biological activity, optimizing plant nutrient availability through biological nitrogen fixation, nutrient recycling and the limited use of inorganic fertilizers, minimizing losses by managing microclimates and water to prevent erosion; minimizing pest and disease problems through IPM, and exploiting complementarities in the use of genetic resources by combining these in farming systems with a high degree of genetic diversity (Vermeulen et al. 2013; Reijntjes et al. 1992).

2.15 Organic Farming and Biotechnology

Organic agriculture is a form of LEIT but not all forms of agricultural technology is organic. Organic farming follows agro ecological principles and rejects the use of artificial chemical fertilizers, pesticides, or GMOs. The promoters of biotechnology advocate that biotechnology can overcome the limitations of green revolution by increasing yield, managing pest, etc. though both these approaches are in opposition to each other. They focus on biologically based technology rather than chemically based technologies that may have potential for realizing complementarities between these approaches. Is it possible to develop a combination of ecologically sensitive and biotechnology-driven approaches to overcome the challenges of agricultural development? Every technology has its drawback, as literature suggests poor farmers are less able to pay the financial and opportunity cost of obtaining organic certification and less able to afford the high cost of GM seeds (Herring 2007). So, what is the possible solution to overcome this dilemma? We should focus on risk-benefit analysis rather than risk alone, as every technology comes with both risk and benefit as elaborated earlier.

GM is one of the many technologies along with proper governance and regulatory framework and there are other key approaches which includes application of genomics to effective plant breeding. To add this development of effective herbicide and pesticide, better fertilizers, improving soil science, etc. will help us improve agricultural productivity and agricultural scenario in general.

2.16 Conclusion

In this chapter, we discussed various facets of knowledge production which led to the transition in agriculture research system in India. Mode I and Mode II forms of knowledge production are discussed which suggests practical applicability of science by

maintaining a synergy between academia research and its applicability. Further, we critically examined the concepts of triple helix model of innovation, basic and applied research, agriculture innovation system, science and technology policies in post-colonial India, and so on. The crux of any policy lies in its implementation and at present in the case of India, implementation of policy at various levels is lacking. It thoroughly examines the science of GMOs, risks, precaution, politics, safety in the context of present agricultural biotechnology research in India and abroad and its alternatives such as LEIT and organic farming.



CHAPTER III

GOVERNMENT-ACADEMIA-INDUSTRY: EXAMINING TRIPLE HELIX MODEL OF INNOVATION IN AGRICULTURAL BIOTECHNOLOGY IN INDIA

In the second chapter, we investigated, through a historical-sociological survey, transition in agriculture research system in India. Specific attention was paid to the post-economic reform issues which led to the transition in agriculture research system in India. In this context it discussed Mode I and Mode II forms of knowledge production, applicability of triple helix in the case of Indian context. Then, it moved on to discuss science and technology policies, agriculture policy, and way of doing science (basic and applied research). Finally, it discussed the issues of emerging technology in the case of agriculture biotechnology which led to the transition in agriculture biotechnology research in India. In this context science of GMOs pertaining to non-food crop (Bt Cotton) and food crop (Bt Brinjal) are discussed by exploring alternatives such as LEIT and organic farming.

It is against this backdrop that the present chapter examines the processes of government, academia and industry networking and how this networking results into knowledge production in agricultural biotechnology in India. For this purpose a detailed study of the profile of scientists working in various research institutions, industry and universities have been studied and interviewed. The profile of the respondents has been discussed in the section on methodology in chapter I. Further, it illustrates the basis of their collaboration, starting with ‘what is scientific collaboration?’ This chapter also tries to answer the factors which lead to the hindrances to collaboration or hamper/discourage the process of collaboration between varied actors. In the process, it also tries to capture how this networking leads to knowledge production/innovation in agriculture through patent filed by scientists, projects, and publications made by scientists in peer-reviewed

journals and other informal collaboration for expensive equipment facilities, informal communication and so on.

3.1 Genealogy of Collaborative Networking in Agricultural Biotechnology in India

The changing nature of research in agricultural biotechnology in developing countries like India requires complementarities of expertise from diverse fields. In a developing economy like India, university-industry networking has remained low. The high yielding varieties of green revolution were owned by the public sector as the state was the sole sponsor of scientific research till the 1980s. It is necessary to develop networking with the private sector so that the benefit of modern technology can be harnessed for the public use. The significance of the private sector has to be understood in the context of changing priorities in scientific research. In other words, the entry of private sector in Indian agricultural biotechnology has paved the way for different modes of institutionalization of agriculture in India. Indian government plays a vital role in the promotion of biotech sector in the country by setting up of institutions, offering technical and financial assistance to the individual and research institutions. This calls for increased participation from government, academia and industry for the production of knowledge. These new forms of networking between varied actors are significant for the creation of knowledge society. The networking between government, academia and industry is necessary for the knowledge production in agricultural biotechnology processes. Triple helix is seen as key to innovation and socio economic development of knowledge societies. Earlier Indian agriculture was predominantly owned by the public sector but with the advent of IPR the role of private sector in Indian agriculture has started growing slowly. There has been a transition from government-academia relations to government-academia-industry relations since the 1990s in India. According to

sociologist Knorr-Cetina (1999), the field of molecular biology was individual centric and non-collaborative science as compared to other fields like physics during the 1980s. But with the advancement of science and increase in the complexity of research, several studies in the 1990s began supporting the evidence of collaboration in biology. Interaction among the actors within a network is an important element for the efficient working of a system of innovation (SI). Innovation performance of a country depends on the interaction and networking between varied stakeholders (Dahlman and Utz 2005). The potential of economic development and innovation in knowledge society lie in the most prominent role in the hybridization of various institutions like government-industry and university and forming the network which generates in new knowledge (Ranga and Etzkowitz 2013). The networking between two public or private domains may be easier or difficult to determine and will depend on the period of networking ties, visibility, membership or activities in the public domain.

The main objective of scientific collaboration is to strengthen the scientific and technological capabilities of India's R&D institution in biotechnology and to establish a network for product development and technology transfer. 'Phenotype' of the triple helix partners (government, academia, and industry) can be expected to carry genotypical functions such as knowledge production (in science), income generation (in the market), and governance at different levels (Leydesdorff 2012; Hodgson and Knudsen 2011). Mutual information in three (or more) dimensions can be positive or negative and thus indicate cooperation or a lack thereof in triple helix networking. Triple helix is one of the most important insights of innovation because the most favourable innovation takes place at the intersection of government, academia and industry.

Networking in agricultural biotechnology in India mainly operates for the purpose of getting expensive laboratory facilities, commercializing laboratory products,

obtaining interdisciplinary expertise and germplasm (IPR-enabled) and other products such as vaccines, bio-pesticides, equipment, software, technologies and services.

3.2 Collaborative Networking in the Present Study

Collaboration in agricultural biotechnology requires expertise from diverse fields. The R&D organizations need research capabilities for the adaptation of technologies to local condition and the development of products addressing local priorities. This requires strategic public-private partnership. Networking is important to bridge the gap between the products developed by university laboratories, on the one hand, and, the industry's ability to use them, on the other. Technology transfer from university laboratories to firms is considered key to strengthening competitiveness. Commercialization of research was supported by the introduction of Bayh-Dole Act (1980) which allowed universities to patent and exclusively licensed discoveries generated as a result of collaboration between private and public sectors (Baldini 2009). Further, Stevenson-Wydler Technology Innovation Act of 1980 paved the way for increased cooperation between academia, federal laboratories, labour and industry through technology transfer, joint research, personal exchange and others (see Lee 1996). When we look at collaboration, it occurs at different levels such as between individual scientists of the same department, between research groups of one department and research groups of another department within the institution, across institutions and different actors (government, academia and industry) at national and international levels. Sometimes these collaborations are overlapping and intertwined.

Scientists interviewed for the present study are engaged in projects with Department of Science and Technology (DST), Department of Biotechnology (DBT), Council of scientific and Industrial Research (CSIR), Indian Council of Agricultural

Research (ICAR) and private industry like seed companies, etc., other state and central universities.

Owing to the advancement of science and technology, a scientist working in biology collaborates with the specialists of other disciplines to arrive at meaningful products with multiple applications (Cohen, et al. 2002). This also explains changing nature of research which is not confined only in one field rather requires specialization of diverse fields of research. Scientists working in basic research tend to collaborate less with the industry and are indulged more in publications of the result output. While scientists working in applied research collaborate with industry for pre-testing, field study, commercialization of research output, and so on. In general, industries do not show their willingness to collaborate with scientists working in basic research. Nevertheless, it is often difficult to carry out applied research without building the foundations for basic research. Collaboration at the individual level often forms the basis of any type of collaboration, be it interdisciplinary, intercontinental or inter-institutional, as it is the individual scientists who find out suitable/compatible collaborators through their own networks. Individual interests of scientists should be compatible with the mandates of their institutes. Scientists interviewed are engaged in basic research, applied research and directed/oriented basic research within the different institutional settings in India. According to Hagstorm (1965), applied research is interdisciplinary in nature and hence attracts more collaboration. This fact can be supported by the view of the scientists working in basic, applied and directed/oriented basic research which state that scientists working in applied research collaborate more with scientists from other disciplines and industry because they need expertise from other fields due to the interdisciplinary nature of the project.

Research objectives of the scientists vary depending upon the nature of institutes they are affiliated with, and their networking partners they are engaged with for a specific project. Research problems are often guided by individual's curiosity, norms of funding agencies, physical facilities, sharing of material for research and public policies. Upon careful and detailed interviews with the scientists of Bose Institute, Kolkata, it was found that the scientists are not willing to work in controversial research areas like transgenic technology as policy and decision change with respect to which government is ruling. As a scientist from Bose Institute, Kolkata, states: *“As issues are not clear from government, there is no usefulness/need in working in those areas.”*

On the one hand, they are investing huge money for transgenic research. On the other hand, they are not allowing its commercial release. There is a mismatch between government policies and scientific practices. Institutes funded by Department of Science and Technology (DST), Department of Atomic Energy (DAE), Department of Biotechnology (DBT), Council of Scientific and Industrial Research (CSIR) tend to collaborate more with industry and firms. The advantage with private sector is that they are time bound. Delay and uncertainty in establishing a partnership may enhance transaction cost. Timely response from public sector would be appreciated and this is possible only when there is a decentralized system. Government policies, institutional mandates and commercial aspects influence the individual's selection of research. Classification of scientists based on national scientific networking shows that 77.8 per cent of scientists are engaged in public-public networking (see Table 3.10) whereas networking between public and private institutions is 66.7 per cent (see Table 3.11). These figures show how public-private partnerships have not fully evolved in India in the field of agricultural biotechnology. More private investment is needed. Private sector engagement in R&D is significantly lower than those in developed and other emerging

economies. Basically funding for basic research has declined and it is more inclined towards applied in nature. Universities are primarily engaged in basic research. However, since there has been a relational decline in the funding for basic research vis-à-vis applied research, universities are expected to reorient their approach towards applied research. It is important to forge an alliance between the academia and industry aiming at concrete deliverables.

Today, technology development is demanding and requires expertise from different fields. Not all have the required expertise and resources. Mutual cooperation and partnership between these individuals will lead into network of learning. Institutes have scientific collaboration among institutions and within the institution. A scientist anticipates the importance of interdisciplinary approach in scientific research and how this can be attained through scientific collaboration. According to a scientist from the University of Hyderabad:

We have expertise in botany, molecular biology; somebody has expertise in other disciplines (say chemistry). So we find out the common research area and work on it. Without collaboration we cannot achieve anything, one cannot be the master of everything. We need to have multidisciplinary/interdisciplinary approach, so that we can increase collaboration between different disciplines. Another is that, same microorganism they also produce different kind of metabolism, those compounds can be anti-microbial against human pathogen, plant pathogen, animal pathogen and they tend and can act as anti-cancer. We try to find out useful metabolism from this microorganism and develop into product (drug form).

Scientific research at present has become an alliance with more competitive partners which is an important reason for network development. If networking between collaborators from different disciplines in different regions takes place, it is considered more significant than the collaboration with the same discipline and same local area.

In the present study, the term scientific collaboration has been defined based on the perception of the scientist working in the agriculture biotechnology field. Owing to high

cost of instruments and use of expensive laboratory materials in the multidisciplinary research areas, researchers from different institutes collaborate in order to get the facility of these costly research instruments (Sonnenwald 2007). These types of collaboration are informal in nature and mostly occur between individual researchers. These are also based on mutual cooperation and past reputation of the collaborators. Some of the features of collaboration are ubiquitous across disciplines. Depending upon the individual's experience the definition of scientific collaboration varies from scientist of one institution to a scientist working in another institutional setup. A scientist from Indian Agriculture Research Institute (IARI), New Delhi states:

Scientific collaboration can be cooperation between two industries or organizations in terms of ideas, methodologies, equipment, expertise, training, data sharing, analysis and publications. All steps are to be involved in converting idea to product. This will lead to collaboration.

From originating a research idea to publication needs an increased specialization and group effort which cannot be performed individually and thus requires collaboration with diverse range of groups. Scientific collaboration involves partners with their individual strength who can come together to solve a multidisciplinary problem. This adds to the concept of multidisciplinary to scientific collaboration. Scientific collaboration involves meaningful networking activities to arrive at concrete results or meet with objectives through channels of communication. Scientists engaged in basic research seldom show interest in the industry-sponsored research projects since the industry aims at immediate utilitarian value by supporting applied research. Finding a suitable/compatible partner for collaboration is a necessary step for forming a partnership. Scientific collaboration often varies with the nature of research. This may be explained by analyzing the responses of scientists working in basic research, applied research and directed or oriented basic research. In India, the boundary between basic

and applied sciences is distinct and should be blurred. As mentioned earlier, scientists working in basic research areas tend to collaborate less with the industry and are indulged more in publications of their research results, whereas scientists working in applied research areas tend to collaborate more with industry for pre-testing, field study, commercialization of research output and so on. In India funding for basic science has decreased recently. There appears to be a disconnect between basic and applied sciences. Application is lacking in biological research work. The relational decline in basic research may be captured in the words of a scientist from University of Delhi, New Delhi:

Many a time basic research is needed to prove some hypothesis and then same basic research will be or results of this basic research will be helpful for applied research. So, there is complementary approach for both types of research.

3.3 Motivational Factors

Complexity of research problems and machines used

Presently research does not depend on one area of expertise and it requires know-how from diverse fields. This can be reflected from the nature of collaboration between scientists from government, academia and industry. A scientist working in university collaborates with scientists working in medical institutes. This shows both complexity of problems and involvement of diverse fields of expertise. Machines used for research purposes are so complex which require the help of operators and thus requires collaboration for smooth functioning of research work.

Rising cost of technological apparatuses and research laboratory facilities

Owing to the high cost of instruments and use of expensive laboratory materials in the multidisciplinary research areas, researchers from different institutes collaborate in

order to get the facility of these costly research instruments. These types of collaboration are informal in nature and mostly occur among individual researchers. These are also based on mutual cooperation and past reputation of the collaborators.

Development of new information and communication technologies

With the advent of new information and communication technologies, collaboration has increased rapidly. Regional or geographical boundaries do not affect the process of networking between prospective collaborators. Most of the information and requirements are shared on email by the networking partners.

Production of technology

Collaboration occurs when samples in research laboratories are in the initial stage and have the potential to create products having commercial application. Collaborative ties play a significant role in developing the product from laboratory stage to market stage. In such cases institutional mandates should be such that will facilitate the networking between scientists working in a government and academia to collaborate with industry personnel.

Integrated expertise

A scientist with basic research may not have the expertise in application research and vice-versa. Different interest groups, from industry to university, are expected to develop a collaborative network in order to utilize the expertise in different fields. The scientific community in India expects the State to play a proactive role in enhancing linkages among the full-time laboratory, university, industry and the market. As a scientist from the Indian Institute of Science (IISc), Bangalore states:

Now newer science does not depend on single technique, it requires combinations of technique, so there is need to do scientific collaboration. At

present we do apply a few techniques for crop improvements such as higher yields, good oil content, protein content, etc. Crop varieties should have disease resistance to avoid pesticide/insecticide use. For this we use traditional and molecular breeding. We use marker assisted backcross breeding for wheat and soybean improvement.

Scientists included in the present study use expertise from diverse dimensions ranging from the creation of ideas to the development of product. This requires collaboration from different networks and integrated expertise to form collaborative linkages.

3.4 Types of Collaboration

Modern research is multidisciplinary in nature and requires knowledge from different fields. This suggests that modern research requires collaboration from other disciplines as well. Collaboration can be of different types, viz., inter-individual, inter-institutional, international, and so on, which suggests that no single researcher will possess all the knowledge, skill or technique, method required to perform a particular research activity. Scientists seek networking among other researchers in the department, institutions, industry, and so on. Collaboration can take various forms ranging from offering general advice and insights to active participation in specific piece of research (Katz and Martin 1997). In this section we will look at different types of collaboration within scientific research. Based on the findings three kinds of collaboration have emerged.

First, where the work is being funded by an organization and the university or research organization is working actively on specific research objectives. In this form, the university or research organization may retain rights over their inventions, or may share their ownership with the funding bodies. In the second type of collaboration, actors are collaborating both financially as well as academically. In this type of collaboration, there are two collaborative partners in research and each of them has their own funding.

This type of collaboration mostly happens in the case of participation of researchers across the continents. This type of collaboration occurs mostly between academic institutions such as the Council of Scientific and Industrial Research (CSIR) that has several networking projects where one model laboratory and several other laboratories collaborate for common research objectives. The model lab manages the entire project and the collaborating labs working under model lab are called task force networking project. The CSIR also has an inter-agency project where various agencies are working together and one of them is a private player. The third form is based on Public Private Partnership (PPP). In PPP, the private company and the public research organization work together with their own objective and deliverables. In all the collaborative projects the collaborating partners have their own deliverables; and their duties and roles are well defined in the agreement; their funding agreements also mention the share of each collaborating and the clause of IPR. For example, it is possible that in some projects one partner has done the work and the other partner has not contributed, so the other partner will not have claim on IPR. These kinds of clauses should be drafted clearly in the agreement regarding the ownership to avoid conflict of interest.

3.5 Hindrances to Collaboration

Most of the respondents (81.2 per cent) have not come across any such hindrance or hindering policies or anything which hinder the R&D and they think it all depends on the mandates of the institute. But after carefully interviewing the scientists some of the limitations to collaboration can be elucidated below in the words of a scientist from the Institute of Rice Research, Hyderabad:

There is a limitation by National Biodiversity Authority, they insist that any project first should be approved by the biodiversity authority and then collaboration will go on.

Nowadays, the biggest challenge lies in bureaucratic procedures because there are a lot of procedures which need to be followed before taking small steps which hinder the process of scientific collaboration. Whatever collaboration takes place should be finally targeted for the agricultural improvement, for example, improvement of agricultural crop health, drug discovery from plant, plant improvement by tissue culture, etc. Collaboration between government and academia is often hindered due to much time spent on bureaucratic processes of the government organization. An administrative process of collaboration is often much time consuming. Scientists often claim how unnecessarily time is spent on getting quotation for almost everything. Based on field study conducted at different research institutes in India, the challenges faced by individual scientists can be summed up as follows:

Lack of understanding

University and industry and their relationship have evolved over time. University's style of working or doing research is different from industry. As some of the scientists interviewed suggest that university's style of research is different from the industry. Further, they suggested that research undertaken by university's scientists is exploratory in R&D, whereas, industry develops a lot of ideas having commercial implications. Thus, there is a need to develop linkages between basic and strategic research, and government often plays an important role in mediating the interests of different stakeholders.

Lack of mutual trust

Mutual trust builds between scientists of academia, government, and industry when there is sharing of data between the partners. Mutual trust helps in the development of technology/product as its involvement initiates the networking between two or more

partners, both working on different methods. Scientists included in the present study view trust as a preliminary source of networking ties. Mutual trust develops when extra effort is voluntarily given and reciprocated. Where there is no feeling of 'being cheated' or loss. A sense of trust develops over time and over successful collaboration between networking parties. Literature on scientific collaboration suggests that for a scientific collaboration to be successful there should be trust between the collaborative partners and also trust is the foundation of collaboration. It is also essential for effective management of collaboration between academia and industry or within academia or industry (Sonnenwald 2007; Knorr-Cetina 1999; Dodgson 1993 and Tartari et al. 2012).

Personality traits among collaborators

Personality traits and social bonding play an important role while forming the collaboration with individual researcher. Scientists choose whom they would like to collaborate and under different circumstances. Here, personal characteristics and working style of scientists play an important role in forming collaboration. For successful collaboration, personal traits are essential.

Unequal collaboration

Scientific collaboration is often successful if the entire team of collaborators participates equally and performs their responsibility agreed in the contract or otherwise. Conflicts arise if one partner performs less than the agreed work as mentioned in the Memorandum of Understanding (MoU) or contract. If one feels burdened in the process of collaboration, it will not lead to successful collaboration and thus will hinder the process of networking in the future too.

Bureaucratic process

The present study suggests that administrative process involved in forming collaboration is quite lengthy and it hampers the output of scientific collaboration. As more time is spent on getting a quotation for a small number of samples. Thus, most of the scientists interviewed suggest that bureaucratic process for should be made flexible and should accommodate the needs and convenience of collaborators.

Inability to send samples abroad

Scientists working on basic research while addressing the collaboration abroad suggest that they cannot often form the collaboration with international partners due to inability to send samples abroad as the rules of the government do not allow so. There is a need for policy changes at this level to facilitate collaboration with the international partners.

Lack of funding

Funding has decreased for agricultural research and is low in case of basic research as compared to applied research. The slash in funding for basic research affects its growth in universities. Funding does not come out at the proper time and this led to the completion of projects in a hurried manner at the last moment due to which result outcome gets adversely affected. Delay of funding is another drawback in agricultural research funding. This not only delays the term of the project but also affects the outcome of particular projects.

Collaboration is not successful when only commercial interest is involved. This mostly happens when industry comes into the picture. The industry is often guided by the commercial interest and risk-benefit factors. In collaboration with the industry, this risk

is often borne by the farmers or government. These are the concerns which should be carefully addressed by involving all the actors in network keeping in mind the benefits or remunerations of all the actors involved.

The advantage with the private sector is that they are time bound. Delay and uncertainty in establishing a partnership may enhance transaction cost. Timely response from public sector would be appreciated and this is possible only when there is increased motivation within the scientist of public institutions like university and other teaching institutes. For collaboration to happen trust is very important. According to a scientist of Agharkar Research Institute, Pune: *“Scientific collaboration... where both collaborators share trust and complement each other... there should not be any conflict.”*

Mutual trust is crucial to determine the effective collaboration between networking partners. Reputation or goodwill of industry is important, while forming collaborative ties between the scientists working in university or mission oriented research institutions and industry.

A university selects a list of reputed companies while forming a collaborative networking with the industry and vice-versa. Sharing of knowledge with diverse collaborators makes the potential collaborative partners more willing to collaborate in future and enables them to trust the processes (Olson and Olson 2000).

3.6 Triple Helix Model of Innovation

Networking is essential and a complex phenomenon in agricultural biotechnology. Networking ties help in the production of new knowledge and facilitate learning. In order to establish a sound collaboration between the three actors, following points should be implemented at policy levels.

At first, terms and conditions should be agreeable to both the industry and the university or collaborating partners in advance. Secondly, coordination between industry

and public institution is lacking, therefore proper communication should be established among the collaborators. Thirdly, government has got the managing role. Project Research Officer of the funding agency can monitor them. If there is any misunderstanding between university and industry then it can be sorted out. The smooth release of fund should be promoted. The role of government is to create institutional framework which will enable actors to carry out different roles both locally and globally.

In India Triple Helix I and Triple Helix II are still more dominant as compared to Triple Helix III form of knowledge production. More private investment is required. In India engagement of private sector in R&D is significantly lower than in developed and other emerging economies. Also collaboration is more in case of applied research as compared to basic research. Specific attention should be given to the relationships originating/forming between government and industry, university and industry, etc. in order to capture the complexity of networking between these actors and also to achieve special expertise so that various stakeholders in triple helix will participate actively. Interaction of actors and interplay of institutions at various levels should be increased by introducing multidisciplinary projects involving scientists from different institutions and various disciplines to promote networking between various actors of the triple helix model.

About 20 per cent of scientists included in the present study suggest that informal links are important to get funding for their research projects. There has been little information on informal collaborative networking between collaborators. Scientists are engaged in informal collaboration for sharing laboratory facilities, and research discussions. Future detailed study on informal collaboration between scientists of different organizational settings will help us understand the development of triple helix

in India. Such informal collaboration takes place for the exchange of samples between laboratories or the use of instruments or expert advice.

3.7 Networking with Industry

Networking with industry is crucial for the commercialization of research. The institutional barriers within which academia or industry is situated restricts the networking between private and public proprietors. This is because institutional norms of each of the actors are different. For example, university focuses on the creation of new knowledge while private R&D focuses on capturing new knowledge that can be commercialised (Dasgupta and David 1994). Recently, the demand of good quality industrial product is also growing because of change in life style and food habit of the urban population in India. Therefore, it is essential to improve its end use quality so as to meet the international standards. Scientists from universities collaborate with scientists from industry on a number of grounds, be it technology diffusion, expertise, field work or any other form of advantages. According to a scientist of Bose Institute, Kolkata:

Genes are collected from the wild varieties which are not easily attacked by the insects. For example, - inferior quality of 'chana' which grows in wild variety are not attacked by the insects. We take the gene of those variety which are resistance to insects. We cannot do the field work, so collaboration with the industry is good. We cannot do all things alone and so we partner and collaborate with others to develop technology for farmers. External technology collaborations are key to our promise of delivering innovative new products in the future. We also license our innovations like germplasm and other traits to seed companies so that farmers can directly purchase from the companies.

