# Dynamics of Scientific Collaboration: A Study of Rice Biotechnology Research in Selected Scientific Institutions in India

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## DECLARATION

I hereby declare that the thesis entitled **"Dynamics of Scientific Collaboration: A Study of Rice Biotechnology Research in Selected Scientific Institutions 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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## CERTIFICATE

This is to certify that Ms. Madhulika Kumari has prepared the thesis entitled **"Dynamics of Scientific Collaboration: A Study of Rice Biotechnology Research in Selected Scientific Institutions 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.

IT Guwahati — Sambit Mallick

January 2018 — Supervisor

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Avinash Kumar

# Abstract

With the appearance of a new set of agricultural biotechnology tools, changes in scientific practices have emerged across the globe. It has profound implications on both plant molecular biologists and plant breeders. This new set of scientific practices constitutes new relationships by fostering significant changes in the nature of expertise on the relations of science and society between government, academia and private R&D institutions. The proprietary nature of agriculture and changes in the governance of science and technology, especially as a consequence of Intellectual Property Rights (IPR) protocols assumes greater significance. It has brought about changes in scientific knowledge and product level innovations vis-à-vis the emergence of new collaborative practices, viz. public-private collaboration. It necessitates the need for new skills, institutions and organizational arrangements to carry out agricultural research in laboratory as well as field. In this context, the present study attempts to examine the nature, process, and organisation of scientific collaboration in rice biotechnology research in the context of India.

Informed by Sociology of Science and Technology (SST), the present study employs mixed-methods to achieve the research objectives. The quantitative methods comprise bibliometric study of scientific collaborations occurring at the micro and macro level in the field of rice research in India. The data for bibliometric study were acquired from the on-line international multidisciplinary edition of the scopus database published by the Elsevier science. The qualitative methods include of in-depth personal interviews with the scientists engaged in rice biotechnology research from selected scientific institutions coming under the aegis of Indian Council of Agricultural Research (ICAR), and the State Agricultural University (SAU).

The bibliometric study suggests that the multiple-authorship paper is predominant as compare to single author paper during the period of 1995-2014. Indian rice scientists show preference for mega-authored patterns. Collaboration pattern according to collaboration institutions changes from local (intra-institutional) papers via domestic papers ((inter-institutional (national)) to international papers. Besides, the international collaboration has been increasingly strengthened. This has enhanced the international visibility of Indian rice scientists. Furthermore, the co-authorship patterns highlights that the collaboration between state agricultural universities and ICAR-sponsored institutes has decreased during 1995-2004 with respect to 2005-2014. The collaboration of state

agricultural universities with industry has decreased, whereas ICAR and industry collaboration has enhanced during 2005-2014. In the context of international collaboration, both SAU and ICAR exhibits decreasing trend in 2005-2014.

The study finds that project formation in rice biotechnology research is not only shaped by agency function of scientists but also by the structure within which they operate. However, in this study, the role of structure was found to be more dominant in comparison to the agency function. The pattern of scientific collaborations measured in terms of research projects (primary data) exhibits that the collaborations of the three kinds - collaboration between different departments of the same institution, collaboration between different institutes within the same country, and international collaboration – are found to be predominant or preferred by the researchers in rice biotechnology research. This suggests that physical proximity and communication does not influences scientific collaborations in rice biotechnology research. Therefore, scientific collaboration in rice biotechnology research is both national and international in character. Nevertheless, one of the concrete findings of the study is weak collaboration between SAUs, ICAR-sponsored institutes, and Industry.

Further, the findings of the study indicate that collaborative practices in rice biotechnology seem to be influenced by various sociotechnical factors that are embedded in local working condition of scientist. The division of labour has emerged as a dominant factor that influences scientific collaboration in rice biotechnology research. The presents study finds that complementarities of expertise, sharing materials for research, physical assets and nature of funding bodies determine the basis of scientific collaboration. The communications among partners in collaborative projects are technology dependent and ICT-driven. The R&D collaborations in rice biotechnology research is highly formalized, involves high incidences of written rules, regulations and formalized responsibilities. The response of the rice biotechnologists suggests that though the scientific community in India at times resists the protocol of the IPRs regime keeping in view the spirit of democratization of scientific knowledge. However, resistance from scientific community in India is not very often seen in its practice. The presence of Matthew effect in research collaboration was found to be very rampant in field of rice biotechnology. It is obvious that status-based factors are dominant than the academic-based factors while allocating project and credit to scientists.

## Contents

**Chapter I**
**Introduction**


1.1 Introduction
1.2 Review of Literature
1.2.1 The Internalist Characterization of Science and Technology
1.2.2 Externalist Approach: Relativism in Sociology of Science and Technology
1.2.3 Sociology of Science in Constructivist and Postmodernist Era
1.2.4 Modes of Knowledge Production
1.2.5.1 Triple Helix Model of Innovation
1.2.5.2 Mode 3 Form of Knowledge Production – Quadruple Helix Model of Innovation
1.2.6 Actor-Network Theory (ANT)
1.2.7 Emergence of Hybrid Scientific Community: Transdisciplinary Approach to Science
1.2.8 The Ontology of Sociotechnical Aspects and Epistemological Consequences
1.2.9 Theory of Remote Scientific Collaboration (TORSC)
1.2.10 Meaning of Collaboration
1.2.11 Classifying Scientific Collaboration
1.2.12 Motivations for Collaboration
1.2.13 Critique of Collaboration
1.2.13.1 Hierarchies of Knowledge within Research Teams
1.2.13.2 Decontextualization of Knowledge
1.2.14 Measuring Collaboration
1.2.15 Co-publication as an Indicator of Collaboration
1.2.16 Problems of Credit Allocations in Bibiometric Study
1.3 Research Gap
1.4 Rationale for the Topic
1.5 Research Questions
1.6 Objectives of the Study
1.7 Methodology
1.7.1 Quantitative Method: Data Collection and Analysis
1.7.2 Qualitative Method: Data Collection and Analysis
1.7.3 Profile of the Respondents
1.8 Structure of the Study


**Chapter II**
**A Socio-historical Analysis of Rice Biotechnology Research in India**


2.1 Evolution of the National Agricultural Research System (NARS)
2.2 The Structure of the Present National Agriculture System in India
2.3 The Indian Council of Agriculture Research (ICAR)
2.4 The Agricultural Universities System
2.5 General Universities
2.6 Other Scientific Organizations
2.7 Private-Sector Development
2.8 International Cooperation

2.9 The Consultative Group on International Agricultural Research (CGIAR)
2.10 Linkages among the Subsystems
2.11 Indian R&D in a Global Context
2.12 Human Resources in the Agriculture Research and Development in India
2.13 Impact of R&D on Agriculture in India
2.14 Factors for the Growth of R&D in Public and Private Sector
2.15 Rice as a Crop Plant
2.16 History of Rice Cultivation in India
2.17 Rice and Food Security in Asia
2.18 Rice Production in India
2.19 History of Rice Research in India
2.20 Rice Breeding Programmes in India
2.21 The Rice Green Revolution in India
2.22 International Collaboration in Rice Improvement Programmes
2.23 Institutionalisation of Agricultural Biotechnology Research in India
2.24 Transgenic Rice Research in India
2.25 A Case of Golden Rice
2.26 Entrance of 'Golden Rice' in India
2.27 Application of Marker-Assisted Selection in Rice Research with Special Reference to Indian Context

**Chapter III**
**Mapping Scientific Collaboration: A Bibliometric Study of Rice Research in India**

3.1 Quantum of Indian Publications in Rice Research
3.2 Relative Growth Rate and Doubling Time
3.3 Collaboration Characteristics
3.3.1 Authorship Pattern
3.3.2 Co-authorship Activity Index
3.3.3 Measures of Collaboration
3.3.4 Domestic and International Collaboration Profile
3.4 Collaboration Profiles according to Institutions
3.4.1 Relative Research Effort
3.4.2 Frequency of Research Collaboration
3.5 Collaboration Profile of State Agriculture Universities and ICAR-sponsored Institutes

**Chapter IV**
**Institutions, Structures, and Organizations: Scientific Collaboration in Rice Biotechnology Research in India**

4.1 Perceptions of Rice Biotechnologists about Research and Collaboration Activities
4.2.1 Different Activities Performed by Rice Biotechnologists within their Academic Area
4.2.2 Motivations of Collaboration
4.2.3 Impact of Collaboration on Research
4.3 Dimensions of Collaboration Formation in Rice Biotechnology Research
4.3.1 Interpersonal Context
4.3.2 Funding Context

4.3.3 Sectoral Context
4.3.4 Organizational Context
4.4 Magnitude of Scientific Collaboration in Rice Biotechnology
4.5 The Structure of Scientific Collaboration in Rice Biotechnology
4.6 Patterns of Collaboration
4.7 Triple helix - Government-University-Private R&D Institutions Networking in Rice Biotechnology
4.8 International collaboration
4.8.1 Actors of International Collaboration
4.8.2 Drivers and Benefits of International Collaboration
4.8.3 The Process of Finding International Collaborating Partners
4.8.4 Possibilities for Improving International Collaboration

**Chapter V**
**Sociotechnical Influences on Research Collaboration in Rice Biotechnology Research in India**

5.1 Nature of Work
5.2 Common Ground
5.2.1 The Role of Previous Ties in Collaboration Network
5.2.2 Tacit Knowledge and Transactive Knowledge
5.3 Collaboration Readiness
5.3.1 Incentives and Rewards
5.3.2 Goals and Imperatives of Collaboration
5.3.3 Knowledge Sharing Culture
5.3.4 Mutual Trust
5.4 Management and Leadership
5.4.1 System of Leadership
5.4.2 Decision-making
5.4.3 Degree of Formalization
5.5 Integrated Use of Information and Communication Technologies
5.6 Problematic of Scientific Collaboration in Rice Biotechnology
5.6.1 Cognitive Empathy: Understanding the Needs of the Laboratory and the Field
5.6.2 Intellectual Property Rights Issues in Research Collaboration
5.6.3 Inequalities in Research Collaboration

**Chapter VI**
**Conflicting Narratives on Innovations in Rice Biotechnology in India**

6.1 Traits Tackled by Scientists in their Current Research Activities
6.2 Basic and Applied: Changing relations
6.3 Scientists’ Opinion on the Development of New Agriculture Technologies
6.4 Scientists’ Opinions on Slow Adoption of New Agricultural Technologies among Farmers
6.5 Scientists’ Perceptions about Genetically Modified Technology
6.6 Development of Indian version of Golden Rice: A Case of Swarna
6.7 Policy Imperatives
6.8 Complexities of GM Policies: A Case of Calcutta University

6.9 Scientists Views on IPR
6.10 Intricacies of the IPR Regime: An Enquiry into the Scramble for Geographic Indication (GI) Rights over Basmati Rice
6.11 Scientists' Views on Marker-assisted Technology (MAS)

**Chapter VII**
**Conclusions**

7.1 Findings of the Study
7.2 Limitations of the Study
7.3 Scope for Further Research

## List of Tables and Figures

Table 1.1: Different Levels and Forms of Collaboration
Table 1.2: Institute-wise distribution of respondents
Table 1.7.3: Profile of the Respondents
Table 1.4: Number of Papers published in peer-reviewed journals (2010-2014)
Table 1.5: Number of research project (inter-institutional) undertaken (2010-2014)
Table 2.1: Public agricultural R&D spending and intensity ratio, 2000 and 2008
Table 2.2: Trends in notified varieties of major field crops
Table 2.3: New pesticide registrations by decade, 1968–2010
Table 2.4: Numbers of field crop varieties by public-and private-sector institutions in India, 2005–2010
Table 2.5: Size of the market and research intensities of private agribusiness
Table 2.6: Rice production in global context (2014-2015)
Table 2.7: Season-wise Area, Production and Productivity of Rice in India (1991-1992 to 2015-2016)
Table 2.8: Major Indian Developments in Transgenic Rice Research and Application in Public and Private Sector
Table 2.9: Transgenic rice under development and field trials Rice from 2007-2013
Table 2.10: Products Developed through marker assisted breeding in rice in India
Table 3.1: Publication outputs in rice research during 1995-2014
Table 3.2: Relative growth rate and doubling time of rice publications in India
Table 3.3: Year-wise authorship pattern of India in field of rice research
Table 3.4: Profiles of CAI from 1995-20014
Table 3.5 Collaboration index of rice research in India
Table 3.6: Degree of collaboration of rice research in India
Table 3.7: Collaboration coefficient of rice research in India
Table 3.8: Modified collaboration coefficient of rice research in India
Table 3.9: Domestic Collaborative Index (DCI) and International Collaborative Index (ICI) for rice research in India
Table 3.10: Publication output of different agencies during 1995-2004 and 2005-2014
Table 3.11: Modified Activity Index of agencies during 1995-2014
Table 3.12: Matrix of research collaboration between agencies during 1995-2004
Table 3.13: Matrix of research collaboration between agencies during 2005-2014
Table 3.14 Percentage change in collaboration between agencies during two blocks

Table 3.15: Collaboration patterns of State Agricultural Universities during 1995-2014
Table 3.16: DCI and ICI of SAU during 1995-2004 and 2005-2014
Table 3.17: Collaboration patterns of ICAR-sponsored institutes during 1995-2014
Table 3.18: DCI and ICI of ICAR during 1995-2004 and 2005-2014
Table 4.1: Academic activities performed by rice biotechnologists
Table 4.2: Scientists' perceptions about research-teaching nexus
Table 4.3: Scientists' perceptions about the importance of research
Table 4.4: Scientists' self-reported individual characteristics
Table 4.5: Perception of the scientists about institutional and departmental research environments
Table 4.6: Relevance of research to external organisation in rice biotechnology
Table 4.7: People based activities
Table 4.8: Problem-solving activities
Table 4.9: Community based activities
Table 4.10: Ways through which external collaborations were initiated
Table 4.11: Collaborating partners according to geographic proximity
Table 4.12: Collaboration with partners, in terms of arrangement
Table 4.13: Scientists' perceptions about motivations for research collaboration
Table 4.14: Scientists' perceptions about impact of collaboration on research
Table 4.15: Scientists' perceptions about impediments of collaboration
Table 4.16: Distribution of project-formation dimensions
Table 4.17: Individual participation in research projects during 2010-2014
Table 4.18: Organization participation in research projects during 2010-2014
Table 4.19: Duration of projects undertaken by scientists during 2010-2014
Table 4.20: Extent of collaborations in Rice Biotechnology (2010-2014)
Table 4.21: Types of collaborative projects undertaken by scientists (2010-2014)
Table 4.22: List of international collaborators in rice biotechnology research
Table: 5.1: Nature of work
Table 5.2: Common Ground
Table 5.3: Various dimensions of collaboration readiness
Table 6.1: Types of traits tackled by scientists in their current research
Table 6.2: Scientists' Response to their own Research

**List of Figures**

Figure 2.1 Present Structure of National Agriculture System in India

Figure 3.1: Research collaboration between agencies during 1995-2004

Figure 3.2: Research collaboration between agencies during 2005-2014

Figure 3.3: Percentage change in collaboration between agencies during two blocks

## List of Abbreviations

| | |
|---|---|
| FAO | Food and Agricultural Organisation |
| IPRs | Intellectual Property Rights |
| SST | Sociology of Science and Technology |
| SSK | Sociology of Scientific Knowledge |
| STS | Science, Technology and Society |
| ANT | Actor Network Theory |
| PPP | Public-Private Partnership |
| NARS | National Agriculture Research System |
| R&D | Research and Development |
| DC | Degree of Collaboration |
| CC | Collaboration Coefficient |
| DCI | Domestic Collaboration Index |
| ICI | International collaboration Index |
| ICAR | Indian Council of Agricultural Research |
| SAU | State Agricultural University |
| DNA | Deoxyribonucleic Acid |
| DARE | Department of Agricultural Research and Education |
| ARS | Agricultural Research Service |
| ASRB | Agricultural Scientists Recruitment Board |
| UGC | University Grants Commission |
| ICSSR | Indian Council of Social Science Research |
| CSIR | Council of Scientific and Industrial Research |
| BARC | Bhabha Atomic Research Center |
| AICRP | All-India Coordinated Research Project |
| AINP | India Network Research Project |
| KVK | Krishi Vigyan Kendra |
| NARP | National Agricultural Research Project |
| NATP | National Agricultural Technology Project |
| USAID | United States Agency for International Development |
| ICMR | Indian Council of Medical Research |
| ISRO | Indian Space Research Organization |
| IIT | Indian Institute of Technology |
| DST | Department of Science and Technology |
| CGIAR | Consultative Group on International Agricultural Research |
| USA | United States of America |
| UK | United Kingdom |
| GCARD | Global Conference on Agricultural Research for Development |
| CIAT | International Center for Tropical Agriculture |
| CIFOR | Center for International Forestry Research |
| CIMMYT | International Maize and Wheat Improvement Center |
| CIP | International Potato |
| ICARDA | Center International Center for Agricultural Research in the Dry Areas |
| ICRISAT | nternational Crops Research Institute for the Semi-Arid Tropics |
| IFPRI | International Food Policy Research Institute |
| IITA | International Institute of Tropical Agriculture |
| ILRI | International Livestock Research Institute Bioversity International |
| IRRI | International Rice Research Institute |
| IWMI | International Water Management Institute |

| | |
|---|---|
| GDP | Gross Domestic Product |
| NTS | National Talent Scholarships |
| O | Oryza |
| OECD | Organization for Economic Co-operation and Development |
| USDA | United States Department of Agriculture |
| HYV | High Yielding Variety |
| CRRI | Central Rice Research Institute |
| DRR | Directorate of Rice Research |
| MoU | Memorandum of Association |
| NERICA | New Rice for Africa |
| NRRS | National Rice Research Systems |
| WARDA | West Africa Rice Development Association |
| NBTB | National Biotechnology Board |
| CPMB | Centres of Plant Molecular Biology |
| NCPGR | National Centre for Plant Genome Research |
| IPRB | International Program on Rice Biotechnology |
| IARC | International Agricultural Research Centre |
| GM | Genetically Modified |
| HICs | High Income Countries |
| LICs | Low Income Countries |
| ABN | Asian Biotechnology Network |
| NRBN | National Rice Biotechnology Network |
| NARES | National Agricultural Research and Extension System |
| IRGSP | International Rice Genome Sequencing Project |
| IIRGS | Indian Initiative for Rice Genome Sequencing |
| UDSC | University of Delhi South Campus |
| NRCPB | National Research Centre on Plant Biotechnology |
| NCFGR | National Consortium for Functional Genomics of Rice |
| IISc | Indian Institute of Science |
| MKU | Madurai Kamraj University |
| OU | Osmania University |
| MAHYCO | Maharashtra Hybrid Seed Company |
| TNAU | Tamil Nadu Agriculture University |
| AFLP | Amplified Fragment Length Polymorphisms |
| SSR | Simple Sequence Repeat |
| MAS | Marker-Assisted Selection |
| MABB | Marker-assisted Backcross Breeding |
| SNP | Single Nucleotide Polymorphism |
| PAU | Punjab Agricultural University |
| BB | Bacterial Blight |
| RGR | Relative Growth Rate |
| DT | Doubling Time |
| CAI | Co-authorship Activity Index |
| MCC | Modified Collaboration Coefficient |
| MAI | Modified Activity Index |
| ICT | Information Communication and Technology |
| PPVFR | Protection of Plant Variety and Farmers Right |
| DRDO | Defence Research and Development Organisation |
| MNCs | Multinational Companies |
| UNDP | United Nations Development Programme |

| | |
|---|---|
| UNESCO | United Nations Educational, Scientific and Cultural Organization |
| GRiSP | Global Rice Science Partnership |
| STRASA | Stress-Tolerant Rice in Africa and South Asia |
| CSISA | Cereal Systems Initiative for South Asia |
| NY | New York |
| ISCB | Indo-Swiss Collaboration in Biotechnology |
| SAARC | South Asian Association for Regional Cooperation |
| BIMSTEC | Bay of Bengal Initiative for Multi-Sectoral Technical and Economic Cooperation |
| ASEAN | Association of Southeast Asian Nations |
| ICGEB | International Center for Genetic Engineering and Biotechnology |
| DAAD | Deutscher Akademischer Austauschdienst (German Academic Exchange Service) |
| TORSC | Theory of Remote Scientific Collaboration |
| VPKAS | Vivekananda Parvatiya Krishi Anusandhan Sansthan |
| ANGRAU | Acharya N.G. Ranga Agricultural University |
| DSR | Direct Sown Rice |
| SRI | System of Rice Intensification |
| DH | Doubled Haploid |
| ZTS | Zero Tillage System |
| MT | Mechanical Transplanting |
| ATMA | Agricultural Technology Management Agency |
| HGT | Horizontal Gene Transfer |
| GMO | Genetically Modified Organism |
| MLTs | Multi-location Field Trials |
| GEAC | Genetic Engineering Appraisal Committee |
| RCGM | Review Committee on Genetic Manipulation |
| SBCC's | State Biotechnology Coordination Committees |
| DLCs | District Level Committees |
| IBSC | Institutional Biosafety Committee |
| CBD | Convention on Biological Diversity |
| CPB | Cartagena Protocol on Biosafety |
| NPA | Nagoya Protocol on Access |
| IMSCS | Indian Minimum Seeds Standard Certification |
| WTO | World Trade Organization |
| GI | Geographic Indication |
| TRIPS | Trade-Related Aspects of Intellectual Property Rights |
| IPAB | Intellectual Property Appellate Board |
| USPTO | United States Patent and Trademark Office |
| AIREA | All India Rice Exporters Association |
| APEDA | Agricultural & Processed Food Products Export Development Authority |
| CIPR | Commission on Intellectual Property Rights |
| PVPA | Plant Variety Protection Act |
| GURT | Gene Use Restricting Technology |
| IGKVK | Indira Gandhi Krishi Vishwavidalaya |

# Chapter I

## Introduction

### 1.1 Introduction

Rice is a staple food for more than half of the world's population – more than 3.5 billion people depend on rice for more than 20 per cent of their daily calories. Rice provided 19 per cent of global human per capita energy and 13 per cent of per capita protein in 2009. Asia accounts for 90 per cent of global rice production and consumption, and total rice demand still continues to rise in Asia (FAO 2009). This indicates to what extent rice is embedded in human society and how it serves as an instrument of production for sustaining human life. As rice carries potentials to influence human society, it becomes an object of study for scientists, generating knowledge about rice as being a crop, a grain, or a bulk commodity and prompting technical interventions to change the growth characteristics and nutritional composition of rice, cultivation techniques, processing methods and distribution channels. Over the last hundred years, science and technology have affected rice in all its dimensions, thereby playing a crucial role in the shaping of rice-growing and rice-consuming societies. As Marx in *Grundrisse* [1858 (1973)] puts it:

> But e.g. rests on scientific activities – if it requires machinery, chemical fertilizer acquired through exchange, seeds from distant countries, etc., and if rural, patriarchal manufacture has already vanished – which is already implied in presupposition – then the machine-making factory, external trade, crafts, etc. appear as needs for agriculture… Agriculture no longer finds the natural conditions of its own production within itself, naturally, arisen, spontaneous, and ready to hand, but these exist as an industry separate from it. This pulling-away of the natural ground from the foundations of every industry, and this transfer of the conditions of production outside itself, into a general context hence the transformation of what was previously superfluous into what is necessary, as a historically created necessity – is the tendency of capital.