Both parties will be benefited by collaboration. As another scientist from National Chemical Laboratory (NCL), Pune points out:

Industry will get a lot of research inputs as Indian industries do not have much of resource advantage and it can be fulfilled by the scientists of public institutions. It will be very useful as public institutions will get fund from the sale of the products.

The engagement of public institutions with industry shifts researcher's agenda towards more applied topics at the expense of the long-term benefits expected from basic research. Industry collaborates with university scientists for testing their products. Products which are at laboratory stage in a public institution can be developed into the final product and further this will lead to commercialization of technology. This will benefit scientists working in both industry and academia. The fund generated through the sale of these products can be reused to strengthen the basic research expertise. Thus, there is a two-way interaction between basic and applied science. Individuals, who were trained earlier periods when university's engagement with industry was less prevalent or even discouraged, might be attached to the norms not compatible with forming collaboration with private industry (Bercovitz and Feldman 2008). An individual scientist is reinforced through a virtuous cycle of achievements and returns on those achievements (Merton 1968). This is because mandates of some of the institutes like the Institute of Rice Research do not allow them to form collaboration with industry though they have developed an improved variety of rice since industry is guided by profit motive. The reason why triple helix has not fully developed in India can be explained with the experience of a scientist from University of Madras:

First collaboration was very good and I was highly satisfied. Second collaboration was bitter. They gave some money, actually to address the problem and to find out the solution. But they hire two people to find out what we were doing. But frankly speaking, that is not the proper procedure to do the research/collaboration. They gave the first installment and didn't give the second installment. Their motive is commercial. We are academicians; ours is not the commercial motive. Ours is public funded institutions and we try to help the industry. And before that they tried to hijack our research work (without giving the second installment).

The above scientist's previous experience with the industry is positively related to the future network of academia and industry. This experience shows how there is a lack of mutual trust on the part of one actor under the agreement of collaboration. The present

study suggests that benefits of collaboration with the industry can be realized, for example, products developed by public-private initiatives may reach farmers and/or end-users. Hard-work of scientists will be rewarded as research output developed by the researcher will get applicability. Industry will obtain more research input as the demand for samples, research output, expertise, etc. that can be furnished by the public institutions according to the requisites of an industry. Public institutions will get fund from the sale of products developed by collaboration with the industry. This will help the prospective collaborators solve the problem of low funding.

Networking with industry adds new dynamics to scientific research. This leads to the formation of contractual research within the realm of scientific research. Scientists think that collaboration with industry is more of contractual research. According to a scientist of Centre for Cellular and Molecular Biology (CCMB), Hyderabad:

Collaboration with industry is more of contractual research, they give us a problem and we provide solution to the given problem on areas like seed, absence or presence of genes using our expertise.

As stated earlier, scientific community in India expects the state to play a proactive role in enhancing linkage among laboratory, university, industry and market. This is well-captured by a scientist from National Centre for Biological Sciences (NCBS), Bengaluru:

It is the state which facilitates the collaboration and most importantly it provides funding for research work as far as India is concerned. So, government should come forward and facilitate interaction and better coordination between universities, research institutes, and industry.

Prior to the WTO provisions on IPR, the state was solely responsible for research in agriculture, but with the advent of economic reforms in the 1990s the role of industry has been increased. This also solves the problem of funding to an extent besides helping in the process of knowledge formation. The above statement confirms that there is a need of triple helix in scientific research and this collaboration can be increased by

government by facilitating interaction between varied actors. While discussing networking between government, industry and academia, it is important to note that university usually does not receive much funding for basic research and most of the duties and roles of universities are confined to teaching. The CSIR laboratories and mission-oriented research institutions get a substantial amount of funding. Let us examine the view of a scientist from Guru Gobind Singh Indraprastha University (GGSIPU), New Delhi.

In India doing animal research has become very difficult and many animal houses are not able to maintain because of activists. So, what we have done, there is laboratory like zebrafish for research. Currently, we are testing some of the ideas which are having in zebrafish. Universities have been deprived of modern facilities and have remained largely teaching institutions whereas national laboratory like Indian Council of Medical Research, and Council of Scientific and Industrial Research have excellent facilities but the scientists have stopped working with their own hands. In the process, they are pouching for the unity in the form of collaboration. But will not acknowledge to us for doing their research in the process. Moreover, universities just become important only for registering their students but they do not share or collaborate with the research organizations. In the 1980s and the 1990s, the governments of India do not encouraged collaboration with industry. They collaborate with industry when there is a dearth of funds. Teaching sector does not have any industrial linkages. During the 1990s, the public-private partnership became a buzz word. But if a person wants to commercialize his/her ideas, the terms and conditions laid down by the industry often are not in favour of public institutions. Many times it happens that, academia people want the promise from the industry and they cheat that your product is not good. So, major problem is to sign a proper MoU and it should be strictly followed.

The above statement suggests how PPP model has become important in agricultural biotechnology. This throws light on the traditional role of university and how funding should be increased for university as compared to CSIR laboratories and mission-oriented research institutions. The institutional normative framework to collaborate with industry should be made flexible. Scientists agree that proper MoU is the best way to avoid any conflict while forming any collaboration. The interaction between industry, government and academia is important. Networking between academia

and industry can be increased by accommodating changes in institutional mandates of the institutes. As a scientist from Agharkar Research Institute, Pune states:

The industry or academia or somebody has to take an initiative to provide each other with platforms, where industry can put: these are our requirements, this is what we need and academia should reorient their research programmes based on the need of the industry and they can form collaboration with the industry.

While working in collaboration with industry it is important that university understands the need of the industry. Further, industry has to fund university and later on both industry and university can share credit. Scientists who are willing to adapt to the research interest of industry can form a successful collaboration with the industry. The above discussions clearly show the increasing trend towards triple helix III model in scientific collaboration. This will be guided by a number of factors like commercial interest, increase in networking, patent and so on. For linking basic and applied research, networking between university and industry is important. Let us take note of the words of a scientist from International Centre for Genetic Engineering and Biotechnology (ICGEB), New Delhi:

First of all find out the problem, fundamentals of the entire problem and then how to address that problem and then try to solve the problem. Without the support of industry, applied research will not see the right path. You need to have meaningful, beneficial collaboration between both university and industry.

Resistance to change on the part of the university scientists may be attributed to their perspective on the functions of the university system, which emphasizes basic research and disciplinary education to the students. The industry-sponsored research was seen as changing the orientation of the university by bringing in commercial values, entangling university researchers with proprietary interests and constraints thus changing the traditional image of university (Nelkin and Nelson 1987; Mallick 2011). Emphasis has been laid on the application of science and traditional mode of knowledge production

which is only confined to disciplinary science is changing. These developments are changing the traditional role of universities by bringing the concept of application to its findings. This suggests that there is a need for third party participation so that collaboration would be successful. It also suggests that there is a need for triple helix model in agricultural biotechnology in India which is not fully developed. There will be greater participation and learning if both industry and academia come together. Long-term funding project is required to bring together private R&D, academia, establish research laboratories, startups, and so on, leading to more innovation. As networking becomes institutionalized, the different interests of scientists in different kinds of R&D institutions will continue to be an issue.

3.8 University's Role as Entrepreneur

University often takes the role of industry, transforms the technology to influence existing firm with new life and help form new firms in incubation facilities. The government takes the role of industry, helping to support these developments through funding programmes and by implementing other supportive initiatives (Etzkowitch 2001). Industry takes the role of the university in delivering teaching and research, often at the same high level as the university (Leydesdorff and Etzkowitch 1998). Along with teaching and research purposes, economic and social development mission/target/object is enhanced. As the university takes up a new role in facilitating innovation, its teaching and research missions are changing. As the university expands its role in the economy, from a provider of human resources to entrepreneurial services, its relationship with industry and government is transformed. There have been institutional changes in the role and activity of university. The emergence of entrepreneurial activities among universities, in e-learning and incubation, presages a tri-evolution. In taking these new

roles and responsibilities, university becomes one of the important stakeholders of the economy, culture and politics. The transformation of university-industry networking from a linear to non-linear innovation model can especially be seen in the evolution of university business incubation from a linear to non-linear model and from an isolated to a networking entity (Etzkowitch 2001). In addition, university's mentored firms, the incubator brings in firms from outside the university allowing both types of firms to interact with and learn from enhancing role of the other. Moreover, linkages among incubators allow joint development and diffusion of technology. As the university becomes closely involved in the transfer of technology and founder of new firms, it attracts a new entrepreneur identity (Etzkowitch 2001). The business expertise that was forming within the university is now being expanded to achieve higher growth, based upon funding capital that can be credited from academic research as well as from other sources (Ahmad and Seymour 2008). Within academic department and centre, members of faculty and other technical persons are assigned special responsibilities to assess the commercial source of research funds and encourage an external partnership.

University is significant to the industry in a number of ways such as contract research, setting up of startups, provisions of business parties, management of intellectual property issues, etc. University can contribute to entrepreneurship by developing and conducting research on behalf of the startups. Also, universities can provide infrastructure and laboratory facilities to new startups, which will save initial investment required to establish research setups. To facilitate this networking, government sponsored programmes allow entrepreneurs to gain access to university laboratories, but these are expensive and limited. Besides providing laboratory facilities, a university can assist in technology transfer activities such as the acquisition of patents. Similarly, small firms with limited ability to conduct their own R&D could leverage the

research capacity from the public sector and this can be mainly seen in startups growing in premier research institutions in India such as the Centre for Cellular and Molecular Platforms (C-CAMP), National Centre for Biological Sciences (NCBS), etc. to name a few. The main strength of academic institutions is their research community which includes professors, students or any other relevant research group which may act as resource persons for the industry. 'Entrepreneurial university is on the rise in the agricultural biotechnology sector in India' (Etzkowitz 2001). This is evident from the expert interviews which suggest that students should be trained to become entrepreneurs. In this regard, young entrepreneur awards and other fellowship grants are provided to students to become individual entrepreneur thus commercializing university research or making it more application-oriented. University selects industry projects, which solves a practical problem and leads to a fundamental advancement of knowledge. Students get training while working for the projects under the guidance of their mentor. University mode has an advantage over industry and government as the regular flow of knowledge is maintained through its students, each a potential investment. This built in renovation mechanism helps create an innovative environment, especially since each research study is expected to produce advanced knowledge or technology in order to graduate.

3.9 Patents

Patent plays an important role in biotechnology development. The significance of commercialization of intellectual capital has been realized in university recently (Mallick 2016). Patent holders can benefit from their inventions by having sole proprietorship to commercialize their research findings. To increase the multidisciplinary approach in agricultural biotechnology in India, increasing number of universities and research

institutes began to integrate the national intellectual property system by means of patenting and technology transfer activities. This increases the culture of innovation and enhances the importance of protecting the research result. The agricultural sector in India experiences a major paradigm shift in the late 1990s from the Convention on Biological Diversity (CBD) and the Agreement under the World Trade Organization (WTO). Provision under the TRIPs Agreement of the WTO established enforceable universal minimum standard of protection for all major forms of IPR, of individuals or institutions, for new knowledge, skills, technologies and products developed by them (www.wipo.int/edocs/lexdocs/laws/en/in/in018en.pdf, accessed on 14 January 2016). Moreover, it extended the application of the IPR regime to living things and agriculture research. It is in this context discussion on patents has a major influence on the future of agricultural research. Commercialization of knowledge is preferred through acquiring patents rather than traditional mode of publishing. University's scientists are encouraged to apply for patents. The changing orientations of scientists towards commercialization are a by-product of both economic reforms and individual scientific curiosity. This suggests transition in the traditional mode of university system. Still publication is preferred by scientists working in academia and basic research areas.

While looking at patents owned by the scientists at various research institutes, central universities, state universities, 3.7 per cent of scientists have 4-5 US patents, 9.9 per cent of scientists have 2-3 US patent and 9.9 per cent of scientist have one US patent (see Table 3.1). This suggests that agricultural biotechnologists in India holding on US patent are low with less number of scientists having right on these patents. This also indicates that innovation and knowledge production in the international arena is low and needs an increased and integrated partnership with the various actors at regional, national and international levels. This also indicates policy level changes at national level which

will facilitate better networking with the individual and group innovators. Similarly, when we look at number of European patents owned by the scientists engaged in agricultural biotechnology, nearly 10 per cent of scientists owned European patents, out of which 2.5 per cent have one European patent and another 2.5 per cent are the holders of 2-3 European patents. Around 3.7 per cent of scientists are the owners of 4-5 European patents. 45.9 per cent of scientists interviewed have owned Indian Patents. This shows that a majority of scientists have more number of Indian patents than the European and US patents.

This indicates the slow spreading of royalties in universities and research institutions in agricultural biotechnology in India. These patents can provide a source of income to research institutions. An increased number of patents filed/owned by the scientists at varied research institutions in India indicate a growing number of innovations and creation of knowledge society for the utilization of solving the real world problems.

Table 3.1: Classification of Scientists by Different Patents since 1991

Patents	Scientists (N=81)		
	US Patents	European Patent	Indian Patent
	Number (Percentage)	Number (Percentage)	Number (Percentage)
No	62 (76.5)	73 (90.1)	43 (53.1)
One	8 (9.9)	2 (2.5)	20 (24.7)
2-3	8 (9.9)	2 (2.5)	9 (11.1)
4-5	3 (3.7)	3 (3.7)	4 (4.9)
6+	0	1 (1.2)	5 (6.2)
Total	81 (100)	81 (100)	81 (100)

3.9.1 Pattern of Collaborative Patents

Let us look at the pattern of collaborative patents held by the Indian scientists in different institutional settings in India. Patents evolved out of interdisciplinary collaboration are more as compared to intercontinental and inter-institutional

collaboration. Scientists from international public organizations like ICRISAT, ICGEB, and other mission-oriented and institutes of national importance like Indian Institute of Technology (IITs) tend to have more patents than scientists from state universities and central universities (see Table 3.2). This implies that the objective of universities is more of teaching, and much of their resources and time is spent on teaching and mentoring students, on account of which scientists from universities and academic institutions tend to have less patents than the research and mission-oriented institutions and organizations. Around 30.9 per cent of scientists are the holders of one or two patents involving interdisciplinary collaboration with both national and international agencies. Around 4.9 per cent of scientists are involved in three or four interdisciplinary collaborative patents and 11.1 per cent of scientists are involved in more than five interdisciplinary collaborative patents with both international and national bodies. Scientists involved in interdisciplinary collaborative patents are more than the inter-institutional and intercontinental collaborative projects. This indicates that there is growing interdisciplinary collaborative networking and development of new networking communication within and outside India. This involves growing use of internet and emails for networking with the respective partners. Around 14.8 per cent of the scientists are involved in intercontinental collaboration. This suggests knowledge sharing between scientists with other continents is less and requires networking ties between the potential collaborators from different continents to focus on broader objectives in order to support global development goals. Around 7.4 per cent of the scientists interviewed are engaged in one or two intercontinental collaborative patents, 1.2 per cent of scientists are engaged in three or four intercontinental collaborative patents involving scientists from different continents and 6.2 per cent of scientists are engaged in more than five intercontinental collaborative patents with the scientist from different continents. Around 17.3 per cent of

scientists hold one or two inter-institutional patents, 4.9 per cent of scientists hold three-four inter-institutional patents and 6.2 per cent of scientists hold more than five inter-institutional patents which are the outcomes of inter-institutional collaboration.

Table 3.2: Classification of Scientists by Pattern of Collaborative Patents since 1991

Collaborative Patents	Pattern of Collaborative Patents (N=81)		
	Interdisciplinary	Intercontinental	Inter-institutional
	Number (Percentage)	Number (Percentage)	Number (Percentage)
No	43 (53.1)	69 (85.2)	58 (71.6)
1-2	25 (30.9)	6 (7.4)	14 (17.3)
3-4	4 (4.9)	1 (1.2)	4 (4.9)
5+	9 (11.1)	5 (6.2)	5 (6.2)
Total	81 (100)	81 (100)	81 (100)

3.10 Collaborative Projects

The number of projects conducted in partnership between universities, research institutes, and industry is growing, but the major challenge remains to obtain practical results from the R&D projects in terms of new products or processes introduced in the market.

Scientists are networking with international partners for projects in interdisciplinary research. Around 23.5 per cent of the scientists interviewed are networking with one to three interdisciplinary projects with the international partners. Around 6.2 per cent of the scientists are engaged in three to four interdisciplinary projects with the international partners. A total of 18.5 per cent of scientists interviewed have worked and are working in more than five interdisciplinary projects with the international partners. Projects require a large number of expertise and resources which basically necessitate the inter-institutional networking. Around 21 per cent of the scientists are engaged in inter-institutional international projects. There is a slow networking with international institutions.

Table 3.3: Classification of Scientists by Different International Projects

International Projects	Scientists (N=81)		
	Interdisciplinary	Intercontinental	Inter-institutional
	Number (Percentage)	Number (Percentage)	Number (Percentage)
No	42 (51.8)	74 (91.4)	64 (79.0)
1-3	19 (23.5)	3 (3.7)	6 (7.4)
3-4	5 (6.2)	0 (0)	5 (6.2)
5+	15 (18.5)	4 (4.9)	6 (7.4)
Total	81 (100)	81 (100)	81 (100)

Let us look at the collaboration of scientists within India in terms of projects undertaken within India. Around 84 per cent of the scientists are involved in interdisciplinary national projects. This indicates that scientists are collaborating for projects with other competent collaborators. This leads to more invention and development of knowledge society within agricultural biotechnology in India. There is more collaboration for applied research in research oriented organizations and ICAR-funded institutions. 16.1 per cent of scientists are working on one or two projects. Around 14.8 per cent of the scientists are working on three to four projects and 53 per cent of the scientists are working on more than five projects. These figures indicate that collaboration within India is more as compared to collaboration outside the India with the international partners.

Let us look at inter-institutional collaboration by the scientists of various research institutions, universities, industry and international organizations in India. Around 43.2 per cent of the scientists are engaged in inter-institutional national projects, out of which 6.2 per cent of the scientists are working on one or two projects, 9.9 per cent of the scientists have undertaken or working on three or four projects and 27.1 per cent of the scientists are working on more than five projects with Indian collaborators. Inter-institutional collaboration within India mostly takes place when funding agency sponsored a project involving partners from different institutional settings when projects

require expertise of different disciplines. When an individual scientist feels to have knowledge or expertise of scientist from another field, collaboration takes place. This type of collaboration becomes useful when scientists collaborate for a project have better compatibility among them and undoubtedly trust and mutual understanding play a key role in such type of collaboration. This type of collaboration also does not occur, in spite of scientists' willingness, if their institutional mandates do not allow such collaboration. Tenure of the project is important in collaboration. Tenure for most of the projects is for a fixed time, say 3-5 years, and this, according to scientists engaged in basic research feel, hampers the idea of the project and within short span of time it is not possible to come up with meaningful results or research outcome. Most of the projects are contractual in nature. Thus, institutional and contextual factors govern collaboration and there is considerable amount of orientation towards collaboration by the individual scientists involved. More number of collaboration for national projects indicates that local knowledge gaps are addressed by scientists working on projects or context-specific research problems.

Table 3.4: Classification of Scientists by Different National Projects

National Projects	Scientists(N=81)		
	Interdisciplinary	Intercontinental	Inter-institutional
	Number (Percentage)	Number (Percentage)	Number (Percentage)
No	13 (16.1)	79 (97.6)	46 (56.8)
1-2	13 (16.1)	1 (1.2)	5 (6.2)
3-4	12 (14.8)	1 (1.2)	8 (9.9)
5+	43 (53.0)	0 (0)	22 (27.1)
Total	81 (100)	81 (100)	81 (100)

3.11 Classification of Scientists by the Area of Research Involved

Scientists interviewed are engaged in basic research, applied research and directed/oriented research within the different institutional settings of India. According to

Price (1986), in applied research, the commercial reason prevails against the societal one because the costs of research determine to seek partners that contributed with funds, equipment or expertise. According to Hagstorm (1965), applied research is interdisciplinary in nature and hence initiate more collaboration. This fact can be supported by the interview undertaken by the scientists working in different disciplines like applied, basic and development research which state that scientists who are working in applied research network more with scientists from other disciplines or industry because they need expertise from another field due to the interdisciplinary nature of the project.

Basic research provides the foundation for applied research which can further lead to commercialization. Around 86.4 per cent of the scientists are working in basic research areas, out of which 53.1 per cent of the scientists are involved with one or two research organizations. Around 22.2 per cent of the scientists are involved in three or four research organizations for the research involving basic research expertise. Around 3.7 per cent of the scientists are involved in five or six research organization for the purpose of carrying out basic research and 7.4 per cent of scientists are involved in more than seven research institutions for the purpose of carrying out basic research.

Around 90.1 per cent of the scientists interviewed are engaged in applied research out of which 29.6 per cent of the scientists interviewed are engaged in one or two institutes for applied research, 18.5 per cent of the scientists interviewed are engaged in applied research with three or four organizations and 23.5 per cent of scientist interviewed are engaged in applied research with more than seven organizations at both national and international levels. Scientists who are performing applied research are also undertaking basic research. In India, there is hardly any demarcation between basic and applied research. The boundary between basic and applied research is not rigid but

porous. Around 51.9 per cent of the scientists interviewed are involved in directed or oriented research, out of which 13.6 per cent of the scientists are engaged with one to two organizations, 21 per cent of the scientists interviewed are engaged with three or four organisations, 7.4 per cent of the scientists interviewed are engaged with five to six research organizations and 9.9 per cent of the scientists are engaged with more than seven institutions. Scientists' engagement in directed or oriented research suggests more collaboration among government, academia and industry. It is also clear that scientists working in directed or oriented research areas is much less than the scientists working solely in basic or applied research. This suggests that scientists' orientation towards directed or oriented research is less as compared to only basic or applied research. Networking between industry and mission-oriented research institutes and basic research organization is less and has not fully evolved in the Indian context. There is a leapfrog in the transfer of knowledge than acts as an incentive for sharing knowledge, and collaboration increases within the networks.

Table 3.5: Classification of Scientists by Area of research involved

Organizations Involved	Scientists (N=81)		
	Basic Research	Applied Research	Directed/Oriented Basic Research
	Number (Percentage)	Number (Percentage)	Number (Percentage)
No	11 (13.6)	8 (9.9)	39 (48.1)
1-2	43 (53.1)	24 (29.6)	11 (13.6)
3-4	18 (22.2)	15 (18.5)	17 (21.0)
5-6	3 (3.7)	15 (18.5)	6 (7.4)
7+	6 (7.4)	19 (23.5)	8 (9.9)
Total	81 (100)	81 (100)	81 (100)

3.12 International Scientific Networking

Let us look at international scientific networking looking at various projects undertaken, number of papers published, patents granted and collaboration if any for

equipment facilities or for the service of integrated expertise by scientists in different institutional settings. Scientists from different institutional settings reflect upon varied institutional mandates and contexts in which they collaborate. These differences can be observed in the type of research projects undertaken and nature of potential collaborators. For example, scientists from university tend to collaborate less with the industry as compared to scientists from CSIR-sponsored laboratory who tend to collaborate more with private research institutions.

Around 51.8 per cent of the scientists are engaged in interdisciplinary collaborative research and 48.2 per cent of the scientists interviewed do not collaborate with other partners for interdisciplinary research purposes. Around 25.9 per cent of the scientists interviewed work with one to two networking partners for the purpose of carrying out research or any other collaborating activity like transfer of technology, diffusion of knowledge or sharing of knowledge, etc. Similarly, 8.6 per cent of the scientists are engaged in three or four projects for the purpose of carrying out research activities and 17.3 per cent of the scientists are engaged with more than five collaborating partners for the purpose of carrying out research activities, sharing of knowledge or transfer of technology or any other useful research engagement. When we look at intercontinental scientific collaborative networking as a whole such as patent, publication, project or any other collaborating activity, it is found that intercontinental networking is less as compared to inter-institutional and interdisciplinary networking. This suggests that developing countries like India have not evolved fully their networking ties across the globe. Scientists in India are more willing to collaborate within the country for any collaborative or networking activities. There is a lack of opportunity on the part of Indian scientists to form networking ties with the global partners. A detailed study is required to determine the processes of networking with the

intercontinental scientific partners and also how networking leads to the innovation in and development of knowledge society.

Alternatively when we look at the process of networking with the international partners or organizations for the inter-institutional collaboration networking, it is less as compared to national inter-institutional collaboration networking. Around 74.1 per cent of the scientists are not engaged in inter-institutional collaboration with the international partners. Scientists with international exposure tend to collaborate more with the international research organizations due to their exposure and research experience abroad. Scientists working in international research organization like ICGEB and ICRISAT will have more networking ties as compared to scientists working in other research institutions. Around 25.9 per cent of the scientists are engaged in inter-institutional international scientific networking for projects, patents, publications or any other collaborative activity. Inter-institutional international networking is more as compared to intercontinental collaboration networking but much less than the international scientific networking in interdisciplinary research activities. Around 8.6 per cent of the scientists are engaged in inter-institutional international scientific collaboration networking with the one or two international scientific collaborators. 3.7 per cent of scientists are engaged in three to four international collaborators for the purpose of carrying out inter-institutional scientific collaboration, 13.6 per cent of scientists interviewed are engaged with more than five collaborators on inter-institutional scientific networking. According to Powell et al. (1996), the locus of innovation can be found in the network of collaboration. These networking ties generate new ideas and formation of new knowledge society.