The situation has become more complex with the appearance of a new set of agricultural biotechnology tools, changes in practices have emerged across the globe. It has profound implications on both plant molecular biologists and plant breeders. This new set of scientific practices constitutes new relationships by fostering significant changes in the nature of expertise on the relations of science and society between government, academia and private R&D institutions. The proprietary nature of agriculture and changes in the governance of science and technology, especially as a consequence of Intellectual Property Rights (IPR) protocols assumes greater significance. It has brought about changes in scientific knowledge and product level innovations vis-à-vis the emergence of new collaborative practices, viz. public-private collaboration. It necessitates the need for new skills, institutions and organizational arrangements to carry out agricultural research in laboratory as well as field. In this context, the present study attempts to examine the nature, process, and organisation of scientific collaboration in rice biotechnology research in India. Sociology of Science and Technology (SST) perspectives, as a speciality, are critically engaged in exploring such aspects.

### 1.2 Review of Literature

This section has been undertaken by keeping two objectives in mind: (a) to identify past and current studies that comprehensively reflects on various dimensions of scientific collaborations; and (b) to identify research designs that have been employed by various scholars to measure scientific collaboration at micro and macro level. These two broad objectives enable us to identify research gaps, rationale for the topic, research questions, research objectives, and research methodologies for the study. We make an attempt to classify this section into three parts, albeit not extensively. Part A examines scientific collaboration from SST perspectives. It outlines theories within the specialty of sociology of science and technology that focuses on scientific collaboration. Moreover, these theories have also been used as analytical framework of the study. Part B emphasizes on politics and sociology of scientific collaboration: concepts, discourses and debates. Part C is devoted to methodologies. This stresses on methods that have developed and employed by scholars to capture various aspects of scientific collaboration quantitatively and qualitatively. This part highlights merits and demerits of using such methodologies and seeks to explore an appropriate method to achieve the objectives of this study.

**Part A – SST Perspectives**

#### 1.2.1 The Internalist Characterization of Science and Technology

The internalist characterization of science and technology may be captured through Mannheim's Ideology and Utopia (1936): "All knowledge except scientific knowledge is socially and culturally conditioned". This intellectual discourse classifies into two broad categories: professional context (normative and cognitive) of development of science and interdisciplinary perspective on science policy. One of the major proponents of this generation was Merton (1973), who articulates how the institutional environment (norms and cultural values) fosters development and growth of science. He points out that sociology of science is not only a conceptual framework but also an empirical tool to observe phenomena underlying growth and development of scientific knowledge. He conceptualizes science as an institution that involves social process, viz. 1) ethos of science (cultural values and norms) guide scientific knowledge, 2) internal social structure of various disciplines (training, communication, information flow and evaluation) nurtures the development of the same, and 3) incentive system (reward system) motivates to publish the results. This tradition is called the 'Mertonian science'. Merton's contributions to the field are noteworthy and well known at this phase. Merton ventured into the area of sociological analysis of growth and development of science. Later it created interest to look at science as *social activity* shaped by social relations and interaction. Sociologically, it was necessary to identify the boundary of the scientific community and explore the bases of its place within the society. Merton explored the problematic of scientific knowledge in his monograph with special attention to the social as well as intellectual sources of investigation in science and became persuaded that further sociological analysis is required for more systematic conception of social structure of science (Merton 1973). Merton's thought was focused on the emergence of science as a social institution and its response to social interest. The study of science begins with its product, scientific knowledge, rather with the individual who occupies the social position of a scientist. Merton decided to concentrate on the social structure of science rather than to continue with study of the social contexts that influence its real output of knowledge. In his first phase of work in this regard, he explains the ideal norms to which scientists are familiar in their relationship to each other. These are universalism, communalism, disinterestedness and organizational skepticism. Firstly universalism implies that scientific claims and results are judged independent of social class, race and religion. Scientists are rewarded exclusively on the basis of the results obtained. Secondly, communalism refers to the idea that results and discoveries are not the property of the individual researcher concerned, but belong to the scientific community and society at large. This imperative is based on the assumption that knowledge is the product of a collective and cumulative effort by the scientific community. Thirdly, disinterestedness implies that every researcher pursues the primary objective of knowledge progress, indirectly achieving individual recognition. Lastly organized skepticism implies that every researcher must be willing to evaluate any hypothesis or result critically, including his/her own, and suspending final judgment until all necessary confirmations have been obtained. These are known as ethos of science. There have been attempts to measure the extent of commitment among the scientists to the norms identified by Merton. Mertonian institutional imperatives of science assume greater significance in context of ethics and war. Many contributions were made to SST perspectives based on Merton's paradigm and Harriet Zuckerman, Stephen Cole, Jonathan Cole, Diana Crane, Warren O. Hagstrom and so on are among those contributors. Sociology of science has expanded to various areas of research with a lot of empirical studies. Sociology of scientific knowledge examines how to deal with the social conditions of science as well as its effects of science. This also focuses on the social structures and processes of scientific activity (Coniglione 2010). This led to the second approach in the sociology of science.

### 1.2.2 Externalist Approach: Relativism in Sociology of Science and Technology

The phase of Mertonian science was severely criticized on the grounds of functionalist explanation of scientific knowledge which protects the substance of science and of scientific work and never allows criticism of the same. Such criticism originated in the later theories of Sociology of Scientific Knowledge (SSK), namely, relativist and constructivist traditions within Sociology of Science (Knorr-Cetina 1999). These two traditions focused on the assumptions of interest, conflict, construction of facts and interactions (material and non material elements) in scientific conduct. This field of research emerged in the 1970s and early 1980s, the major proponents of which are Barry Barnes, Gaston Bachelard, David Bloor, Paul Feyerabend, Martin Kusch, Bruno Latour, Lucy Suchman, Anselm Strauss, Harry Collins, Thomas Kuhn, Mike Mulkay and Steve Fuller. They argue that sociology of science left the cognitive content of science out of sociological account whereas sociology of scientific knowledge aims to provide sociological explanations of scientific ideas. The works of Thomas Kuhn (1962), David Bloor (1976) and Barry Barnes (1974) are important. Bloor (1976) and Barnes (1974) developed the relativist tradition of Sociology of Scientific Knowledge (SSK): contributing to the interest based approach in understanding the development of scientific knowledge and its cause – the strong programme in social studies of science. Bloor articulates the strong programme consists of three basic tenets; 1) causality – strong condition which brings about beliefs or status of knowledge, 2) symmetrical – describes the patterns of causal explanation of all beliefs and cognitive claims, whether true or false, rational or irrational, success or unsuccessful involving resource inputs such as material input, psychological processes and social processes and 3) reflexive – sociology of science as a tool to critically evaluate and explain sociology of knowledge itself. Barnes rejects Bloor's law and general theories in the sociology of science. He articulates legitimate interest (system of belief – focused on technical requirement of communities to justify cognitive and knowledge claim) and ideological interest (hiding the criteria of assigning positive values to cognitive structure) contributes to the growth of knowledge. He claims ideology as illegitimate claims. Manier (1980) suggests that there are huge differences existing between Bloor's argument on the strong programme and Barnes'. The former contrasted 'weak programme' with 'strong programme' which considers sociological factors as influencing all beliefs.

### 1.2.3 Sociology of Science in Constructivist and Postmodernist Era

Science and Technology Studies is the study of social, cultural and political values affecting scientific research and technological innovation and how the scientific research and technological innovation affect society, culture and politics. The historical growth of science studies has gone through fundamental transformation with the intervention of constructivist and postmodernist sociologists of science in which the Mertonain science is not only questioned but also revived with the changing context of scientific practice. This has started since 1945 when 'little science' turned to be 'big science' in socioeconomic, cultural, and political senses. For instance, science and technology are considered the most important components of development of any nation since 1945 onwards. It has become a well known social fact that more advanced a nation's science and technology is, the more advanced and modern a nation is. The S&T drives the process of modernization and secular form of society. It influences almost all aspects of our life and brings the science-society relations more closely than earlier. In this regard, Yearly (2005) argues that society is filled with technologies and with insights and beliefs derived from science. In modern culture, people think about themselves and their own lives through the lenses of science. In the mid-1980s, a crucial moment in the development of STS which brought into focus Social Construction of Technology by Bijker, Hughes, and Pinch (1987), Social Shaping of Technology by MacKenzie and Wajcman (1989). For instance, (Jasanoff 2004 and Nowotony et al. 2001) describe the relations between science and society as mutually influencing and shaping each other. They have conceptualized the relations between the two as co-production and co-evolution. To elaborate further, Rosenberg (1974) in his reviewed work states about

Marx's views on science, "just as the economic sphere and the requirements of the productive process shape man's political and social institutions, so do they also shape his scientific activity at all stages of history… it is not an autonomous sphere of human activity. Rather science needs to be understood as a social activity which is responsive to social, economic and political forces. It is man's changing needs as they become articulated in the sphere of production which determines the direction of scientific progress."

The SST in the 21st century looks beyond such dichotomies (Bourdieu 2003) to examine and interrogate the Mertonian empirically confirmed and logically consistent statement of regularity. Disenchantment with demarcation, autonomy and cognitive authority of science has led several scholars to delve into the examination of science in its historical integrity (Kuhn 1962).

The emerging frontiers of science and technology studies may be put in philosophical shorthand, "what is the normative import of contingency, rather than necessity as the modality for making sense of science and technologies" (Fuller 2008)? Fuller (2008) divides the field of science and technology studies into three fundamental problems, viz. demarcation (conceptual space occupied by science in our culture), democratization (political organization appropriate to science in society), and transformations (material horizons within which we want science to change our world including ourselves.

The SST perspectives, in this context, assume greater significance to understand the dialectic between science for-its-own-sake and the application of science for the development of our economy, culture and polity. The present study of scientific collaboration in rice biotechnology qualifies for the above argument. It explores two sets of issues: one, how collaborative practices have been changing in rice biotechnology research; and two, what are the underlying dynamics of such changes. How the knowledge is being produced with an orientation to human and non-human interactions. This would focus on how open scientific practice is facilitated and examines the means and methods of knowledge production. Moreover, it is also necessary to understand the changing culture of science and its practitioners. In this regard, the study employs different perspectives within sociology of science, which focuses on scientific collaboration, such as different modes of knowledge production, triple helix model, Actor-Network Theory (ANT), and sociotechnical aspects of scientific collaboration.

These theoretical approaches are important to explore the social, economic and political aspects of scientific collaboration in the field of rice biotechnology research.

### 1.2.4 Modes of Knowledge Production

The term 'mode 1' refers to a form of knowledge production comprising ideas, methods, values and norms – that emanated with the Newtonian mode of enquiry and then permeated to other areas of knowledge production. This form of knowledge production has since then set a normative benchmark. Science confirming to the framework and values of mode 1 was seen as sound science. Mode 1 involves new knowledge being produced primarily within individual disciplines, mainly in universities and other academic institutes. There is little direct connection to societal needs and the results of research are transferred at the end of the project to users who may or may not take up those results. There is also only fairly limited societal accountability required from those engaged in research in terms of justifying the expenditure of public funds used to support their work. There is a considerable degree of autonomy for those engaged in basic research in universities and academic institutes to choose their own problems on which to work (Gibbons et al. 1994).

In 'mode 2' knowledge is produced in a relatively broader framework of production. Such knowledge should be useful to an enterprise whether industry or government, or society more generally and this consideration is present right from the beginning of the knowledge production process. Knowledge is often produced under the aspect of continuous negotiations and controversies. Thus, mode 2, by contrast, generally involves multi-disciplinary or trans-disciplinary research carried out in a growing variety of institutions (i.e. not just universities) and with a blurring of the boundaries between the traditional sectors (university, industry etc.). Knowledge is increasingly being produced "in the context of application" – in other words, with societal needs having a direct influence from an early stage and with relatively explicit social accountability. However, the feature of mode 2 knowledge production that is most relevant to collaboration is its transdisciplinary character. In mode 2 transdisciplinarity has four distinct features:

First, the framework for the problem solving effort is dynamic and is constantly evolving. This is generated and sustained in the context of application and not developed first and then applied to the context later by a different group of practitioners. The problem solving effort certainly borrows elements from preexisting knowledge but the solution is not solely a product of the application of knowledge that already exists. Second, the solution to the problem constitutes of both empirical and theoretical components and therefore there is definite contribution to knowledge though it may not fit necessarily in any known disciplinary framework of knowledge. Transdisciplinary knowledge develops its own distinctly theoretical structures, research methods and modes of practice. Third, unlike mode 1 where institutional channels are used to convey the results, in mode 2 knowledge production the results are communicated to those who are active in the course of participation. The initial diffusion of the results occurs simultaneously with the process of production. When the original practitioners move to new problem contexts, further diffusion of results takes place. Despite the fact that problem contexts are transient and problem solvers highly mobile, communications networks are not broken and the knowledge contained in them is available to be reapplied in different settings. Fourth, transdisciplinarity is a dynamic process. A particular solution can provide the cognitive setup from where further advancement can be made but as far as the process of development and its applications are concerned, these cannot be predicted.

Scientific collaboration as phenomena could be located in mode 2 form of knowledge production, which involves a variety of actors engaged in knowledge production activities. It could be conceived as both means as well as outcome of mode 2 knowledge production. As scientific knowledge keeps on accumulating, its classification becomes more and more elaborate. This is what we are witnessing today with the number of scientific disciplines growing steadily. One of the outcomes of this process is the emergence of specialists and specialized knowledge. The amount of knowledge has increased and it has become impossible for a single person to have expertise in more than one domain. Specialized knowledge is at a premium for the firms, which are often at the forefront of serious competition, but its acquisition is difficult and often too expensive for individual firms to be produced entirely by in house research. To meet this exigency firms develop a complex array of collaborative arrangements involving universities, govemments and other firms sometimes from within the same sector. The next section provides a brief overview of triple helix model of knowledge production.

#### 1.2.5.1 Triple Helix Model of Innovation

The concept of the triple helix of university-government-industry relationships gained momentum in the 1990s by Etzkowitz and Leydesdorff (1997). It elucidates the transition from a dominating industry-government dyad in the industrial society to a growing triadic relationship between academia, industry and government in knowledge society. Industry operates in the triple helix as the locus of production; government as the source of contractual relations that guarantee stable interactions and exchange and the university as a source of new act of knowing and new act of doing. The increased importance of knowledge and the role of the university in incubation of technology-based firms have given it a more prominent place in the institutional firmament. Universities, heretofore primarily seen as a source of human resources and knowledge, are now looked to for generating technology as well (Leydesdorff and Etzkowitz 1998). The triple helix paradigm is premised on three helices: state, academia, and industry. Etzkowitz and Leydesdorff (2000) forwarded different modes of interaction between the helices. In the "strong state" model the government controls academia and industry, whereas in the "laissez-faire" model each of the three helices develops quite independently, separated by clear borderlines. Finally, in the model of "trilateral networks and hybrid organizations," the dynamics of the helices can be best characterized by increased overlapping and the emergence of so-called hybrid organizations at their interfaces. This pattern of amplified scenario is preferred for the development of advanced and knowledge-based economies. Communication is important for R&D interaction within and between the helices. Communication helps in establishing complex networks, feeds into these, and partially also recodes networks. On the one hand, interaction across different helices is not necessarily stable, implying that an *a priori* synchronization of process is not possible in a triple helix framework. Through mutual co-evolution of the helices and adaptations in the university-industry-government arrangements, a certain degree of stable development, however, can be achieved. This may lead to the formation of a globalized regime. General propositions of the triple helix are that (1) government-industry arrangements can cross-cut specific industrial sectors and link regional, national, and international clusters; (2) the "expectations of profit" is important for driving networking; (3) the modeling of innovation in a society may run through different stage; (4) the human capital factor gains in importance; (5) tensions resulting from the impossibility of a perfect *a priori* synchronization of interaction between the helices are not necessarily seen as negative, since they accelerate the dynamics of the whole system; (6) conventionally, the communication patterns within a helix (the specific context of academia, industry, or the state) express a higher degree of density among the helices following the maturing of an advanced knowledge-based society, also an increase of communication is expected that cross-cuts and connect the different helices (Etzkowitz and Leydesdorff 2000).

### 1.2.5.2 Mode 3 Form of Knowledge Production – Quadruple Helix Model of Innovation

Mode 3 form of knowledge production is relatively a recent phenomenon propounded by Carayannis and Campbell in 2006. It is developed by expanding and extending the "mode 1" and "mode 2" knowledge production systems. It consists of "innovation networks" and "knowledge clusters" for knowledge creation, diffusion, and use (Carayannis and Campbell 2006). This is a multilayered, multimodal, multinodal and multilateral system, encompassing mutually complementary and reinforcing innovation networks and knowledge clusters consisting of human and intellectual capital, shaped by social capital and underpinned by financial capital (Carayannis and Campbell 2006).

The mode 3 knowledge production system architecture focuses on and leverages higher order learning processes and dynamics that allow for both top-down government, university, and industry policies and practices and bottom-up civil society and grassroots movements initiatives and priorities to interact and engage with each other toward a more intelligent, effective, and efficient synthesis. Putting it succinctly mode 3 per the comments above is the knowledge production system architecture that engages actively higher order learning (learning, learning-to-learn, as well as learning-to-learn-how-to-learn (Carayannis 1994; Carayannis 2000) in a multilateral, multimodal, multinodal, and multilayered manner involving thus entities from government, academia, industry and civil society. It drives co-competition, co-specialization, and co-evolution resource generation, allocation, and appropriation processes that result in the formation of modalities such as innovation networks and knowledge clusters. These modalities form as they represent topologically and thematically optimal resource agglomeration and leveraging schemes in the context of a mode 3 knowledge production system architect.

The "mode 3" knowledge production system is, in short, the nexus or hub of the emerging twenty-first century innovation ecosystem, where people, cultures and technologies (Carayannis and Gonzalez 2003) meet and interact to catalyze creativity, trigger invention and accelerate innovation across scientific and technological disciplines, public and private sectors: in a top-down, policy-driven as well as bottom-up, entrepreneurship empowered fashion. One of the basic objectives of such an attempt is co-existence, co-evolution, and co-specialization of different knowledge paradigms.

### 1.2.6 Actor-Network Theory (ANT)

The ANT was propounded by Bruno Latour, Michel Callon, and John Law in early 1980s to describe and explain the entanglement of the social and the technological (Callon 1999). It is a material-semiotic approach in that it studies associations and connections which are not considered either social or technical, but simultaneously social and technical (Latour 1999). Putting it succinctly, the social and the technical are inseperable. The unit of analysis is actor-network, an ordered network of heterogeneous human and nonhuman actors, including people, organizations, things or animals. Hence, an actor-network is made of, and links together, both social and technological entities. The ANT links the terms actor and network in order to avoid the dualism between agency and structure, which has been a main concern in sociology for a long time. Callon (2005) affirmed that an actor is "made up [not only] of human bodies but also of prostheses, tools, equipment, technical devices, algorithms, etc." Agency is not seen as a property of individuals, not of institutions, cultural values, or symbolic systems, but it is a property of hybrid networks composed of humans and nonhumans.

The centrality of ANT is about the heterogeneous network. In other words, the participation of multiple actors forms the structured pattern of network among humans and non-humans in which the scientific language becomes a medium of communication. In a sense, ANT maintains people and objects as equal and also clarifies that this position does not treat humans as machines in theorization. However, it highlights that social agent or actor is not a body alone, rather a patterned network of heterogeneous relations that are social in nature. Like earlier proponents of sociology of knowledge, Law maintains that knowledge is a social product or outcome of a heterogeneous network generated through constant interaction between people and machines, animals, texts, money and architecture, etc. The task of sociologists of science is to characterize these networks in their heterogeneity, and explore how they come to be patterned to generate, organize and co-produce knowledge in which exploring the social relations in terms of power, resistance and domination becomes the prime means for addressing the social inequality in the process of manufacturing knowledge. We often see disorder not in a single block, but in the network itself. The existence of a permanent social order depends on local process of patterning, ordering and resistance. Understanding such processes helps us explore the social conditions which contribute to the persistence of power, domination and resistance. One may examine 'network as resource' like agents, devices, technologies, etc, that contributes to the survival of the network itself.

### 1.2.7 Emergence of Hybrid Scientific Community: Transdisciplinary Approach to Science

The pluralist orientation to knowledge production has emerged with the notion of capitalization of knowledge/commercialisation. It has created fundamental transformation in the way the university (academia) used to function earlier limiting its role only to knowledge development. With the orientation to commodification of science, culture of doing science witnessed transformation in terms of emergence of entrepreneurial university and science that was closely associated with the scientist-entrepreneur relations or industry-academia interactions. With the increase in specialization and diversification of knowledge, the organizational landscape of knowledge production has changed. Science has become internally fragmented with the increase in new theories of sciences and its applications in a variety of fields. In this regard, a research problem (academic and industrial) is approached from the multi-disciplinary point of view. This approach has increased the participation and communication in heterogeneous knowledge development processes which led to the formation of hybrid scientific community and collaborative research. This group formation is a potential source for the emergence of multi-disciplinary and trans-disciplinary research programmes. On the one side, it creates a common culture and a common language within the scientific specialties and forms new sub-culture within the structure of scientific knowledge production. For instance, Graham (2003) puts forth three interconnected concepts to define transdisciplinary mode of knowledge production: 1) contextualization (collectively accepted as problem); 2) transgressiveness (brings all the specialization and experts into the production of knowledge); and 3) hyper-rationality (logics and evaluation of knowledge production decided by multiple perspectives and methods). On the other side, the collaborative research creates conflicts and tensions due to conflict of interest and eventually the initiative comes to an end. Various scholars (Rose and Rose 1976; Uberoi 2002) claim that the mission mode research as complex military-industrial and commercial research in which different sub-disciplinary cultures, machines, materials and practices and business strategies are employed. This kind of research practice brings in conflict between research goals and societal values. This larger transformation of science is called 'post-academic science' (Ziman 1996) which is a hybrid of academic and industrial research in general (Nowotny 2006). Within this network of relations, boundaries are getting blurred among organizational setting.

### 1.2.8 The Ontology of Sociotechnical Aspects and Epistemological Consequences

Collaborations are seen as being held together by sociotechnical aspects of work organization. These sociotechnical aspects form a set of structural relations that either enable or constrain actors' decisions and activities. Treating sociotechnical aspects as structural means that they are more or less stable entities that shape – but are relatively unshaped by – the actions that take place on the stage (Bijker and Law 1992): examining these aspects as more or less stable entities does not imply to discard the belief in their ongoing, unfolding, temporal and constructive nature, asserting that sociotechnical aspects are constructed means that their role is not fixed and predefined, but it does not imply that they do not exist.

Reducing them to social construction of meaning would deny their capacity of making resistance. The ANT's position on realism has been a subject of controversy between those who criticized it for leading to an extreme form of constructivism and those who see a commitment to some sort of realism (Sismondo 2010). The concept of 'quasi object' (Latour 1992) describes the ontological nature of sociotechnical aspects:

> …much more social, much more fabricated, much more collective than the "hard" parts of nature, but they are in no way the arbitrary receptacles of a full-fledged society. On the other hand, they are much more real, nonhuman and objective than those shapeless screens on which society – for unknown reasons – needed to be "projected" (Latour 1992).

Based on these premises, sociotechnical influence on collaboration is contingent and does not follow a necessary trajectory. Pivotal actions and unexpected events may create change in trajectories. Hence, enablements and constraints are not intrinsic to sociotechnical aspects but are the effects of their interplay with what actors do. This position avoids treating the structural relations formed by sociotechnical aspects as a "predetermined context". As Latour (1996) affirms, in a given context the same project does or does not feel an impact. The same set of structural relations can bring about contrary effects. A "predetermined context" is an abstract notion devoid of real people and things. As he said, every context is composed of social and technological entities that do or do not decide to link their interests and ambitions to the fate of a project.

Instead of assuming a division between collaboration and context, the description of collaboration and its context occur simultaneously (Callon 1991) by describing the making of collaboration through the network of actors' decisions and actions and their interplay with sociotechnical aspects. This relational epistemology holds promise for understanding the connections between sociotechnical aspects and the processes of formation and development of collaboration. To understand these connections, these processes must be unpacked, described and explained. Unpacking these processes implies two things: (a) investigating which voices are represented, which intentions are realized, which interests are spoken for, and which patterns of action are embedded in; and (b) bringing back to surface the voices of the relevant stakeholders, both human and nonhuman. The voices of the stakeholders may emerge through the analysis of inscriptions, e.g. documents, artifacts, work routines, legal documents, prevailing norms and habits, and organizational arrangements and procedures which materialize the translations of their interests, as well as through the analysis of interviews with the stakeholders. Particular attention needs to be paid to the actors that are "left out", in the sense that they are not represented by the voices speaking through the sociotechnical aspects under observation. This sensitivity is necessary to avoid taking into consideration only the actors whose interests have been explicitly translated and whose status is higher, and downplaying or neglecting the interests of underprivileged stakeholders. Following Callon (1991), four aspects of inscriptions must be explored: (a) what it is inscribed; (b) who inscribes which stakeholder(s); (c) how it is inscribed, and (d) how powerful it is (what it takes to go against the inscription). This last point relates to the level of irreversibility of the translations of the interests inscribed. Some inscriptions "bind" the aligned actor-network, some others may provide some room for flexibility and change. Some inscriptions become actors and trigger the formation of new networks, whereas some others play an intermediary role.

### 1.2.9 Theory of Remote Scientific Collaboration (TORSC)

The TORSC was propounded by Olson et al. in 2008, delineating various sociotechnical aspects that are important in the success or failure of remote collaboration in science. Drawing from the data collected for the SOC project (SOC 2003), and from literature on computer mediated communication, organizational, behaviour, management information systems and science and technology studies, Olson et al. (2008) have clustered abroad set of success measures into five key factors. These factors were first described in Olson and Olson (2000), with the exception of the management issues. In their seminal work, Olson et al. (2008) pinpoint five key elements that shape distributed collaborations and are vital to collocated (intra-institutional) projects. These factors constitute the nature of work, the quantum of common ground among partners, partners' readiness to collaborate, collaborators' management style and leadership and technology readiness. The main argument of TORSC is that groundbreaking thinking can occur because collaboration involves working together of scientists from diverse backgrounds, which brings in multiple perspectives to carry on a common objective or problem. Technology fosters smooth functioning of collaboration. It enables distant and diverse scientists to carry and coordinate their collaborative projects. They affect collocated collaborations but appear to be critical to distributed projects as well.

Nature of the work implies coupling of work and division of labour. One of the keys to success is dividing the work of the team so that it can be done with relative ease. The more modularized the work at the different locations, the more likely is success. Sometimes work requires participants to continually define and refine their understanding of what to do as well as how to do it because it is new, somewhat ambiguous, or highly interdependent, requiring what has been called ''tight coupling'' (Olson et al. 2002) or what James Thompson (1967) refers to as reciprocal interdependence.

The common ground indicates that in order to make collective progress, people engaged in collaboration need to have mutual knowledge, beliefs, and/or assumptions, and know that they have this (Clark 1996; Clark and Brennan 1991). Collaborations can be hindered if one or more of these aspects of common ground are absent. The ability to work toward common ground is more difficult when the collaborators are geographically distributed.

Understanding what motivates people to collaborate, whether they trust each other, how well their goals are aligned, and how empowered they feel are all important to success, a concept we collectively call collaboration readiness. These factors can be related to work or personal and social dimensions.

Collaboration management, leadership and decision making deal with the ways in which the work of a distributed collaboration is organized and carried out. The skills that leaders possess and the time they have to devote to running the collaboration, the effectiveness and timeliness of communication, the mechanisms for decision making, and the clarity of institutional and individual roles as well as responsibilities are all critical aspects of management. The larger the collaboration, the more significant these elements become (Cummings and Kiesler 2005).

Virtually all collaboratories connect people via technology for both communication and core work. Many collaboratories use generic or commercially available tools like e-mail, instant messaging, data or video conferencing (like WebEx or Centra Symposium), and basic file servers. Others use specially designed and built software, like the Environmental Molecular Science Laboratory's online laboratory notebook. The adoption of any technology, whether off the shelf or custom designed, is driven by its fit to the work (providing the right functionality) and ease of use (Olson et al. 2000).

## Part B – Politics and Sociology of Scientific Collaboration

### 1.2.10 Meaning of Collaboration

Collaboration in research and/or development is assumed to be 'a good thing' and thus it should be encouraged (Katz and Martin 1997). There is considerable policy enthusiasm for collaboration. However, collaboration is difficult to define. Partly, this is because the notion of research collaboration is largely a matter of social convention among scientists. What some might deem collaboration, others may merely regard as a loose grouping or a set of informal links. In reality, the concept of collaboration is not fairly understood, it has multiple meanings in practice and is a complex phenomenon.

The lexical definition of collaboration suggests 'the situation of two or more people working together to create or achieve the same thing' (https://dictionary.cambridge.org, accessed on August 26, 2014). Thus research collaboration could be defined as the working together of researchers to achieve the common goal of producing new scientific knowledge. But how close the researcher should work to be considered a collaborator? At one extreme we have whole galaxy of scientific community coming together through conferences, seminars etc, and sharing ideas, hypothesizing them, deciding on the instrumentation to be used, coming out with different theoretical models, testing the hypotheses, seeking the advice of experts, and so forth. Some scientists give shape to the idea through designing experiments and some research fellows perform those experiments and finally technicians. This means anybody giving inputs would be part of the collaboration. Moreover, the basic science is truly a global activity and involves discussions and deliberations among the scientists coming from different geographical locations and disciplines and thus also showing a form of collaboration. However, this is one of the weakest definitions of collaboration as it brings in so large numbers of collaborators that it becomes impractical for any fruitful activity.

Collaboration occurs wherein only people who contribute directly to all the main research tasks over the duration of the project. No single individual could possess all the knowledge required to contribute to all aspects of a complex piece of research, an interdisciplinary project or a 'big science' experiment. The boundaries of collaboration are fuzzy and the contours are defined is a matter of social convention and is open to negotiation. Perception about boundaries may vary across institutional structures, fields, sectors, countries and so on (Katz and Martin 1997).

Because of this multidimensional and multifaceted study of the concept of research collaboration, a common definition of the term does not exist (Bukvova 2010). Amabile et al. (2001) define collaboration among the individuals who differ in notable ways, as a process of sharing information and working towards a particular purpose. Jassawalla and Sashittal (1998) define it as the coming together of people having diverse interests to achieve a common purpose and goal through interactions, sharing of information and coordination of their activities. Sonnewald (2007) emphasises on the social context of research collaboration and its place within scientific community. According to him, scientific collaboration can be defined as interaction taking place within a social context among two or more scientists that facilitates the sharing of meaning and completion of tasks with respect to a mutually shared, super ordinate goal. Scientists who collaborate may also bring about additional individual goals to collaboration. This fulfillment of the individual goals adds to their efficiency and motivation and enhances the chances of collaboration becoming successful thus increasing the scientific productivity. Melin and Persson (1996) also provide a similar understanding of collaboration. They also point out the importance of communication as well as sharing of competences and resources. Katz and Martin (1997) suggest some putative criteria for distinguishing collaboration from other researchers, according to whom collaborators will normally constitute the following:

- People who work together on the research project throughout its duration or for a large part of it
- Those whose names or posts appear in the original research proposal.
- Those who make frequent or substantial contributions.
- Those responsible for one or more of the main elements of research (e.g. the experiment design, construction of research equipment, execution of the

experiment, analysis and interpretation of the data, writing up the results in a paper).

- Those responsible for a key step (e.g. the original idea or hypothesis, the theoretical interpretation).
- The original project proposer or fund raiser, even if his main contribution subsequently is towards the management of the research (e.g. as team leader) rather the research per se.

The group of collaborators will generally exclude the following:

- Those who make only an occasional or relatively minor contribution to a piece of research;
- Those not seen as, or treated as, 'proper' researchers (e.g. technicians, research assistants).

The above mentioned criteria provided by Katz and Martin leave scope for much subjectivity in determining who all would be considered collaborators and who would not be. In a nutshell, scientific collaboration is an interaction between two or more individuals, a knowledge producing activity, and a goal-oriented action. A critical review of studies on these dimensions of collaboration will help us understand the role of collaboration in plant biotechnology research.

### 1.2.11 Classifying Scientific Collaboration

Research collaboration can be characterized in terms of the disciplines involved, the geographical setting, and the organizational and community focus (Sonnenwald, 2007). Collaboration can involve participants at different levels, from the micro-level of individuals (e.g., dyads, triads), to the meso-level of departments and institutions, and the macro-level of countries (Sonnewald, 2007). Katz and Martin (1997) offer a very good starting point by looking at the different levels of collaboration, thereby distinguishing among individuals, groups, and departmental, institutional and national levels.

**Table 1.1: Different Levels and Forms of Collaboration**

| Level | Intra | Inter |
|---|---|---|
| Individual | - | Between individuals |
| Group | Between individuals in the same Groups | Between groups (e.g. in the same Department) |
| Department | Between individuals or groups in the same department | Between departments (in the same institution) |
| Institution | Between individuals or departments in the same institution | Between institutions |
| Sector | Between institutions in the same Sector | Between institutions in different sectors |
| Nation | Between institutions in the same Country | Between institutions in different countries |

Source: Katz and Martin (1997)

The need to make an analytic distinction between individual and organization varies according to the purpose of a study. The present study does not attempt to make a distinction between the two dimensions because they are dependent. Creating a dualism between the two levels runs the risk of configuring organizations as structures with a capacity to collaborate on their own. Instead, it is important to establish a link connecting the two levels, to make visible the individual in the organizational and vice-versa. Collaboration is not a process engaging either individuals or groups disembodied from their organizations, or organizations devoid of individuals. A collaborator often operates in a set of organizational and material circumstances that contribute to the shaping of the processes and their outcomes.

### 1.2.12 Motivations for Collaboration

A general rise in collaborative research necessarily poses a question: why do researchers collaborate? Many authors have tried to explore the reasons by conducting studies in the form of questionnaires put to the researcher in order to gauge their expectations from the collaboration. Collaboration grows historically as science gets institutionalized and professionalized and becomes a mechanism for both gaining and sustaining access to recognition in the professional community (Beaver and Rosen 1978).

Besides macro structural circumstances there are also individual reasons for collaboration. Even if the collaboration is between organizations or the institutions, the study of motivating factors for collaboration at the micro level is important because individuals also try to further their personal goals and aspirations through organizational mandates (Melin 2000). Therefore it is important to understand and examine organizational mandates and personal goals of the researcher.

These two goals should not be mutually exclusive and should be in tandem in order to generate scientific knowledge. There are many motivations for the researchers to pool in their resources and enhance the frontiers of knowledge. With the use of cutting edge technology, research has become very expensive. It is not possible for the funding agencies to provide facilities to every research group separately. Therefore, pooling of resources by different scientists is being encouraged by the government and other non-government funding agencies (Birnholtz 2007). Access to sophisticated and expensive instrument is one of the major reasons for collaboration to take place (Bozeman and Corley 2004). Researchers also collaborate to gain the expert knowledge, which is otherwise not available. Every part of scientific knowledge cannot be communicated through publications. There are certain tacit components of scientific knowledge which can be conveyed through collaboration (Lee and Bozeman 2005). There are other factors that have encouraged collaboration. Air transportations and communication have become relatively cheaper. Nowadays people from far off places can communicate in no time through electronic mail and fax. This enhanced connectivity has stimulated researchers across the globe to shed the years of isolation.

Beaver and Rosen (1979a) examine many motives of collaboration taking place such as access to special equipment and facilities, access to special skills, access to unique materials, access to visibility, efficiency in use of time, efficiency of use of labor, to gain experience, to train researchers, to sponsor a project, to increase productivity, to multiply proficiencies, to avoid competition, to surmount intellectual isolation and need for additional confirmation of evaluation of a problem. Some collaboration is serendipitous also. Drivers of collaboration can be a single factor from the above mentioned factors like access to a robust and sophisticated instrument without which research is not possible or it can be the outcome of many different motivations.

Melin (2000), in his survey of 195 university professors, studies their motives for collaboration and the chief benefits of collaborations. Around 41 per cent of them answered that their chief motive for collaboration is that the co-author has special competence. Other common motives included co-author has special data or equipment (20%), social reasons such as old friends, past collaboration (16%), supervisor-student relation (14%). With regard to the benefits of collaboration, the respondents point to increased knowledge (38%), higher scientific quality (30%), contacts and connections for future work (25%), and generation of new ideas (17%). Scientists collaborate for pragmatic reasons too.

Heinze and Kuhlmann (2008) mention a number of factors involved in motivating the researcher to collaborate. Access to resources, which is otherwise difficult to have one's hands on, is an important motivational factor for entering collaboration. Government and other funding agencies are embracing collaboration. So access to funding is also an important stimulator for forging collaboration. Also it helps in enhancing the skills of the researchers as much collaboration is cross-disciplinary so it helps in getting the skills of the researchers as well as insights from other disciplines. It also helps focus on one's own activity.

As intellectual collaborations yield high impact factor and highly cited publications, a new trend of increase in international collaboration is seen across many disciplines. Although, spatial proximity play an important role in bringing researchers together to form collaboration. But it does not hold true in many of the cases as information and communication technologies have reduced the boundaries between the countries. Ideas and information can be freely exchanged in no time using internet. Scientists collaborate based on preferential treatment i.e. they mainly collaborate for rewards and recognition (Wagner and Leydesdorff 2005). All other factors, namely, ICTs and spatial proximity, funds are mere enablers of collaboration not the facilitators, recognitions and rewards by the peer group are the main facilitators of collaboration.

The above-mentioned studies have indicated that socio-cognitive factors are main drivers of collaboration, although different authors differ in their opinions about the role of social or intellectual forces in stimulating collaboration. Collaborative authorship arises more from economic than from intellectual dependence.

### 1.2.13 Critique of Collaboration

The team work and collaboration have become a central feature of scientific research and there is a growing trend and increasing pressure towards undertaking larger research projects which are inter or multi-disciplinary and multi-institutional multi-sites and international, and involve managing complex research teams (Montz et al. 2003). Factors related to funding mechanisms, career incentives, government rewards for increased productivity, the maturation of discipline, increased complexity and scale research, and ease of travel and information technology have fuelled research in this direction.

Although this trend is proliferating, there has been little dialogue about the relationship between collaborative research, as an academic mode of production and the knowledge that it produces. The scientific community has been generally reflexive and in its adoption of team-based research models and practices. This appears to be an unspoken assumption that team research is better than solo research (Mauthner and Doucet 2008).

There are serious lacunae in our cognizance of academic collaborative processes and it is tough to ascertain precisely what goes on in real practice within the team. Even the social science guidelines on research conduct issued by professional associations like British Sociological Association and funding agencies like Economic and Social Research Council mainly speak about the issues of authorship and a brief mention of power relationships within research teams. The issues of collaborative relations and practices are hardly addressed. Even the scientific journals do not require authors to detailed divisions of labour within research teams. In contrast, eminent scientific journals such as *Nature* have recently adopted a policy of encouraging authors to incorporate a statement to specify the contribution of each co-author describing the research tasks of individual authors.

**1.2.13.1 Hierarchies of Knowledge within Research Teams**

Collaborative research can take up different forms and divisions of labour and may vary across the research teams contingent upon the nature of the research, size of the project, structure and organization of the team, and the research questions involved. Division of labour can also change over the course of a project. The distribution of tasks and the joining of specialized work enable collaborators to increase their efficiency and enhance the overall quality of their work since groups of individuals may be able to handle research problems faster and in a better way than a single researcher.