Table 3.6: Classification of Scientists by International Scientific Collaborative Networking

Collaboration/ Networking	Scientists (N=81)		
	Interdisciplinary	Intercontinental	Inter-institutional
	Number (Percentage)	Number (Percentage)	Number (Percentage)
No	39 (48.2)	57 (70.4)	60 (74.1)
1-2	21 (25.9)	11 (13.6)	7 (8.6)
3-4	7 (8.6)	2 (2.4)	3 (3.7)
5+	14 (17.3)	11 (13.6)	11 (13.6)
Total	81 (100)	81 (100)	81 (100)

3.13 National Scientific Collaborative Networking

Scientific collaborative networking is more within the country as compared to networking outside the country. Mandates, motivations, and missions of each research institute generate different channels and networks through which these scientists collaborate. An individual scientist's motivation is important for collaboration with the third parties. Institute provides facilities, guidelines, funding and normative institutional framework for collaboration with other research groups of an institution but it is the individual scientist's willingness, research agenda, etc. should match with the other collaborators. To use equipment and samples from other institutions, mutual trust and reputation are essential between individual scientists of different institutes.

The DST, DBT, DAE, CSIR are playing the role of boundary organizations which provide funding to the project and for university it provides scholarship to the students to carry out research. Often do boundary organizations provide a broad area and invite proposals from researchers working in those areas and based on the competency of the scientists it accepts proposals of the competent scientists and provide funding to carry out research. A few forms of collaboration can be captured through projects undertaken by the scientists, patents owned, papers published, but there are other collaborative efforts like seeking laboratory facilities or using expensive samples from other institutes within India. The degree of collaboration in different institutional settings varies and is a

complex process. Let us look at national scientific collaborative networking through publications, patents, projects, expert advice, expensive material facilities, and transfer of technology, and so on.

Interdisciplinary collaboration within India is more as compared to interdisciplinary international collaboration. In the present study, 87.7 per cent of the scientists are engaged in interdisciplinary national scientific collaboration, whereas 12.3 per cent of the scientists are not engaged in interdisciplinary collaboration within India. These scientists are from universities who are devoting most of their service for teaching and mentoring young researchers. Around 17.3 per cent of the scientists are engaged in interdisciplinary scientific collaboration with one or two collaborators within India. Around 23.5 per cent of the scientists are engaged in interdisciplinary research activities with three or four collaborators within India and 46.9 per cent of the scientists are engaged in scientific collaboration with more than five collaborators for scientific networking within India. Intercontinental networking connects collaborators from all regions of the world. In this era of tremendous internet growth all layers of network should be improved and upgraded. One reason for decreased intercontinental collaboration is probably due to the increased connectivity costs between international partners. Intercontinental collaboration is also required to address global problem like climate change through supporting sustainable and climate resilient agriculture. When we look at the overall inter-institutional networking within India including collaboration for projects, patents, publications, data analysis, equipment facilities, etc., around 29.6 per cent of the scientists are not engaged in inter-institutional scientific networking within India. Around 70.4 per cent of the scientists are engaged in collaboration networking within India for various research activities, out of which 28.6 per cent of the scientists are working in close cooperation of one to two institutions for collaboration

activities, 17.3 per cent of the scientists are engaged in three to four collaborators for the purpose of carrying out collaboration activities and 18.5 per cent of the scientists are working with more than five collaborators for various collaboration activities. Inter-institutional collaboration is developing in India. It is more between government and academic research organizations and compared to academia-industry or government-industry. It has developed more between two actors based on Mode 2 knowledge production. Networking ties between government, academia and industry are complex and expected to produce more innovation as compared to simple collaboration between two individual scientists from academia or industry.

Table 3.7: Classification of Scientists by National Scientific Collaboration/Networking

Collaboration/ Networking	Scientists (N=81)		
	Interdisciplinary	Intercontinental	Inter-institutional
	Number (Percentage)	Number (Percentage)	Number (Percentage)
No	10 (12.3)	40 (49.4)	24 (29.6)
1-2	14 (17.3)	13 (16.0)	28 (34.6)
3-4	19 (23.5)	5 (6.2)	14 (17.3)
5+	38 (46.9)	23 (28.4)	15 (18.5)
Total	81 (100)	81 (100)	81 (100)

3.14 Publications

Publication is an obvious and desirable outcome of any research activity. Scientists interviewed for the present study have more international publications as compared to national publications. The publications made by scientists are taken into account for the period, 1991-2015. If not patented, research output is published and these studies can contribute to existing knowledge society through continued publication in peer-reviewed and reputed international and national journals. Around 86.4 per cent of the scientists have published more than ten international papers in reputed journals, 13.6 per cent of the scientists interviewed have published less than ten papers in international

journals. Around 17.3 per cent of the scientists have 10-20 papers in international journals, 19.7 per cent of the scientists have 21-30 papers, 14.8 per cent of the scientists have 31-40 papers, 13.6 per cent of the scientists have 41-60 papers, 9.9 per cent of the scientists have 61-80 papers and a total of 11.1 per cent of the scientists have more than 80 papers in international journals. The reason for this increased number of publications in international journals is that 54.3 per cent of the scientists interviewed for the present study are senior scientists, aged above 50 years.

Let us look at the scientific publications in national journals by the scientists in different institutional settings in India. In this case, 51.9 per cent of the scientists have less than 10 papers in national journals. It is also observed that a publication made by the scientists in national journals is much less as compared to publications made in international journals. Around 23.5 per cent of scientists have published 11-20 papers in national journals, 24.6 per cent of the scientists have more than 20 papers in national journals. Scientists publish less in the initial phase of their professional careers as compared to the later phase of their professional careers.

Around 69.1 per cent of the scientists interviewed for the present study have publications during the phase 1991-2000. During the phase 2001-2005, 92.6 per cent of the scientists of the scientists interviewed for the present study have publications. During 2006-2010, the publications have increased to 97.5 per cent showing almost all scientists interviewed for the present study have publications in the peer reviewed international and national journals. During 2011-2015, 98.8 per cent of the scientists interviewed for the present study have publications in national and international journals. Also, most of the scientists interviewed have citation index in PubMed.

The role of the government in networking between university and industry is important as it facilitates cooperation, partnership, and institutional facilities. It is

important to understand how government, industry and academia form networking. Attention should be given to the relationships between government and industry, university and industry in order to capture the complexity of networking between these actors.

Table 3.8: Classification of Scientists by Publications

Publications	Scientists Publications (N=81)	
	International	National
	Number (Percentage)	Number (Percentage)
< 10	11 (13.6)	42 (51.9)
11-20	14 (17.3)	19 (23.5)
21-30	16 (19.7)	7 (8.6)
31-40	12 (14.8)	5 (6.2)
41-50	6 (7.5)	3 (3.7)
51-60	5 (6.1)	1 (1.2)
61-70	5 (6.3)	1 (1.2)
71-80	3 (3.6)	0 (0)
81+	9 (11.1)	3 (3.7)
Total	81 (100)	81 (100)

Table 3.9: Classification of Scientists by Publications in different phases

Publications	Publications phases (N=81)			
	1991-2000	2001-2005	2006-2010	2011-2015
	Number (Percentage)	Number (Percentage)	Number (Percentage)	Number (Percentage)
No	25 (30.9)	6 (7.4)	2 (2.5)	1 (1.2)
1-10	17 (21.0)	33 (40.7)	23 (28.4)	18 (22.2)
11-20	18 (22.2)	22 (27.2)	29 (35.8)	19 (23.5)
21-30	9 (11.1)	11 (13.6)	12 (14.8)	14 (17.3)
31-40	7 (8.6)	7 (8.6)	11 (13.6)	21 (25.9)
41+	5 (6.2)	2 (2.5)	4 (4.9)	8 (9.9)
Total	81 (100)	81 (100)	81 (100)	81 (100)

3.15 Government-Academia-Industry Networking

The corporate strategy adopted by Indian industry affects the R&D in agricultural biotechnology research in India. Nevertheless, the intricate social and funding ties between policy makers, industry personnel and media representatives complicate the

networking between government, industry and academia. The critical analysis of government, academia and industry networking in agricultural biotechnology will add to the policymaking process of GM crops in India. Most of the forms of networking between actors do not occur through formal meetings but rather through social networking and informal meetings where opinions can be shared more freely and more easily than formal meetings with government officials.

The present study argues that firms in agricultural biotechnology in India are able to enjoy the institutional influence and are responsible for forming direct connections with the key elements in policymaking in agricultural biotechnology. It is argued by a majority of scientists that industry has links everywhere especially with key government officials involved in policy decisions regarding GM crops. In this context, it is important to address the issue of the influence of networking in terms of links between particular associations. There are multiple formal institutional channels which can be used to form networking between academia and government at different levels.

Table 3.10: Association between Scientific Collaboration of Public-Public Organizations and Performance Level

Public-Public	Percentage	Sample (n)	Performance Level				X ² Test
			Moderate		High		
			N	%	N	%	
I. Government-Government	5.6	9	7	77.8	2	22.2	0.13^{NS} (p=0.988)
II. Government-Academic	51.4	57	46	80.7	11	19.3	
III. Academic-Academic							
a) National	46.6	59	47	79.7	12	20.3	
b) International	22.4	36	28	77.8	8	22.2	

NS: Non-significant

X² (0.05, 3df) = 7.815

Collaboration between government, academia and industry has been measured based on the networking ties in terms of publications, patents, projects, laboratory

facilities, personnel expertise, research and training, any formal or informal research collaboration in both India and outside in various research institutions, universities, MNCs, private industry and so on. There has been little information on informal collaborative networking among scientists. Scientists are engaged in informal collaboration for sharing laboratory facilities, research discussions, etc.

The analysis focuses on Indian agricultural biotechnology research system. In the present study, there has been 5.6 per cent of collaboration between government and government organizations with respect to number of projects undertaken by individual scientists in different organizations. A total of 51.4 per cent of the scientists are engaged in government-academia collaboration. Also, we classified collaboration between academia-academia as national and international collaboration. There has been 46.6 per cent of collaboration between universities within country. In the present study collaboration between national universities and international universities is 22.4 per cent. Let us describe the various heads between public-public collaboration. It can be collaboration between government-government organization, government-academia organization, and academia-academia. Under collaboration between academia-academia, it can be divided between national and international category. Let us discuss association between scientific collaboration of public-public type and its performance level. When we look at collaboration between government and government organization and its performance level, 22.2 per cent have high performance level. However, 19.3 per cent have high performance when we analyse the collaborative networking between government and academic institutions. Further, when we consider the collaborative networking between academic and academic institutions at international and national levels, the performance level are 20.3 per cent and 22.2 per cent respectively. The Chi-square test for the present study is non-significant.

Table 3.11: Association between Scientific Collaboration of Public-Private and Performance Level

Public-private	Percentage	Sample (n)	Performance Level				X ² Test
			Moderate		High		
			N	%	N	%	
I. Government-Industry	6.1	6	4	66.7	2	33.3	0.41 ^{NS} (p=0.939)
II. Academic-Industry	44.3	43	27	62.8	16	37.2	
III. Government - Academic-Industry							
a) National	31.0	30	19	63.3	11	36.7	
b) International	18.6	18	10	55.6	8	44.4	

NS: Non-significant

$$X^2 (0.05, 3df) = 7.815$$

Let us examine the collaboration between public and private organizations. This can be studied by examining the networking between government and industry, academia and industry, and government, academia and industry at both national and international levels. Around 6.1 per cent of the scientists are engaged in collaborative networking with government and industry. A total of 44.3 per cent of the scientists are engaged in collaborative networking with academia and industry. As scientists from universities collaborate with industry for the purpose of commercialization of their research results, transfer of technology, field test, etc. triple helix model can be located within networking between government, academia and industry and this type of networking is useful while considering the complexities and requirement of present day research in agricultural biotechnology. Looking at government, academia and industry networking within India, 31 per cent of the scientists are working in collaboration with government, academia and industry. A total of 18.6 per cent of the scientists are engaged in collaborative networking between government, academia and industry at international level.

Let us discuss association between scientific collaboration of public-private type and its performance level. When we look at collaboration between government and

industry and its performance level, 33.3 per cent have high performance level. However, 37.2 per cent have high performance when we analyse the collaborative networking between academic and industry. Further, when we consider the collaborative networking between government, academia and industry at international and national levels, the performance levels are 36.7 and 44.4 per cent respectively. The Chi-square test for the present study is non-significant.

These figures suggest that academia-industry, university-national research laboratories, national research laboratories-industry collaboration is more dominant in agricultural research in India. Though some initiatives by the Department of Biotechnology of the government of India have been undertaken to bring in public and private research organizations on particular projects but growth of such type of partnership is limited to few research institutions and universities. For example, C-CAMP, Bengaluru under the Biotechnology Ignition Grant (BIG) initiative is trying to bring about private R&D and startups in close interaction with the universities where initial development grant is provided by the government and equipment facilities, mentoring facilities and infrastructure facilities are provided by the C-CAMP.

Table 3.12: Association between Scientific Collaboration of Private-Private and Performance Level

Private-private	Percentage	Sample (n)	Performance Level				X ² Test
			Moderate		High		
			N	%	N	%	
I. Industry-Industry							0.04^{NS} (p=0.850)
a) National	62.5	5	3	60.0	2	40.0	
b) International	37.5	3	2	66.7	1	33.3	

NS: Non-significant

$$X^2 (0.05, 1df) = 3.841$$

Let us examine the collaboration between private and private organizations. The collaboration between industries is not the focus of the present study and its impact on the present study is non-significant. However, based on the data available, 62.5 per cent

of industries are collaborating with the industry within the country and 37.5 per cent of the scientists working within industry are collaborating with industry outside the country. Let us examine the association between scientific collaboration of private-private and its performance level. Around 40.3 per cent have high performance when we compare collaboration between industries within the country. Similarly, 33.3 per cent have high performance level when we compare the association between scientific collaboration of private and private institutions and its performance level within industry at international level. The Chi-square test for the present study is non-significant.

3.16 Conclusion

There is an inadequate linkage between scientists of public institutions and private industry. Interaction of actors and interplay of institutions at various levels should be increased by introducing multidisciplinary projects involving scientists from different institutions and various disciplines to promote networking between various actors of the triple helix. Those believing that science is a public good are less likely to pursue commercialization (Perkmann et al. 2013). Scientists interviewed for the present study are more likely to collaborate with industry for 'field test' opportunities, their own research, learning and new insights from collaboration. Government's role in networking between university and industry is important as it facilitates cooperation, partnership and institutional facilities.

The government, industry and academia form networking but particular attention should be given to the relationships between government and industry and university and industry in order to capture the complexity of networking between these actors and also to achieve special expertise so that actors in triple helix will participate actively. In triple helix, all actors should participate actively while university should participate actively in research activities apart from teaching role. Interaction with other scientists is crucial for

the advancement of science. Most of the networking between actors of government, academia and industry do not occur through formal meetings rather through social networking and informal meetings where opinions can be shared more freely and more easily than formal meetings. For individual scientists working in a university, possibility to pursue research freely and on its own terms is favoured more as compared to funding opportunity from different sources. The conflict between industry and academia personnel can be avoided if proper MoU is signed in advance. Also, industry-university networking is more of contractual in nature and it is argued that short-term project is not useful in bringing about meaningful results. Thus, there is a need to introduce long-term R&D projects by the industry. It calls for increase in investment by private sector in R&D activities besides non-R&D activities. Networking in agricultural biotechnology in India mainly operates for the purpose of obtaining expensive laboratory facilities, commercializing laboratory products and procuring interdisciplinary expertise, germplasm (IPR-enabled) and other products such as vaccines, bio-pesticides, equipment, software, technologies, services, and so on. The hindrances to collaboration have surfaced through a lack of understanding, trust and cooperation, personality clashes, unequal distribution of work load based on expertise, structural, institutional and organizational frameworks, bureaucratic administrative processes, lack of networking skills abroad and debilitating effects of funding.

CHAPTER IV

TRIPLE HELIX MODEL OF INNOVATION AND THE POLITICS OF GENETICALLY MODIFIED CROPS: CASES OF BT COTTON AND BT BRINJAL IN INDIA

The previous chapter titled, “Government-Academia-Industry: Examining Triple Helix Model of Innovation in Agricultural Biotechnology in India” dwelt upon the triple helix model of innovation in agricultural biotechnology in India by examining the networking between government, academia and industry. The networking between government, academia and industry has been initiated through scientific collaboration. It investigated the motivational factors, attitudes, interests and meanings to form such collaboration by the scientists working in different institutional setups in India. Further, networking between government, academia and industry in agriculture biotechnology sector is examined through patents, publications, projects, etc. undertaken by the scientists included in the present study.

In this context, the present chapter attempts to understand the implications of proprietary technologies in agriculture in India where two genetically modified crops namely Bt cotton (non-food crop) and Bt brinjal (food crop) are analyzed critically. Further, an attempt is made to discuss the debates on the policies of biotechnology, in general and Bt crops, in particular. This chapter examines how diverse actors are guided by differing interests and meanings. It attempts to study the networking between government, academia and industry, with special focus on GM crops, for example, Bt cotton and Bt brinjal. This chapter further argues that if proper networking and interaction between these three actors namely, government, academia and industry is conducted it will have better adoption of agricultural biotechnology as well as it will lead to policy level changes required for GM crops. This chapter discusses the politics

embedded in the triple helix model of innovation in the context of GM crops and the influence of GM technology on Indian agriculture.

The first breakthrough in agricultural technology was high-yielding variety of wheat developed by the CIMMYT in Mexico in the 1950s. In India, agricultural technology was initiated by Indian Agricultural Research Council (IARC). Later with the development of modern technology it was realized that advantage of new technology generated by the International Research Centre is contingent upon the development of national research and extension, and with economic reforms it is dependent upon networking between different actors.

The development of insect resistance crop was seen as significant step by the industry such as Monsanto. If we look at the country-wise views on GM crops briefly, then it is a mixed scenario. In European countries, the death of butterflies leads to serious investigation on the matter and a finding was linked to damage of ecosystem on account of which GM crop is not advocated in European countries. Also, in Europe in the 1990s, fuelled by social movements based on environmental risk, threat to human health, and corporate control, pharmaceuticals, medical and industrial technology were exempted from GM. In the United States, risks associated with GM crops are clearly mentioned. On the contrary, in India, risks associated with GM crops are not clearly defined, and at times are seldom evaluated in terms of scientific and cultural specificities. Thus, dimensions of institutionalizing state science vary greatly across crops and nations (Herring 2015a). Scientists in India argue that GM crops in agricultural biotechnology are protested and even facing a moratorium and activists groups want a permanent ban on GM crops. Transgenic crops have recorded the fastest adoption rate of any crop technology since the 1990s, for example, the case of Bt cotton in India, area under cultivation has increased up to 96 per cent (James 2012).

4.1 Scientists' Perception on GM Crops

Scientists included in the present study are of the opinion that no genetically engineered crops had been successfully released from the public sector till 2015 in India (Herring 2015b). China sought to actively promote private-public partnership in the case of GM crops, while in India a few MNCs have monopoly in the case of Bt cotton (Choudhary et al. 2014). This shows corporatization of GM crops in Indian agriculture. As a scientist from University of Agricultural Sciences, Bengaluru suggests that the involvement of public institution for the broader development of farmers will bring in public welfare and commercial interest of the industry. There should be more networking between public and private sector that would benefit both sectors. This will result in commercialization and diffusion of GM crops. In the words of a scientist of the University of Agricultural Sciences, Bengaluru:

Most of the companies are selling GM technology. So we cannot depend on them but we should be ready with new technology along with indigenous technology. The public sector should come out, so that farmer will get seeds at cheaper rate.

The commercialization of GM seeds is dominated by the private sector or seed companies. Owing to the involvement of private sector in the release and marketing of seeds by MNCs, the prices charged for the GM seeds are high. Involvement of public sector in pursuance of the commercialization of seeds will ensure the availability of GM seed at a reasonable price. In the process of developing modern varieties it is also argued that indigenous variety should be protected and we must not lose our indigenous varieties.

4.2 Case of Bt Cotton

Bt cotton has almost replaced its non-Bt counterpart in India and occupied 95 per cent of the total cotton area (Choudhary et al. 2014). Maharashtra occupies highest

grown area under Bt cotton followed by Gujarat and Andhra Pradesh. Bt cotton is not banned and its cultivation has increased manifold and it has almost replaced non-Bt cotton.

By 2010, 700 of Bt cotton seeds were marketed in India by 30 small and medium private seed companies. The development of Bt cotton in India inspired other R&D organizations to develop more biotech crops such as rice, mustard, chickpea, sorghum, soybean, sugarcane, and so on. Bt cotton was introduced in India keeping bollworm infestation, chemical sprays, high yield, early harvesting, assured market price, etc. in mind. As discussed earlier, area under Bt cotton has increased and non-Bt cotton areas have been replaced by Bt cotton. India has become the second largest producer of cotton after China. But this has been protested by the anti-GM group which suggests an ill-effect on cattle, farmers' suicides, and so on (Venkat 2016). This debate is often compared to green revolution during which hybrid crops were introduced in India to increase agricultural production. The green revolution had adverse effects like use of hazardous pesticides and fertilizers. The Green Revolution in the 1960s and 1970s increased food production fulfilling the need of growing population. However, the Green Revolution was not adopted in the various regions of India and was limited to states like Punjab, Haryana and western Uttar Pradesh. The transition from green revolution (phenotypic knowledge) to gene revolution (genotypic knowledge) has significant implications for industrialization of agriculture in India. In green revolution, the state was the owner of HYV seeds. On the contrary, in gene revolution, the ownership over new technology shifted from the state to MNCs, particularly the collaboration between Monsanto and Maharashtra Hybrid Seed Corporation (MAHYCO). Bt Cotton was the first seed which came under the ownership of such collaboration between two industries.

There are risks associated with Bt cotton. The industry in India claims that agricultural yields cannot be achieved through traditional or organic farming. Genetic engineering is important to fix plants depending on the environment and nutrient elements. The Genetic Engineering (GE) is important as it tries to minimize agro-chemical uses. While discussing the possible risks and benefits associated with Bt cotton in India, its adverse effects on the farming community are often protested by civil society organizations.

New technologies such as genetics or biotechnology are used to develop traits that can address the problems of drought, salinity stress, disease, and so on. Can organic farming overcome these challenges? As argued by a senior scientist of Bose Institute, Kolkata: '*Can we find suitable organic crops which can be replaced for cryogene [study of the effects of low temperatures on organisms]?*' Nevertheless, there is huge opposition to GM crops in India especially when scientists are ready with any new GM crops. This opposition is strong in the case of food crop, for example- the case of Bt brinjal and GM mustard. Whether, these oppositions are based on science or politics. According to a scientist from University of Agricultural Sciences (UAS), Bengaluru:

Opposition is simply a case of not being aware of the merits of new technology. There is no scientific basis of opposition. There is a positive effect of Bt cotton, pesticide use has been cut down. Opposition is mainly on the basis of food safety, loss of biodiversity, environmental effect, etc. But these are false as there is no scientific evidence to it.

Similarly, a scientist from National Centre for Biological Sciences (NCBS), Bengaluru states:

In 1973, GM technology was claimed unnatural by activists. But it is important to note that from natural knowledge scientists develop new technology, so it is not unnatural. Further, rDNA technology is a part of nature. Science modifies plants for better production. Insects develop through GE which in biomedical field helps a lot. Similarly in agriculture, Bt crops, maize, etc. are produced in more than 100 million hectare for the last ten or more years.

The above statements suggest that GMOs are naturally conditioned. It is useful in biomedical field besides agriculture. The GMOs should address the questions of equity, sustainability, conservation, environment, etc. Moreover, these modifications have been occurring in nature for several years. Similarly science modifies plant for better production and use.

4.3 Case of Bt Brinjal

Bt brinjal is developed by inserting a crystal protein gene from the soil bacterium *Bacillus thuringiensis* (Bt), few other genetic elements into the brinjal genome. These are mediated using another soil bacterium, *Agrobacterium* which transfer DNA between itself and plants. The insertion of Bt into brinjal genome provides resistance against insects such as fruit and shoot borer (FSB). In India, Bt brinjal was developed by the Maharashtra Hybrid Seeds Company (MAHYCO) together with Monsanto which is modified further by the scientists of Tamil Nadu Agricultural University, Coimbatore and University of Agricultural Sciences, Dharwad.

In India, brinjal is grown on nearly 5,50,000 hectares making the country the second largest production after China with a 26 per cent world population share (Choudhary et al. 2014). Whereas in Bangladesh, it is the third most important vegetable in terms of production and grown on about 50,000 hectares across the country. Eggplant is an important source of income for many Asian farmers. Interestingly as there is much apprehension about Bt brinjal in India, Bangladesh becomes the first country in the world to approve the commercial planting of Bt brinjal. Four varieties of Bt brinjal were approved for rerelease on October 30, 2013. These four varieties are: Bt Uttara, Bt Kajla, Bt Nayantara and Bt ISD006. One of the important points to note here is that based on the experimental data, Bt brinjal can increase yield by at least 30 per cent and reduce the number and cost of insecticide application by 71-90 per cent. Despite the field trial was

conducted during 2002-2006, it faced a moratorium in 2010 due to huge public protest. Research trials were conducted in multi-location which showed that Bt brinjal can reduce the uses of insecticides by 77 per cent.

The transformation of Bt brinjal first began in 2000 by MAHYCO in India under a partnership with Monsanto and using its cry1Ac gene which was already in use in India. The case of Bt brinjal is highly debatable and there is huge public protest on its commercial release in India. The moratorium on Bt brinjal in 2010, due to huge public protests has created a state of chaos, disillusion on the part of scientific community, and they are under the state of confusion. The ban on the release of Bt brinjal was mainly on the ground of risks associated with it. This poses a critical question on the safety and sustainability of Indian agriculture, with probable effect on human and animal species. This has also changed the scientists's choices of research problem. Scientists explain this problem with common example of cell phone where there is some evidence of hazard but no proof of hazard and still used by everyone. Similar is the case of GM crops.