Collaborative research is valued high because of its ability to build a platform where multiple researchers with distinctive and specialist perspectives come together to tackle large or complex research problems. Viewing it from the pluralistic stance of postmodern and post- foundational epistemologies, the bringing together of multiple researchers and perspectives is seen to give team research an epistemological edge over individual research. But the problem remains as to how these viewpoints are accommodated in practice.

Division of labour as practiced in current times generates hierarchies of knowledge. Researchers bring in different personal and academic backgrounds to the research, and their differential involvement and motivations in research tasks generates different types and levels of knowledge. Each researcher develops a project related knowledge base that is partial and is reflective of their particular position in the unit. As Wasser and Bresler (1996) have argued, 'knowledge once divided can be hard to put together again'. Still the putting together of multiple perspectives in the construction of knowledge has been largely taken for granted and is not problematized by the scientists. This normative division of labour practiced within qualitative scientific research teams gives rise to hierarchies of knowledge production.

This division of labour reflects and reinforces the differential status, value and worth of research tasks and of the researchers carrying them out (Mauthner and Edward 2007). The division of academic labour between grant holders and contract researchers becomes constituted as a mental and manual one in which fieldwork is downgraded and trivialized as the mechanical collection of data by dehumanized machine. Division of labour in this way gets translated into academic hierarchies of knowledge in which distance is equated with the objectivity and understanding is acquired through a detached positioning as superior to that gained through conducting fieldwork (Mauthner and Doucet 2008). Fieldwork is viewed as a technical activity that can be performed by anyone, rather than an intellectual process in which meaning and the knowledge are being and shaped and created by subjective researchers. But to recognize fieldwork as knowledge producing activity means regarding contract researchers as intellectual partners are equally engaged in the production and construction of knowledge. This radically shifts the power relations and dynamics within research teams.

#### 1.2.13.2 Decontextualization of Knowledge

In social science research, it is a standard practice to condense realities into textual forms. Data from the fieldwork and interviews with respondents are converted to text in the form of transcripts. Interviews are conducted and recorded in the field by a researcher, and are sent to other staff members who apply statistical tools and interpret the data. In this process, much of the context that gives meaning to the textual transcript, and that the interviewer would be aware of, is lost. Other than the difficulty faced by a researcher in reducing what was recorded in the interview in the form of the transcript, there is also a problem of depriving or misinterpreting the context of the study. The nuances of the language and all the nonverbal signs, coordinated with the verbal ones, which indicate either how a given utterance is to be interpreted or how it has been interpreted by the speaker gets eroded.

Some researchers despite being the part of a collaborative work or project work in an individualistic manner such that the product of such work appears to be a federation rather than a unified whole. Although there are some examples of teams working in collective, synergistic and reflexive ways in developing knowledge, much of team research is characterized by solitary practices with researchers tackling tasks on an individual basis (Barry et al. 1999). Rarely, researchers in a team come together systematically as an interpretive community where the multiple and distinctive subjectivities and perspectives of the researchers, including those who conduct fieldwork, are exchanged in an interpretive zone. Rather, there is a tendency to decontextualize, reduce and objectify fieldwork into textual transcript (Mauthner and Doucet 2008).

Researchers engaged in limited explicit reflexive processes take into account the contexts, subjectivities and research relationships through which the texts and the knowledge are produced and are made meaningful. The problem of decontextualization of knowledge arises mainly where there is a separation of data collection from data interpretation. This trend is seen quite often in social science research where data collection is given to contractual researchers. Contract researchers collect data and at times are even involved in the initial interpretation by coding the data thematically. The final interpretive work and moulding of the data into theoretical framework is often done by lead researchers or grant holders (Wasser and Bresler 1996). The people who are involved in final interpretation are required to make sense of textual data in the absence of much of the contextual, tacit knowledge that plays a subtle but significant role in providing meaning to the study. This tacit knowledge component is taken for granted and assumed to be of no significance in understanding the nature of work.

One of the main epistemological objections to division of labour as currently practiced is that they privilege textual over contextual knowledge. Knowledge that can be objectified in textual form takes precedence over the contextual knowledge and embodied knowledge surrounding the production of texts, data acquired through physical presence in the field. These practices, which give insistence on discursive or textual materials, disown the eyes, ears, and skin through which researchers take in the intuitive perceptions of the world. Hence, marginalizing non-textual, embodied and sensual knowledge come to be viewed as background information rather than as data or knowledge in their own right (Mauthner and Doucet 2008).

## Part C – Measurement of Scientific Collaboration

### 1.2.14 Measuring Collaboration

How to measure scientific collaboration is a subject of contention among scholars. It is difficult to measure collaboration accurately because it involves complex human interaction and intangible inputs. However, across the time and space scholars have developed a few methods, qualitative and quantitative, to measure collaboration. Quantitative methods primarily constitute of bibliometric studies and qualitative method comprises observations, interviews, focus group discussions, questionnaires, case studies and so forth. For decades bibliometric studies, frequently referred to as a co-authored publication, has been used as a basic counting unit to measure collaborative activity. The term "bibliometrics" is assigned to Pritchard (1969), who defines it as: "… the application of mathematics and statistical methods to books and other media of communication." Bibliometric studies use the public evidence of research activity, most often papers and reports, patents and agreement as indicators of trends and processes. Co-authorship is typically employed as an indicator of collaboration. Because scientific journal articles include the organizational affiliations of the authors. Bibliometric studies can determine trends in collaboration across nations and across areas of science (Shrum, Genuth and Chompalov 2007). Smith (1958) was one of the first researchers to observe an increase in the incidence of multiple-author papers and to suggest that such papers could be used as a proxy measure for collaboration among groups of researchers. However, he warned that nothing short of a complete description of the kinds of relationships and activities of all persons concerned in the final product would give an approximation of the amount of group effort going into the papers presented. Subramanyam (1983) took the argument further and suggested that one needs to adopt a holistic perspective while evaluating collaboration because the nature and magnitude of collaboration cannot be easily determined by the usual methods of observation, interviews or questionnaire. The complex nature of human interaction that takes place between or among collaborators over a period of time and the nature and magnitude of contribution of each collaborator will change during the course of a research project. Furthermore, only some of the more tangible aspects of a collaborative piece of work can be quantified while others most certainly cannot. Even a qualitative assessment of collaboration is extremely difficult because of the indeterminate relationship between quantifiable activities and intangible contributions. For example, Subramanyam (1983) notes that a brilliant suggestion made by a scientist during casual conversation may be more valuable in the shaping of the course and outcome of a research project than weeks of labour-intensive activity of a collaborating scientist in the laboratory. Bibliometric analysis of multiple-author papers can only be used as a partial indicator of collaborative activity (Katz and Martin, 1997): collaboration cannot be synonymous to co-authorship nor to co-inventorship. Co-inventions are often based on a formal contractual agreement that stipulates the modalities under which intellectual property will be shared. Co-authorship is a result of values and day-to-day practices. Both reflect to some extent collaborative efforts and engagements and thus both are imperfect or partial indicators of research collaboration on various levels.

The more serious limit on co-authorship data is that such data cannot generate insights into the internal dynamics of collaboration. Bibliometric studies examine group specific collaborative projects in static snapshots, without any indication of the underlying processes of formation, organization and outcomes. The published result is the only evidence of collaboration, divorced from social organization and context. Why did these scientists collaborate? How important was the distinction between leaders and followers? How often did they meet? How did they resolve their difficulties? In short, what happened during the process of collaborative work (Shrum, Genuth and Chompalov 2007)?

Anthropologists and sociologists have observed collaborative research projects and have provided important interpretive tools (Traweek 1988; Zabusky 1995; Collins 1998; Knorr Cetina 1999). Qualitative studies do overcome the main limits on bibliometric research, but they represent a beginning rather than an end. They share a microsociological focus, a qualitative methodology, acultural-anthropological or narrative orientation, and (owing to the research intensity required by the approach) an emphasis on single organizations, centers, or projects. Their strengths are in providing theoretical guidance, identifying social processes, and raising questions about important organizational and cultural dimensions. But when the findings of these studies are contrasted, they display such diversity as to defy generalization. Qualitative case studies, while illuminating both structural and cultural aspects, are unable to provide a systematic assessment of the relative importance of one process over another. Dimensions such as communication, the division of labour, work as a process, technology, negotiation, and size are all “crucial” to the scholar who discovers their importance, but little attempt is made to show why some may be more important than others (Shrum, Genuth and Chompalov 2007). Therefore, it is evident that bibliometric method and other qualitative methods have their own merits and demerits and neither of them qualifies as a perfect indicator of collaboration.

### 1.2.15 Co-publication as an Indicator of Collaboration

Even though co-authorship is by no means a perfect indicator it is frequently used and widely accepted for the analysis of research collaboration. Co-authorship equates collaboration with publications listing two or more authors, two or more institutions, two or more countries. In much of this work, collaboration has been simply equated with co-authored papers. In particular, the increase in the incidence of multiple-authorship has been seen as an evidence of growth in collaboration. The notion that a unit of collaboration may be adequately defined in terms of multi-authored papers, and that the latter may be utilized to measure collaborative activity. Katz and Martin (1997) argue that co-authorship should only be seen as a "partial indicator" to measure research collaboration because only those activities, which eventually lead to jointly authored papers, are reflected. Not all collaborations, however, result in publications and conversely, a joint paper does not always mean that the results presented are based on research collaboration. Contrary to this, Glänzel and Schubert (2004) outline that this is in particular the case as far as intramural collaboration is concerned while in the case of international collaboration the parties involved are, as a rule, well acknowledged. They conclude that even taken into consideration those problems as well as the phenomena of multi-institutional authors, co-authorship "seems to reflect research collaboration between institutions, regions, and countries in an adequate manner" (Glänzel and Schubert 2004) and thus may be used as an analytical tool.

Despite the limitations of co-authorship measures, many studies have used this technique to investigate collaboration. For example, de Solla Price (1963) was an early advocate of the use of multiple-author papers as a measure of changes in collaboration. He produced evidence to support Smith's observation that multiple-authorship has been increasing, a trend since confirmed by several other investigators (Balog 1979, 1980; Beaver et al. 1978, 1979a, 1979b; Hicks and Katz 1996; Meadows 1974; Merton 1965).

However, such studies have also shown that the rate of increase in multiple-authorship varies with subject areas (Hicks and Katz 1997; Meadows 1974).

There is general consensus that the observed growth in multiple-authorship is evidence of an increase in collaboration (Beaver et al 1978, 1979a, 1979b; Clarke 1964; Gilvarry and Ihrig 1959; Meadows et al. 1971). However, the assumption that multiple-authorship and collaboration are synonymous must be qualified with the recognition that in some instances not all those named on a paper are responsible for the work and should not share the credit accorded to it. For example, Hagstrom (1965) found evidence that some publications listed authors for purely social reasons. More recently, the investigation of several instances of scientific fraud has revealed how common the practice of making colleagues honorary co-authors has become (Follette 1992). Although the assessment of collaboration using co-authorship is by no means perfect, it has certain advantages (Subramanyam 1983):

- It is invariant and verifiable given access to the same data-set, other investigators should be able to reproduce the results;
- It is a practical method for quantifying collaboration;
- Due to the size of sample that it is possible to analyse using this technique the results should be statistically more significant than those from case-studies.

Subramanyam (1983) argues that bibliometric studies are unintrusive and non-reactive, that is, the measurement does not affect the collaboration process. This may be true in terms of an immediate effect but others have suggested that the results from a bibliometric investigation may influence collaborative practices over the longer term (Martin 1992).

### 1.2.16 Problems of Credit Allocations in Bibiometric Study

In the case of multi-authored works, there is also the problem of allocating credit to the various authors. In other words, which weighting procedure should be applied in allocating credits to authors of multi-authored works? A similar problem is encountered when dealing with patent: how a patent should be counted and attributed to the different inventors or applicants or countries. In general, there are three ways to deal with this problem: (1) straight count; (2) normal count; and (3) adjusted count (Lindsey 1980; Egghe and Rousseau 1990). In the case of straight counts, multi-authored works are treated the same as single-authored works, in the sense that the first author receives all the credit. This is by far the simplest approach and, in addition, it greatly reduces the work required to collect the data. The use of straight counts can be considered a sampling strategy that, as such should be examined in terms of its representativeness. In this rationale, while using the straight count procedure, it is assumed that the set of publications in which an author's name occurs first constitutes a representative sample of all of this author's publications. It is concluded that neither strong empirical evidence, nor theoretical rationale is found to support the assumption underlying the use of straight counts (Egghe and Rousseau 1990). By using normal counts the problem of distributing credit for multi-authored publications is solved by giving full credit to all contributors. This is also called whole count method. The problem with this approach, however, is that it tends to inflate the publication or citation scores of those researchers who produce many multi-authored papers. Moreover, problems can occur due to the fact that, in the normal count approach, the sum of the number of publications of all authors becomes larger than the actual number of papers under study. 'A share of 10% of country X means in this sense that 10 out of every 100 papers in the world have at least one contributor from country X'. Furthermore, it seems that the 'meaning' of a 10% share in the adjusted count (or fraction scale) is far more difficult to explain (Braun et al. 1991). Third method is adjusted count or fractional count. It addresses the problem of multi-authorship by assigning credit proportionally. In the case of adjusted counts, every co-author is assigned a fraction of the authorship. Thus, if two authors write an article, each would be assigned half a credit, in the case of three authors, each would get a third, and so on.

### 1.3 Research Gap

There is a need to carry out a comprehensive study on various dimensions of scientific collaboration occurring in the field of rice biotechnology at micro and macro levels from the SST perspectives. The internal dynamics of collaboration, such as what are the underlying processes of formation, organization and outcomes of such networking or collaboration is studied previously with very little focus. An in-depth study on how various sociotechnical factors influences scientific collaborations in field of rice biotechnology seems to be lacking in literature, so this study will fill the gap in this particular research topic. The study employs mixed-method approach by integrating quantitative and qualitative into a holistic design. A detailed study regarding formal and informal collaborations between varied actors of government-academia-industry is carried out to better capture the emergence of knowledge society. Furthermore, the Government of India is promoting the Public-Private Partnership (PPP) in the case of agricultural biotechnology in India but how PPP model works in National Agriculture Research System (NARS) in general and rice biotechnology in particular is not fairly explored. Therefore, this study is a topical as well as methodological contribution.

### 1.4 Rationale for the Topic

Scientific collaboration is increasing in frequency and importance and also has occupied a central position in the new mode of knowledge production. It has the potential to solve complex scientific problems and promote various scientific, political, economic, and social agendas. It is imperative to understand the scientific collaboration practiced in the rice biotechnology research and the factors shaping it. The construction of productive collaboration between practice and academia is increasingly important to help focus and enrich academic research, and to enable the dissemination and sharing of research results with practice. Therefore, it is necessary to understand the processes through which collaboration is initiated and sustained. Further, the agricultural biotechnology sector in India is one of the fastest growing knowledge based sectors and is expected to play a key role in shaping India's rapidly developing economy. By focusing on single crop (rice), the present study is sociologically significant in the context of production of knowledge in rice biotechnology and its application in developing countries such as India.

### 1.5 Research Questions

The present study investigates the following research questions:

a) What is the pattern of scientific collaboration operating at micro and macro level in the field of rice research in India? What is the nature and extent of scientific collaboration? What is the collaboration trends at different aggregations such local, national and international level?

b) How scientific collaborations are being formed and organized in field of rice biotechnology in India. What are the underlying processes of formation, magnitude, organization, and outcomes of such collaborations?

c) To what extent and in what ways the various sociotechnical aspects of work influence research collaboration in rice biotechnology research in India?

d) What is the sociopolitical construal of innovation in rice biotechnology in India? What are the implications of new agriculture technologies on rice biotechnology research? How new agricultural technologies are conceived and practised by scientific community engaged in rice biotechnology research?

## 1.6 Objectives of the Study

The objectives of the present study are to:

a) Analyse the different patterns of collaboration operating at micro and macro level in field of rice biotechnology research in India;
b) Explore the underlying processes of formation, magnitude, organizations, and outcomes of scientific collaborations in rice biotechnology in India;
c) Explore the various sociotechnical aspects of work that influence scientific collaboration in rice biotechnology in India;
d) Examine the socio-political construal of innovations in rice biotechnology in India

## 1.7 Methodology

The theoretical approach adopted in this study was informed by various SST literatures as described in section review of literature. Based on recent trends, the ontological position in SST could be considered constructivism, which implies that reality is the outcome of social processes. The underlying assumption in SST is that "science and technology are thoroughly social activities" (Sismondo 2010). Within STS, there is a greater thrust to investigate the constitution of scientific knowledge and technological artifacts. Science is seen as an active and socially-situated process, and critics argue that there is a danger in adopting a constructivist approach (highly human-centric perspective) entirely, as it ignores the materiality of the social world (Murphy and Dingwall 2003). It may be argued, therefore, that the construction of reality is subject to the external scholars argue that it should be studied as such (Sismondo 2010). Epistemologically, this informs us that knowledge is not value-free, rather socially constituted; therefore, the phenomenon under consideration should focus on questions such as 'what counts as knowledge?' and 'how are facts constructed?' (Bijker 1993; Sismondo 2010). Bryman (2008) notes that "an epistemological issue concerns the question of what is (or should be) regarded as acceptable knowledge in a discipline." The underlying assumption of SST suggests that epistemologically (the nature of knowledge) it is more close to interpretivism, which emphasizes analysing the subjective meaning of social action. This approach demands the analysis of "the perceptions and actions of social actors" (Bryman 2008) which is essential to understanding any social reality. However, environment needs to be taken into account while applying this approach.

The study is informed by philosophy of qualitative research as well as philosophy of quantitative research. The study adopts a mixed-method approach. It combines qualitative and quantitative research methodologies to investigate research questions and to reach at a better and comprehensive understanding of research topic. However, simultaneously this study acknowledges that choice of any methodology "should depend on the nature of what we are trying to describe, on the likely accuracy of our descriptions, on our purposes, and on the resources available to us; not on ideological commitment to one methodological paradigm or another" (Hammersley1992). According to Johnson and Owegbuzie (2004) research methods should follow research questions in a way that offers best chance to obtain useful answers. There are two reasons why mixed-approach methods were required for the study. First, the dimensions of scientific collaborations have been studied either through statistical studies of authorship patterns in the published scientific literatures (bibliometric studies) or detailed narrative of projects, organizations, or sites collected through personal interviews, case studies, observations, focused group discussions, questionnaires etc. Both of these set of methods (quantitative and qualitative) have its own advantages and disadvantages, neither of them qualify for perfect method to study scientific collaboration (ibid).Therefore, keeping these methodological disputes in mind, an attempt is made to have a holistic research design for the study. Second, the nature of the research questions also demands the use of mixed- method design. For an instances, first research question of the study, which focuses on patterns of scientific collaboration can be effectively captured by bibliometric study (quantitative method), whereas other research questions which examines socio-politics of scientific collaborations in rice biotechnology research can be effectively examined by conducting in-depth personal interviews (qualitative method) with the respondents. The mixed-method design used in the study blended quantitative and qualitative methodologies sequentially, with quantitative research conducted at the beginning, followed by qualitative research. However, the role of quantitative part is to supplement the qualitative part of the study. It makes initial exploration, whereas the qualitative part expands the study by aiming to deeper understanding of the topic. Consequently, more emphasis is accorded to the qualitative part of the study. Quantitative study employs bibliometric methods and source of data collection is secondary, whereas qualitative study employs in-depth personal interviews and is primary data based.

### 1.7.1 Quantitative Method: Data Collection and Analysis

This study uses bibliometric study to measure scientific collaborations occurring in the field of rice research in India. Bibliometrics is the generic term used to describe indicators to measure the output of scientific and technological research through data from scientific literature and patents. Bibliometric data enables us to explore trends, both within a country and worldwide, as well as track patterns of collaboration among countries, institutions and among individual researchers. According to Sengupta (1985), bibliometric is an organization classification and quantitative evaluation of publication patterns of all macro- and micro-connmunications along with their authorships by mathematical and statistical calculus. In the study, multi/co-authorship method has been employed to capture pattern of scientific collaboration operating at micro and macro level in field of rice biotechnology research. Co-publication method assumes that any collaboration activity can be simply equated with papers containing name and addresses of two or more authors. The data for publications in the present study were acquired from the on-line international multidisciplinary edition of the Scopus database published by the Elsevier science.

Principally, there are two primary reasons for selecting Scopus database for the study. First,the study selected Scopus database because of its size. It is the largest international multi-disciplinary database of peer- reviewed literature. Scopus covers more than 49 million records including trade publications, open access journals, and book series. Almost 80% of these records include abstract. It contains 20,500 peer-reviewed journals from 5,000 publishers, together with 1200 Open Access journals, over 600 Trade Publications, 500 Conference Proceedings and 360 book series from all areas of science (www.elsevier.com). Second, Scopus offers the new sorting and refining feature for researchers to access above 27 million citations and abstracts going back to 1960s (Boyle and Sherman 2006). Boyle and Sherman (2006) believe that choosing Scopus is due to its quality of outcomes, time savings, ease of use and possible effect on research findings.

Information on publications in the field of rice research was retrieved by using the keyword “Rice” OR “OryzaSativa” OR “Dhan” OR “Paddy” OR “Chawal” but not rice bean. Using “key phrase” as a search strategy is widely recognized by research community in their studies (Garg 2002; Garg and Padhi 2001; Guan and MA 2004). It is expected to be more precise than using all the classification codes. Moreover, it is convenient to retrieve maximum records. Following their approaches, the same key words were applied as mentioned in Tripathi and Garg (2014) study of Indian crop science research as reflected by the coverage in Scopus, CABI and ISA databases during 2008-2010.

The search was limited to the year 1995-2014. The rationale behind selecting 1995 as starting year of the study is that India became signatory to World Trade Organisation on 1 January 1995, which led to beginning of post-IPR regime in India. IPR regime has profound impact on Indian agricultural R&D sector. Furthermore, the search was also limited to three broad areas, i.e. agriculture and biological sciences, biochemistry, genetics and molecular biology, and environmental sciences. The selection of these three areas is based on the suggestions given by rice scientists. During the field study, these areas were identified by rice researchers as the core areas where most of publications related to rice biotechnology research are published. Moreover, these three broad areas constitute 98.3 percent of total published work in rice research indexed by Scopus database. Also, five document types, namely article, conference paper book chapter, and reviews were selected for the study. The primary reason for selecting these document types are that they constitute98.8 per cent of collaborative papers out of total publications. The search was also limited to the country India. There are no more limitations in language or any other attributes. The bibliometric details for each record contained year, research area, document type, author(s), affiliation, source, and country. A total number of 9375 publicationoutputs were indexed by Scopus in field of rice research during 1995-2014. Out of 9375records 689 were found to be duplicate records, which were duly deleted. Therefore, 8663 appeared as cleaned data on which bibliometric study was conducted. In the study, collaborative papers were whole counted (ibid). The figures have been interpreted as the number or percentage of papers. This is a straightforward and intuitive method of interpreting publication figures. This method does not involve auxiliary, unproven assumptions about the amount of work represented by authorship on a paper and it is a method that facilitates analysis of this most important component of national scientific output by making it visible. Based on review of literature, different bibliometric techniques, such Degree of Collaboration (DC), Collaboration Coefficient (CC), Domestic Collaboration Index (DCI), International collaboration Index (ICI), and so forth have been employed to analyse the publication output. The bibliometric analysis is presented in chapter III.

### 1.7.2 Qualitative Method: Data Collection and Analysis

> Not only do different scientist's accounts differ; not only do each scientist's accounts vary between letters, lab notebooks, interviews, conference proceedings, research papers, and so on; but each scientist furnishes radically different versions of events within, say, a single recorded interview transcript or a single session of a taped conference discussion (Mulkay and Gilbert 1992).

Mulkay and Gilbert (1992) highlight why it is important to interview scientists in science and technology studies. In the present study, the qualitative method includes in-depth personal interviews with the scientists engaged in rice biotechnology research. The study elicits the responses of scientists from selected scientific institutions coming under the aegis of Indian Council of Agricultural Research (ICAR), and the State Agricultural University (SAU). The rationale behind selection of these two institutional set up are twofold: firstly, the most of R&D activities in agricultural research in general and rice research in particular in India are commanded by these two (ICAR-sponsored institutes and SAUs) government undertaking institutional setups. Secondly, the selection of institutes is based on their comparability in terms of structure, organization, administration and resources. For an instance, SAUs are administered and funded by provincial government, whereas ICAR-sponsored institutes are directly funded and controlled by central government. Scientists, who are involved in rice biotechnology research, were approached for interview. Scientists for the present study are selected based on their research expertise, broadly in agricultural biotechnology, viz. plant breeders and plant biotechnologists. The difference between plant breeders and plant biotechnologists lies in the type of biotechnological tools used by them. Plant breeders subscribe to conventional agricultural biotechnology tools, such as cross breeding, hybridization, mutagenesis, tissue culture, and so forth. Whereas, plant biotechnologists utilizes modern agricultural biotechnologytools, such as Recombinant DNA techniques, bioinformatics, genomics, proteomics, metabolomics, to name a few.

In qualitative research, sampling is viewed as a very complex issue (Coyne 1997). Johnson and Waterfield (2004) stated that the sampling strategy in qualitative research does not look to accomplish statistical representativeness; rather, it strives for diversity within the study population. According to them, "the sample must be sufficient to generate depth rather than breadth and may comprise a small number of participants or just one" (Johnson and Waterfield 2004). Sample size depends upon the research questions and aims of the study and the type of data to be collected. Murphy and Dingwall (2003) argued that, "using non-probability sampling methods in qualitative research is best seen as a pragmatic compromise between breadth and depth". Therefore, it can be argued that in qualitative research there should be a balance between depth and breadth of sample size.

This study had employed purposive sampling method. The potential respondents are selected from two different institutional set up, viz. SAU and ICAR. Purposive sampling was carried-out at two different levels. One is at the institute level and the other is at the scientist level. At the institute level, only those SAUs and ICAR-sponsored institutes, which are extensively involved in rice research, were selected for the study. An internet-based screening by visiting web page of each institutes coming under the aegis of SAU and ICAR was conducted. Finally, 15 SAUs and 11 ICAR-sponsored were found to be extensively involved in rice biotechnology research. However, 12 (out of 15) SAUs and 09 (out of 11) accepted the invitation to participate in the study (table1.2). At the scientist level, scientists (plant breeders and plant biotechnologists) from the selected SAUs and ICAR-sponsored institutes, who are extensively as well as intensively engaged in rice biotechnology research, were selected for the study. The sampling process of scientist's involved the same technique, which was used earlier in sampling of institutes. An internet-based screening of scientists was conducted after visiting their on-line profiles at their institute's web page. Finally, 123 respondents were screened for the study. These selected scientists were invited through email and telephone to participate in the study. Out of 123 selected scientists, 71 scientists agreed to participate in the study.

**Table 1.2: Institute-wise distribution of respondents**

| Name of the Institutes | Number of the Institutes | Number of the Respondents |
|---|---|---|
| **State Agricultural Universities (SAUs)** | **12** | **37** |
| Orissa University of Agriculture & Technology, Bhubaneswar | | 03 |
| Tamil Nadu Agricultural University, Coimbatore | | 04 |
| University of Agricultural Sciences, Bangalore | | 03 |
| Acharya N. G. Ranga Agricultural University, Hyderabad | | 03 |
| Punjab Agricultural University, Ludhiana | | 04 |
| Rajendra Agricultural University, Pusa (Samastipur), Bihar | | 03 |
| Bihar Agriculture University, Sabour, Bihar | | 03 |
| Birsa Agricultural University, Jharkhand | | 03 |
| G B Pant University of Agriculture and Technology, Uttrakhand | | 02 |
| Indira Gandhi Agricultural University, Chhattisgarh | | 03 |
| Jawaharlal Nehru KrishiVishwaVidyalaya, Jabalpur, Madhya Pradesh | | 03 |
| Assam Agricultural University, Jorhat, Assam | | 03 |
| **ICAR-sponsored Research Institutes (ICAR)** | **09** | **34** |
| Indian Agricultural Research Institute, New Delhi | | 04 |
| Indian Agricultural Research Institute, Regional Research Center, Tamil Nadu | | 03 |
| Indian Agricultural Research Institute, Pusa, Bihar | | 03 |
| Indian Institute of Agricultural Biotechnology Ranchi, Jharkhand | | 03 |
| National Research Centre on Plant Biotechnology, New Delhi | | 03 |
| ICAR Research Complex for Eastern Region, Patna | | 02 |
| Indian Institute of Rice Research, Hyderabad | | 06 |
| National Rice Research Institute, Cuttack | | 07 |
| ICAR Research Complex for NEH Region, Shilong | | 03 |
| **Total** | **21** | **71** |

Source: Field study

Interviews were conducted using the semi-structured interview, which allows freedom for the informants to express their views on the topic under investigation. The interview guide was developed before going into the field for the data collection; it includes the key themes and questions. An interview schedule containing open-ended questions were prepared to understand the underlying meaning, nature and process of scientific collaboration occurring in the field of rice biotechnology research. Questions were mainly prepared according to the research objectives and actors, i.e. scientists. Questions were refined throughout the data collection process. A set of questionnaires were also prepared to capture the perception of scientists about the R&D and collaborative activities in rice biotechnology research. The perception of scientists were measured at two point Likert Scale, i.e. agree, and disagree; important and not important. Moreover, statistical data pertaining to scientist's research output as reflected by their publications, conferences, research projects, patents, and so forth were also collected through questionnaires. A pilot study was also conducted on 5 scientists to make sure that questions were phrased clearly and to reduce possible ambiguities

Informants were contacted by e-mail and telephone with a brief introduction of the project. The interviews were conducted during the period, September 2015 to June 2016 All interviews were carried out face-to-face in respondents' working place. The respondents of the study are from various institutes, which are scattered throughout the geographical area of India. Consequently, a lot of time was invested in travelling. In general, each interview was around 40-50 minutes; however, in some cases it was more than one hour and in three cases it was only 15 minutes. Most of the interviews were recorded using a digital recorder with the permission of interviewees. It has been argued that, in qualitative research, the way of saying matters as much as what people say. The taping of the interview allows for more in-depth analysis of what people say (Bryman 2004). However, four (out of 71) interviewees refused permission to record the conversation. In that case their responses were noted down.

Content analysis is used to analyze the interview transcripts. 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 (Marying 2000).The analyses of interview data started first with the transcription, i.e. the written translation of a recorded interview. All interviews were transcribed. Although it was a laborious and time-consuming task, this exercise helped in bringing closer to the data in terms of identifying key themes and in-depth analysis of various narratives of research participants (Bryman 2008). Initially, the interviews were conducted and transcriptions were done simultaneously as there was some time between interviews. The initial transcriptions were very helpful in refining questionnaires further. For emergent themes, transcripts were analysed by content and then coding was carried out (Strauss 1987; Weber 1990). Coding was done on the basis of themes and off-repeated statements. Emerging themes were named and the data obtained from different stakeholders were collated and included in each of the themes. The analyses of interview data are presented in Chapters IV, V and VI.

Ethical issues in qualitative research are one of the most important aspects which cannot be ignored as they directly related to the integrity of the research work (Bryman 2004). There is an imperative to ensure the anonymity, privacy, confidentiality and informed consent with respect to the participants in the research process (Daymon and Holloway 2002). This project was designed as per the Indian Institute of Technology Guwahati ethical guidelines and, after approval from the institute, field work interviews were conducted. Empirical data were collected using face-to-face interviews and recorded using a digital voice recorder with the permission of the interviewee. Research participants were asked for written consent for the participating into the interview and recording to take place. The permission was also taken to use their quotations taken from their answers for the reproduction in the thesis and any subsequent papers derived from the thesis. In addition, participants were assured that their responses would be kept confidential and also their identifications were anonymised. Their reference in the data chapter was highlighted as per the institutional affiliation. Participants were informed of their right to withdraw from the study at any time without giving explanation.

### 1.7.3 Profile of the Respondents

The profile of the scientists (respondents) included in the study will be useful to analyze the field data. The profile of scientists includes disciplinary backgrounds, professional status, age group, gender group, intellectual antecedents, paper published in peer-reviewed journals, and research projects that capture the dynamics of scientific collaborations practiced in the field of rice biotechnology.

**Table 1.3: Profiles of the respondents (n = 71)**

| Demographic Category | Individual | Percentage |
|---|---|---|
| **Disciplines** | | |
| Plant breeding | 39 | 56 |
| Plant molecular biology | 32 | 44 |
| **Professional status** | | |
| Professor/principal scientist | 18 | 25 |
| Associate professor/ senior scientist | 32 | 45 |
| Assistant professor/ scientist | 21 | 30 |
| **Age group** | | |
| 31-40 | 09 | 11 |
| 41-50 | 29 | 40 |
| 51-60 | 31 | 44 |
| >61 | 04 | 05 |
| **Gender** | | |
| Male | 60 | 84 |
| Female | 11 | 16 |
| **Intellectual antecedents** | | |
| PhD (India) | 33 | 46 |
| PhD (abroad) | 06 | 08 |
| PhD (India) PDF (India) | 09 | 13 |
| PhD (India) PDF (abroad) | 19 | 27 |
| PhD (abroad) PDF (abroad) | 04 | 06 |

**Source:** Field study

As indicated in table 1.3, out of 71 scientists included in the study, 39 scientists are plant breeders and 32 scientists are plant molecular biologists. Perhaps, the tools used by plant molecular biologists and plant breeders demarcate the two disciplines. On the one hand, plant molecular biologists use sophisticated tools to carry out their research in their laboratories. Genetic engineering is an example of this. On the other, plant breeders are not much in tune with the contemporary sophisticated tools and they mostly operate their research on the field.

The systems of academic titles and ranks vary between institutions in context of India. Most of the SAUs in India follow three faculty ranks "Assistant Professor", "Associate Professor" and "Professor”, whereas academic titles and ranks followed by ICAR-sponsored research institute are “Scientist”, “Senior scientist” and “Principal scientists”. However, in this study professional status has been classified by clubbing both ranking system together based upon seniority and juniority. Table 1.3 suggests that out of total scientists (71) interviewed, 45 percent holds status of Associate professor/Senior scientist followed by 30 percent as Assistant professor/ Scientist and 25 as Professor/Principal scientist. Moreover, majority of scientist interviewed are experienced as about 71 percent of them falls under the category of Associate professor/Senior scientist and Professor/Principal Scientist.

The majority of scientists in the study are over 50 years of age. The average age of a scientist stands at 49.79, which shows that the scientists interviewed are very senior captured by table 1.3.Multi-year experience of senior scientists enables them to reflect on topic more clearly, deeply and effectively, which further enhances the quality of this study. Thus, respondents in this study, particularly senior scientists have experiences of handling various R&D projects at national and international level. They possess in-depth knowledge about the field and have contributed tangibly and intangibly to the rice biotechnology research. This description of their work fit what we have defined as research collaboration, an important aspect of a genuine scientific enquiry in field of plant sciences. During interview, they demonstrated greater interest, intellectual independence, and responsibility.

The importance of mainstreaming gender in all kind of study cannot be over-emphasized. This is not just to ensure that women should get an equal opportunity to participate and share their experiences in these kind of qualitative studies but because it is also essential for the balanced development of any society. In fact, the rationale behind considering women in scientific research, it is even more important because research is a highly creative and individualistic enterprise, where each person makes his/her unique contribution.

Institutions covered in the study for primary data collection were found to be unevenly distributed in terms of gender. The percentage of female respondents (16) is less than quarter of male respondents (84). This low representation of women accentuates gender imbalance in field of science and technology in general and rice biotechnology in particular. This further possesses questions on the rational and objective nature of plant science research.

Out of 71 scientists interviewed, 33 scientists completed their doctoral research work in India and six scientists did their doctoral research work abroad. Nine scientists did their PhD and post-doctoral research work in India. Nineteen scientists did their PhD and post-doctoral research work abroad. Only four scientists pursued their PhD and post-doctoral research work abroad. In other words, 32 (45.07%) have had international exposure.

**Table 1.4: Number of Papers published in peer-reviewed journals (2010-2014)**

| Number of paper published | Frequency | Percentage |
|---|---|---|
| 1-10 | 11 | 15 |
| 11-20 | 57 | 80 |
| 21-30 | 3 | 4 |
| >30 | 0 | 0 |
| Total | 71 | 100 |

**Source:** Field study

The majority of scientists (80.28%) have 10 to 20 research papers published in peer-reviewed journals in last five years. The average number of papers published in peer-reviewed journals by individual scientists per year stands at 10.35.

**Table 1.5: Number of research project (inter-institutional) undertaken (2010-2014)**

| Institutes | Number of project undertaken | Percentage |
|---|---|---|
| State Agriculture Universities | 71 | 37 |
| ICAR-sponsored institutes | 116 | 63 |
| Total | 187 | 100 |

**Source:** Field study

Table 1.5 displays that in total 187 inter-institutional projects were under taken by 71 respondents in 5 years (2010-2014). Out of 187 projects, the scientists of SAUs undertook 71 (37 percent) projects, whereas scientists from ICAR-sponsored institutes under took 116 (63percent) projects in 5 years. Further, this suggests that scientists from ICAR-sponsored institutes are more productive than the scientists of SAUs in terms of bringing research projects. However, scientists from SAUs have more teaching responsibilities than the ICAR-sponsored institutes. This may be a reason for SAUs scientists to be less productive than the ICAR-sponsored institutes in terms of research projects.

The variations pertaining to research projects undertaken, publication of research papers in peer-reviewed journals, fund-seeking behavior of the scientists interviewed may be traced to their intellectual antecedents. At the first sight, perhaps, motivations to “do” science vary. Of course, motivations are inculcated as a pan of training in the formative stage of the professional career of the scientists. As a corollary, motivations enable them to select "new" areas of research and resort to novel techniques. Obviously, research problems very often evolve new and more refined techniques to arrive at solutions. For example, scientists have been orienting their research in understanding the phenomena from phenotypic to genotypic or molecular level. Genetic engineering is an example of this where manipulations are made at the level of genes. In addition, this has attracted very lucrative funding from both national and international funding agencies. The scientists who are exposed to the training from top educational institutions in India and abroad are in a better position to carry out their research in the "new" areas and with novel techniques. As such, "new" areas and novel techniques aiming at concrete deliverables suit the inter-institutional research projects, which assume greater significance in the context of the R&D collaboration in field of rice biotechnology research.

### 1.8 Structure of the Study

The thesis is divided into seven chapters. The first chapter introduces various facets of the thesis attempting to capture review of literature, research gaps, rationale for the topic, research questions, objectives of the study, method of analysis, structure of the study, and so forth.

The second chapter dwells upon a socio-historical analysis of agricultural research and development with special reference to rice research in India. The chapter discusses evolution of National Agricultural Research System (NARS), India's R&D in global context; impact of R&D on agriculture in India; and institutionalization of rice research in India. Establishment, development, expansion of agricultural universities and institutions in the pre-and post- independent India, is the major focus of the chapter. An attempt is also made to capture social, political, and economic factors shaping agricultural National agricultural Research System (NARS) in general and rice research in particular. The latter section of the chapter reflects on the institutionalization of rice biotechnology research and its historical context of struggle in India. The chapter explores the extent and ways the institutional mechanisms have evolved to enable rice biotechnologists to re-orient their approach towards research in the changing context of knowledge production in addressing the challenges in their day-to-day research activity. The development and deployment of the new genetic technologies, such as golden rice, Marker Assisted Selection, and so forth, have been also covered in the chapter. This chapter is qualitative in nature and banks on secondary literature for its analysis.

The third chapter, under a broad canvas, dwells upon bibliometric study of the knowledge base of Indian rice research community, based on the bibliometric information in field of rice research from Scopus database during the period of 1995-2014.The primary objective of third chapter is to capture the pattern of scientific collaboration operating in field of rice research. The chapter measures knowledge production based on several parameters, country annual growth rate, authorship patterns, degree of collaboration, collaboration coefficient, and so forth. Further, Domestic Collaboration Index (DCI) and International Collaboration Index (ICI) have been also calculated at micro and macro level to examine the nuanced and subtle picture of scientific collaboration occurring in field of rice research. The third chapter addresses the first research question of the study. This chapter is quantitative in nature and rests on secondary data for its analysis.

The fourth chapter is a modest attempt to capture how scientific collaborations are formed and organized in the field of rice biotechnology research and what are the underlying process of such formation, organization, and outcomes. By highlighting the socio-politics of project formation and organization, the chapter focuses on the internal dynamics of scientific collaboration. How are scientific collaborations formed? Why do scientists collaborate? What are the principal means of organization? What are the magnitudes and extent of such collaborations? What are the significant structural dimensions of national and international collaborations? This range of questions forms the skeleton of fourth chapter. Furthermore, the chapter also examines the networking between government-academia-industry in formal structure by directly investigating the motivation, interest and organizational mandates of SAUs and ICAR-sponsored institutes.

The fifth chapter sheds light on the various sociotechnical factors that are embedded in local working conditions and how they influences the collaboration process at initiation, development, and conclusion of collaboration between rice biotechnologists in distributed/inter-institutional projects. By addressing third research question of the study, the chapter provides a promising way to understand the influence of sociotechnical aspects of work organization on the making of collaboration, by uncovering how these aspects were concretely organized, how they interplayed with other elements, and how they effected and affected collaboration. Contingent upon ANT and TORSC for its analytical framework, the chapter investigates five key elements: nature of work; the quantum of common ground; collaboration readiness; management style and leadership; and technology readiness that shapes inter-institutional/distributed collaborations in field of rice biotechnology research. Furthermore, the chapter also elicits the problematic of scientific collaboration in terms understanding the needs of the laboratory and the field, IPR issues, and status based discrimination in allotment of research projects and credit allocation among partners.