In the case of risks associated with Bt brinjal, international networks also played a critical role in producing a claim to oppose Bt brinjal in compliance with international norms of food safety testing. A paper indicating a specific Bt food hazard, by Professor Gilles-Eric Seralini of Caen university, France concluded: 'the risk on human and mammalian health is too high for authorities to take the decision to commercialize this GM brinjal (MOEF 2010). Bt eggplant was declared unsafe by Professor Seralini in 2008. He specified hazards to humans in consuming cry Bt proteins as 'organic toxicity' and risk of organ failure, potentially resulting in death. The finding of Professor Seralini became critical in subsequent controversy because it was the only evidence cited with respect to potential food hazards. Let us put this in the words of a scientist from MS Swaminathan Research Foundation (MSSRF), Chennai:

A lot of students are under disillusion and even funding agency asks what the use of this technology? So, people should come out and discuss. 30-year long term effect is not feasible practically because then nothing will be in the market. It is very unfortunate that agriculture is being targeted. We are consuming GM medicine and they are already in market. If I have to choose between GM brinjal and non-GM brinjal, then definitely I will choose GM, as it is with less pesticide.

Bt brinjal is engineered in such a way that it can be of resistance to several pests and thus will reduce the use of pesticides. It is in this context scientists argue that Bt brinjal will be used with less pesticide and hence better than conventional brinjal with pesticides. Public awareness of GM technology would be helpful in minimizing the public fear pertaining to new technologies such as GM technology. If a field trial is conducted for a long term say 30 years, then it will make a technology obsolete and thus it is not feasible. Decision on GM crops should be based solely on scientific basis is an argument made by the scientific community which ignores the fact that science on its own cannot determine policy decisions. There is a mixed response from the scientific community on the release of Bt brinjal. According to a scientist from ICGEB, New Delhi:

As far as the case of Bt brinjal is considered it should not be banned if all the test is performed. When law is clear than why it is banned. We should not reduce the research and trials for coming years and subsequent field trials have been conducted and moreover Bt brinjal case study passed all the test and guidelines then why it is not allowed.

The above statement suggests that the research and trials related to Bt brinjal have been completed. Despite this, it is not allowed for the commercial release in India. One of the drawbacks in the case of science and policymaking in India is that the reports pertaining to field test of GM crops are not made public. This adds to the lack of trust in public with respect to GM crops. This suggests how fate of new technology is embedded with social, political, institutional and policy factors rather than the scientific factors. The moratorium on Bt brinjal is not affecting MNCs rather than Indian scientists who are

ready with more than a dozen of GM crops such as chickpea, rice, wheat, mustard, etc. The MNCs like Monsanto are moving to other developing countries like Bangladesh and Pakistan for commercializing GM crops like Bt brinjal, Bt corn and Bt potato. It is argued that Bt brinjal can kill pests. It is a food crop, if consumed, it will have adverse effects on human and animal health. Thus, it is not safe to consume Bt food crop. But this claim is explained in scientific term by a scientist of Osmania University, Hyderabad, who is working on Bt eggplants since 1997:

Genetically modified crops are high yielding as well as resistance to adverse conditions. It is completely safe to consume GM foods. Bt brinjal... where the pest resistance against lepidopteran insects is provided by the crystal protein CryIAc of bacillus thuringiensis, but the protein is friendly to crop friendly insects and other species.

The above statement suggests that Bt brinjal kills *lepidopteran insects* but does not harm crop-friendly insects or other species. Since, Bangladesh is already cultivating Bt brinjal, it can act as a testing ground for Bt brinjal. Again, cultivation of Bt brinjal in Bangladesh is protested by the civil society organizations of India due to its possible contamination to an indigenous variety of brinjal in India as Bangladesh is a neighbouring country of India.

The GEAC was the institutional locus of regulatory science for genetic engineering in agriculture with approving germplasm transformation, mandating field trials, assessing results and approving over a thousand cotton hybrid varieties. The discovery of double-helix model by Watson and Crick allowed manipulation of the Deoxyribonucleic Acid (DNA) which can come from different species (plant, bacterium, virus and animal). This helps in creating desirable traits such as pest-resistance or vitamin A (Venkat 2016). Controversies over the approval of Bt brinjal successfully challenged its scientific conclusions and diminished its authority. According to a senior scientist of University of

Agricultural Sciences, Bengaluru, *“We are not ready for Bt brinjal, as rules and regulation to test Bt brinjal is not ready. Let them test it for 3 to 4 years.”*

This shows a lack of communication among actors that impedes technological innovations. Scientists who are working or actually performing the research on Bt brinjal or any other GM crops and scientists who are not working on GM crops differ on their opinions on this variety. In India settled authoritative knowledge about genetic engineering often guides the political trajectory of GM technology (Herring 2015b).

4.4 Triple Helix Model of Innovation and the Politics of GM Crops

Agricultural sector is transforming and should be seen as agricultural enterprise in order to increase efficiency of agriculture through technological innovations. Since the Green Revolution in the 1960s, there has been transition of seeds from hybrid to genetically modified seeds by government and industry initiated programmes in agriculture. Biotechnology is regarded as a key technology to handle agricultural problems like insecticides, pesticides and increasing yield. Along with other modern technologies like nanotechnology, ICTs, genomics, tissue culture, India relies heavily on biotechnology. Whenever a technology is introduced in Indian agriculture, there is huge protest or debate on its usefulness keeping the farmer communities and the larger section of the society as whole in mind. When we look at the Green Revolution, HYV varieties were not accepted initially but it became successful though only in some parts of India. Let us list out perception of scientists on expected benefits of biotechnology which is crucial for the advancement of Indian agriculture. In agriculture, biotechnology has enabled genetic alteration of plants/crops, improved soil productivity and enhanced natural weed and pest control. Further, GMOs may help us solve problems of salinity or drought but cannot be treated as miracle seeds. This suggests that GM technology is one of the many available technologies so it cannot solve all agricultural problems and

should be applicable to specific use. The current challenge of Indian agriculture is not just producing in terms of quantity but also in terms of nutrient rich food crop. However GM foods are going through field trials and biosafety tests for safer consumption of human and animal species but safety of GM crops is always questioned. As a scientist from Osmania University, Hyderabad, states:

GM technology is safe for mammals and has been herbicide tolerance. DNA marker assisted breeding was selected which provided various benefits like drought resistance as result of growth in molecular biology and genomics. During green revolution only one dwarf in wheat and rice varieties was used. Management side was not taken care of as present need is 'more food with the existing resources'. Water is limited, too much use of fertilizers which made difficult to optimize the cost of agricultural production. Minimum irrigation, resource conservation technology, zero tillage, minimum tillage raised by plant deep irrigation is required to optimize the cost of production. Scientists have started incorporating modern technology faster, improvement is possible. They can bring some exotic traits very easily.

The present study argues that how advancements in molecular biology and genomics helped in combating the challenges of modern society where land is limited and resources are scarce. Also, these advancements are not limited to one or two groups rather a wide variety of crops are being researched keeping in view the problems of agriculture. Incorporation of modern technology in Indian agriculture since the 1990s has increased many folds as compared to green revolution of the 1960s. While in India, a viable 'science-society contract' is elusive and contested on grounds of the credibility of state institutions in which science is conducted and evaluated. Without such a contract, the legitimacy of state science – whatever its objective standing in the epistemic community of scientists – will prove unstable (Gupta 2011).

The case of GM varieties is debatable and controversial in Indian agriculture and the status of GM crops in India plays a major role in forming the debate on GM crops globally. GM crops, especially GM food crops, have faced serious protests by the civil society organizations and activist groups. Scientists are ready with GM crops but the

latter has already faced a moratorium due to public protests mostly by the civil society organizations. Civil society organizations protest GM crops on a number of grounds like loss of biodiversity, indigenous right, farmers' rights, inefficiency of technology, not better than traditional one, high cost, no proper testing, and so on (Herring 2008). Scientific community claims that necessary field trials for GM crops have been conducted and these GM crops are ready for direct use. Let us put this in the words of a scientist from Institute of Rice Research, Hyderabad:

There is a positive and negative side of technology. Unfortunately most of the negative side which is highlighted by the NGO/private companies particularly the pesticide companies is on the basis of unscientific reasons. Bases are not scientific, but for pro GM/positive support bases are scientific. In developed countries like USA they are adopting GM technology, not from now but they have been using for more than 15 years and they have not faced any problem. They have GM corn, GM canola. They have lot of other GM crops. There they are doing all sort of biosafety tests. They never had any problem. Since they are consuming already from 10-15 years, they did not faced any problem but unfortunately in India due to the interest of some NGOs, private companies, particularly pesticide companies, did not support; otherwise there is no problem. There is no problem for human health or animal health besides pesticides opposition. Traditionally people used breeding but now it is transgenic and there is now artificial use of technology.

There are concerns about the consumption of GM foods in general public but GM foods have been consumed for 15 years and there is no adverse effect on human health (Herring 2008). The scientific community claims that they advocate GM technology on the basis of scientific grounds whereas opposition is not based on scientific grounds. They also suggest that every technology is associated with risk and benefit factor and GM technology is no exception. One of the key findings of the argument is that GM technology, especially, in case of Bt cotton and Bt brinjal, are designed to reduce the use of pesticides and insecticides. Thus, it can help us increase the productivity and profitability by reducing the cost of production by the less use of pesticides and insecticides.

The present study demonstrates that the pesticide companies are trying to defame the GM technology so that they can sell their pesticides to farmers, while previous studies on GM crops by Herring (2015b) suggests that pesticides companies adapt with the market needs and do not feel threatened by the adoption of GM crops. This suggests that the politics embedded in GM crops is more complex. The studies related to GM controversies (Herring 2015b) suggest that protest on GM technology by Civil Society Organizations (CSOs) is on the basis of sustainability or environmental basis. The consensus on the part of CSOs is clear that they do not want GM crops at present in India, if it is allowed then long term field trials of more than 30 years should be conducted which is practically unfeasible. So, there is a clear consensus on the part of CSOs that they do not want GM crops in India. However, views of scientific community on GM crops are fragmented while a few completely reject this technology and suggest that there are other technologies available which can tackle the problem of Indian agriculture, while most of the scientists suggest how GM technology is required for good research and support GM technology, while others do not want to be engaged in controversial topics like GM. Based on the interviews of scientists in various research institutes, universities and industry it is clear that views of scientists on GM technology are fragmented and there is no consensus on GM technology by the scientific community in India.

The idea of increased participation by CSOs in the triple helix with concern about GMOs is gaining importance. For example, in the case of Bt brinjal, where CSOs' protests banned the commercial release of Bt brinjal in Indian agriculture (Menon and Siddharthan 2015). As the triple helix model of innovation states, in addition to knowledge infrastructure of academia, government and industry relations, an overlay of communications and negotiations among institutional partners is increasing importance

for the dynamics of overall system. Leydesdorff and Etzkowitz (1998) suggest that the formulation of public demand for technological innovation may help in the creation of knowledge society.

However, the politics of pesticide companies is not highlighted much which can be seen as how diverse actors are adding to the controversies of GM technology and thus shaping the technology politically, economically and socially. There is no robust or parsimonious explanation for why some countries accept agricultural biotechnology with little contention, whereas others change positions over time or reject the technology altogether. In this case, India has been a pivotal case. The state officially promoted biotechnology, but remains unable to gain consensus on deployment. Thus, the state officially promotes huge investment on its research in laboratories but when its release for the commercial purposes is to be considered, it may not constitute a uniform opinion. Huge public and private investment, scientific expertise, time, and so on are invested in developing a particular technology. There is a need to conduct field trials for a long time but this is not feasible as it requires heavy investment, human skills and most importantly time. Also, it will make commercialization of particular technology very long and practically not feasible. At present public sectors do not have sufficient money, time, or scientists who can invest their time on the uncertain future of GM crops. While MNCs are conducting field trials which are not of long duration, they try to bring crops as early as possible into the market and try to maximize their profit. The government rules and policies regarding GM crops are not clearly examined keeping in mind the interest of larger communities of farmers and are often contested and negotiated by the civil society organizations in India. There is clear need of proper examination of rules and policies regarding GM technology involving scientific communities, policy makers, industry, farmers, and so on. The benefits of new technology can be utilized effectively. It is in

this context long term impacts of GM crops are difficult to evaluate. Conducting field trials are a part of commercializing a crop or product and it is also mandatory to test in the field. But the demand for long-term field trial is not feasible and should be understood in the light of practicality (keeping in mind limited fund, scientific personnel, time, and so on).

The government and academia cannot invest all the time and money required for the field trials and safety test as there is a need of involvement of industry which can invest more funds for biotechnology research in general and for field trials and biosafety test of GM crops in particular, while full risk of GM technology or any other technology cannot be known in advance. There has been a transition from disciplinary science to business of doing science, as science was supposed to create new knowledge. The case of GM technology is not just a scientific issue rather it is also a policy issue embedded with social, political and economic factors.

The cases of Bt Cotton and Bt brinjal clearly depict a lack of consensus on the part of state science. The comparison between these two cases suggest the implications of modern technology in India and future of other GM crops like rice, wheat, gram, mustard, chickpea, etc. which are under laboratory stage and huge public investment is made for the research of these GM crops. The Genetic Engineering Approval Committee (GEAC), in October 2009, approved Bt brinjal the first GM food crop, to receive commercial clearance in India. But there was huge protest by the public on commercial release of Bt brinjal in India and as a result the Government of India passed a moratorium on Bt brinjal (Herring 2015a). The Bt brinjal contains the same Bt cry1Ac transgenic as the Bt cotton hybrids.

Developers claimed similar advantages in pest protection, pesticide reduction and benefits to the farmers but it failed to gain approval due to huge public protest which also

evoked a crisis of state science. Since the introduction of Bt cotton in 2002, its usefulness to Indian agriculture is debated and questioned. But it did not face moratorium as area and profit generated under Bt cotton has increased substantially since its introduction. Prior to Bt cotton, introduction of modern technologies in cotton was objected. The main function of Bt cotton is to reduce the use of pesticides and resistance to bollworm. Moreover cotton is a cash crop which has increased the state revenue. If we discuss the case of Bt brinjal, then it faced moratorium in 2010 based on the argument that it is a food crop which can adversely affect human health. Moreover it is not a cash crop like cotton and thus lacks its importance to national economy. According to a scientist of IARI, New Delhi:

The transgenic events are currently undergoing tests in the regulatory system. An application for patent protecting to gene targeting in brinjal is under consideration. They advocate that one of the promising approaches to counteract those problems is development and usage of genetically modified crops, which are high yielding as well as resistance to adverse conditions.

He further added that it is completely safe to consume GM foods. He exemplified his statement with the case of Bt brinjal, where the pest resistance against lepidopteran insects is provided by the crystal protein Cry1Ac of bacillus thurigiensis, but the protein is friendly to crop friendly insects and other species. The above statement depicts that Bt brinjal causes harm to pest and thus making it pest resistance. According to James (2012), Bt cotton provides significant and multiple agronomic, economic and environmental benefits to farmers and society. Choudhry et al. (2014) state that a total of 522 Bt cotton hybrids were approved for planting in 2009 compared to four Bt cotton hybrids in 2004. Also, it is projected that the Bt cotton will occupy approximately 90 per cent of total Bt cotton area in 2010. There is an increase in the number of farmers planting biotech crops in India as the number of farmers growing Bt cotton hybrids in India has increased from 50,000 in 2002 to 5.6 million farmers in 2009.

With the commercial release of Bt cotton in 2002, India ranked fourth in the world in terms area under transgenic crops in 2010 with an increase in agricultural production and reduction of pesticide applications. In 2015, India is the second largest cotton producing nation, only next to China. From being a major importer of cotton, India has become a major exporter.

There are conflicting views on the data of Bt cotton too. Reports on livestock deaths from the ingestion of Bt cotton leaves reinforced the narrative of toxicity that carried over to brinjal (Rao 2007a, 2007b). A majority of the scientists interviewed for the present study suggest there is an element of politics in this case by the pesticide companies. Pesticide companies resist Bt cotton as due to the introduction of Bt cotton, sale of pesticides to be used on cotton have gone down which causes heavy loss to pesticides companies. So, they created this artificial scenario with the help of media in order to spread the ill-effects of Bt cotton. The views on Bt cotton vary from public, government, private to civil society organizations. As a scientist from GGSIPU states:

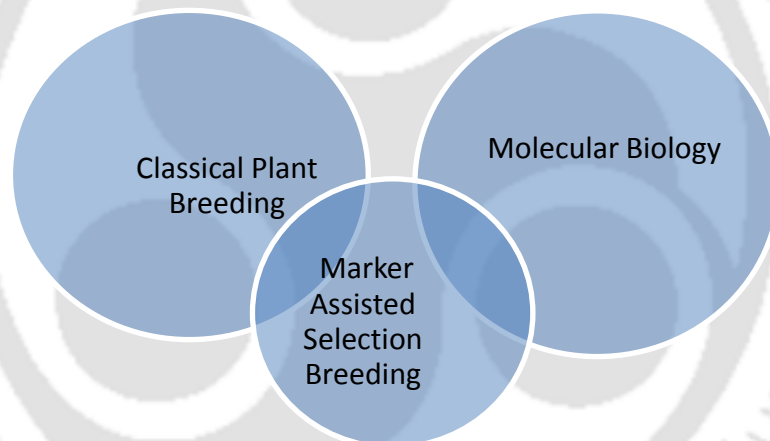
The State Agricultural Commissioner reports on the popularity of Bt cotton conflicts with International Service for the Acquisition of Agri-biotech Applications (ISAAA). The exact story/current status of Bt will depend on which data you want to rely.

Whenever Bt cotton is concerned, its success or failure is debated. Discussion is important in the context that it is the first GM crop commercialized in Indian agriculture and its success or failure will shape the future of other GM crops in India which are being researched in laboratories, but decision on commercial release is on halt. For example, GM mustard is facing a protest and previously Bt brinjal faced a temporary moratorium in 2010. A scientist from the University of Hyderabad (UoH) suggests:

Bt cotton is a success story in Karnataka except some story of farmers suicides due to the ignorance of the farmer like non-spraying of pesticide. The government of India should release Bt brinjal as all research is already done.

Scientists' views on GM crops and particularly in the case of Bt cotton and Bt brinjal are fragmented with one set of scientists hesitant to dwell upon the issue and simply willing to follow mandates of the institute, while others supporting the GM crops, its usefulness on scientific basis. In contrast, a small set of scientists clearly reject GM or Bt crops and suggest other technologies like Marker Assisted Selection (MAS) breeding which is non-controversial may be used to handle the issues of agriculture. They suggest how MAS breeding takes the benefits of both classical molecular breeding and molecular biology.

Figure 4.1: Components of MAS Technology



Source: Field Study

The MAS breeding combines classical plant breeding with the tools and discoveries of molecular biology and genetics, most specifically the use of molecular marker. There are different types of uncertainty and complexity in agricultural biotechnology research in India. Let us list out some of the complexities existing in agricultural biotechnology research in India:

- Do we need GM technology?
- Demand of long term field trial – is it feasible economically, socially, politically culturally and scientifically?

Debates on agricultural biotechnology in India centre on GM crops especially Bt cotton and Bt brinjal. There are disagreements over the social and political construal of GM crops. This debate still continues as various social and political groups, viz., the state, industry, academia and civil society see Bt crops differently. We cannot decide the future of technology based on politics and discourses alone. Rather proper evaluation of science, laboratory testing along with the social, economic, political and institutional factors should be evaluated before taking a decision regarding emerging technologies. Let us examine the view of a scientist from Indian Institute of Science (IISc), Bengaluru:

Working with the gene is very important if we want to produce good research. Work done by breeders is not high-quality research. This was conducted by our forefathers. Breeding, unless done in a newer way is not a research. We are trying to mix something and we are trying to get something out of it. So, that it may have some new property. But we are not trying to see how this new property came. They were trying to breed variety which becomes more salt tolerant or salt resistant but why that happens and what makes it salt tolerance is not demonstrated. Just like Ayurveda, which is effective but 'will you call that science' not really just like modern science. They are more on the applied science, without really pick up the basic science. In fact, breeding itself is an applied science. That is why I said, somebody who does basic science and somebody who is on the applied science, there should be 'Collaboration Bridge' between these two by the university or any other institutions.

Debates on GM crops are not just scientific or technological rather it involves non-technological factors like politics and policy. It will be interesting to answer how biotechnology is shaped by the conflict of interest between varied stakeholders. Decisions on GM crops are not shaped solely by scientists as science is guided by number of factors like politics and governing of the state. A lack of communication, trust and coordination on the part of actors of triple helix model of innovation results improper diffusion, use and regulation of agricultural biotechnology in India, thus

adversely affecting the technological innovations in India. Let us put these in the words of a scientist of NCBS, Bengaluru:

Pesticides will be sold very nicely in the market. People have to go for GM or pesticides. Traditional growers used none of these. It is like partial advertisement of GM. GMO is good or bad? It is not the right question. GM is used for a good research. In our country probably 800 tests is to be done for GM. We can do that but who will be able to put that many resources for this. Can scientific community will have these much resources. The industry can put so much of resources. These hypes are used by the industry people. For example- currently I work on rice which is sold at Rs. 50 per kg in the market and there is GM variety of rice which is sold at Rs. 45. Then definitely everybody will purchase rice at lower price. So, it is money that matters. Even the policymakers will purchase rice at a lower price. In India, we have the products which are banned in many countries but not in our country without any rules and regulations. But most of the pesticides we use are banned in many countries, even cosmetic industry or any other industry it is banned in many other countries. But it is probably in India, these things are going on without any check. So, the breeders abroad have changed a lot themselves with time but these people never change with time. ICAR system was very much against the GM crop for long time. In 1970s, ICAR system- biggest employee- very less money goes to the basic research. Our country does not support molecular biology. Scientists do not get any funding for their basic research work.

While talking about labeling and information about GM crops in developed countries, proper labeling is done. Its outcomes are properly maintained and clearly shown. In developing countries, no proper labeling or information about GM crops like its composition is shown on the product. From the above discussion it is clear that fear of GM crops is introduced into public through media and how seed companies play a crucial role in the politics of GM crops. The above statement also suggests how rules and regulations regarding many pesticides (which are banned in other countries) are still not working in India. This also suggests how breeders have evolved globally. If we take the case of Bt brinjal which has faced moratorium mainly due to its consumption then in India people are already taking GM in the form of medicine, for example, insulin contains GM which is consumed without reporting any harm to human. During the pre-reform period, the ICAR was the largest employer of the scientists working in

biotechnology and it has not whole-heartedly supported the research of GM crops. But the situation has changed since the post-reform period and funding is available for applied research and less or no funding is granted to basic research. This will affect the foundation of doing science as applied research is based on sound basic research. Hence, the government policies regarding the funding for basic, applied or developmental research should be appropriately distributed.

4.5 Clearing Doubts

Mahyco-Monsanto Biotech did enjoy privileged market position in the case of India. There is lot of apprehension on the safety and hazards of GM crops in India since the introduction of first commercial crop, Bt cotton, in India. Bt cotton has been linked to farmers' suicides in certain parts of India. The opposition to GM crops is addressed by the scientific community. Let us put this in the words of a scientist from CCMB, Hyderabad:

On October 2009, the Genetic Engineering Approval Committee (GEAC) clears the commercial cultivation of the first food crop in India, Bt brinjal. Plant pathogens interact at molecular level. Plants are to study the function and regulation of certain genes that can be transferred to crop plants. Government should have policy which allows the commercial cultivation of Bt brinjal. Bt brinjal, it is tested so more safe. Genetic manipulation can be done by simple testing. As far as problem of drought is considered, problems of drought resistance came into picture as crops are not drought resistance and are planted in drought prone areas which were not supposed to be done.

The above statement states that proper training and information to use a particular technology is lacking in farming community. Proper training and awareness should be imparted to the end users. The government policies should be strengthened for the regulation of GM technology, diffusion of technology and commercialization of technology. Critical policy changes are required for the effective use of modern technology. Civil society organizations wage struggle against GM technology based on the interests of farming community, and the issues of environmental protection and

sustainable development, ill-effect on flora and fauna, and so on. While scientists argue that protest by anti-GM crops are not based on scientific grounds, decisions regarding GM technology cannot be based on scientific grounds alone and all other factors like economic, political, social, institutional factors contribute to the overall adoption of technology in the society. Scientists from Monsanto suggested that GM technology is not altering the natural process of breeding and genetic modification is something which is not new and has been occurring in nature for a long time. According to a scientist of Monsanto:

We have options like patents, trademarks, geographical indicators, variety protection Acts etc. to protect our IP rights. In nature, the genetic modification has been happening for thousands of years without any negative effects. Hence, there are no 'ethics' involved in GM technology. We only need to educate masses to clear their doubts and adopt technology. The collaboration has been highly successful. Mahyco had the market and Monsanto, the technology. Both the companies benefitted by the collaboration. However the Bt cotton has now almost fully replaced the non-Bt cotton as farmers have adopted the Bt Cotton due to the numerous benefits it offers.

In India Bt Cotton is released by Monsanto with the help of local industry called Mahyco. It is important to understand how collaborative networking with the local seed companies helped Monsanto to commercialize its technology. This collaborative networking is successful in India as far as the case of Bt cotton is concerned.

4.6 Regulating GM Technology

One often witnesses business rivalry between GM seed companies and pesticide manufacturers (greater GM use diminishes the demand for the product). After 20 years of wide scale global use of GM crops and products are subjected to fierce controversies worldwide (Stone 2012). In 2015, the global market value of biotech products is estimated at \$15.3 billion that represents 20 per cent of the \$76.2 billion global crop

protection market whereas in 2014, it stood at 34 per cent of the \$45 billion global seed market (Sally 2016).

Institutional capacity to regulate transgenic crop was called into question when illegal Bt cotton, undetected by the state and civil society, was discovered growing in Gujarat in 2001 (Ramaswami 2002). A majority of the scientists included in the present study examine the failure of GEAC to detect or control stealth of Bt cotton hybrids that spread through underground networks and produced a 'cottage industry' of illicit transgenic plant breeding. The GEAC is India's apex biotech regulatory committee which functions as a statutory body under the Environment Protection Act, 1986 of the Ministry of Environment and Forests (MoEF). The GEAC is responsible for granting permits to conduct experimental and large-scale open field-trials and for commercial release of biotech crops.

At the outset, we have seed certificate agency, but certification should be proper in order to check the illegal sale of transgenic crops. Secondly, seeds should be sold from authentic sources. Thirdly, official personnel should check whether seeds are proper or not. Lastly, accountability should be there. The GM seeds are often expensive and beyond the reach of small and marginal farmers. It is in this regard that the government has recommended a mandatory cut in the trait fees paid on Bt cotton seeds-70 per cent reduction in royalty fees payable to technology companies like Monsanto and overall lowering of seed prices. If this recommendation is accepted by the Monsanto then it will benefit about 8 million cotton farmers in India. The nine-member cotton seed price control committee formed by the Centre has recommended a maximum sale price of INR 800 for a 450g packet of Bollgard II Bt cotton seeds. These packets are currently sold at INR 830 per packet in Maharashtra, INR 893 in Telangana and Andhra Pradesh and INR 1100 in northern states such as Punjab and Haryana. There is state-wide variation in the

prices in india. But this is not acceptable by the Mahyco-Monsanto Biotech (India) Private Limited (MMBL) and they commented: “such a drastic intervention overrides the existing private bilateral commercial contracts and undermines the overall operating environment in India” (cited in *The Economic Times* 2016).

The contamination of Indian cotton with illegal Bt cotton was made in Gujarat in 2001 which shows serious regulatory failure in the country. Biosafety is an important consideration with transgenic crops since they have known environmental and health hazards, and once released into the environment are irreversible. It is to be noted that India is the centre of origin of brinjal and any gene transfer and/or contamination from transgenic plant could prove to be disastrous for the crop itself. Kuruganti (2006) states that due to civil society investigation the cotton fiber of Bt cotton was known to be causing a lot of allergies. She also states that non-chemical IPM methods have yielded equal or better results than the ones being claimed by the Bt brinjal promotion. An independent agency should do the toxicity studies on collaboration with Mahyco. According to a scientist of Institute of Rice Research, Hyderabad:

In 1960s, when dwarf wheat and dwarf rice was introduced same concern was there. If we will produce the new variety, we will lose the germplasm but it was not the case. Similarly in the case of Bt crops, we need to understand the need and demand of present agricultural scenario. In India, there is no Science and Technology policy. There is no definite policy. On the other hand they are funding the research of Bt crops and GM crops and on the other hand they are not allowing it.

The potential benefit and risk of emerging technology can be regulated by scientists, industry and policymakers by undertaking policy changes which will serve the interest of varied actors. Policy level changes by the government are important as scientists are hesitant to work in the controversial areas like Bt brinjal and GM crops. According to a scientist of Bose Institute, Kolkata:

Policy level change is required. Unless it is properly designed there is no reason to work in such fields. Certain guidelines should be followed without

proper guideline we cannot go for GM. India should not loose patentship, proper measures, proper guidelines everything is in writing but at field level it is not there.

In the context of GM crops in India, the idea of public is more often absent in the realms of the triple helix, which calls for reflexivity beyond research laboratories. In this regard, many studies support the involvement of actors (civil society organizations, farmers, etc.) in addition to the government, industry and academia networking of innovation. According to a scientist of NCPGR, New Delhi:

Independent authority like autonomous institute increases public acceptance/confidence building which is lacking in case of India. In the US we have FDA, if FDA approve than people believe that it is right, so, main thing is to build confidence. Right now confidence is lacking.

Policymaking in the US is such that general people can freely access the rigorous decision regarding scientific policy issues, while in India decisions on safety, field trials, etc. are not made available to civil society organizations even if they demand those tests reports. These add to the lack of confidence regarding science-related policy issues in general public. The lack of interaction among actors in the triple helix creates a state of confusion and misunderstanding. This may have implications for the adoption of new technology as happened in many parts of the world (Yamaguchi et al. 2003; Zeckendorf 1994)

4.7 Networking in Biotech Crops

The Government of India is supportive of biotechnology research as this can be reflected through government-sponsored schemes to encourage R&D institutions, capacity building and development of GM crops. Genetic engineering is used for conducting specialized and advanced research and has potential to contribute to research related to salinity stress, drought stress, increase in yield, and so on. In India biotech sectors function with the support of the Department of Biotechnology, Department of

Science and Technology, and Council of Scientific Industrial Research along with private sectors. There is always a conflict between modern and traditional technological system. It is often understood that modern technology with the passage of time becomes traditional, and knowledge society makes a consistent effort to improve upon it in order to create new knowledge constantly. In recent times, collaboration helps in creating modern or advanced technology by bringing together expertise from various disciplines. This can be captured in the words of a scientist from the National Chemical Laboratory (NCL), Pune:

For more than two decades, the collaboration was primarily aimed at the development of Indian research capacities. The main goal of the current program phase is the establishment of sustainable research partnerships and capacities which are of economic, social and ecological relevance. In this context, superior technology for modern agriculture should be developed.

Technology development, which is influenced by the IPR, is likely to influence the degree of investment by the public and private sectors. Public sector will continue to play a predominant role in basic research as it requires long gestation period, huge investment on infrastructure and training personnel (Ravishankar and Archak 2000). In India, 96 per cent of its cotton area is under GM varieties. Regulatory uncertainty for GM crops like Bt brinjal, Bt mustard, etc. is affecting the investment in agricultural biotechnology, in general, and development of other GM crops in particular. The approval of event named (truncated Cry1Ac gene) developed by the Indian Institute of Technology Kharagpur in collaboration with J.K Seeds Pvt. Ltd, and GFM, Cry1a (Cry1Abt Cry1Ac) of Chinese Academy of Sciences (gene sourced by Nath seeds Pvt. Ltd) in 2006, broke the monopoly of MMBL on Bt technology. Further in 2008, the first public sector event known as BNLA-601 expressing the Cry1Ac gene for commercial sale widened farmers' choice for Bt cotton hybrid and varieties. It is interesting to note that trial of dozen other GM food crops by the government in 2010 and its research is going on in several

research institutes, both public and private, but commercial cultivation of one particular crop that is Bt brinjal was banned. Until May 2012, a total of 1128 Bt cotton hybrids were commercially released by 49 seed manufactures by MMBL. Thus, cotton seed market is dominated by the private R&D through multinational collaborative networking i.e. Mahyco-Monsanto Biotech India Limited. Recently in 2016 same debate is growing over agricultural biotechnology concerning GM food crops. These debates over GM crops have adversely affected the research on GM crops and as a consequence of which research on GM crop has come to a halt (Venkat 2016).

The present study shows that 29.6 per cent of scientists are engaged in research on Bt cotton, while 18.5 per cent are engaged in research in Bt brinjal and 14.8 per cent of scientists are engaged in both Bt cotton and Bt brinjal research (see Table 4.1). Around 37.5 per cent of the scientists working on project under Bt cotton are undertaking a project between 1 and 4, while 33.3 per cent of the scientists, 5-9, and 29.2 per cent of the scientists are working on projects under both Bt cotton and Bt brinjal (see Table 4.2).

Table 4.1: Classification of Scientists working on Bt Cotton and Bt Brinjal (2000-2015)

Projects	Scientists (N=81)	
	Number	Percentage
Bt Cotton	24	29.6
Bt Brinjal	15	18.5
Both	12	14.8

Table 4.2: Scientists engaged in the projects on Bt Cotton and Bt Brinjal (2000-2015)

Number of Projects	Scientists (N=81)			
	Bt Cotton		Bt Brinjal	
	Number	Percentage	Number	Percentage
1-4	9	37.5	10	66.7
5-9	8	33.3	5	33.3
10-14	7	29.2	0	0.0
Total	24	100.0	15	100.0

Similarly, if we look at the number of scientists working on project on Bt brinjal then it is different story as compared to Bt cotton. This difference requires critical analysis as it shapes the implications of proprietary technologies and attitudes of scientific community on debated GM crops. Around 66.7 per cent of scientists are working on 1-4 projects on Bt brinjal, while 33.7 per cent are engaged in 5-9 projects on Bt brinjal. After critically analysing the data, it is also found that less number of scientists from the world of academia are engaged in research in GM crops.

The MNCs such as Monsanto working on Bt cotton collaborate with Indian seed company Mahyco. So, this is a private-private partnership on GM crops. This suggests monopoly of private companies in over GM crops in India. This also suggests areas in which networking has not evolved between public institutions on the one hand and private industry on the contrary. It was often argued that moratorium on Bt brinjal would hamper ongoing research in public-sector institutions on transgenic potato, tomato, rice, mustard, chickpea, groundnut and pigeon pea etc. the State's policy decision is not to allow GM crops, even field trials and declare a moratorium at least for the next 50 years (MoEF 2010). According to scientists included in the present study, conducting field trials require lot of time and money and both of which are not available, as nobody has adequate resources to invest in such controversial areas. Also whether such transgenic will develop into product and will be of use is another question. Thus in India politics of risk and safety have a major effect on the working of science and technology. This dichotomy between food and non-food crop as far as India is concerned suggests contested views and governance of science. When diffusion of agricultural biotechnology is considered, the State plays a non-significant role. Scientists under study suggest that Bt brinjal is already under cultivation illegally. This shows a lack of ability on the part of GEAC to control the illegal use of Bt brinjal. Also, Bangladesh has

approved commercial cultivation of four open-pollinated varieties of Bt brinjal and Bangladesh is a neighboring state of India and open pollination is beyond the boundary of politics, governance or risk.

The GM technology has been adopted and made available by the agriculture extension department. Though it is applied, most of the technology is still in demo house or sink house of the research laboratory. The scope and ambit of applied research is plenty that is conducted by research institute. If funding agencies generate a link between applied research of academia and industry then it will increase the economic viability or performance of research. The university and industry have different perspectives on research. They can collaborate together through the funding agency of government. There will be greater participation and learning. Scientists working on GM technology suggest that they are approached by a number of industrial units for participation in their projects but at present they as a scientific community are reluctant to go to one industry. If it is within institutional framework of government and it funds particular project with industry then can work with industry as it will have some kind of credibility. So, it requires the intervention of the state to perform proactive role in forming collaboration with academia and industry in the case of GM crops.

Public-private partnership in technology transfer (Bt brinjal project) in Bangladesh has been successful. The public-private partnership was conducted in Bangladesh under the collaboration between Mahyco, Agricultural Biotechnology Support Project (ABSP II) and Cornell University. Mahyco also donated Bt brinjal technology to public sector in India and the Philippines. The trials for Bt brinjal were conducted in multi-location for seven years (Choudhary et al. 2014). also states that seven years of rigorous field testing for Bt brinjal were conducted under the direct supervision of the public sector scientists of the BARI Ministry of Agriculture in

compliance with the biosafety and regulatory guidelines of the Ministry of Environment and Forest. Also the report suggests that Bt brinjal is as safe as its non-Bt counterparts and all the safety tests have been conducted. The small planters of Bt brinjal in Bangladesh are reported to be successful but its long term effect is yet to be seen. As Bangladesh is a neighboring country to India, its open pollination to India and other neighboring country is bound to occur and cannot be prohibited. Moreover, scientists interviewed for the present study reported that Bt brinjal is already in the market albeit unofficially. The report on “Cultivation on Genetically Modified Food Crops-Prospects and Effects” (2012) also states that regulatory and biosafety assessment of Bt brinjal was already conducted in India and the Philippines before Bangladesh but its access was denied due to policy and regulatory constraints. The policy debate about the development and regulation of biotechnology is strongly affected by the global contestation of interests within the scientific, corporate and civil society organizations. Regulation of Bt cotton by the government is opposed by Mahyco-Monsanto Biotech India Limited suggests that corporate interest of India and ostentatious behaviour of GM industry.

There is growing cooperation between multinational companies and public sector institutions in developing countries to field test globally deregulated biotech events. Major public-private partnership projects include Bt brinjal, Bt chickpea, LBR (Late Blight Resistance) potato, GM mustard and Bt cotton in India, drought tolerant sugar cane in Indonesia, Bt brinjal, LBR potato, Bt cotton and Golden rice in Bangladesh, drought tolerant maize in Africa, insect resistance, herbicide tolerant soybean and VR beans in Brazil. As stated by expert numbers of home-grown GM crops are either deregulated or are at the advanced stage of regulatory approvals in Brazil and Argentina in South America, and India and China in Asia and South Africa in the African countries.

This feat of promoting home-grown GM crops through PPP model is effective in developing and delivering GM crops to farmers, and this could not be achieved without strong government support and political will. The scientific community in India is capable of developing GM crops that are relevant to India, and the PPP mechanism is an ideal proposition to overcome the danger of monopoly, provided the Government of India recognizes and facilitates PPP to achieve desirable outcome in agriculture. Interaction with CSOs and other interested groups on GM Crops helps us develop better understanding of making policies regarding GM Crops. The practice of agricultural system by relocating in the case of changing paradigms helps in guiding, and shaping policy problems in the course of action.

4.8 Policy Implications

In the case of GMOs, NGOs play a predominant role, especially in India. Implementation of policies is major issue in the case of agricultural biotechnology research in India. Public research organizations in India provide germplasm to 66 per cent of cotton breeding firms. Agriculture research is often applied, e.g. plant breeding. From net importer of cotton, India has become one of the leading exporters of cotton. Qaim (2005) suggests that the secondary pest infestation in cotton crop is on rise which is one of the major drawbacks for Bt cotton. It is further suggested that in India R&D investments in technology and development supportive policy for such R&D investments are required for both public and private sectors. Decision on effective regulatory policy will boost the agri-biotech industry and also safety assessment and other issues raised by the civil society organizations will contribute positively to the R&D of agricultural biotechnology.

It has been reported that though the farmers had a better yield as a result of the Bt cotton seeds resistance to bollworm initially, but productivity declined due to more

virulent pests and weeds (Murali 2016). One of the greatest moves by the present government in the case of Bt variety is that it tries to regulate the prices of Bt cotton seeds and making available GM seeds at affordable prices to the farmers (Sally 2016). Monsanto controls 95 per cent of India's cotton seed supplies. Imposing of royalty on local seed companies of cotton becomes a major threat in regulating the Bt cotton prices by the government. If we critically analyze the data and results regarding Bt cotton or GM technology particularly then it is clear that though productivity increases initially it has a mixed result in different regions owing to climatic conditions and other socioeconomic factors. And it is also observed that though for example if we consider the case of Bt cotton then productivity increases slowly but other challenges like virulent pests and weeds emerge causing a decline in the productivity of Bt cotton in the long-run. This causes a major loss to resource-poor farmers (Rao 2013). Whether GM technology can be used in the long run or will make situation better or worse by increasing the number of pests and weeds requires critical analysis by the scientists, policy makers and other interested parties. Emphasis has been on adopting better agronomic practices where farmers could improve productivity as well as through open pollinated cotton seeds which could naturally adapt to local conditions and change in climatic conditions.

The Genetic Appraisal Committee recently stated that India needs more data before making a decision on GM mustard. The Genetic Engineering Appraisal Committee on Genetic Manipulation (RCGM) works as the regulatory body of GM crops. Regulatory system is not independent and till date it has failed to establish an independent regulatory system for GM crops. Critics question the release of Bt brinjal on a number of grounds and most important one is lack or inadequacy of biosafety data. In case of GM mustard, environmental and biosafety data were not made public. It is

interesting to note that there is no national framework on mustard or oilseed crop as such and where GM mustard will fit in is a question to ponder about. But the Indian Council of Agriculture Research (ICAR) has a dedicated outfit called Directorate of Rapeseed-Mustard Research, which acts as an umbrella body for mustard research and dissemination of technology to farmers. When we consider the use of biotechnology in agriculture it is highly debated and no consensus has been achieved yet. Science is adjusting with the uncertainties of policies undertaken by the government. Science informs policy by producing objective valid and reliable knowledge (Funtowicz and Strandz 2007).

Developing a policy is a matter of becoming informed by science and then in sorting out values and preference in order to formulate the correct and rational policy. This represents a critical gap in policy processes in agricultural biotechnology. There is a significant disconnect between the public who support the practice and funding of science on the one hand and the practitioners of science, on the other.

Bt crops are useful as it will help to minimize pesticide uses and thus harmful effects of pesticides can be prevented. But again this argument is contested by the CSOs as Bt cotton does not reduce the uses of pesticides as compared to non-Bt cotton seeds and thus becomes ineffective. There are public apprehensions on GMOs but regulatory processes in India need to evolve so as to address the concerns in a way that do not come in the way of adapting to high yielding technologies.

The MMBL has sub-licensed Bt cotton seed technology since 2002 to various domestic seed companies. Also, Monsanto Chief warned it would be difficult to introduce new technologies in India at a time when there is no sanctity of contracts between the two private parties and no guarantee of recovering investments made in research activities: *“It will be difficult for MMBL to justify bringing new technologies*

into India in an environment where such arbitrary and potentially destructive government intervention makes it impossible to recoup R&D investments focused on delivering extensive farmer benefits and where sanctity of contracts is absent” (cited in The Economic Times 2016). Competition Commission of India has ordered a detailed probe against MMBL for alleged abuse of dominance by the Indian arm of the US-based GM seed giant Monsanto.

The National Institution for Transforming India (NITI) Aayog, Government of India needs technological breakthrough in oilseeds and pulses and it suggests the success story of Bt cotton in India and other GM seeds in the worlds and credits the potential of GM technology in providing a major boost to productivity in agriculture (Government of India 2015). Many smaller companies are adding biotechnology research to their existing R&D capacities. Researches in agricultural biotechnology are mostly contractual in nature if it is collaboration between public institutions and the industry.

Scientific barriers cannot be overcome without adequate fund. But at present in India, government support for R&D is too diffuse and limited to have a major impact. It is in this context it will be prudent to ponder about investment of such limited funds on GM crops with uncertain and long return. After more than a decade of introduction of GM crops in India, policy and priority areas are not finalized yet as outputs and risks are uncertain. The discussions regarding GM take these two extreme ends, which can be interpreted only as either acceptable or unacceptable. Bt technology should be evaluated by taking into views of varied actors with feasible or practical field trials and biosafety assessment. What would be interesting to look at is the role of organic crops/support by civil society organizations? It is important to adopt business strategies and policies that take into account the importance of emerging technological innovation (Juma 2016).

In the case of GM crops political nature of policymaking is hidden by the use of technical language as policy reports are often termed objective and scientific through the use of scientific and legal language. As perceived by different scientists working in agricultural biotechnology hold the opinion that decision on policymaking regarding GM crops should be purely based on scientific ground as GM crops are developed by scientists and the right to take decisions on GM or for that matter any other science and technology related areas should be taken by scientists. In case of the GM crops, it should be developed in partnership with the public and private sectors.

The potential benefits and risks associated with emerging technologies can be addressed by scientists, industries and policymakers by undertaking policy change and relevant business strategies which will serve the interests of varied actors. The decision regarding appropriate public policy is critical for the appropriate utilization of new technologies in Indian agriculture.

4.9 Conclusion

The role of science as a social institution is crucial in determining the fate of any technology and making public policy. Every technology is associated with risks and benefits. So, risk-benefit should be evaluated rather than discarding the technology immediately. Huge amount of public funds, time, scientific expertise etc. are invested before developing any technology. Hence, unambiguity, possible risks, ill-effects etc. should be evaluated not just based on science but keeping in mind social, economic, political and institutional factors in which a particular technology is embedded. Even CSOs do not represent one voice as some reject GM on the basis of safety and field trials while scientists claim that NGOs are motivated by the pesticide companies thus defaming the GM crop.

Based on the interviews with scientists in various research institutes, universities and industry, it is clear that views of scientists on GM technology are fragmented and there is no consensus on GM technology by the scientific community in India. While a few scientists completely reject this technology and suggest that there are other technologies available which can tackle the problems of Indian agriculture, a majority of the scientists suggest how GM technology is required for conducting good research and support GM technology. A few scientists try to refrain from being engaged in controversial topics like GM crops. Networking in Bt crops mostly has been operational through Monsanto-Mahyco partnership. Public universities and research laboratories carry out research work on GM crops but have not released any GM crops yet. In the case of GM crops in India, triple helix models I and II seem to be prevalent while the analysis of triple helix model III in the form of networking between government, academia and industry requires further articulation.

CHAPTER V

DEBATING THE CONTROVERSIES: A STUDY OF AGRICULTURAL INNOVATION SYSTEM IN INDIA

The fourth chapter critically examined the risks associated with controversial technologies such as Bt cotton and Bt brinjal. An attempt was made to study the networking between government, academia and industry in the case of Bt cotton and Bt brinjal in India. It suggested the role of public policy in determining the fate of new and emerging technologies. Further, it dwelt upon the institutional mandates, science, technology policymaking processes, interaction between varied actors in agricultural innovation system in India, and so on.

Against this background, the fifth chapter foregrounds the controversies embedded in the institutional mandates outlined to promote or restrict innovations in agricultural innovation system in India. Further, it discusses how the framing of public policy and networking between varied actors leads to transition in the modes of agricultural innovation system in India. Here the Public-Private Partnership (PPP) model is discussed in order to capture the process of knowledge creation from the stage of product development to diffusion of technology. In this chapter, the Scientific Policy Resolution (1958), the Technology Policy Statement (1983), the Science and Technology Policy (2003) and the Science, Technology and Innovation Policy (2013) along with National Agriculture System, National Agriculture Policy (2000) and various initiatives of the Department of Biotechnology like Biotechnology Industry Research Assistance Council (BIRAC) are discussed critically in order to study the underlying institutional mandates resulting in innovations in agriculture biotechnology. Understanding of the improved networking between varied actors like the government, academia and industry is required to develop R&D in agricultural innovation system in India, i.e. how far the

model of triple helix is relevant in present agricultural innovation system in India. The function of academia-industry networking can be performed by different institutional arrangements such as transfer offices, incubation, science parks, technology parks, startups, etc.

The concept of innovation systems was introduced in the 1980s where institutions and learning processes are central importance (Freeman and Lundvall 1988). With the introduction of National Innovation System (NIS), intervention of the government in building innovative culture, enhancing technology diffusion, promoting networking and clusters, leverage of R&D across sectors, attracting foreign direct investment, and so on increased (Singh 2004).

The concept of national innovation system lies in the networking between various actors involved in innovation process. From triple helix perspective, the non-linear interaction between these actors can generate new combination of knowledge and resources that can advance innovation at the regional level. Further, it will help us identify the gap or a distance which exists between the actors. This interaction can take a variety of forms like sharing of laboratory facilities, infrastructure facilities, joint projects, patenting, publications and other research facilities. These actors include university, government, private research institutions, industry, national laboratories and hybrid actors like startups, individual entrepreneurs, and so on.

5.1 Role of Industry in Agricultural Innovation System in India

Scientific knowledge is distributed through value chain that includes universities, research institutions, private companies and foundations. Scientific knowledge and the associated technical artifacts lead to various form of intellectual property (Mansfield 1991).

Technology transfer from academia to industry is complex. Besides formal mechanism of patenting, informal mechanisms such as research collaboration, facility and credit sharing are on the rise. Informal mechanisms focus more on knowledge transfer. Innovation in agriculture results in intellectual property, land rights, commercialization of products, product development for the use of farmers and consumers. Improved interaction between these actors for the purpose of increasing the quality and type of interaction is necessary for the innovation within Indian agriculture. Indian agriculture research system is structured in such a way that it allows developing partnership and networking with multiple actors. In India as there is a constant effort to reach a tri-lateral or hybrid organizations in order to attract increased private investments in research, innovation and development. This can be captured in the words of a scientist at the National Centre for Biological Sciences (NCBS), Bengaluru: *“Industry has to take the responsibility to test technology in the field.”*

When university, government and industry collaborate for a particular project it leads to a lot of significant advantages. If we look at this networking, from the perspective of university then hard work and expertise of scientists will be rewarded. If we analyze it from the perspective of the society, then the actual research will reach the field from laboratories.

The Department of Biotechnology and Department of Science and Technology are trying to bring in the academia and industry together, through which they can have a co-grant and industry will be working on particular parameters and scientists will be working in a different way at laboratory level so that grant and credit can be shared between the two and this is encouraged by the two. Institutional mandates often support the networking between academia and industry. University’s interaction with industry is crucial for commercializing the research of scientists. But the traditional role of

university as knowledge creator should be safeguarded by strengthening the basic research expertise. At present, government funding mechanism is more towards applied research which may impede the progress of basic research tradition in university setups. A balance between basic and applied research is required to strengthen agricultural research. At present collaboration with industry is more of contractual nature, and industry approaches scientists with specific problems and scientists provide solutions to the given problems on the areas like seed, absence or presence of genes using their expertise.

5.1.1 Weak Linkages between Academia and Industry

The networking between industry and academia in agriculture sector is weak in India. Industry requires proven technologies, but the institutions can only offer technologies at considerably earlier stages (i.e. at laboratory or pilot stages). This requires a lot of work and funding which will develop technology from laboratory stage to market stage. One of the crucial factors leading to such underutilization of such technology is that investment by private sector is less in this area. Moreover there is no early exchange of human skills between academia and industry which limits the process of technology transfer and mutual understanding between the actors.

Agricultural production and technological revolution are the major objectives in the State incurring 92.9 per cent of the total R&D expenditure during 2009-2010 (OECD 2014). In recent times, science and technology is not only an individual work rather it has evolved as a collaborative work. The ICAR, DBT, CSIR, DST are the main funding sources for the scientists working in agricultural biotechnology. Since the 1990s there has been constant effort to harness the innovative capabilities of various innovation structures by connecting them to one another.