The sixth chapter emphasizes on the transformations that have occurred in field of rice biotechnology research due to the advent of new agricultural biotechnology tools. By addressing the fourth research question of the study, the sixth chapter examines the socio-political construal of innovations in field of rice biotechnology research. How are new agricultural technologies conceived of and practiced by the scientific community? What are the new discourses about the role of biotechnology and rice biotechnologists? What are the responses of scientists towards genetically modified crops? What are the policy implications? The answer to these questions forms the content of sixth chapter. In the chapter, a few case studies have been also discussed in order to substantiate the argument.

The seventh and final chapter summarizes the findings of the study. Based on the findings, the chapter makes concluding remarks in relation to the argument presented earlier. The concluding section further sheds light on the limitations of the present study and points out the need for further research in the field.

# Chapter II

## A Socio-historical Analysis of Rice Biotechnology Research in India

### Introduction

India is an agriculturally predominant country. Agriculture plays an important role in the Indian economy and contributes a substantial share for the development of the country. This chapter delves into a socio-historical analysis of agricultural research and development with special reference to rice biotechnology research in India. This chapter attempts to capture social, political and economic factors shaping agricultural research system in India. Principally, there are three main objectives of this chapter. One is to review the growth and development of agricultural research in India. The second objective is to capture the initiatives undertaken by the state to improve the state of agricultural sector in general and, rice in particular. It is important to look at the ways in which various institutional mechanisms have evolved to mediate such transitions. The third objective is to reflect upon contemporary issues of the restructuring of research institutions, dynamics of university-industry relations, growing private sector involvement, extent of national and international collaboration, and so forth. Careful emphasis is bestowed to the analysis of historical text especially, on the archival material including the back volumes of the journals brought out by the Indian Science Congress Association, Indian Science News Association, for the attainment of aforesaid objectives.

### 2.1 Evolution of the National Agricultural Research System (NARS)

India has built up a fairly advanced agricultural research system. The NARS in India is one of the largest political imperatives in the world. The effective functioning of this system, in close association with education and extension systems, has greatly contributed to the rapid growth of agriculture after independence. This section focuses on how NARS has evolved to cater to the need of a strong R&D system in India.

The Famine Commission Report of 1880 led to the creation of the Departments of Agriculture at the Center as well as in the Provinces with the primary duties of undertaking scientific enquiry and improvement in agriculture apart from famine relief. Dr. J.A. Voelcker, Consulting Chemist to the Royal Agricultural Society of England, laid the foundation for agricultural research in India in 1890s. His recommendations led to the appointment of the Imperial Agricultural Chemist in 1892, the Imperial Mycologist in 1901, and the Imperial Entomologist in 1903. This was the beginning of inducting scientific temper into agriculture. Most importantly, his work was instrumental for the establishment of the Imperial (now Indian) Agricultural Research Institute in 1905 at Pusa, Bihar (Randhawa 1979, 1987). Agricultural Colleges were also established at Pune, Kanpur, Sabour, Nagpur, Coimbatore, and Lyallpur (now in Pakistan). Organized scientific research on the problems of livestock started with the establishment of the Imperial Bacteriological Laboratory (now known as Indian Veterinary Research Institute) at Mukteswar in 1889. This was preceded by the establishment of Veterinary Colleges at Bombay, Calcutta, Madras and Lahore (now in Pakistan) (Balaguru and Raman 1988).

With the constitutional changes in 1919, the responsibility for agriculture was transferred to the Provincial Governments. On the recommendation of the Royal Commission on Agriculture (1928), the Imperial Council of Agricultural Research (ICAR) was established as a Registered Society in 1929, which was funded mainly through a lump sum grant from the Government and the proceeds from the cess levied on certain commodities exported from India. After independence, the Council was renamed as the Indian Council of Agricultural Research (ICAR) on June 10, 1948 (Randhawa 1979, 1987). In addition to the ICAR, a number of Central Commodity Committees were established to deal with research in respect of particular crops or commodities. These committees were semi-autonomous bodies financed by grants from the Government of India, or by income from the cess levied on particular commodities. The Indian Central Cotton Committee was established in 1921 and set the tone for an organized research based on a network (Balaguru and Raman 1988). Its success subsequently led to the establishment of a number of other Commodity Committees, viz. Indian Lac Cess Committee (ILCC) in 1931; Indian Central Tobacco Committee in 1945; Indian Central Oilseeds Committee in 1947; Indian Central Areca nut Committee in 1949, and Indian Central Spices and Cashew nut Committee in 1958 (Raman and Balaguru 1990).

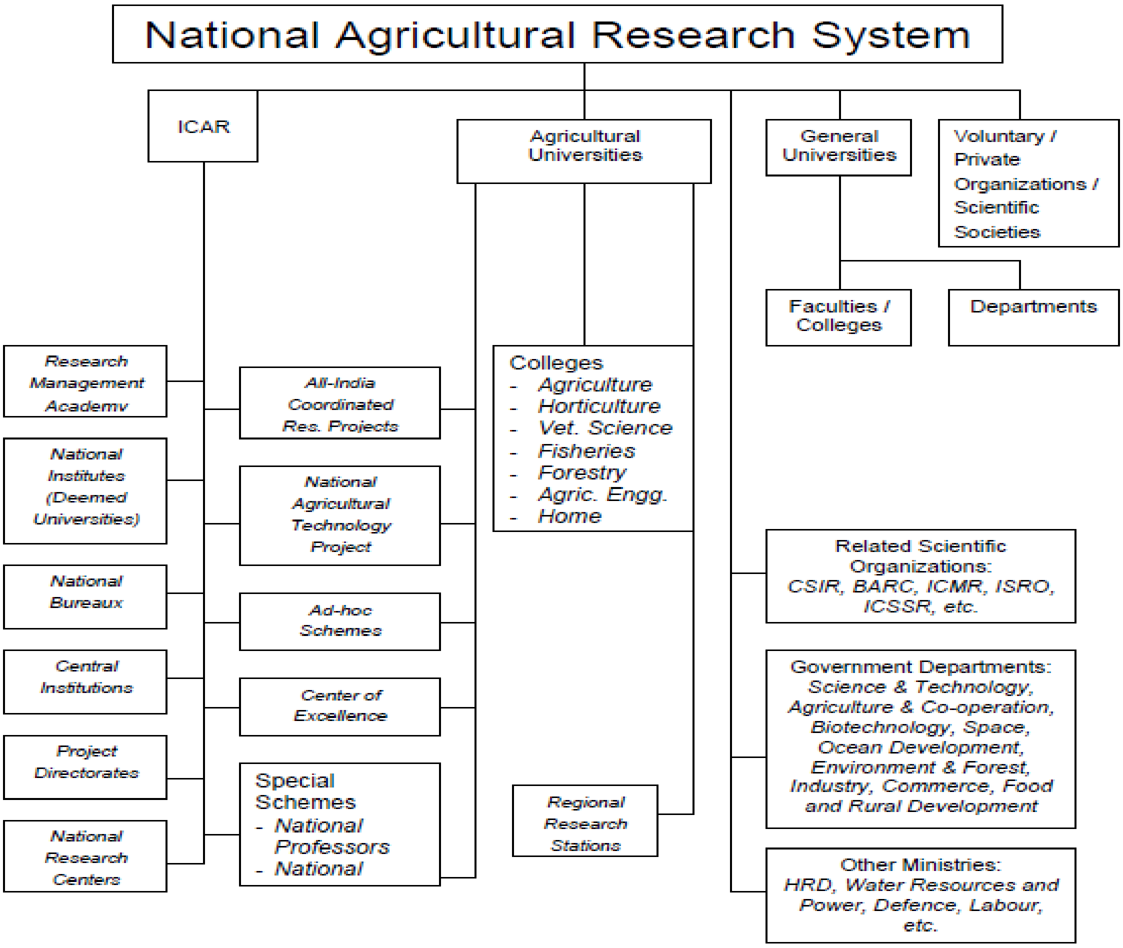
After independence, the research system has undergone some major changes. First, a number of State Agricultural Universities were established following the recommendations of the first Joint Indo-American Team in 1955 (Naik and Sankaram 1972). The first one was established in 1960 at Pantnagar in Uttar Pradesh and other States followed suit. Secondly, on the basis of critical reviews and specific policy issues emanating from the recommendations of various Review Committees, the ICAR was reorganized first in 1965 to bring centrally sponsored research activities relating to crops, commodities, animal sciences, and fisheries under one umbrella. The Commodity Committees were abolished and their research institutes as well as those under the Ministry of Food and Agriculture were merged with the ICAR so that problems of agricultural research could be viewed in their totality. The rules and bye-laws of the Council were revised to make it functionally more effective, technically competent and autonomous. The Governing Body was reconstituted, making it pre-eminently a body of scientists and those with interest in or knowledge of agriculture. An eminent agricultural scientist was appointed as the Executive Head of the ICAR and was designated as the Director General (ICAR 1982).

Though this greatly increased its responsibilities, the Secretariat of ICAR continued to be an attached office of the Department of Agriculture (DoA), thus limiting its effectiveness. In particular, the personnel policies and recruitment systems were not found appropriate. Later, the second reorganization, following the appointment of another Review Committee in 1973, conferred on it greater autonomy and flexibility in operation, management and recruitment. A new, but small, Department of Agricultural Research and Education (DARE) was set up in the Agriculture Ministry to provide the ICAR with necessary linkage to deal directly with the Central and State Governments on the one hand and the International Organizations on the other, without going through the Department of Agriculture. The Director General of the Council concurrently became the Ex-officio Secretary (DARE) to the Government (FAO 1982). The composition of the Council was modified so as to restrict the membership and make it a more business-like body with the Minister for Agriculture as its President. The Governing Body was also restructured and made much more effective with the Director General as its Chairman. The country was divided into eight agro-ecological zones and Regional Committees were set up for each of these zones. To broad base the decision-making process at the institute level, Management Committees were set up under the Chairmanship of their respective Directors. A new personnel policy was evolved and an All India Service called the Agricultural Research Service (ARS) was created in 1975 to facilitate optimum utilization of the available manpower. Consequently, a new Agricultural Scientists Recruitment Board (ASRB), with an eminent scientist as a full-time Chairman and assisted by two scientists as Members, was established to recruit scientists to various positions in the ICAR (ICAR 1988).

### 2.2 The Structure of the Present National Agriculture System in India

The present agricultural research system comprises essentially two main streams, viz. the ICAR at the national level and the Agricultural Universities at the state level. Besides, several other agencies such as the Conventional / General Universities, Scientific Organizations, and various Ministries / Departments at the Center, and also Private or Voluntary Organizations participate directly or indirectly in research activities related to agriculture

**Figure 2.1 Present Structure of National Agriculture System in India**




Source: http://aiasa.org.in/wp-content/uploads/2015/07/NARS-India.pdf

### 2.3 The Indian Council of Agriculture Research (ICAR)

Among the major scientific organizations in the country, the ICAR is unique in having concurrent responsibility for both research and education. As an apex body at the national level, ICAR is mainly responsible for the promotion and coordination of agricultural research in the various branches of agriculture and allied sciences in the country. In addition to its promoting and coordinating roles, ICAR is also directly involved in undertaking research at the national level, basic as well as applied, on diverse problems facing production of crops, animals, fisheries, etc., with the objective of evolving new production technologies suited to different agro-climatic conditions. Just as the University Grants Commission (UGC) plays a major role for the general education in the country, ICAR plays a similar role in the area of agricultural education. The Charter of the ICAR also includes extension education, which is carried out through a network of projects and other mechanisms (http://www.icar.org.in/ accessed on 7 May 2016). The mandates of ICAR are:

- To plan, undertake, aid, promote and coordinate education, research and its application in agriculture, agro-forestry, animal husbandry, fisheries, home science and allied sciences.
- To act as a clearinghouse of research and general information relating to agriculture, animal husbandry, fisheries, home science and allied sciences through its publications and information system, and instituting and promoting transfer of technology programmes.
- To provide, undertake and promote consultancy services in the fields of education, research, training and dissemination of information in agriculture, agro-forestry, animal husbandry, fisheries, home science and allied sciences.
- To look into the problems relating to broader areas of rural development concerning agriculture, including post-harvest technology by developing cooperative programmes with other organizations such as the Indian Council of Social Science Research (ICSSR), Council of Scientific and Industrial Research (CSIR), Bhabha Atomic Research Center (BARC) and the Universities.
- To do other things considered necessary to attain the above objectives of the Society.

As a registered scientific society, the ICAR now enjoys an autonomous status and follows *mutatis mutandis*, Government of India rules and regulations. It observes all procedures for the preparation of its plan, their scrutiny and approval by the Planning Commission, Finance Department, etc. The Minister for Agriculture in the Government of India is the President and the Minister of State for Agriculture is the Vice-President of the ICAR. The Agricultural Scientists Recruitment Board (ASRB), charged with the responsibility of recruiting scientists as well as for looking after their career advancement in the ICAR system, is headed by a full-time Chairman who is assisted by two eminent scientists as Members. The Chief Executive of ICAR is the Director General, who is an eminent senior agricultural scientist. S/he concurrently acts as the Ex-officio Secretary (DARE) to the Government of India. S/he advises the Government on all matters connected with agricultural and animal husbandry research and education in the country that are referred to them. Currently, ICAR comprises 49 ICAR institutes, 17 national research centers, six bureaus, 25 project directorates, 91 All-India Coordinated Research Projects (AICRPs) and all India Network Research Projects (AINPs), 607 krishi vigyan kendras (KVKs), 52 state agriculture universities, four central agricultural universities, four central Universities having faculty of agriculture (http://www.icar.org.in/ accessed on 7 May 2016). In addition to its institute-based research, ICAR promotes research schemes / projects in agriculture and allied areas to resolve location-specific problems. It is involved in a cooperative endeavour with other research organizations in carrying out multidisciplinary research programmes. Such promotional schemes fall under the categories of the All India Coordinated Research Projects (AICRPs), National Agricultural Research Project (NARP), National Agricultural Technology Project (NATP), Technology Mission in Agriculture, Ad hoc Research Schemes and Special Schemes.

### 2.4 The Agricultural Universities System

As agriculture is a state subject, the responsibilities for research, education and extension rest with the state governments. Prior to 1960, agricultural research in the states, especially on local problems, was carried out by the State Departments of Agriculture supported by Agricultural Colleges. Since India's Independence, research and education have been transferred to the Agricultural Universities, and the State Departments of Agriculture organize extension services. The Universities are supported by their respective state governments. The ICAR provides financial support and assists their research and education programmes.

The University Education Commission (1949) recommended the setting up of `Rural Universities'. This was endorsed by the two Joint Indo-American Teams in 1955 and 1959, as well as the Ford Foundation Study Team in 1959. In 1960, the Agricultural Universities Committee constituted under the Chairmanship of Dr Ralph W. Cummings prepared certain guidelines for the establishment of agricultural universities in different states, and the ICAR gave necessary support (Randhawa, Raman and Rajagopalan 1986).

The first agricultural university was established at Pant Nagar in Uttar Pradesh in 1960, patterned on the Land-Grant System of the United States. The Second Education Commission (1964-66) recommended at least one agricultural university in each State, and ICAR prepared a Model Act in 1966. All the States have now at least one agricultural university each. Though the Model Act specifies that only one university shall be established in each state, which was later endorsed by the National Commission on Agriculture, many states have established multiple Universities to meet regional needs (Naik and Sankaram 1972). In 1978, a Review Committee appointed by the ICAR reviewed the functioning of each agricultural university and made a number of recommendations. In 1988, the USAID evaluated the impact of agricultural universities and made several agricultural universities autonomous institutions established by an Act of State Legislature. Although the administrative structure differs somewhat from state to state, the general outlines are similar. As Chancellor, the State Governor is the nominal head of the University. In some States, the Agriculture Minister acts as the Pro-Chancellor. The Vice Chancellor is the Chief Executive of the university. In some states, more than one university has been established through a Common Act; their activities are coordinated through a State level Agricultural Research and Education Coordination Committee. Of the 67 agricultural universities in the country, some are mono-campus while the others are multi-campus Universities. The number of teaching campuses in each university varies from 1 to 10 (http://www.icar.org.in/ accessed on 11 June 2016).

### 2.5 General Universities

Many general universities with well-developed faculties in agriculture, or strong departments engaged in areas such as genetics, plant physiology, mycology, entomology, biochemistry, economics, chemistry, marine biology, home science, etc. have made distinctive contributions to agricultural research in the country. Besides, the central universities like the Banaras Hindu University, Vishwa Bharti University, etc. have institutes/schools of agricultural sciences, which are engaged in research in agriculture and allied areas, some of which are supported by the ICAR.

### 2.6 Other Scientific Organizations

Many other scientific organizations either directly undertake research, or sponsor programmes related to agriculture. The Council of Scientific and Industrial Research (CSIR), through its network of national laboratories, provides support in areas like processing of agricultural products, recycling of agricultural wastes, development of various agro-chemicals, etc. The Indian Council of Medical Research's (ICMR) studies on the nutritional qualities of various agricultural produce including toxicity and occupational health of agricultural workers have greatly helped the ICAR in planning its research programmes. Some of the areas in which the Bhabha Atomic Research Centre (BARC) is actively engaged in are the development of newer varieties of crops and preservation of agricultural produce. The Indian Space Research Organization (ISRO) is helping the research system to assess India's soil and water resources.

Technological institutions like IIT Kharagpur are active in the fields of agricultural engineering, soil and water management, and agronomy. The Department of Science and Technology (DST) promotes research on genetic engineering, post-harvest technology, and areas of basic sciences supportive to agriculture. The Department of Non-Conventional Energy Sources works on the utilization of solar and wind energies, and biogas for agricultural purposes. The Department of Meteorology is actively engaged in research on crop-weather forecasting. The Department of Ocean Development is involved in promoting and assessing the fishery resources in the country.

### 2.7 Private-Sector Development

Historically, a few private companies invested in agriculture inputs i.e., pesticides, fertilizers and machinery which comes under the product development. Although, after the Green Revolution during the period of 1980s the situation has changed because of liberalized policies to support private sector development, the growing availability of trained scientists, rapid expansion of markets for agricultural inputs and processed foods. Now the private companies have been supplying more than 50% of agriculture inputs. These companies have focused on hybrid seed, biotechnology, pesticides, fertilizer, machinery, animal health, poultry, and food processing. The cause of this investment is because the government provided strong incentives in the form of tax exemptions on research expenditures and venture capital, and liberal policies on the import of research equipment to encourage participation of the private sector in research. The development of the seed sector has ensued after the implementation of a new seed policy effective in 1988. This policy allowed the importation of seed materials, as well as majority share of ownership of seed companies by foreign companies. This led to an increased number of foreign seed companies entering the market, and several local seed companies have established considerable research capacity with the collaboration of other companies

(Pray, Ramaswami, and Kelley 2001). Private hybrids now account for a significant share of the market for sorghum, maize and cotton (Singh, Pal, and Morris 1995; Pray, Ramaswami, and Kelley 2001), and companies with some foreign ownership account for about one-third of this market (Pray and Basant 2001). Similarly, participation of private non-profit organizations in agricultural research has also increased. There are now a few private foundations, as well as NGOs, actively engaged in agricultural research. In particular, the M. S. Swaminathan Research Foundation and Mahyco Research Foundation have developed considerable research capacity with a national presence and are working in close collaboration with the ICAR/SAU system. In addition, many small, regional, and local NGOs are engaged in agricultural research, such as those managing some ICAR-sponsored KVKs.

## 2.8 International Cooperation

International co-operation has played a significant role in developing and strengthening the research system in India. Many developed countries like USA, UK, Russia, Canada, Australia, Japan, several European countries; Charitable Institutions, etc.; Rockefeller and Ford Foundations; various International Agencies like FAO, UNDP, UNESCO, World Bank, etc.; and the International Agricultural Research Centers under the Consultative Group on International Agricultural Research (CGIAR).

The first international collaboration in Indian agriculture system came in the year 1954, the first joint Indo-American team was formed to explore the possibilities of setting up rural universities in the India based on the model of US land-grant universities. However, The substantial credit of initiation of international collaborations in Indian agriculture system are attributed to All-India coordinated research projects (AICRP), when two international agencies United States Agency for International Development (USAID) and 'Rockefellar Foundation' entered into agreement with The Ministry of Food and Agriculture, government of India in 1956. Subsequently, in the year 1959, the second joint Indo-American team was formed, which led to formation of a few agriculture universities in third five-year plan. During green revolution, India collaborated with many international agencies, such as Rockefeller foundation, CIMMYT, IRRI and so forth.

The Government has authorized ICAR, assisted by the DARE, to enter into bilateral cooperative agreements with several countries and agencies. The mode of collaboration normally follows the pattern of: (a) exchange of germplasm of plant and animal origin; (b) exchange of scientific and technical information; (c) visits of scientists and experts; (d) training of scientists; and (e) infrastructure development.

**2.9 The Consultative Group on International Agricultural Research (CGIAR)**

The CGIAR system has contributed extensively to the cause of agricultural research in India. The Consultative Group on International Agricultural Research (CGIAR), established in 1971, is a strategic partnership of diverse donors that support 15 international Centers, working in collaboration with many hundreds of government and civil society organizations as well as private businesses around the world. The CGIAR donors include both developing and industrialized countries, international and regional organizations and private foundations.