5.2 Funding Mechanisms

There is chronic dearth of funding in R&D for agriculture and particularly in the basic research. Scientists included for the present study receive funding for their research activities from Department of Biotechnology (DBT), Department of Science and Technology (DST), Council of Scientific and Industrial Research (CSIR), Indian Council of Agriculture Research (ICAR)-Sponsored projects along with projects from a few international agencies. Triple Helix model III suggests that partnership of any two actors leads to something new. The active partnership of all three actors requires special expertise and is the most advanced stage of interaction. With the change in the role of universities, issues of intellectual property and technology transfer have become the goal of policymakers in universities, especially public universities like state and central universities in India. Scientists interviewed have also suggested that informal links are important to get funding for their research projects.

Another issue concerning funding for agriculture research is that often funding for project is of short duration and short span is not adequate to yield meaningful research outcomes. Projects are funded for the short duration which hinders the usefulness of projects. It is in this context that the government along with industry should support long term holistic project funds.

Funding often does not get disbursed at proper time and this has led to the completion of projects in a hurried manner due to which research result outcome get affected. Moreover, funding is not adequate. Funding for agriculture research has decreased significantly and this is low for basic research as compared to applied or developmental research work. The entire mechanism is not proper in developing countries such as India as compared to developed countries. Despite having limited resources, collaboration is encouraged where resources can be shared between larger

groups of different geographical locations and institutional settings. The State mainly sponsors R&D in agriculture in India. The investments on R&D in agricultural biotechnology should be made by both the State and industry. Such situation calls for tightening of PPP model.

5.3 Bases of Selection of Projects

Interaction between scientists in the academia and industry may be strengthened by initiating joint projects mediated by the government which will bring together expertise of varied actors for the fulfillment of a common objective. Projects are selected by a joint project committee consisting of representatives from the Department of Biotechnology (DBT), International Society for Computational Biology (ISCB), and so on the selection is based on the relevance for the development of a specific institute or region as well the potential for technology transfer and future commercialization. Projects are usually set up jointly with the research institutions, industry, regulating state agencies, authorities dealing with safety measures and organizations, or individuals dealing with ethical questions.

Further the government may reexamine its institutional mandates to facilitate better collaboration between the industry and government. According to a scientist of M.S. Swaminathan Research Foundation (MSSRF) states:

Government can look at long term funding which have some proven quality because in three years they want to do something and another year they want to do some other thing. So, we do not provide stability and they all are lying with us. Three-year project terms are very short and it is very difficult to come up with meaningful results/products. One important ways to increase cooperation between applied and basic research is to develop collaborative projects particularly network projects involving scientists from different institutions, working in basic and applied research.

The long term collaborative project is required to increase interaction between scientists engaged in basic and applied research. Interaction between varied actors is

required in research areas like biotechnology which is complex and uncertain. The DBT is active in undertaking the collaborative projects, and is involved in programmes such as Biotechnology Industry Partnership Programme & Small Business Innovation Research Initiative (BIPP & SIBRI), where public and private organizations are involved in collaborative projects. The main advantage of such collaborative projects between public and private sectors is how to develop products with a wider reach.

By clearly noticing the differences between the nature of work, attitudes of scientists working in different institutes, differing research objectives, following distinctions between the university research and industry research can be made. In the words of a scientist of University of Madras, Chennai:

Without basic research applied research has no meaning. University has some style of research. All the research what we have done is exploratory in R&D. It is not a product development. Profit will not come in picture. As I mentioned basic and strategic research, governments do not have industry-institution partner linkages. Industry develops lot of ideas and commerce/profit plays an important role. In public institution freedom is that we can do, what we want, I mean there is no restriction/ hesitation. While on the other hand private institutions are more rigid they do not find the core theme.

The above statement asserts the views of scientists who are working in state university setups. This reflects a lack of flexibility on the part of scientists engaged in basic research who do not wish to work in cooperation with the industry personnel whose style of working is different from the university's scientists. Also, they see their research superior to the industry's research whose main motive is product development which brings out the concept of application. The above statement asserts that in state university still Mode 1 form of knowledge production is prevalent which gives less or limited importance to application of their findings.

The current structure of agriculture research is such that there is a decline in funding for basic research. Institutional mandates and funding policies are such that it

supports applied research more than basic research. There is a pressing need to modify the current structure of science and policy. Scientists suggest that knowledge of basic research is crucial to carry out quality research. Curiosity-driven research or basic research is influenced by the desire to seek new understanding of knowledge rather than applied research or user-driven research which is motivated to use that knowledge in a more practical way. The distinction between basic and applied science is blurred for 28 per cent of scientists interviewed for the present study.

5.4 Traditional Knowledge in Agricultural Innovation System (AIS)

The Agricultural innovation system consists of all types of actors from industry, the state, farmers, researchers, civil society organizations to research extension (Klerx and Leeuwis 2009). Basically it involves all the actors involved in agriculture related activities and agricultural innovation system is constantly changing. Farmers are the most important part of any agricultural system as these are the farmers who perform on the field. Hence, the protection of farmers' right is of utmost importance especially after the introduction of the WTO provisions on IPR. India has huge plant diversity and we have not worked enough. We have enough traditional knowledge. Our own ancestors develop their own system, how to deal with disease and rain resistance. Those preparations have their own significance. Those preparations are culturally mediated. It is important to understand the significance of these preparations and application and try to develop a product. According to a scientist from NCL, Pune: *"The traditional knowledge must be aptly protected. The patents need to have provision to pay off some portion of the earnings for social causes."*

Scientists interviewed for the present study suggest that traditional knowledge which is developed by farmers and breeders should be protected. Most of the farmers are

not aware of the IPR attached to their invention. It is the duty of government and scientific community to help farmers protect their rights through various initiatives. There are several digital banks to protect breeders' rights. In India as well as in many other countries, traditional knowledge is not patentable. In order to protect traditional breeders' rights CSIR has made data base and digital data base to protect the relative autonomy of alternative systems of medicine. For example, when we file a patent for turmeric, it goes to the examiner, and the examiner reviews the existing literature (patent/non-patent literature) and they want to see whether somebody has done it or not. Prior to this, the use of *turmeric* as medicine was not recorded in any book or any medium, it was passed from one generation to another orally which is traditional knowledge but it was not documented anywhere but some NRIs claim patent over *turmeric* and a lot of money were spent and then that patent was rejected by the United States Patent and Trademark Office (USPTO). So, the documented patent would not be granted.

5.4.1 Protection of Plant Varieties and Farmers' Rights Act (PPVFRA)

Post-economic reforms brought about a series of development paradigms in Indian economy. One of such development paradigms is the granting of IPR on biological materials. According to TRIPS agreement (1994), member nations require to grant patents on microorganisms, non/biological and microbiological processes as well as effective protection for plant varieties. Now a member country will have the choice to protect the plant varieties. One can choose from patents, *sui generis* system or a combination of the two. The *self-generating* system provides protection to plant breeders' rights. It does not limit the breeders' right by limiting their ownership over specific rights. A country can formulate policies and can act depending on their local

conditions to implement the commitment made under TRIPS agreement. The Plant Variety Protection and Farmers Rights Act, 2001 is the Indian *sui generis* system. Apart from providing a breeder's rights, it also protects farmers' rights in the case of India. The PPVFRA 2001 provides breeders' rights over their innovation. They can commercialize their varieties under their names or designate rights to anyone they choose. This act includes the breeders' rights to produce, sell, market, distribute, import or export a variety, in short, full control over formal marketing.

A striking balance between IPR systems and breeders' rights is important. For example, plant breeding should not shift to few corporate/individuals rather should be used in the best interest of public. In this regard, a strong or exclusive right over food crops or similar products should not be granted to breeders which often led to the adverse effect on farming community. Breeders should be rewarded which will motivate them for further innovation. Thus, a balance between individual rights and public interest will be a key to innovative environment. Bt and Bt-like method which introduces resistance to disease or increase value of the product will be patentable. The use of farmers' breed should be paid by the respective users. The present PPVFRA Act protects breeders and farmers' rights and thus serves in the best interest of the public though some issues like payment of fee for the use of breeders' product, proper drafting of policies on unclear issues need to be implemented.

5.5 Mandates of Institutes

The mandates of the institute are significant in establishing collaborative ties between varied actors. They form the basis of collaboration between scientists of different institutes, and often guide the research activities of scientists. A university or

research institutions will flourish and develop more if more scientists are working towards the mandates of the institutes. According to a scientist of Osmania University:

It all depends on the mandates of the institute. If some institute is there for providing services then naturally much R&D is not expected because they are service providers. Also mandates of the organization have to be research oriented then only they will take the R&D forward. The mandates of organization must include both research and teaching components. Further, they must include the policy towards strengthening of R&D. But, our universities emphasize more on teaching than creating the foundations for R&D.

The above statement reflects the traditional role of university and research institutions. Universities in India are designed as service providers. Universities are expected to be engaged in teaching only. They are expected to provide services to industries as and when required. Consequently, they are not able to be engaged in product-oriented research. Also, universities lack equipment and infrastructure that are required for R&D. Increased interaction among the scientists from basic and applied fields will increase openness and confidence, which can increase cooperation. If their institutional mandates encourage scientific collaboration particularly with industry, then only they can collaborate. So, institutional mandate of institute should be towards scientific collaboration where scientists can collaborate with their choice. In India, there is no demarcation between basic and applied research. So, mandates should be made clear that would enable scientists to know which type of research they are undertaking and what type of collaboration is required.

In order to strengthen basic research and its applicability, policies and programmes should be formulated in such a way that the inadequacy of funding can be addressed. This is possible only when issues of basic research are addressed separately from applied and directed or oriented basic research. The managing of scientific collaboration has become problematic. The traditional concept of agricultural innovation system states that knowledge once created will disseminate itself. This does not hold true, especially with

the advent of social, economic, institutional changes with time. There is a need to create a channel by which knowledge created in laboratories and academia can be disseminated. This can be supported by encompassing changes in institutional mandates supporting varied actors in agricultural innovation system. According to a scientist of University of Agricultural Sciences (UAS), Bengaluru:

In the US transgenic crop is in since 1956 and there point is much advanced and developed and they are exporting the soybean oil and maize to other countries. Farmers are going to get affected. New industry collaboration is required so that we can sell products outside. Small industry project is required in rural areas so that they will not move to cities. Bring the working culture to all people be it rural or urban areas. Only 21 per cent of areas in agriculture are irrigated. Major areas are dependent on rain.

The MNCs such as Monsanto Limited work in India with partnership with various seed industry and government institutions and universities. Monsanto has a successful partnership with six states, viz., Rajasthan, Gujarat, Uttar Pradesh, Madhya Pradesh, Andhra Pradesh and Karnataka – to increase crop production and other R&D and non-R&D activities. Non-R&D activities like production and diffusion are performed by the industry. Clearly, there is a weak interaction of university with industry, especially with state universities.

5.6 Public-Private Partnership in Agricultural Innovation System

One of the knowledge flows in agricultural innovation system is the networking between public and private sector. The link between academia and private R&D is a valuable addition to any knowledge economy. This potential has been realized recently in India and the government is trying to connect the link between public and private sectors through various initiatives. Evidence suggests that rate of technical change and economic growth depends on efficient diffusion (Freeman and Lundvall 1988). Developing countries are the emerging centres of R&D collaboration. The transnational

corporations are expected to add new innovative capacity bringing in new technology, global knowledge network and the resultant diffusion of knowledge.

Triple helix plays a crucial role in understanding the process of networking among various stakeholders in agricultural biotechnology. Networking between academia and industry is often initiated through government funded projects. Individual scientist plays a key role in facilitating such type of collaborative networking. In the case of GM crops private-private collaboration is still prevalent in India. Though laboratory research has been underway for several other GM crops in universities and research institutions no major breakthrough in GM crop has been released by them (Herring 2015b). One of the advantages of triple helix is that academia and industry perform the role of the other. Industry undertakes the traditional role of teaching by providing internship and workshop to university and making them efficient to be occupied for the job. Similarly, the role of the university has transformed from teaching and research to being an entrepreneur where individual scientists are trying to form a networking with farmers and market. The networking between government, academia and industry can be seen for the training of professional who get employed at these institutes. Academia-industry networking is prevalent for the realization of commercial applicability of products as well as for field trials and field work. The traditional mode of solving any research problem of the industry as a client is prevalent in universities, which helps in transferring products from laboratory to farm. Still triple helix I and triple helix II forms of knowledge production are prevalent in the case of Bt Cotton in India. Even interaction between individual actors is not strong, and private industry is an active performer in the case of GM crops in India. For industrial collaboration, technical change is contingent upon internal organizational conditions and the relationship of organization to the receiver adding to their judgment of trust and reliability (Clark 2002). University

collaboration with industry and government is limited as it mostly provides graduates to industry and government. Research environment is not much developed in university setup in India. Industry lacks trust due to their orientation towards profit while government lacks confidence due to bureaucratic process.

The government-sponsored BIRAC aims to support numerous exciting ideas which have an unmet need for funding and mentorship. This strategy is fulfilled through a grant funding scheme called Biotechnology Ignition Grant (BIG) which is available to scientists, entrepreneurs from research institutions, academia and startups. The applicant must be either an incubatee or must have a registered company with a functional R&D laboratory to be eligible for the grant. This scheme is designed to stimulate commercialization of research discoveries by providing very early stage grants to help bridge the gap between discoveries and invention. The initiatives under BIRAC are:

Small Business Innovation Research Initiative (SBIRI)

This scheme is a Department of Biotechnology initiative introduced in 2005 to boost public-private partnership (PPP) efforts in the country. It works as a platform which helps organizations to realize the potential in terms of product and process development and taking them to the market. It has facilitated innovation and risk taking by small and medium companies and bringing together the private industry, public institutions and government under one roof to promote the research innovation.

Biotechnology Ignition Grant (BIG)

This initiative tries to create “bio-innovation capital” by commercializing novel ideas which have a commercializing potential and that evolve out from startups or academic spin-offs. BIG grant strategy is to support the numerous exciting ideas which have an unmet need for funding and mentorship. There are five BIG partners

organization namely IKP Knowledge Parks, Hyderabad, Foundation for Innovation and Technology Transfer (FITT), New Delhi, Venture Centre, Pune and KIIT Bio Incubator, Bhubaneswar. These are chosen as these organizations possess necessary scientific infrastructure, expertise and high-end platform technology access to nurture early stage inventions through proof of concept stage.

Biotechnology Industry Partnerships Programme (BIPP)

It is a government partnership with industry for support on a sharing basis for path-breaking research in frontiers futuristic technology areas having major economic potential and making the Indian industry globally competitive. It is focused on IP creation with ownership retained by Indian industry and wherever relevant by collaborating scientists.

Contract Research Scheme (CRS)

It aims to enable validation of academic research that has commercializing potential and to engage the contract research and manufacturers (CRAMS) industry to carry out the validation of a process or prototype.

BIRAC University Innovation Cluster (UIC)

BIRAC has developed a focused strategic action plan to foster the culture of innovation and techno-entrepreneurship in Indian Universities, leveraging the University Innovation Cluster (UIC) and Cluster Innovation Centre (CIC) model. Five universities have been identified to establish cluster. Still this number is low and increased participation of university and industry are required to promote this innovative environment in scientific collaboration.

Cluster Innovation Centre in Biotechnology (CICB)

Cluster Innovation Centres in Biotechnology (CICB), hosted in universities, are acting as the nerve centres to manage the university innovation cluster activities. Along with facilitating the creation of networks, partnerships between stakeholders to strengthen the innovation ecosystem, the CICB provides pre-incubation support. One of the main aims of the initiative is to promote university-industry collaboration by providing graduates a platform to share their ideas with industry. It also develops and standardizes policy of intellectual property, technology transfer.

Bio-Incubator Support

This programme supports the entrepreneurial potential of start-ups by providing access to infrastructure as well as mentoring and networking platforms that the startups could use. BIRAC has strengthened and upgraded the existing incubation facilities at certain strategic locations in the country. C-CAMP (Centre for Cellular and Molecular Platforms) is one such platform which provides incubatees with infrastructure, mentoring facilities. Considering the vacuum that exists at the interface of academia and industry, such initiative is very much needed in the country.

5.6.1 Challenges of Biotechnology Industry

The major challenge of biotechnology industry in India would be acquiring intense capital and high-end infrastructure required from startup stage. A long gestation phase (anywhere between 5 and 10 years) for products to reach the market from ideation stage, and intense regulatory scrutiny is required as human and animal health are under the scanner. Besides providing funding to early and late stages of innovation research, BIRAC provides services to promote the innovation ecosystem like IP management, technology transfer, project management, and so on.

The BIRAC has supported 270 companies through its programmes such as SBIRI, BIPP and CRS. The total amount of funding is INR 1300 crore where in BIRAC's contribution is INR 550 crores while industry has committed INR 750 crores. This figure suggests the transition of NIS with increased participation of industry for R&D. It also suggests that given the right funding tools (such as BIRAC's SIBRI and BIPP) overall involvement of industry for R&D will change. This leads to change in organisational structure of agricultural research by increasing involvement of private sector in R&D. Till now, BIRAC'S programmes has fostered 68 collaborations between industry and academia. These developments have led to growing trend of biotech startup scenario in India with BIG (Biotechnology Ignition Grant) scheme transforming the present NIS in India. The BIG has supported 140 entrepreneurial ideas over five calls at pre-proof-of-concept stage.

The DBT established Biotech Consortium India Limited (BCIL) in 1990 under which various technologies were transferred to industry under the collaboration of Jawaharlal Nehru University, New Delhi. Also, more than 60 technologies and research leads from the government funded R&D projects have been transferred by BCIL to industry for the process of commercialization of technology.

We are weak as far as technology sector is considered. Investment in science and technology is very important. Knowledge production should be patented. R&D, science and education is very important for the generation of technology. Most importantly scare, fear, unknowingness, illiteracy about new technology should be removed through awareness (BCIL 2003).

Most of the collaborative initiatives are initiated in order to get funding from the institutes. The nature of funding for R&D may be captured in the words of a scientist from GGSIPU, New Delhi: *“Science is kind of biased. If it fits to their own theme then only they will provide funding. Terms and conditions should be clear.”*

The integration of public-private is very much needed. The IPR is important since WTO has operated since the end of the Uruguay Round. Any technology has protection. The GM technology has much scope for protection. Usually this protection is provided through patent. Patent gives right to the owner of the product an exclusive right over the commercial benefit of the product for the life of patent. This is up to 20 years for standard patent. Most of the seeds are bought by the public through company.

The public-private partnership helps modern agriculture to reach new heights. Public private partnership is the need of present day and several products developed by public institutions need to be legalized and this requires private partnership. Hence, it is imperative to evolve effective public and private partnership and undertake confidence building measures for development of technologies which are good for both public and private sectors. Cooperation from both public and private sectors is required to create and utilize knowledge in biotech sector. Private R&D, startups, entrepreneurs, etc. help university to create infrastructure facilities, mentorship, expertise, etc. According to a scientist of Monsanto India limited, Bengaluru:

Public-private partnership is very crucial for the development of agriculture. While collaborating with university, we get resources in the form of talented students of university and academia. The technology or products developed are used for the benefit of society. Private investment from industry should be increased because funding is very much necessary for the development of research and development. Private investment should be increased so that society will be benefited in a better way.

Freeman and Lundvall (1988) point out that external collaboration plays an important role in successful collaboration in the case of biotechnology sector which requires high development cost for establishment. By using university's expensive instrument and infrastructure, even startup can perform pivotal research. It provides access to scientific infrastructure, expertise and cutting edge technology which would be vital for entrepreneurs and startups. Currently there are a few organizations and

individuals that are incubating at C-CAMP in Bengaluru and have also been utilizing the technology development and scientific expertise of campus. For example, Sea6 Energy Pvt. Ltd, Pandorum Technologies Pvt. Ltd., Achira Labs Pvt. Ltd, Codon Biosciences Pvt. Ltd, etc. are some of the incubates at C-CAMP. Besides these startups, individual entrepreneurs are also incubating at C-CAMP under BIG (Biotechnology Ignition Grant) scheme.

5.7 Triple Helix and Networking in Agricultural Innovation System

In India, commercial awareness of science, knowledge and legal or intellectual property rights on life sciences, patents is low among scientists. A majority of the respondents from universities and research institutions suggest that it would have been better if a course on intellectual property rights or consultancy services on know-how of IP rights are provided to the scientists. It would create awareness in advance about the commercial applicability of their research work and would have a creative relationship between the laboratory, on the one hand, and field and market, on the other. Around 81 per cent of the scientists interviewed for the present study are engaged in government-sponsored projects. Collaboration mostly occurs between ICAR, DBT, DST, CSIR-funded projects with university and national research laboratories. This is because in India still a large portion of investment for projects are undertaken by the State. These projects are often jointly carried out by the public institutions. The major challenges for the private sector are to increase the investment in R&D projects.

One way to increase investment and partnership by private sector in agricultural biotechnology is to strengthen the intellectual property right regime in India. This will also tackle the problem of underfunding in agricultural research system in India. Industry consults scientists drawn from university and research laboratory to solve their specific

problems. Sectoral interaction is a necessary step to come up with meaningful results, e.g. transfer of knowledge from the public funded research labs to the private sector firms in order to support commercial product development and utilization. Such collaborative networking requires integration of basic, applied and adaptive research leading to innovations.

Innovative research requires institutional arrangements and organizational mechanisms to provide incentives for private investments in agricultural R&D through publicly governed agriculture R&D. An important role of public sector in this direction would be implementation of policies leading to the emergence of institutional mechanisms through the mechanism of public-private partnership.

5.7.1 Gap between the Laboratory and the Field

Technological output is useful only when it reaches the field. Industries willing to undertake non-R&D activities such as production and diffusion of technologies would be useful. In that case actual result of research laboratories will reach farms. Otherwise most of the technologies are lying with the sink house of public laboratories. Let us put this in the words of a scientist from NCBS, Bengaluru:

Research institutions in the country [India] should bridge the gap between lab and farm. For animal science we have transnational health science in Gurgaon (THSTI Gurgaon). So, the similar ones in plant science is lacking. We have actually ICAR institutions to do this but they are more towards the basic research. They do not do basic research but they are more interactive to the farmer. Somebody who does more basic research and some agriculture university which is good in application side, so somebody should bridge the gap between the two. It is possible only when we have special institutional setup.

The above statement suggests that there is a need for institutional setup which will link research findings of disciplinary science to its application. This will be successful only when there is more participation between government, academia and industry.

Triple helix model is significant in this case and often enhances knowledge production by leading into more innovation. Also innovation is not something which is just related to creation of technological invention rather it is the interaction between varying actors in the network leading to more adoption of particular technologies. At present there are a few institutions which are trying to bridge the gap between basic research and its application. The government policies are required in this direction through setting up of more institutions which identify the commercial value of basic research through its applicability.

In the case of Monsanto, it tends to rely on their internal reasons to perform short-term tasks such as handling of simple technical problem. However small or local companies like Criyagen tend to seek external assistance usually through universities or colleges located nearby. So, Criyagen and small-size firms have a tie up with local universities like University of Agricultural Sciences, Bengaluru, and MNCs such as Monsanto are more likely to offer short-term R&D projects to university and individual scientists to explore new technological opportunities. These collaboration networking ties help the industry assess advanced science and technology linkages possessed by scientists, who have great exposure to international networking. They get well-settled research laboratory and university infrastructure to carry out their research. This helps them minimize their cost of research and benefits the industry especially in the case of small startups.

Another type of collaboration between industry and academia can be seen in the form of long term and strategic collaborations is now PhDs are sponsored by the industry. There are several government initiatives which bring university students together with industry to be engaged in projects to facilitate government and industry networking. Besides building infrastructure, laboratory facility, access to expert

knowledge, industry gets the access to young students who are the major sources of knowledge in academia. This gives an opportunity to industry as well as students to work in close cooperation with each other. Motivations, incentives for and norms of conducting R&D activity in business and academia differ significantly. Academic enterprises as well as PPP model are at an early stage in many developing countries.

5.8 Scientists on Intellectual Property Rights

Patent system can be considered a typical product of industrial competition. Regulation of knowledge production through patent system became crucial for managing intellectual property in the late nineteenth century when knowledge market emerged in chemistry and later on in electrical engineering. A scientist from Monsanto India Limited interviewed for the present study suggests how protection of inventions encourages inventors to invent more by protecting their right. Also, to keep in close cooperation with the international markets protection of IPR is necessary. Industry is fully aware of its property rights and patent is one of the impediments to carry any research projects for them. The concept of patent, intellectual property rights is relatively new in the case of universities who are traditionally publishing their research findings. With growing awareness about patenting of technological inventions and impact of external factors like economic reforms, the significance of IPR has been realized in the university. According to a scientist from University of Delhi, New Delhi:

Traditional breeders do not know that their methods and products can be protected. If you develop or innovate something that can be protected, probably you are encouraging people to innovate more. Government should allow a policy which encourages people to innovate more and protect them in their name so that it protects their right, otherwise people will keep on innovating and will keep on losing.

The demand for IPR in India has created awareness about the processes and significance of patenting activity. Patent facilitating cells, innovating centres,

programmes and, private consultancy are keen to support because for accessibility of private data base. There is one skill, patenting, which requires to be learned in order to provide services. Each lab has IPR expert like in Defence Research and Development Organisation (DRDO), IARI, Federation of Indian Chambers of Commerce and Industry (FICCI), CSIR, PhD chamber, etc. In universities these need to be implemented and University Grant Commission (UGC) has also instructed universities to set IPR and the IPR regulation cell and it should be managed by legal experts. Plant is not patentable in India under the section 3 of Indian Patent Act, so plant variety can be registered. Plants should be protected, whether GM or non-GM variety.