Eleven of the CGIAR Centers maintain international gene banks. These preserve and make readily available a wide array of plant genetic resources, which form the basis of global food security (http://www.cgiar.org/ accessed on June 21, 2016).

In December 2009, the CGIAR adopted a new institutional model designed to improve its delivery of research results in a rapidly changing external environment. The reforms should give rise to a more results-oriented research agenda, to clearer accountability across the CGIAR and to streamlined governance and programs. The new model consists of a balanced partnership between donors and researchers. The new CGIAR fosters stronger and more dynamic partnerships, which generate high-quality research outputs while strengthening national research institutions. Stakeholders, including donors, partners and beneficiaries, will provide input into the design of the Strategy and Mega Programs. The Global Conference on Agricultural Research for Development (GCARD) represents a key opportunity for engaging end users, including farmers, forest and fishing communities, and National Agricultural Research Systems (NARS), in the development of new research programmes (http://www.cgiar.org/ accessed on June 21, 2016).

Currently, there are 15 international agricultural research centres supported by CGIAR.

1. International Center for Tropical Agriculture (CIAT)
2. Center for International Forestry Research (CIFOR)
3. International Maize and Wheat Improvement Center (CIMMYT)
4. International Potato Center (CIP)
5. International Center for Agricultural Research in the Dry Areas (ICARDA)
6. International Crops Research Institute for the Semi-Arid Tropics (ICRISAT)

7. International Food Policy Research Institute (IFPRI)
8. International Institute of Tropical Agriculture (IITA)
9. International Livestock Research Institute (ILRI)
10. Bioversity International
11. International Rice Research Institute (IRRI)
12. International Water Management Institute (IWMI)
13. World Agroforestry Centre
14. World Fish Center (WFC)
15. Africa Rice Center (AfricaRice)

### 2.10 Linkages among the Subsystems

Strong working relationships and complementarily in research efforts amongst the components of the research system is necessary in order to optimize resources and check avoidable duplication. The ICAR, as the coordinating agency at the national level, has established close-working relationships with the Agricultural Universities and other agencies involved directly or indirectly in agricultural research through formal arrangements and informal exchanges.

At the policy making level, the Vice-Chancellors of Agricultural Universities are represented in the Governing Body, and in the Norms and Accreditation Committee of the ICAR. The senior level research managers of the ICAR, in turn, are represented in the Management Boards of these Universities. The Regional Committees of the ICAR provide an important forum for the scientists from these two agencies to come together and look at the regional research needs. Through Interdisciplinary Scientific Panels of the ICAR, the experts from the Agricultural Universities play a critical role in selecting research programmes at the national level as well as at the regional level. More importantly, various research schemes of the ICAR like the AICRPs, NATP, and ad hoc research schemes provide opportunities for the two subsystems to work jointly on problems of national as well as regional relevance.

As far as the General Universities are concerned, they participate in research activities under different types of research schemes and projects financed by different agencies. Through the AICRPs and ad hoc research schemes, these Universities have established linkages with the ICAR and Agricultural Universities subsystems. Joint programmes in specific areas like plant physiology, biological nitrogen fixation, biotechnology, etc. have been taken up by the ICAR with scientists working in these

Universities. ICAR has also established close linkages with various scientific organizations like CSIR, ICMR, ISRO, BARC, etc. through Joint Panels. Problems of mutual interest have brought the ICAR closer to various Departments and Ministries at the Center to find solutions through collaborative research efforts.

### 2.11 Indian R&D in a Global Context

Developing countries like India, China and Brazil where the economy is based on agriculture have become major forces in the global agricultural economy. It is therefore useful to compare Indian agricultural R&D investment trends with those in these two other emerging economies. India's recent spending growth in public agricultural R&D was impressive at 25 percent during 2000–07, but comparison with China provides relative perspective as China's spending almost doubled during the same period. Similarly, Brazil has one of the most well established and well-funded research systems in the developing world, although spending levels there have fluctuated over the past two decades. Rapid growth, particularly in China, has meant that investments by the three countries combined accounted for at least half of the developing world's total public investment in agricultural R&D in 2000 (Beintema and Stads 2010).

**Table 2.1: Public agricultural R&D spending and intensity ratio, 2000 and 2008**

| Countries/Regions | Year | | | |
|---|---|---|---|---|
| | 2000 | 2008 | 2000 | 2008 |
| | Billion 2005 | | $ per $100 of Ag GDP | |
| India | 1.5 | 2.3 | 0.36 | 0.40 |
| Brazil | 1.2 | 1.3 | 1.86 | 1.80 |
| China | 1.7 | 3.4 | 0.38 | 0.50 |
| Australia | 0.8 | 0.6 | 4.57 | 3.56 |
| Japan | 2.6 | 2.7 | 4.06 | 4.75 |
| South Korea | 0.6 | 0.7 | 1.60 | 2.30 |

Source: Pal, Rahija and Beintema (2012)

From the table 2.1, India invested $0.40 for every $100 of AgGDP in 2008. This is less than the comparative figure for China, which invested $0.50 for every $100 of AgGDP in 2008; it is also less than the average of $0.56 for developing countries in 2000. In contrast, Brazil and Asia's high-income countries invested much larger shares of their AgGDP in R&D, ranging from $1.80 for Brazil to $4.75 for Japan. However, investment in R&D depends on availability of funding and Government policy. The current national agricultural policy anticipates that market forces will guide future agricultural growth through domestic market reforms, an increasing role for the private sector, and removal of price distortions. For example, the policy intervention targeting public distribution of food grains to the poor can have substantial effects on the food grain market. Thus, there is a need to study the cross-functional interactions between the R&D team as well as the marketing and sales team. Additionally, the legal team has to ensure that IP due diligence has been complied with, i.e., patents, trademarks, copyright and designs have been filed, appropriate non-compete confidentiality agreements and deed of assignments have been executed, etc.

### 2.12 Human Resources in the Agriculture Research and Development in India

In spite of an increasing number of private companies supplying agriculture inputs, public-sector research institutes form the backbone of the Indian agricultural research system. Most agricultural scientists in India work for Government agencies and are engaged with the triple function of education, research and extension. It is roughly estimated by Pal et al. (1997) and Ramaswamy and Selvraj (2007) that the number of scientists working in the ICAR/SAU system during the late 1980s was approximately 4,189 in ICAR and 14,851 in the SAUs, giving a total scientific strength of 19,040. The number of scientists remained steady in the ICAR during the 1990s (4,092 in 1998) and increased to 4609 in 2005-2006 (DARE/ICAR 2006). However, the numbers decreased significantly in the SAUs. It has declined by 24 percent in the last decade (Ramaswamy and Selvraj 2007) because of non-replacement of retiring faculty and restrictions on recruitment. Adjusting the number of scientists by share of research expenditure relative to extension and education (for ICAR) and percent time spent on research (for SAUs), the number of full-time scientists in the late 1990s was 2,999 in ICAR and 8,132 in SAUs, giving a total of 11,131 full-time researchers in the country and making it one of the largest agricultural Research and Development (R&D) systems in the world. In 2005-2006 the agricultural scientists of the ICAR institutes were supported by a large technical staff (7355), administrative staff (4705) and supporting staff (9067). However, the ICAR as well as the SAUs are downsizing the administrative staff to balance the ratio of scientific staff to supporting staff.

To provide experience-based and skill-oriented hands-on training to students, 19 Experimental Learning Units were added in 51 universities to the existing 264 units.

Operational guidelines for the National Professorial Chairs and National Fellowships were revised for more functional autonomy and efficient execution, and 16 new ICAR National Fellows were appointed. Three universities (Sri Venkateswara Veterinary University, Tirupati; Shere-Kashmir University of Agriculture and Technology, Jammu; and Navsari Agricultural University, Navsari) were accredited. Niche Areas of Excellence were supported to achieve global competence in agricultural research, teaching and consultancy in the specific fields. In order to reduce inbreeding, 1,763 students in the undergraduate level and 2,076 students in the postgraduate level were admitted through centralized admission by the ICAR. Besides, the ICAR International Fellowships, the India-Africa Fellowship and India-Afghanistan Fellowship programmes were continued for higher studies in the Indian Agricultural Universities.

All-India Entrance Examination for Admission to UG and PG: For admission up to 15% seats in agriculture and allied subjects other than veterinary sciences, 16th All-India Entrance Examination for Admission to undergraduate degree programmes (AIEEA-UG-2011) including the award of National Talent Scholarships (NTS) was conducted on 16 April 2011. In this examination, 34,741 candidates appeared and a record number of 1,763 candidates were finally recommended for admission in 49 Universities through counseling. All the candidates who joined a university falling outside their State of domicile were awarded NTS of 1,000 Rupees per month. For admission to 25% seats in PG programmes at 56 Universities, including award of ICAR Junior Research Fellowships, AIEEAPG-2011 examination was conducted on 17 April 2011. A total of 19,413 candidates appeared in the examination and admissions were recommended to 2,076 candidates, out of which 472 students were awarded JRF in 20 major subject groups. A total of 186 Senior Research Fellowships were awarded and 561 candidates were declared qualified for Ph.D. admission without fellowship in 13 major subject groups and 56 sub-subjects through an examination held on 12 December 2010 (ICAR 2013).

### 2.13 Impact of R&D on Agriculture in India

Recently, the number of agriculture innovations has increased i.e., seeds, pesticides, mechanization etc. which demonstrates positive growth in agriculture. It can be seen in table 2.2 that during the period 1990 to 2000 registrations is fluctuated. One measure of innovation in the seed industry is the number of cultivars the Department of Agriculture notified or recognized as new cultivars during various periods. This is an incomplete measure of innovation because notification is not required except for cultivars from public breeding. Government allows private companies to introduce cultivars without notification, which companies have preferred, and so only few private cultivars have been notified. Even with this partial measure, the rate of innovation holds steady from the 1980s to the 1990s but then grows rapidly after 1999.

**Table 2.2: Trends in notified varieties of major field crops**

| Crop | Number of notified varieties and hybrids by decade | | |
|---|---|---|---|
| | Year | | |
| | 1980-1989 | 1990-1999 | 2000-2010 |
| Rice | 198 | 188 | 303 |
| Wheat | 84 | 66 | 112 |
| Maize | 43 | 64 | 113 |
| Pearl millet | 38 | 45 | 51 |
| Sorghum | 55 | 49 | 55 |
| Cotton | 72 | 78 | 95 |
| Total | 490 | 490 | 729 |

Source: Pray and Nagarajan (2012)

Similarly, pesticides registrations have increased rapidly since the 1980s. Twice as many pesticides were registered in the first decade of the 21st century as were registered in the 1980s below figure. These registrations, all by private companies, are primarily new formulations of active ingredients, but some new active ingredients and formulations for new crops, especially horticulture crops, have been developed (table 2.3).

**Table 2.3: New pesticide registrations by decade, 1968–2010**

| Year | Number of Pesticides registration |
|---|---|
| 1968 | 130 |
| 1970–79 | 105 |
| 1980–89 | 104 |
| 1990–99 | 174 |
| 2000–10 | 228 |

Source: Pray and Nagarajan (2012)

Other innovations in the seed industry were primarily developed by the private sector. Varieties of other crops such as cotton, maize, pearl millet, and sorghum, which are all hybrids in India, primarily come from the private sector (Table 2.4).

**Table 2.4: Numbers of field crop varieties by public-and private-sector institutions in India, 2005–2010**

| Crops | Private Hybrids | Notified Public Varieties |
|---|---|---|
| | Year | |
| | 2005-2010 | 2005-2010 |
| Rice | 79 | 240 |
| Wheat | 40 | 95 |
| Maize | 136 | 87 |
| Pearl millet | 97 | 48 |
| Sorghum | 75 | 46 |
| Cotton | 255 | 70 |
| Total | 603 | 346 |

Source: Pray and Nagarajan (2012)

Despite this success, India faces many critical challenges such as the lack of the public investment in the agriculture sector particularly in irrigation, power, rural roads, market and mechanisation. Also, subsidies on fertilizers have decreased which leads to increases in the cost of production. Further problematic issues include: First, to reduce poverty and malnutrition, which are most prevalent in rural areas, India needs not only to improve the availability of food but also to generate income and employment opportunities for the poor to provide them with access to food. Second, because accelerated economic growth and rapid urbanization are driving demand for high-value commodities, particularly livestock and horticultural products, future agricultural growth needs to be much more diversified. Third, sustainable management and use of natural resources is a growing challenge, with depletion of groundwater, agrochemical pollution, and land degradation by waterlogging, salinity, soil erosion, and deterioration of soil fertility. Fourth, public investment in agriculture in real terms has shown a persistent decline, while subsidies for agriculture have increased over time despite the new economic policies. The decline in public investment has serious implications for agricultural growth and poverty reduction (Roy 2001). Fan, Hazell, and Thorat (1999) found that investment in agricultural research provides a high marginal return relative to other investments in terms of both growth and poverty reduction.

### 2.14 Factors for the Growth of R&D in Public and Private Sector

The growing demand for agricultural products and the need to ensure food security are major factors inducing R&D growth and innovation in India. These also have effects on the market structure. For instance, increases in per capita income have increased demand for food, especially high-quality food such as vegetables, fruit, milk, and meat. Increased income and urbanization have also increased the demand for processed and fast foods. Hence, to meet the growing demand for food, there is a need to increase R&D.

**Table 2.5: Size of the market and research intensities of private agribusiness**

| Sector | Market Size 2009 (in millions of 2005 $US) | % Research intensity Year 1990 | |
|---|---|---|---|
| | | 1990 | 2009 |
| Seed and Biotechnology | 1,300 | 3.5-3.8 | 6.9 |
| Pesticides | 3,200 | 0.8-0.9 | 1.1 |
| Fertilizers | 13,732 | 0.22 | 0.1 |
| Agricultural machinery | 2,100 | 1.0 | 1.2 |
| Poultry and feeds | 1,010 | 1.0 | 0.8 |
| Animal health | 325 | NA | 5.7 |
| Food, beverages, processing, and plantations | 5650 | NA | 0.5 |

Source: Pray and Nagarajan (2012)

The table 2.5 demonstrates that research intensity has been increased from 1990 to 2009 in mostly all the sectors except fertilizers and poultry and feeds. One of the reasons for the decreasing growth in fertilizers is due to environmental concerns. Within this context, the organic farming concept has become important. One can see from the table that seed and biotechnology research has been increased rapidly. The reason of increment in research intensity is the liberalized policy of the Indian Government and success of the Green Revolution, which has attracted investors in the field of agriculture. Moreover, the strengthening of the laws governing appropriate benefits of new technology has encouraged more R&D in innovation. The agricultural sector increasing its research intensity the most is seeds/biotech, which has the second-highest number of agricultural patents and protects its innovations with plant variety restrictions. Pesticide research has the most agricultural patents, which may account for some of the growth and intensity of research in that industry. In addition to market size and somewhat stronger IPRs, other major factors contributing to growth of private agricultural R&D in India are rapid advances in basic biological research and information technology, and growth of public-sector R&D. Biotechnology spread to the agricultural sector in India through both private-and public-sector research laboratories, and the private seed industry has disseminated the technology to farmers. This has continued to be an extremely important factor in the growth of R&D in India in the last decade.

### 2.15 Rice as a Crop Plant

Rice belongs to the genus Oryza and the tribe Oryzeae of the family Gramineae (Poaceae). The genus Oryza contains 25 recognized species, of which 23 are wild species and two, O. sativa and O. glaberrima are cultivated (Morishima 1984; Vaughan 1994; Brar and Khush 2003). O. sativa is the most widely grown of the two cultivated species. It is grown worldwide including in Asian, North and South American, European Union, Middle Eastern and African countries. However, O. glaberrima is grown solely in West African countries.

The centre of origin and centres of diversity of two cultivated species O. sativa and O. glaberrima have been identified using genetic diversity, historical and archaeological evidences and geographical distribution. It is generally agreed that river valleys of Yangtze, Mekon rivers could be the primary centres of origin of O. sativa while Delta of Niger River in Africa as the primary centre of origin of O. glaberrima (Porteres 1956; OECD 1999). The foothills of the Himalayas, Chhattisgarh, Jeypore Tract of Orissa, northeastern India, northern parts of Myanmar and Thailand, Yunnan Province of China etc., are some of the centres. O. sativa and O. glaberrima are believed to have evolved independently from two different progenitors, viz. O. nivara and O. barthii and they are believed to be domesticated in South or South East Asia and tropical West Africa respectively.

Domestication of Asian rice, O. sativa, is considered to have occurred in 7,000 BC (OECD 1999). It has spread and diversified to form two ecological groups, Indica and Japonica (Oka 1988). There are other studies indicating that the two groups were derived independently from the domestication of two divergent wild rices in China and India, respectively (Second 1982, 1986).

### 2.16 History of Rice Cultivation in India

India is an important centre of rice cultivation. The rice is cultivated on the largest areas in India. Historians believe that while the Indica variety of rice was first domesticated in the area covering the foothills of the Eastern Himalayas (i.e. north-eastern India), stretching through Burma, Thailand, Laos, Vietnam and Southern China. The japonica variety was domesticated from wild rice in southern China, which was introduced to India. Perennial wild rice still grows in Assam and Nepal. It seems to have appeared around 1400 BC in southern India after its domestication in the northern plains. It then spread to all the fertilised alluvial plains watered by rivers. Southwest Himalayas has various types and varieties and indicated probable centre of origin. De Condolle (1886) and Watt (1891) mentioned south India is the centre of rice origin. The great botanist and plant breeder 'Vavillov' suggested that India and Myanmar should be regarded as the centre of origin of cultivated rice. According to D. Chatterjee (1948), there are altogether 24 species of genus Oryza of which 21 are wild and two viz., Oryza sativa and Oryza glaberrima are cultivated. Oryza sativa is grown in all rice-growing areas, but Oryza glaberrima is confined to the West Africa only. Thus, it indicates that there might have been two centres of origin of our cultivated rice; South-eastern Asia (India, Myanmar and Thailand) and West Africa.

### 2.17 Rice and Food Security in Asia

Rice is the major staple crop of nearly half of the world's population, and is particularly important in Asia, where approximately 90% of world's rice is produced and consumed (Zeigler and Barclay, 2008; Khush, 2004).The introduction of high-yielding varieties in the late 1960s, which marked the beginning of the Green Revolution, has more than tripled Asian rice production in the past four-plus decades, from 200 million t (paddy equivalent) in the early 1960s to more than 600 million t in 2010. This has been possible with the introduction of modern varieties in tandem with assured irrigation, subsidized inputs (such as fertilizer, fuel, and pesticide), and guaranteed prices. During this period, more than 1,000 modern varieties were released to farmers in Asian countries, with adoption going from 30% in 1970 to about 70% in 1990.

The success of the Green Revolution in the 1960s witnessed a steady rise in Asia's per capita rice consumption from 85 kg in the early 1960s to nearly 100 kg by 2010; on the other hand, global per capita consumption rose from 50 to 65 kg during the same period. The rising per capita consumption in combination with the growing population resulted in a tripling of total Asian rice consumption during this period from 150 to 450 million t (milled rice equivalent). In line with the rising rice consumption, per capita calorie intake also increased by more than 40% from 1,891 in 1960 to 2,706 in 2009. Similarly, life expectancy and infant mortality witnessed significant improvements during the post-Green Revolution era. Although the contribution of rice to total calorie intake dropped in Asia during this period (from 38% in 1970 to 29% in 2009), it still accounts for 45–70% of the total calorie intake in many rice-consuming countries in the region, including, Bangladesh, Cambodia, Indonesia, Vietnam, and many other Asian countries.

**Table 2.6: Rice production in global context (2014-2015)**

| **Rank** | **Top 10 Countries** | **Production (Thousand Metric Tons)** |
|---|---|---|
| 1 | China | 144560 |
| **2** | **India** | **105482** |
| 3 | Indonesia | 35560 |
| 4 | Bangladesh | 34500 |
| 5 | Vietnam | 28166 |
| 6 | Thailand | 18750 |
| 7 | Myanmar | 12600 |
| 8 | Philippines | 11915 |
| 9 | Brazil | 8465 |
| 10 | Japan | 7849 |
| | Others | 71308 |
| | Total | 479155 |

Source: United States Department of Agriculture (USDA) (2016)

The above-mentioned table 2.6 depicts that world-wise rice production in 2014-15 was 479155 thousand metric tons. China tops the list with 144560 thousand metric tons, accounting for 30 percent of global rice production in 2014-15.India is the second largest producer of rice with 105482 thousand metric tons, contributing 22 percent to global rice production in 2014-15. One interesting fact is that the above-mentioned top ten rice-producing countries accounts around 85 percent of global rice production. Further, nine out of top ten rice-producing countries are from Asia, contributing 84 percent to global rice production in the same year. China and India together accounts for 52 percent of total rice production in the world. Therefore, Asia is locus of rice production in the world.