Still a lot of incentives are required in the field of agriculture to use it effectively for the promotion of agricultural innovations for the development of our economy, culture and politics. In this emerging knowledge society, knowledge has become the primary wealth and different nation states are in a rush to capture it through mechanisms such as patents and IPR (Jasanoff 2005). In this knowledge society, IPR plays an important role if we want to promote innovation in agriculture. According to a senior scientist of the National Centre for Biological Sciences (NCBS), Bengaluru:

The number of US patents filed by scientists in India is very less. Even lawyers do not know the various laws pertaining to biotechnology and agriculture. It is an integral part of collaboration and IPR should encourage investment in research. It is a kind of incentive to do serious research. Government of India should introduce a separate course for IPR in biotechnology for agriculture. If I spend time and money, then my labour should be awarded and IPR in agriculture should be maintained. Most of the institutes do not have proper IPR consultants.

Most of the researchers who file petition for IPR are not fully aware of what IPR is. Proper training is required to increase awareness on IPR. Without ideas or innovation nothing can be achieved. Without the use of science and technology development cannot be achieved. Most of the scientists interviewed for the present study have agreed that there are sufficient policies in written form but they are not being implemented properly.

Policies are important but implementation is an issue. Technology takes science forward.
Curiosity-driven research carried out by scientist takes technology forward

5.9 National Agriculture Innovation System in India

The ICAR conducts its operation in agricultural research in India through its control and linkages with huge networking. In India, agriculture research is largely funded by the public sector. The ICAR disseminates its responsibilities through 43 research institutes, four national research bureaus, 20 national research centres, nine project directorates, 70 all-India coordinated research projects, and 109 Krishi Vigyan Kendras. The ICAR plays an important role in transferring the technology from laboratory to land. Besides, ICAR coordinates programmes on education in 26 agricultural universities and four national research institutes.

The budgetary allocation of 2015-2016 suggests that there is a need to increase investment by both public and private sectors and since India's independence ICAR has been at the forefront of agricultural development in India (Expenditure Budget 2015-16: Plan outlay 2015-16). The government has planned to establish institutions of similar pattern in Assam and Jharkhand with an initial sum of INR 100 crore in 2016-17. The government tries to sustain 4 per cent of growth in agriculture and is driven to bring about the second green revolution with focus on higher productivity and include 'protein revolution' as major thrust areas. Incubator in academia community has been the most direct route to industry-academia interaction in research institutions and laboratories which bring in individual entrepreneur to industry under one network. Earlier Memorandum of Understanding (MoU) was the only formal pattern to establish the networking between academia and industry. Formal licensing arrangements have not been in practice as in most MoUs the ownership of any intellectual property was

unilaterally given to the funding agency. The present study suggests that the intellectual property is shared based on the agreement made in the MoUs. Several industries are coming forward with research awards, scholarships and workshops in order to collaborate with the academia.

5.9.1 Infrastructure of Patent Office in India

The infrastructure of patent office in India is undergoing a series of transformations from computerization to maintaining of electronic database for every search and retrieval. But the lack of database on Indian patent filed and granted is a major weakness in the system. Since TRIPS Agreement, filing of Indian patent has increased significantly. Since India has become a member of the Patent Cooperation Treaty (PCT), the number of patents of Indian filing has dropped significantly (Gruber and Piroi 2014). Interestingly, decline in filing the patents is not because of reduction in invention activities by India but because of a deficit of examiners as well as more stringent examination guidelines for patent applications. The decline from 2008-2009 to 2012-13 was 72.96 % in granted patents. Increase in filing in India by foreign investors or their assignees accounting to more and thus amount to more than 70 per cent filings in India are either as convention application or through the PCT (Elangovan 2013).

The Indian Patents Act (1970) was subject to only process patents. It implies that one can arrive at the same product by using different processes. India became signatory to the WTO agreement in 1995. As part of the agreement, India entered the phase of product patent regime on January 1, 2005. This heralded a change in the erstwhile patent policy in India since both processes and products came under the purview of patenting. But legislative scenario concerning IPR changed with the signing of WTO agreement and by 2005 India enacted various IPR laws. This development poses a significant

impact on public R&D in agriculture. Under the IPR regime public-private partnership will play an important role for the development of agriculture research. Without proper IPR mechanism, misuse of research is possible. It is in this context that protection of property is important with the help of IPR. Further, the respondents in the present study suggest that IPR creates incentives for more innovations.

The commercialization of Indian agriculture is supported with amendments in the existing IP laws and introduction of new IP laws. The ICAR policies encourage scientists to share their knowledge and expertise through partnership with prospective clients which may include other public sectors, private sectors, civil society organisations, international research centres, other agencies and institutions. The largest recipients of research funding from ICAR are the State agricultural universities. Intellectual property generated by the ICAR institutions under collaborative research projects are often jointly owned by the ICAR and collaborative partners on mutually agreed terms.

The information technology systems are the core components in the transition from laboratories to the field. The ICAR has emerged from the aid-based research funding institute to loan-based research funding institute supported by the World Bank (NSTMIS 2013). Strict implementation and monitoring of IPR regime will generate favourable environment for private investments in agriculture research. According to the National Science and Technology Management Information Systems (NSTMIS) report (2013), 63 per cent of the expenditure is incurred by the government and total R&D expenditure incurred by industry is equivalent to the amount that just one global MNC spends on its in-house R&D.

5.10 Science and Policymaking in India

Scientific research in India is carried out mainly by a number of organizations operating with financial assistance from the government such as the Council of Scientific and Industrial Research (CSIR), Department of Atomic Energy (DAE), Indian Council of Agricultural Research (ICAR), Indian council of medical research (ICMR) and Defense Research and Development Organisation (DRDO).

The total activities of various organizations in the field of scientific and industrial research form an integral part of the national planning process. The role of the National Academy of Agricultural Sciences (NAAS) is to provide a forum to agricultural scientists to deliberate on important issues of agriculture research, education and extension and present views of the scientific community as policy inputs to planners, decision/opinion makers at various levels. In India these discussions are limited as compared to the United States where the US Academy of Agricultural Sciences provides many suggestions on the issues related to public policy. Also, these academies ensure that general people can freely access rigorous evaluation of science policy issues, while Indian science academy remains silent on the sensitive issues related to policymaking (cited in Menon and Siddharthan 2015).

Every country follows a specific mechanism by which scientific advice reaches to the person who is involved in policymaking. One of such mechanisms is the appointment of advisory body which is drawn from eminent personnel from different disciplines such as science, technology, education and so on. In India, principal scientific advisors are appointed to the prime minister and the Government of India. The Science and Technology Division of the Planning Commission is the nodal division for all matters relating science and technology plans formulating (both five-year and annual plans) and for the appraisal of the science and technology programmes of the six major science and

technology agencies— Department of Atomic Energy, Department of Space, Department of Science and Technology, Department of Biotechnology, Department of Scientific and Industrial Research (including the Council of Scientific and Industrial Research) and the Ministry of Earth Sciences. The advisory committees draw services of the eminent scientists on the matter related to the funding of scientific research, while crucial areas like climate change, GM crops, desirability and safety of nuclear power are kept untouched by the advisory committee. This is in contrary to the US National Academy where independent and expert advice systems are accessible by the scientific community. In addition to the Planning Commission, Indian Academy of Science (IASc), Bengaluru, Indian National Science Academy (INSA), New Delhi and the National Academy of Sciences (NASI), Allahabad, Indian National Academy of Engineering (INAE), National Academy of Medical Sciences (NAMS) and National Academy of Agricultural Sciences (NAAS) act as advisory bodies for matters related to scientific research.

5.10.1 Science, Technology and Innovation Policy (2013)

The Science, Technology and Innovation Policy (2013) of the Government of India aims to increase gross expenditure in R&D from less than 1 per cent to 2 per cent of Gross Domestic Product (GDP) for the next five years (2013-2018) through PPP mode. This cannot be realised unless private sector raises its R&D investment to at least match the public sector R&D investment from the current ratio of 1:3 (Krishna 2013). In order to do so, the government should formulate and implement a series of S&T laws to govern and regulate incentives and research innovation schemes involving the private sector under PPP mode. National Science, Technology and Innovation Foundation will be established as Public-Private partnership investment in crucial areas of research thus attracting private investments in R&D.

The Science, Technology and Innovation Policy (STIP 2013) aims to increase the number of full-time R&D personnel by two-third within five years. The policy calls for strengthening the government, academia and industry partnerships and facilitating the mobility of experts from academia to industry and vice-versa. The mobility of experts from academia to industry is not frequent and moreover experts, researchers from academia should be mobilized to industry to get expertise in industry know-how and this will accelerate the mobility of human skills and expertise from academia to industry and vice-versa.

The STIP (2013) emphasizes on the sharing of risk by the government which will eventually increase private sector investment in R&D and technology development. The CSOs will be given major importance in the diffusion of rural technologies. This calls for the participation of multiple actors in innovation process by connecting geographical boundaries. The involvement of CSOs in diffusion of technologies or participation of private sectors in accessing public R&D can be hindered by the bureaucratic processes. University research is bound to suffer as universities are allocated five per cent of gross expenditure on research and development (Krishna 2013). Scientists interviewed for the present study suggests that there is a decline of funding to carry out R&D activities and this is particularly low for basic research in universities. The STIP (2013) aims to target number of issue but a gap exists between paper work and its implementation.

Innovation is essential for the development of any sector, be it agriculture, pharmaceuticals or Information Technology. According to a scientist from University of Delhi:

When we are inventing a new technology, it may not result in innovation. We should not confuse innovation with invention. Innovation can be a small thing or for better use. For example, a pen can be used in a different manner. It can be used for scratch, press or for impression and somebody can use it for writing. It is actually an innovative use of thing. Further, innovation occurs when a product is commercialized. In other words, innovation occurs

when market value or industrial utility is attached to a product. So, innovation is important for our policy development. It is same as in any kind of collaboration be it agriculture, pharmaceutical, or anything... I have visited Agricultural University in Kanpur where farmers were taken into consideration. Farmers have better practices for improving the crop variety and so it is important to encourage farmers while dealing with innovating agricultural technologies.

There is a need to reframe science and agricultural policies in the wake of changes in the realms of economy and polity, especially in the product patent regime. Policymakers should be aware of the changing structure of Indian agriculture while framing science and agricultural policies. According to a scientist from Anna University, Chennai:

When ploughing was undertaken with cattle, of course your policy should be based on the small size of the farm. They cannot work in a big farming setup. For example, when harvest machines came, you have to think in terms of bigger farms that would enable you to handle the machines. With the advancement of technology now, one can handle 1000 hectares of land. Technology is great as long as we are using it properly.

Adoption of any new technology in agriculture should be socially and culturally embedded. Technological change is an ongoing process. It is important to avoid risks associated with any new technology. The government creates opportunities for startups, technology incubation centres and biotech parks. This has led to the emergence of collaborative networking between government, academia and private R&D institutions. Enhancement of partnership with public and private industry can be seen as a source of innovation (Sorensens and Torfing 2012). Technological innovations will definitely influence science and technology policies in India. Several technologies with respect to planting method, planting time, planting density, planting geometry, fertilizer requirement, weed and pest control have been developed.

The present study suggests that there are losses of crops due to pest danger and environmental factors. It is by the use of GM technology that we can prevent losses. We can enhance the production of pharmaceuticals and medicine compound and vaccines by

this technology. So, technological research and development are very important for innovation and change. According to a scientist of Monsanto India Limited,

To establish a crop in the market it takes a lot of time and by the time a new product can be developed, market is flooded with several other technologies. So there should be flexible mechanisms for the commercialization of a product or crop. Government policies and decisions regarding a particular crop should not be delayed.

The government should not unnecessarily delay the decision on particular technology. These problems can be addressed timely only when there is increased participation of all actors including the industry as well as CSOs in commercializing technology with university and research laboratories.

Private sectors invest mostly in profitable areas. This attitude of private sector should be changed so that they can participate in uncertain and risky areas in a socially inclusive manner. For example, the biotechnology areas and several other innovative areas are complex and risky. In India mostly, public sector invests in these areas even if results are uncertain.

In order to promote innovative environment in the country, private sectors and startups should include the concerns of the university and civil society organizations. In basic research, experiments do not always give successful results but even scientists conduct their laboratory tests. Similar practice should be developed in private sector. Private sector is more interested in the application of findings and thus collaborate less with the basic research scientists. This is one of the drawbacks which limit the collaboration of basic research scientists with the industry.

Diffusion process depends or requires the development of the capability to acquire, adapt, improve and produce technology consistent with the local conditions. The time path involved in the diffusion process depends upon the nature of new technology and its novelty, complexity and profitability. This also reflects the symbiotic relationship

between technological change and its institutional context and emphasizes the need for considering both together (Rosenberg 1983). Linking of public sector science to commercial world is essential for the diffusion of technology and its implications.

Previously, non-R&D innovations were confined to the industry for technology transfer, incubation activities, financing, fieldwork, etc. However, these are not just confined to industry but also the government, academia sphere and non-profit institutions. The triple helix model of innovation is yet to develop in agricultural biotechnology in India. But government Policy (PPP model) is supportive of government, academia and industry networking in agricultural biotechnology in India.

5.11 Conclusion

The challenge for developing countries like India is to implement policies through proper mechanism. There may be overlapping and competing agendas. For example, public participation in agriculture biotechnology tries to increase investment and collaboration by industry keeping in mind the interest of farmers. For successful implementation of national innovation system, there should be multiple linkages between varied actors such as government, academia, industry and civil society organizations. Similarly, external linkages such as internationalization of research, technologies and innovation process, and science, technology and innovation policies also effect the functioning of NIS in any economy. Science and technology policy should handle failures which hamper the process of underutilization of products step by step. Knowledge generation, diffusion and exploitation are fostered by networking cluster and other intermediaries. And these interaction and communication are determined by the institutional mandates, priorities etc.

The questions of negotiation and bargaining assume greater significance in the context of scientific collaboration in agricultural biotechnology. Networking is crucial in forming policy as it has the ability to bring in varied actors to change narrative as well as reinforce them. So, agricultural innovation system in India is transforming with the change in public policies. Policies at present require increase partnership between the private and public sector. Though, it is at very early stage of its development but need and requirement of the current state of agriculture supports the interaction between government, industry and academia with the change in policy measures. The triple helix model of innovation is equally significant in bringing about these transformations in agricultural innovation system in India. But, industry will collaborate with university only when research, knowledge production, teaching and infrastructure of university are useful. Thus, the current agricultural innovation system is oriented towards innovation, startups and business with increased interaction among varied actors.

CHAPTER VI

CONCLUSION

The present chapter provides a summary of the chapters along with findings of the study, foregrounds the limitations of the study and sheds light on scope of further research in the field.

6.1 Summary of the Chapters

The first chapter provides a holistic view of the concepts, review of literature, research gaps, rationale of the topic, research questions, objectives of the study, methodology used for the present study and the scientists' affiliation and the profile of the respondents interviewed for the present research study.

Indian agriculture is confronted with a major paradigm shift in the 1990s in the wake of economic reforms and subsequent WTO provisions on IPR. The post-economic reforms demanded new paradigm of agricultural innovation system. This led to commercialization of agriculture and increased complexity and requirement of conducting research. This calls for integration of expertise from varied actors. This also encouraged participation of private sector in agriculture R&D. The Bayh-Dole Act which legalized the interaction between university-industry and research outcome of university is a historical step towards commercialization of research outcome.

According to (Kuhn 1962), scientific facts were seen as products of scientists' socially conditioned investigation rather than an objective representation of nature. This explains how the sociology of science and technology is important as science is something which is produced within society. It varies across cultures and changes over time. Science is not risk-free and it may pose dangers to the society.

It is important to understand the role of the state in funding research, participation, decision making, life forms, patentability, risks, public understanding of science, scientific collaboration, science, agriculture and public policies, etc. Sociology of science and technology seeks to overcome the divisions particularly between the interpretive inquiry and rational analysis.

The first challenges to policy came from the social movements, and from civil society which identified policy and experts as mere extensions of the state. The movements grew around the Bhopal Gas Tragedy and the Narmada dam. Narratives of displacement and dispossession raised critical questions about policy, expertise and public perception. Governance is now seen no longer as a statist expertise and the question of governmentality involves civil society articulating new epistemologies, notions of citizenship, ideas about democratization of knowledge and the assessment of public policy impact (cited in Menon and Siddharthan 2015).

The scientific community in India advocates that policy regulation on GM crops should be solely based on scientific grounds. But the important question here is: can debates on GM crops be articulated independent of social, economic, political and cultural conditions? Modern biotechnology offers diverse innovation pathways and it is imperative to adopt appropriate/reasonable political perspective on the pros and cons of GM technology. It is true that GM technology is subject to costly overregulation in India and many other countries. However, the important questions which require urgent attention are: What will be the cost of this regulation? What is the time required to capture the benefits of new technology? Are these regulatory policies inhibiting innovations?

With respect to the risks associated with GM crops, the scientific community insists that GM/Bt is not distinctive or special and there are many other technologies

which need to be focused. The R&D cost is high for innovative agricultural technologies which definitely need to be protected in order to assure benefits from this technology for the wider part of the society. Directing the application of available and innovative technology is important to address the need of poor and hungry people.

The public policy goals with respect to scientific endeavours, technology development and local innovations will offer more sustainable options for the future. According to the STIP (2013), partnership between private and public sectors is encouraged with special attention to the creation of innovations in agricultural sector. The public policy further needs to answer what policy measures or action will best deliver policy objectives such as social development, economic growth and environment sustainability. Innovation is not a research-driven process simply relying on technology transfer instead it is a process of generating, accessing and putting knowledge into use (Hall et al. 2015).

The concept of scientific collaboration becomes more significant in the biotechnology sector. The biotechnology research is expensive and complex and requires expertise and investment from varied actors and new knowledge can be created at the intersection of government, academia and industry. This potential has been realized in India and there is a constant effort to reach Triple Helix III through increased networking between university and industry. But the development of these partnerships is in its initial stage. There are various challenges which hinder the partnership between government, academia and industry such as technological, social and economic factors (Hall 2006). Government plays an important role in formulating policies as 75 per cent of total science and technology funding is granted by the government. There is a need to increase investment by private sector in R&D activities. This can be initiated through joint projects involving participants across institutions. This will strengthen the

collaboration between basic, applied and strategic research. Cases of Bt Cotton and Bt Brinjal suggest that science and agricultural policies must take into account differing perspectives of various actors. In other words, the introduction of Bt Cotton and Bt Brinjal cannot be examined by ignoring various socioeconomic and politico-cultural factors. This suggests increased coordination between scientists, academicians, industrialists, CSOs, etc. through strengthening institutional mechanisms. The creation of robust agriculture innovation system is utmost important for any country. This has not fetched much attention in the current Science, Technology and Innovation Policy 2013 in India. The type and quality of links between these actors determine the functioning of a given national innovation system.

The second chapter captures the transition in agriculture research in India. Historical background to agricultural research in India is important as it locates the transition in agriculture research in India, its adaptation and outcomes. Public policy is highly interdisciplinary in nature and should change based on the current trend of the economy. The second chapter discusses Mode 1 and Mode 2 forms of knowledge production marking a shift from disciplinary science to the application of its findings. The triple helix model by Etzkowitz and Leydesdorff (2000) suggests that the networking between government, academia and industry is necessary for the knowledge production in agricultural biotechnology processes. Triple Helix III is balanced configuration and most favourable situation for any country and most of the countries are trying to reach this balanced configuration. Further, this chapter discusses the agricultural innovation system, directed basic research, science and technology policies in India, agricultural policies in India, public-private partnerships, networking between government, academia and industry, international politics of genetically modified food, situating biotechnology debates in the context of triple helix model of innovation,

biosafety, science of GMOs, risk, cases of Bt Cotton and Bt Brinjal, technology input in agriculture, Low-External-Input Technology (LEIT) and organic farming.

The third chapter examines the networking between academia, government and industry in the agricultural setting in India. It studies the perception of scientists on scientific collaboration with industry and other public-funded research laboratories, universities and private research foundations. It studies the interest, motivations of scientists for scientific collaboration and directly investigates the problem or hindrance while collaborating with industry. These challenges will give a useful insight to capture the adaptation of triple helix model in the agricultural biotechnology sector in India. There could be so many reasons which results into the poor innovative environment of the country. Firstly, there appears to be a lack of interaction among scientists engaged in basic and applied research. There is a greater level of concentration in basic research in academia and public institutions whereas there is a greater level of concentration in applied research in industry. Secondly, there is an inadequate linkage between scientists of public institutions and private industry.

The third chapter also discusses the various types of collaborative networking. Further, it discusses experiences of the scientists interviewed for the present study with the industry. It discusses issues, challenges underlying while forming the collaboration with the industry. The present study suggests that benefits of collaboration with the industry may result in transfer of technology leading to the application, obtaining research inputs, strengthening funding mechanisms, and so on. In order to establish a sound collaboration between varied actors, it is important to de-bureaucratise the administrative processes, frame MoUs, share work as well as credit.

The fourth chapter attempts to analyze the implications of two proprietary technologies in agriculture in India, viz. Bt Cotton (non-food crop) and Bt Brinjal (food

crop). It discusses the debate, politics related to GM crops and how diverse actors involved are guided by the different interests and meanings. Proper networking between these three actors namely, government, academia and industry is likely to result in adoption of agricultural biotechnology aiming towards policy level changes required for GM crops. This chapter also attempts to capture the perception of scientists on GM crops in general and Bt Cotton and Bt Brinjal in particular. While the case of GM varieties are highly debatable and controversial in Indian agriculture and status of GM crops in India plays a major role in forming the debate on GM crops globally. Scientists interviewed for the present study suggests that there is a monopoly of the private sector in the case of GM crops. Till date, no genetically engineered crop has been released by the public sector in India. This leads to the corporatization of GM crops in Indian agriculture. This requires increased networking between the public and private sector that would benefit both the sectors. Despite protests the area grown under Bt Cotton has increased to 96 per cent.

However, a moratorium on Bt Brinjal was imposed in 2010 due to huge public protests. This has major implications on the farming community on the one hand and scientific community on the other. Funding mechanism, scientists' research choices are changing with respect to GM crops. In the case of Bt Brinjal the CSOs play a crucial role by imposing a moratorium on Bt Brinjal. Though scientists interviewed suggest that huge time, money, expertise, personnel, etc. are invested before developing any technology but the incident of Bt Brinjal suggests the inability of scientific community to critically voice their opinion. The scientists' views on GM crops are fragmented with one set of scientists hesitant to dwell upon the issue and simply willing to follow the mandates of the institute. Scientists interviewed for the present study suggest that GM technology is required for conducting good research and support GM technology.

The fifth chapter discusses how the framing of public policy and networking between varied actors led to the transition in the models of agricultural innovation system in India. This chapter discusses the Public-Private Partnership (PPP) model in order to capture the process of knowledge creation from the stage of product development to diffusion of technology.

Scientists interviewed for the present study suggest that traditional knowledge which is developed by farmers and breeders should be protected and there is PPVFRA Act, 2001 which provides strong protection to the farmers and breeders. Most of the farmers are not aware of the intellectual property rights attached to their invention. So, it is the responsibility of the government and scientific community to help farmers protect their rights through conducting various awareness programmes.

This chapter also discusses the ways to strengthen basic research and its applicability through specific government policies and programmes. This chapter also discusses the initiatives undertaken by the Government of India to promote networking between government, academia and industry. Since the 1990s, there has been constant effort to harness the innovative capabilities of various innovation structures by connecting them together. It has initiated various programmes that try to bring academia, research institutions, and private industry together for product or process development. BIRAC is one such initiative. By using university's expensive instrument and infrastructure, even startup can perform pivotal research. It provides access to scientific infrastructure, expertise and cutting edge technology which would be vital for entrepreneurs and startups.

6.2 Findings of the Study

The thesis has provided an in-depth study of networking between government, academia and industry in India. It has examined the perspectives of scientists on scientific collaboration. The perspectives of scientists from different universities, industry and government are analyzed to examine the various factors which lead to scientific collaboration between scientists. The findings of the study include:

The motivational factors which lead to the formation of collaboration between scientists are the complexity of research problems, technological apparatuses, research laboratory facilities and complementarities of expertise. Most of the scientists interviewed for the present study have not come across any such hindering policy and attribute the hindrances to the mandates of the institute. The hindrances faced by the individual scientists can be manifold such as lack of understanding between the scientists drawn from university and industry. Scientists working in academia believe that research personnel associated with the industry are not familiar with scientific collaboration due to the differences in research experience, production and diffusion of knowledge. In other words, for the scientists working in academia, finding collaborators with complementarities of expertise is important while forming collaboration. Several initiatives like BIG and SIBRI are trying to bring in scientists from academia and industry. Such initiatives will be successful only when there will be adequately funded projects with competent partners. It also addresses bureaucratic processes existing in government organizations that make collaboration process time-consuming. Timely management of project is crucial for its smooth functioning and completion. It also addresses the chronic dearth of funds for agricultural research in general and for basic research specifically. At present in 2016, government policies are more inclined towards applied and developmental research but a sound basic research is required for the smooth

functioning of applied research. State universities lack basic infrastructure (such as laboratory facilities, instruments and fund) to conduct research. There is a need to strengthen basic infrastructure and research facilities in state universities in India.

There is more networking between central universities and national research laboratories. There is also collaboration between industry and university. These collaborations are mostly contractual in nature and are client-based, i.e. university's scientists function as service providers to the industry for their specific problems. It is clear that government, academia and industry networking have not fully developed in the case of agricultural biotechnology.

Networking with industry is adding a new dynamics to scientific research. This leads to the formation of contractual research within the realm of scientific research. Collaboration at the individual level appears to be more frequent than the other forms of collaboration, which may be attributed to the relatively weaker institutional mandates in India. Interdisciplinary collaboration within India is more as compared to interdisciplinary collaboration abroad.

Scientists interviewed for the present study are engaged in projects with the DST, DBT, CSIR, ICAR and private industry like seed companies etc. and international collaborators. Most of the scientists interviewed collaborate with DST, DBT, and CSIR or with other state or central universities for projects with a less number of scientists working with industry or in collaboration with international organizations.

Research objectives of scientist varies depending upon the nature of institutes in which they are affiliated, and also depends on their networking partners with which they are engaged for a project. Individual interests often guide the research problem undertaken by the scientist mediated by the rules and regulations of government and funding bodies.

In the knowledge society, IPR plays an important role if we want to promote innovation in agriculture. Patents filed by the university scientists are slowly increasing. These patents can provide a source of income to research institutions if income is generated for the institution as a whole rather than the individual scientist.

In India, commercial as well as social awareness of science and the associated IPR is relatively low among scientists. Most of the scientists interviewed for the present study suggest that there is a need to introduce a separate course on IPR in universities and other research institutions besides strengthening IPR consultancy services on the know-how of IP rights. They can be aware in advance of the commercial applicability of their research work and can tie up their research in the laboratory to industry for market use.

In India, triple helix I and triple helix II forms of knowledge production are more prominent as compared to triple helix III form of knowledge production. A majority of the respondents are of the opinion that when government, academia and industry work in cooperation with each other, it leads to more innovations and minimizes the expenditure on infrastructure, instruments, etc. The government is trying to promote private sector involvement in agricultural biotechnology. Private sector engagement in R&D is significantly lower in India as compared to those in developed economies.

There is a thin line between basic and applied research in India. Scientists engaged in basic research are not or less engaged with industry as industry is more interested in applied or direct research. Government funding and policies should be such that will bring together basic and applied research scientists together for project. This will certainly enhance the quality and outcome of the project.

Interaction of actors and interplay of institutions at various levels should be increased by introducing multidisciplinary project involving scientist from different

institutions and various disciplines to promote networking between various actors of the triple helix. According to the Joint Committee of Industry and Government (JCIG), public-private partnership and well-designed incentive mechanism to trigger commercialization of R&D outputs would be required to stimulate private sector investments into R&D as commercialization of R&D output is a key step. In developed and emerging economy, the private sector investments in R&D are generally in the range of 2:1. While private investments in R&D are estimated to be only half of the investment of public sector in India. Private-public partnership is important for the development of technology. It is seen that the country where the private sectors engagement in R&D is more/large, time taken to commercialize a technology is shorter. According to Kartz and Martin (1997), qualitative assessment of collaboration is extremely difficult because of the indeterminate relationship between quantifiable activities and intangible contribution. Moreover, exact investment in R&D by the private sector is difficult to estimate due to unrecorded information. For this, government (Department of Science and Technology) recommended that public universities, research institutions, and private industry should provide information about the exact investment in their annual reports.

With the advancement of modern science, the complexity of instruments has increased. This requires technicians and research professionals for the operation of the instruments and the government should increase the number of technicians for the operation of the instruments and machinery. This requires imparting of training and expertise that will strengthen research personnel in different institutes.

A majority of the respondents realize that a common forum should be instituted bringing in scientists from academia and industry to forge collaboration. Even some of the initiative is undertaken by the government. But this type of collaboration is less and limited to a few institutes. This suggests that triple helix III will take the time to evolve.

In India Triple helix III form of knowledge production in agricultural biotechnology can be found in few institutes. Like, some local company like Criyagen which is situated within the infrastructure of University of Agricultural Sciences Bengaluru, provide internship to student besides performing the traditional role of technology diffusion. On the one hand, industries working in close cooperation with universities are benefitted in terms of infrastructure, pre-established laboratories and expertise from scientific personnel. On the other, industries help university researchers develop the laboratory-based research into final product.

Further, the perspective of scientists from the different institutions have been captured in order to study the politics embedded in the triple helix model of innovation in the context of GM crops and suggests policy implications for better utilization of GM technologies in Indian agriculture. It is observed how a lack of awareness of any technology can lead to its uncritical evaluation. A huge amount of public investment, time, scientific expertise, and so on are invested in developing any technology. So, decisions on GM crop or any controversial technology should take into account views of experts from academia, policy, scientific community, business to CSOs. Policy debate is crucial for the development of research and development in agricultural biotechnology in India. Cases of Bt Cotton and Bt Brinjal depict a lack of consensus among several social, economic and political actors.

The views of the scientific community on GM crops are fragmented. A few scientists completely reject GM technology and suggest that there are other technologies available which can tackle the problem of food grain production, whereas a majority of the scientists suggest that GM technology is required to address the problem of food grain production. Putting it succinctly, there is no consensus on GM technology by the scientific community in India. A lack of consensus on GM crops has adversely affected

the interests of public institutions. A majority of the respondents suggest that public institutes should distribute Bt Cotton seeds through public distribution system in order to benefit the farmers growing Bt Cotton.

Government policies are weak whether it is concerned with the regulation of GM technology, diffusion of technology or commercialization of technology. Critical policy changes are required for the effective use of modern technology. Proper training and awareness should be provided to the end-users such as farming community and consumers. Multinational corporations like Monsanto working on Bt Cotton collaborate with Indian seed company Mahyco, which is an Indian industry. This is a case of private-private partnership on GM crops in India.

Academic enterprise and the PPP model is at an early stage in many developing countries. Institutes funded by Department of Science and Technology (DST), Department of Atomic Energy (DAE), Department of Biotechnology (DBT), Council of Scientific and Industrial Research (CSIR) tend to collaborate more with industry and firms.

The ICAR policies encourage its scientists to share their knowledge and expertise through the partnership with prospective clients which may include other public sector, private sector, civil society, international research centers, and other agencies and institutions. The largest recipients of research funding from ICAR are the State Agricultural Universities (SAUs). Intellectual property generated by ICAR institutions under collaborative research projects will be jointly owned by the ICAR and in collaborative partners on mutually agreed terms. The study suggests how time taken to take a decision regarding a particular crop hampers the technological innovations. So, the government should not unnecessarily delay the decision on the particular technology.

The present study suggests a critical balance between IPR regulations and breeders' rights in India.

The problem in policy in the context of agricultural biotechnology in India can be summed up as expert disagreement, need to bring consensus on decisions regarding GM crops, uncertainty and conflict of interest. Formulation and implementation of policies at various levels to strengthen public-private partnership are required. For successful implementation of National Innovation System, there should be varied linkages between different actors such as academia, government, industry, policy makers, civil society organizations, extensions etc.

The present study suggests policy suggestions to improve networking between government, academia and industry like increase R&D investment in basic research, increase participation of private sector in basic research, increase investment by private sector, exchanges of research personnel across government, academia and industry, increase in the number of long-term collaborative project, integration of varied discipline is significant to solve the challenge of modern day agriculture, attraction of funding through interdisciplinary research and competitive researchers and so on.

Mandates of the institute are a guiding factor in determining the collaborating relationship between individual scientists. In comparison to academia, scientists from CSIR-Laboratory, mission-oriented research institutes tend to collaborate more with the industry.

Public supported basic research forms the foundation of applied research carried out by both public and private organizations. ICAR, CSIR, DBT, DST are the major funding agency in these research institutes.

The collaboration between industry and university is contractual in nature where industry gives some problem to scientists working in government research laboratory or

university and they provide the solution to those problems. So, scientists who are willing to adapt to the research interest of industry can form a successful collaboration with the industry. This will be guided by the number of factors like commercial interest, increase networking, patent and so on. Networking between academia and industry should be encouraged for the realization of commercial applicability of products as well as field trials. However, universities at present have become merely the service-providers to the industry.

The conflict between industry and academia personnel can be avoided if proper MoU is signed in advance. Also, industry-university networking is more of contractual in nature and it is argued that short-term project is not useful in bringing meaningful results. Thus, there is a need to introduce long-term R&D projects by the industry to personnel, as personnel in academia who are much interested in long-term projects. Resistance to change on the part of the university scientists may be attributed to their perspective on the functions of the university system, which emphasizes basic research and disciplinary education to the students. The industry-sponsored research was seen as changing the orientation of the university by bringing in commercial values, entangling university researchers with proprietary interests and constrains thus changing the traditional image of the university (Nelkin and Nelson 1987; see also Mallick 2011).

There is a need for an institutional setup that will link research findings of disciplinary science to its application. At present, there are a few institutions which are trying to bridge the gap between basic research and its application. These intuitions and ideas are at very early stage in case of India. The link between the research laboratory and farm can be increased by the linking institutions. One such link is startups which have emerged as important steps in India's innovation systems. Institutes like C-CAMP in Bengaluru and TIFR in Mumbai provide an infrastructure base for such startups.

Public-Private partnership is at an early stage in many developing countries. For successful implementation of National Innovation System, there should be varied linkages between different actors such as academia, government, industry, civil society organizations, etc.

6.3 Limitations of the Study

The present study is limited in terms of its scope. The study could not include other intermediary organizations which help in the commercialization or diffusion of technology. In order to provide deeper insights into the study, the perspectives of farmers, policymakers and CSOs may be included. Industry personnel, to a large extent, could not be included. Similar studies in other developing and developed countries may be explored to compare the findings of the present study. Interviews with policymaking agencies may provide a deeper understanding of the decisions on GM crops in order to implement appropriate policies in the future.

6.4 Scope for Further Research

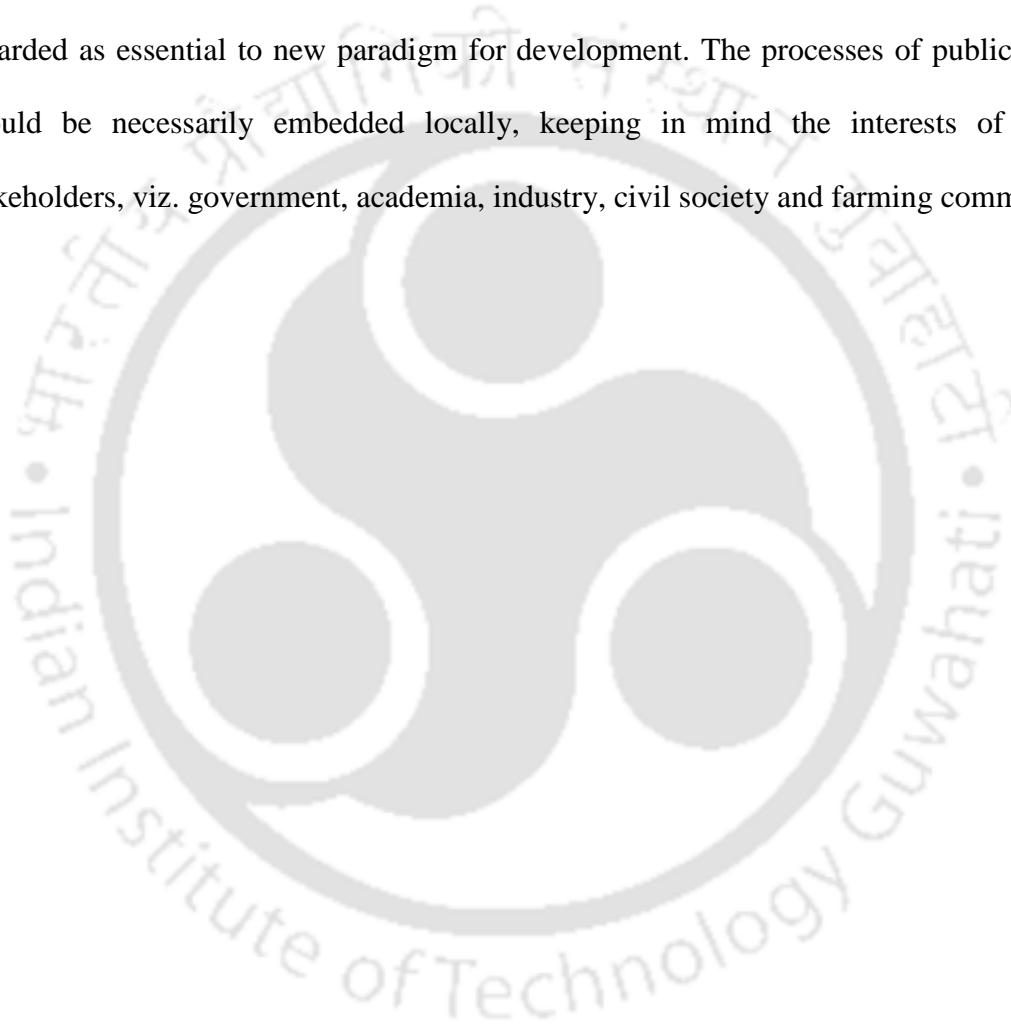
The motivation of the industry to collaborate with academia and government research laboratories may be studied. This may be intellectually stimulating for scientists drawn from the academia to collaborate with industry. Since the WTO provisions on IPR, India has gradually established relatively substantial infrastructure for basic and applied research. Public and private funded research institutes and universities in India are experiencing transformation largely to incorporate an entrepreneurial practice and culture. How university is developing as an entrepreneur may be explored more widely by studying the 'Entrepreneurial University' in the case of biotechnology and university's role towards creating an environment that will attract different stakeholders.

The entrepreneur in a university would be stirred up, motivated and equipped to proceed in creation of knowledge. Different manifestations of this emerging trend may be captured in collaboration of academia-industry-government vis-à-vis their role in promoting consultancy and incubation centres. Further, the role of independent entrepreneurs, government, industry and CSOs assumes greater significance in strengthening the National Innovation System in India. The process of networking between government, academia and industry is non-linear and more complex, providing ample scope for further research.

The triple helix model of innovation is evolving in myriad forms in developing countries including India. The model which exists in the West may not be suitable for Indian context. India has to evolve an independent model of innovation guided by an independent science and technology policy. The compliance with the international patent regime has not been able to create new vistas of knowledge production, for example, agricultural biotechnology, pharmaceutical biotechnology, and so on. One significant change in the operation of scientific communities, which can be observed under such compliances, is the gradual loss of their conventional research autonomy. This may be a consequence of the changing nature of production and diffusion of technology. The science and technology policies must be framed in a socially inclusive manner. In other words, the science and technology policies must include the aspects of equity, democracy, sustainability, etc. while evaluating a new technology. Such situation demands appropriate policy and institutional support, upgrading of skills and technology, recurrent motivation to respond to industrial needs and most importantly, a primary concern for human and social development indicators.

The interaction between science, technology and bureaucratic and political processes creates forms of collaboration in which scientific and technological expertise

are central to the processes of policymaking. It is important to examine the implications of such relationships between government, academia and industry for policymaking and the broader governance of science and technology applications. A combination of scientific, technological and business expertise is required in policymaking circles in India. With government, academia and private R&D institutions being seen as forming the core of scientific collaboration, accumulation of expertise in these areas may be regarded as essential to new paradigm for development. The processes of public policy should be necessarily embedded locally, keeping in mind the interests of varied stakeholders, viz. government, academia, industry, civil society and farming community.



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ANNEXURE I

Indian Institute of Technology Guwahati Department of Humanities and Social Sciences

SCIENCE, AGRICULTURE AND PUBLIC POLICY: A STUDY OF GOVERNMENT-ACADEMIA-INDUSTRY NETWORKING IN INDIA

Data obtained through questionnaire will be used for research purpose only. Strict confidentiality will be maintained.

INTERVIEW SCHEDULE

Name:

Age:

Gender:

Designation:

Organisation:

Job Description:

1. How do you assess the state of agriculture in India today?
2. How do you view the green revolution technology in agriculture in India in the 1960s and 1970s?
3. How do you see the incorporation of modern technological system in agriculture in India today?
4. In what ways can we assess the shifts in the paradigms of technologies in agriculture in India?
5. What is the influence of modern technologies, say GM seeds, on agriculture in India?
6. What are the ways by which we can increase cooperation between applied and basic research?
7. What is scientific collaboration?
8. How are you and your research laboratory engaged in scientific collaboration across disciplines and institutions?
9. Would you kindly reflect on the differing institutional mandates which may help or hinder in the process of forging any scientific collaboration?
10. Do you collaborate with industry? If so, in what forms? What are the challenges that you might have faced while collaborating with the industry?
11. Would you kindly reflect on the nature of funding for your research?
12. What is the role of boundary organizations in the SI that you are engaged in?
13. What is the role of the Government of India in mediating the sessions arising out of such scientific collaboration?
14. What are the significant advantages associated with collaboration between the public and private sectors in agricultural research and development?
15. Do you think scientists should collaborate with the NGOs in terms of technology and wider reach? Comment.

16. Do you think that the major challenge for both private sector and public sector is to find ways to collaborate in sharing and transferring appropriate new and superior technologies, which often are proprietary, from the private sector to the public sector? Comment.
17. Do you think there is a tension between two disciplines if they share same technical goals and especially if these goals are commercial in nature? Comment.
18. What are your views on the networking between government, academia and industry in creating market for Bt seeds?
19. According to Herring and Rao (2012), 'Politics and policy towards agricultural biotechnology in India for the future will be conditioned by the success or failure of Bt cotton'. Would you kindly comment on this?
20. What are the potential benefits or otherwise of producing Genetically Modified crops to small-scale subsistence farmers?
21. Compare and contrast the environmental effect or environmental risk caused by Genetically Modified crops and chemical control of weeds.
22. What are the policy options which are available to developing countries to protect their proprietary rights?
23. What an effective *sui generis* system for Plant Variety Protection should be?
24. How is GM technological system socially or ethically justifiable?
25. Why is chronic toxicity studies on GM crops in India refused?
26. How do you see the influence of proprietary non-food crops and proprietary food crops on agriculture in India today?
27. What are your views on the collaboration between MAHYCO and Monsanto in creating a market for Bt cotton? What are the industrial interests in creating the market?
28. How does your organization examine Bt cotton in agriculture in India?
29. Would you kindly provide suggestions to tackle the problems arising out of Bt cotton in agriculture in India?
30. What is the effect of Bt brinjal on diverse flora of brinjal existing in the country? For example, what are its effects on agriculture, health and environment?
31. Do you think that there should be check on the entry of GM food in India?
32. Introduction of GM Crops or Bt cotton/Bt brinjal have led to the non-availability of traditional varieties of seeds. So, do we need to protect our traditional seeds?
33. Does Bt cotton require more fertilizers than non-Bt cotton/non-GM crops?
34. What are the proprietary issues involved in such modern technological systems in agriculture in India?
35. What are the conflicting interests between traditional and modern knowledge systems in agriculture in India?
36. What are the implications of such technological innovations on the science and technology policy in India?
37. How must patent protection be better adapted to fit with the interests of traditional knowledge holders?

ANNEXURE II

Indian Institute of Technology Guwahati Department of Humanities and Social Sciences

SCIENCE, AGRICULTURE AND PUBLIC POLICY: A STUDY OF GOVERNMENT-ACADEMIA-INDUSTRY NETWORKING IN INDIA

Data obtained through questionnaire will be used for research purpose only. Strict confidentiality will be maintained.

QUESTIONNAIRE

Name:

Age:

Gender:

Designation:

Organisation:

Job Description:

Q.1. Do you think current challenge of agriculture in India requires new partnerships in agricultural R&D between the public and private sectors that enhance the mutual coexistence of both sectors?

(a) Strongly Agree (b) Agree (c) Disagree (d) Strongly Disagree

Q.2. Do you think innovation is possible as a resultant of joint endeavour between industry and university?

(a) Strongly Agree (b) Agree (c) Disagree (d) Strongly Disagree

Q.3. Does changing nature of scientific research in India emphasize competition among scientists located in various institutional settings in India?

(a) Strongly Agree (b) Agree (c) Disagree (d) Strongly Disagree

Q.4. Do you think there should be specific regulatory system for GMOs by the Government of India?

(a) Strongly Agree (b) Agree (c) Disagree (d) Strongly Disagree

Q.5. Is there a slow spread of Genetically Modified Crops in India?

(a) Strongly Agree (b) Agree (c) Disagree (d) Strongly Disagree

Q.6. Do you think present *sui generis* system for plant variety protection is effective?

(a) Strongly Agree (b) Agree (c) Disagree (d) Strongly Disagree

Q.7. Do you think chronic toxicity studies on GM crops in India should be allowed or prohibited?

(a) Definitely allowed (b) Probably allowed (c) Probably prohibited (d) Definitely Prohibited

Q.8. Do you think that there should be quality assessment of GM crops that enter into India?

(a) Strongly Agree (b) Agree (c) Disagree (d) Strongly Disagree

Q.9. Do you think introduction of GM crops have led to the non-availability of traditional varieties of seed?

(a) Strongly Agree (b) Agree (c) Disagree (d) Strongly Disagree

Q.10. Does Bt cotton requires more fertilizers than traditional cotton?

(a) Strongly Agree (b) Agree (c) Disagree (d) Strongly Disagree

Q.11. Do GM crops reduce environmental pollutants?

(a) Strongly Agree (b) Agree (c) Disagree (d) Strongly Disagree

Q.12. Do you think intellectual property is one of impediment to the development and adoption of GM crops in developing countries like India?

(a) Strongly Agree (b) Agree (c) Disagree (d) Strongly Disagree

Q.13. Do you think environmental safety aspect of Genetically Modified Crops varies depending upon the local conditions?

(a) Strongly Agree (b) Agree (c) Disagree (d) Strongly Disagree

Q. 14. Whether GM technology is suitable for large landholders of developing countries?

(a) Strongly Agree (b) Agree (c) Disagree (d) Strongly Disagree

Q.15. Do you think there is a problem of integrating the techniques of different disciplines into a unified process of plant improvement/ agricultural development/GM etc?

(a) Strongly Agree (b) Agree (c) Disagree (d) Strongly Disagree

Q.16. Do you think there is a tension between two disciplines if they share same technical goals and especially if these goals are commercial in nature?

(a) Strongly Agree (b) Agree (c) Disagree (d) Strongly Disagree

Q.17. Do you see the importance of the entry of industry as a viable means for the production and distribution of agricultural commodities in India?

(a) Strongly Agree (b) Agree (c) Disagree (d) Strongly Disagree

Q.18. Does herbicide-resistant plant variety results in decrease in chemical usage?

(a) Strongly Agree (b) Agree (c) Disagree (d) Strongly Disagree

Q.19. Do you think interaction between government-sponsored research institutions and industry has still not been extensive?

(a) Strongly Agree (b) Agree (c) Disagree (d) Strongly Disagree

Q. 20. Do you think public funding for basic agricultural research has declined?

(a) Strongly Agree (b) Agree (c) Disagree (d) Strongly Disagree

Q.21. Do you think private sector research will not fill the gap that exists between goal and reality?

(a) Strongly Agree (b) Agree (c) Disagree (d) Strongly Disagree

Q.22. Do you think linkages between farmer and research system are weak?

(a) Strongly Agree (b) Agree (c) Disagree (d) Strongly Disagree

Q.23. Is it important to protect our Intellectual Property Rights as role of private sector in biotechnology has increased since the 1990s?

(a) Strongly Agree (b) Agree (c) Disagree (d) Strongly Disagree

Q.24. Do you think current policies are sufficient to protect public from potential risk of new technologies?

(a) Strongly Agree (b) Agree (c) Disagree (d) Strongly Disagree

Q. 25. Do you think that there should be check on GM Crop which enters India?

(a) Strongly Agree (b) Agree (c) Disagree (d) Strongly Disagree

Q.26. Do you think we need to focus more on basic research in agriculture?

(a) Strongly Agree (b) Agree (c) Disagree (d) Strongly Disagree

Q.27. Thinking about current research status of Genetically Modified Crops, do you think research or trial on Bt Brinjal should be allowed or prohibited?

(a) Definitely allowed (b) Probably allowed (c) Probably prohibited (d) Definitely Prohibited

Q.28. Do you think significant benefits can be derived from the collaboration of public and private sectors?

(a) Strongly Agree (b) Agree (c) Disagree (d) Strongly Disagree

Q.29. Do GM crops reduce environmental pollutants?

(a) Strongly Agree (b) Agree (c) Disagree (d) Strongly Disagree

Q.30. Do you think scientists should collaborate with the civil society organizations (CSOs) in terms of technology and wider reach?

(a) Strongly Agree (b) Agree (c) Disagree (d) Strongly Disagree

Q.31. Can the GM crop movement develop into an agricultural revolution on the scale of the Green revolution?

(a) Strongly Agree (b) Agree (c) Disagree (d) Strongly Disagree

Q.32. Do we need this technology? Is this socially or ethically justifiable?

a) Strongly Agree (b) Agree (c) Disagree (d) Strongly Disagree

1. Intellectual Antecedents

PhD(Abroad), PDF (India)	
PhD(India), PDF (Abroad)	
PhD(India), PDF (India)	
PhD(India)	
PhD(Abroad)	
PhD/PDF (Abroad)	

2. Patents

Number of Patents

US Patents	
European Patents	
Indian Patents	

3. Projects

Types	Interdisciplinary	Intercontinental	Inter-institutional
International			
National			

4. Publications

Number of publication

International	
National	

5. Pattern of Collaborative Patents

Number of collaborative patents

Interdisciplinary	
Intercontinental	
Interinstitutional	

6. What are the areas of research in which scientists are involved

Research Areas

Organisations involved

Basic Research	
Applied Research	
Directed/Oriented Research	

7. Nature of collaboration in their respective fields**Scientific Collaboration/Networking**

Types	Interdisciplinary	Interinstitutional	Intercontinental
International			
National			

8. Number of research paper published during different phases**Different Phases****Number of paper published**

1991-2000	
2001-2005	
2006-2010	
2011-2014-15	

9. Nature of collaboration**Organizations involved**

Public-Public collaboration	
Public-Private collaboration	
Private-Private collaboration	