### 2.18 Rice Production in India

India is an important center of rice cultivation. The rice harvesting area in India is the world's largest. India ranks 2nd in rice production and rice-consuming countries in world. The per capita availability of rice in Asia decreased considerably from 154kg in 1989 to 139 kg in 2003, similarly in India it has fallen from 133 kg to 122 kg during same period (FAO 2006). Rice cultivation requires large amounts of water and due to growing scarcity of water in many arid and semi-arid regions farmers are shifting to cultivation of less water-demanding crops (Thiyagarajan2001). Declining profit-ability owing to high input costs and low prices of rice is also leading to farmer's withdrawal from rice cultivation, and thus jeopardizing future rice supply (Thiyagarajan 2001). There is a need to make rice cultivation more efficient in terms of returns on farmer investments and use of water resources.

Rice yields increased by more than 70 per cent between 1966 and 1999 with the introduction of modern HYV accompanied by new management practices such as farm mechanization and the replacement of biological fertilizers by chemical fertilizers (Khus 1999 cited in Frei and Becker 2005). However, the average rate of growth in rice production began to decline during the 1980s (Dawe 1998 cited in Frei and Becker 2005). Technological innovation since the 1960s has helped India to shift from subsistence farming to a productive farming system. That change has led to overexploitation of soil and water. In many parts of the country, the yields of many crops including rice have reached a plateau and further increase in yield without adverse impact on natural resources has become a great challenge for scientists and farmers (Satyanarayana 2005). Biotechnology and greenhouse technology, which have the potential to boost crop yields, are used widely in India. The existing system of rice production, particularly green revolution technology is input intensive and favors cash rich farmers. Increasing prices of agricultural inputs prevent poor farmers from completely adopting modern production technologies.

**Table 2.7: Season-wise Area, Production and Productivity of Rice in India (1991-1992 to 2015-2016)**

| Year | Area (In ' 000 Hectare) | | | Production (In ' 000 Tonne) | | | Productivity (In Kg./Hectare) | | |
|---|---|---|---|---|---|---|---|---|---|
| | Kharif | Rabi | Total | Kharif | Rabi | Total | Kharif | Rabi | Total |
| **1991-1992** | 39594 | 3055 | 42649 | 66368 | 8310 | 74678 | 1676 | 2720 | 1751 |
| **1992-1993** | 38901 | 2875 | 41775 | 65243 | 7625 | 72868 | 1677 | 2652 | 1744 |
| **1993-1994** | 39140 | 3401 | 42541 | 70723 | 9575 | 80298 | 1807 | 2816 | 1888 |
| **1994-1995** | 39441 | 3373 | 42814 | 72603 | 9211 | 81814 | 1841 | 2731 | 1911 |
| **1995-1996** | 39440 | 3397 | 42837 | 67879 | 9097 | 76975 | 1721 | 2678 | 1797 |
| **1996-1997** | 39787 | 3646 | 43433 | 71323 | 10414 | 81737 | 1793 | 2856 | 1882 |
| **1997-1998** | 39546 | 3874 | 43446 | 71571 | 10729 | 82535 | 1810 | 2769 | 1900 |
| **1998-1999** | 40456 | 4347 | 44802 | 71092 | 13238 | 86077 | 1891 | 3073 | 1921 |
| **1999-2000** | 40949 | 4213 | 45162 | 77480 | 12202 | 89683 | 1892 | 2896 | 1986 |
| **2000-2001** | 40703 | 4009 | 44716 | 72778 | 12198 | 84976 | 1788 | 3043 | 1900 |
| **2001-2002** | 40619 | 4285 | 44904 | 80522 | 12818 | 93340 | 1982 | 2992 | 2079 |
| **2002-2003** | 38037 | 3139 | 41176 | 63084 | 8737 | 71821 | 1658 | 2783 | 1744 |

| | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|
| **2003-2004** | 39231 | 3362 | 42592 | 78619 | 9907 | 88526 | 2004 | 2947 | 2078 |
| **2004-2005** | 38364 | 3542 | 41907 | 72230 | 10902 | 83131 | 883 | 3078 | 1984 |
| **2005-2006** | 39332 | 4325 | 43657 | 78272 | 13522 | 91794 | 1990 | 3127 | 2102 |
| **2006-2007** | 39601 | 4212 | 43814 | 80171 | 13185 | 93355 | 2024 | 3130 | 2131 |
| **2007-2008** | 39472 | 4442 | 43914 | 82703 | 13990 | 96693 | 2095 | 3149 | 2202 |
| **2008-2009** | 40810 | 4727 | 45537 | 84951 | 14231 | 99183 | 2082 | 3011 | 2178 |
| **2009-2010** | 37618 | 4300 | 41918 | 75959 | 13134 | 89093 | 2019 | 3054 | 2125 |
| **2010-2011** | 38018 | 4845 | 42862 | 80607 | 15363 | 95970 | 2120 | 3171 | 2239 |
| **2011-2012** | 40123 | 3883 | 44006 | 92738 | 12563 | 105301 | 2311 | 3235 | 2393 |
| **2012-2013** | 38914 | 3840 | 42754 | 92368 | 12873 | 105241 | 2374 | 3353 | 2462 |
| **2013-2014** | 39449 | 4687 | 44136 | 91497 | 15149 | 106646 | 2319 | 3232 | 2416 |
| **2014-2015** | 39828 | 4282 | 44110 | 91391 | 14091 | 105482 | 2295 | 3291 | 2391 |
| **2015-2016** | 39656 | 3843 | 43499 | 91413 | 12995 | 104408 | 2305 | 3382 | 2400 |

Source: Indiastat (1991-2016)

Rice is one of the most important food crops of India in term of both area, production and consumer preference. As table 2.7 indicates that rice production in India has increased from 74678 thousand tons in 1991-92 to 104408 thousand tons in 2015-2016. The year 2001-02 marks lowest yield with 71821 thousand tons, whereas the year 2013-14 marks highest yield with 106646 thousand tons. Rice production in India crossed the mark of 100 million metric tons in 2011-12. The productivity of rice has increased from 1751 kg per hectare in 1991-1992 to 2400 kg per hectare in 2015-16. However, area under rice cultivation has fluctuated between 41000 thousand hectare to 45000 thousand hectare during 1991-2016. The year 2008-09 marks highest area under rice cultivation with 45537 thousand hectare, whereas the year 2002-03 marks lowest area coverage with 41176 thousand hectare.

### 2.19 History of Rice Research in India

The extant literature suggests that innovations in rice in India are almost a century old. As a surprise, it was found that single-seedling planting method for higher yield was known around 100 years ago in Tamil Nadu. A century ago, an innovative farmer in Tamil Nadu had the idea of modifying the existing agronomic practices for rice cultivation by using single seedlings, also wider spacing, and some intercultural operation, with a reported yield of 6,004 kg ha–1. This method, called the *gaja* method, employed interrow spacing of 1½ feet (45 cm) and within-row spacing of 1 foot (30 cm) between single rice plants, resulting in a sparse plant population of only 7–8 plants m–2. Further research into the history of rice cultivation in Tamil Nadu has revealed that in

1911, several farmers published articles in Tamil language on such single-seedling planting (Veludaiyar 1911; Anonymous 1911). The scanned copies of these articles in Tamil and their English versions have been published separately in Thiyagarajan and Gujja (2009). It was also found that this single seedling planting was popularized by the then British Government in the Madras Presidency. By 1914, single-seedling planting was reportedly being adopted in 40,468 ha (Chadwick 1914). Vaidyalingam Pillai's (1911) reported yield of 6,004 kg grain ha-1 with gaja planting methods in Thanjavur district was 2.7 times greater than what had been obtained from the same field the previous year, when using standard bunch planting. Yanagisawa (1996) had estimated that the average rice yield in Thanjavur District in 1911 was 1,693 kg paddy ha-1, while the average yield in this district for the period 1911-1915 was 1,492 kg ha-1 (Sivasubramanian 1961). Thus, the gaja method increased the standard rice production by several multiples. It is fascinating that such high yields were being obtained by farmers with their own innovations a century ago, when no chemical fertilizers were applied. Unfortunately, such farmer innovations have disappeared after scientific recommendations were promoted by the Green Revolution.

### 2.20 Rice Breeding Programmes in India

Rice breeding developing improved varieties has been one of the major thrusts of rice research since its beginning. The rice breeding programme in India was started in 1911 by Dr. G. P. Hector, the then Economic Botanist in undivided Bengal, which had its headquarters at Dacca (now in Bangladesh). Subsequently, in 1912, a crop specialist was appointed exclusively for rice in Madras Province. Prior to the establishment of the Indian Council of Agricultural Research (ICAR) in 1929, Bengal and Madras were the only provinces which had specialists exclusively assigned to improve the rice crop. Subsequently, rice research projects were initiated after the establishment of Indian Council of Agricultural Research in 1929 in various provinces. By 1950, 82 research stations in 14 provinces were established fully devoted to rice research. These research stations released 445 improved varieties mainly by pure line method of selection. These varieties were bred for various ecotypes and other traits such as earliness, deep water and flood resistant, lodging resistant, drought resistant, non-shredding of grains, dormancy of seed, control of wild rice, disease resistant and response to heavy manuring. Thus, during the pure line period of selection from 1911-1949, the advantage of natural selection have been fully exploited and there have been varieties available for every rice ecology. The

Central Rice Research Institute (CRRI) was established in 1946. An inter-racial hybridization programme between japonicas and indicas was initiated during 1950-54. Rice yields thus remained practically very low and stagnant until the launch of the *Indica/Japonica* Hybridization Programme by the FAO in 1952 aimed at recombining the fertilizer responsiveness of *japonica* rices and wide adaptability and preferred grain quality of *indica* rice. It was the earliest international effort to explore the possibilities of breaching the yield barrier in tropical rices. A decade long ambitious *Indica-Japonica* project with CRRI at Cuttack (India) as the primary hybridization centre and major rice growing countries in the region for study of segregating populations of interest proved, however a disappointing experience. This programme continued in India up to 1964 without much success. The International Rice Research Institute was established in the Philippines in 1960. This Institute helped in evolving dwarf high yielding varieties based on the use of a gene from semi-dwarf varieties from Taiwan. Major breeding efforts in rice were thus initiated in the early 1960s and resulted in improved productivity, higher quality and increased tolerance to various biotic and abiotic stresses. Maximum impetus was achieved with the advent of the spontaneous mutant Dee-Geo-Woo-Gen which possessed a dwarfing gene. Dwarf, photo-insensitive and upright-effective plant types which were highly responsive to added dosages of inputs then gave new direction to the rice improvement programmes. Following this plant type concept, Indian rice breeders developed many semi-dwarf rice varieties that increased the productivity of rice in the country and India became self-reliant in its rice production. with a mission mode project and this helped India earn the distinction of being the second country after China to make hybrid technology a field reality. The first four rice hybrids were released in the country viz. APHR-1, APHR-2, MGR-1 and KRH-1 during 1994. Due to concerted efforts made both by the public and private sectors, 42 hybrids have been released so far and about 1.4 mha was covered under hybrid rice during 2008.

The breeding priority has changed over the decades from purification of landraces placing emphasis on early maturity , consumer preference and blast resistance to recombining of desired traits through hybridization and recombinant DNA technology giving emphasis to high yield and value addition. Other important breeding objectives include disease/ pest resistance, field resistance against rice blast, tolerance to unfavourable conditions such as drought, submergence, salinity etc. and improvement in cooking and nutritive quality. Cytoplasmic genetic male sterility (CMS) system is being widely utilized for development of rice hybrids. The first commercially usable CMS line was developed in China in 1973 from a spontaneous male sterile plant isolated in a population of the wild rice O. sativa f. spontanea (Yuan 1977) This source 'Wild Abortive' or 'WA' type is considered a landmark in the history of rice breeding. The first rice hybrid for commercial cultivation was launched by China in 1976. Efforts to develop and use of hybrid rice technology in India was initiated during 1970 but the research works were systematized and intensified since 1989. Indian Council of Agricultural Research (ICAR) started All-India Coordinated Rice Improvement Project (AICRIP) in 1965 at Hyderabad. The coordinated variety improvement and testing programme covers 46 funded cooperating centres in addition to 72 voluntary centres in different rice growing ecologies in the country and involves more than 300 scientists (ICAR, DRR, Progress Report). Under AICRIP, the following trials are carried out at 118 locations spread across 26 Indian States and 2 Union Territories. The AICRIP programme helps to exchange and evaluate breeding material quickly across the country. The aim of AICRIP programme is to improve yielding ability, increase efficiency in the use of external inputs and incorporate resistance to biotic and abiotic stresses. The multi-locational testing of breeding stock developed at different research centres is organized by AICRIP. More than 850 high yielding varieties have been released for different states through the coordinated system.

### 2.21 The Rice Green Revolution in India

In the 1960s, scientists quickly realized that most tall traditional rice varieties lodged easily when nitrogen fertilization was applied, which was the major limitation to grain yield (Khush et al. 2001). The semi-dwarf (sd1) IR8 was the first high yielding rice variety developed from a combination between the Indonesian variety ‘‘Peta’’ and ‘‘Dee Geo Woo Gen’’ from Taiwan. The key factor responsible for the increase in yield potential was the improvement of the harvest index. However, even though IR8 had a major drawback regarding its poor grain quality, it still became the symbol of the green revolution in rice. Within a few years, many countries around the world were replacing their traditional cultivars with the modern high-yielding varieties. The icon of the rice green revolution, when compared to traditional varieties, exhibits certain distinct characteristics; it has shorter stature, a shorter growth cycle, higher tillering ability, higher photosynthetic capacity, responsiveness to fertilizers (mainly nitrogen), and consequently much higher yield potential to high-input environments. In the following decades IRRI developed IR36, which became the most widely planted variety in the

1980s and IR64 was the most used in the 1990s (Peng and Khush 2003). In addition to these varieties, IRRI released a large series of IR coded varieties. However, while these newer materials were characterized by their resistance to disease and insects, they did not contribute significantly to genetic gains for grain yield. Scientists then believed that a new breakthrough in yield potential had to come through a new plant type.

An important development that accelerated breeding research at global level was the establishment of IRRI in the Philippines in 1960. Breeding activities began the very next year with the primary objective of evolving non-lodging semidwarf varieties with higher yields, led to the development and release of IR8 in 1966. This modern variety heralded green revolution in India. IR8, a rare recombinant from the cross between Peta, the popular javanica (tropical japonica) variety of Indonesia and Dee-geo-wugen, the dwarfing gene source from Taiwan, IR8 was the ideal plant type with the highest yield potential the breeders had been dreaming for. The pace at which it was adopted in a short span of time almost in every rice-growing continent, provided the momentum for development of a series of high yielding semidwarf varieties at IRRI and NARS.

The introduction of semidwarf varieties from IRRI to India occurred in 1964 when C. Subramaniam, Minister of Food and Agriculture, visited IRRI and was given seeds of new rice varieties that included TN-1. By 1966, IR8 and other IRRI lines were tested in various experimental fields in India. Shortly after their introduction, these IRRI varieties were crossed with local varieties and by 1998 about three-quarters of the rice area in India was sown to HYVs (Indiastat 2002).The Green Revolution dated from about 1967, reached a peak of adoption around 1978. It involved improvements in crop genetic materials and agricultural practices, especially increase in external inputs that dramatically increased food production, especially wheat and rice. The government began to develop facilities for expanding farmland area and introduced modern irrigation systems, making it possible for farmers to plant two crops a year instead of one. Most notably, Indian farmers planted genetically-improved seeds that greatly increased crop yields. Within a decade, India became one of the world's largest producers of farm products. In some years, farmers produced more food grains than the Indian people needed, so the excess was sold to other countries. Famine in India, once considered as inevitable, has not returned since the introduction of Green Revolution crops (http://www.bigsiteofamazingfacts.com). In wheat, for example, production increased by a third from 12.3 million tonnes in 1964-1965 to 16.6 million tonnes in 1967-1968, and 20 million tonnes in 1969-1970. Rice production increased more slowly (due to the late introduction of IR-8), growing from 30.5 million tonnes in 1964-1965 to 40 million tonnes in 1969-1970. More importantly, these gains in yield were resilient to fluctuations in the monsoon, the primary natural driver of Indian macro-level food shortages. An early example of this was seen in the poor weather of 1968-1969, when there was a decrease of 2% against the previous year's record yield. By 1977, India no longer required significant cereal imports, and in later years it became an intermittent exporter. Clearly, these statistics show that India achieved the primary goal of the Green Revolution, the restoration of agricultural self-sufficiency on the national level (Arena 2005). The achievements through the Green Revolution have come with a price, however, as many traditional varieties were ignored or lost, and reliance on chemical fertilizers grew, forgetting to maintain the organic sources of soil fertility restoration from animals and plants, and most importantly, making farmers totally dependent on other inputs not only for their seeds, fertilizers, and pesticides, but even for their knowledge and cultivation methods. By the end of the Green Revolution, with erosion of local varieties, replacement of organic fertilizer, and dependence of farmers on scientific institutions for guidance and advice, had resulted in agriculture being driven by factors other than the farmers themselves in the entire sphere.

### 2.22 International Collaboration in Rice Improvement Programmes

Speedy evolution and extensive adoption of progressively improved varieties/hybrids in the last four decades would not have been possible but for the well-organized institutional mechanism for accessing needed genetic variability, tools and techniques for generating breeding material and systems for reliable and rapid evaluation of them and production and supply of quality seed. Establishment of the IRC in 1949 under the FAO framework was the first global initiative for promotion of rice research and development. Since its inception it has been engaged in various rice improvement related research and development programmes. Among several, cooperative varietal testing, collection cateloguing and maintenance of rice cultivar germplasm and Asiawide indica-japonica hybridization for yield enhancement of tropical rice are important. Involved in setting up several regional networks/working groups during the 80s, it has been supporting Interregional Cooperative Research Network on Rice in the Mediterranean Climate Areas, Wetland Development and Management Network/Inland Valley Swamps, Working Groups on Hybrid Rice in Latin America and International Task Force on Hybrid Rice. FAO has MoUs with IRRI for strengthening collaborative action aimed at promoting wider adoption of hybrid rice technology outside China and with WARDA for rainfed rice technology diffusion in West Africa. Under the Rice Development Programme as approved by IRC member countries, FAO and International institutions, have the many programmes such as Hybrid rice development & use, Rice Integrated Crop Management, New Rice for Africa (NERICA), Prospecting with rice and Support to the special programmes on Food Security (Rice Almanac 2002) The second major institutional support for improvement of rice was the establishment of IRRI with the mandate of improving the well-being of present and future generations of rice farmers and consumers by generating and disseminating rice related knowledge and technology and strengthening the National Rice Research Systems (NRRS). Its problem focused activities vis a vis the mandate broadly cover (a) collection, conservation and evaluation of genes of value, documentation and exchange of germplasm (b) improvement of rice for enhanced productivity, stability and profitability for diverse rice ecologies and (c) facilitating flow of germplasm and knowledge to NARS through International Rice Testing Programme/ecoregional research networking on problems of mutual interest (eg: Rainfed Lowland and Upland Research Consortia Research networks on Hybrid Rice; Asian Rice Biotechnology Network etc and training). Other major institutional initiatives for improvement of rice include establishment of West Africa Rice Development Association (WARDA) in Africa established in 1970 as an autonomous intergovernmental research association of 17 West and central African countries (since 1980, a member of the CGIAR) is mandated with ensuring food security and allevation of poverty in the region through technology development for sustainable growth of rice sector. Yet another effort for improvement of rice in Africa has been through the International Institute for Tropical Agriculture (IITA) located in Nigeria. The CIAT was established in 1967 in Latin America with the mandate of alleviating hunger and poverty in the tropical developing countries through enhancement of agricultural productivity by developing and applying science and technology. Among its major mandated crops rice has been one since its inception. The rice programme aiming at improving the nutritional and economic well-being of rice growers in Latin America and the Caribbean focuses on germplasm improvement for increasing production/productivity on sustainable basis.

### 2.23 Institutionalisation of Agricultural Biotechnology Research in India

By 1980, several national research council's in India had become aware of the potential importance to India of the advances being made in North America and Western Europe in modern biotechnology in the areas of medicine/pharmaceutics, agriculture and industry. At the initiative of the Council for Scientific and Industrial Research (CSIR) and the Department of Science and Technology (DST), two meetings were held in 1981 (April and July) to discuss the strategy for the development of biotechnology in India. The meetings were attended by a select group of senior scientists, the leadership of CSIR and DST and some top government officials. Within days of the July meeting, the Scientific Advisory Committee to the Cabinet met and recommended to the government the creation of a National Biotechnology Board (NBTB). The NBTB was set up in 1982, with the initial objective of creating awareness among leading circles in the medical/pharmaceutical, manufacturing and agricultural industries, as well as in relevant government departments, of the possibilities offered by biotechnology (Naresh Sharma and Janaki 1999). At first, the NBTB concentrated on vaccines, plant tissue culture, afforestation of dry lands, and subjects related to these areas. This limited mandate was soon widened and NBTB was transformed in 1986 into the Department of Biotechnology (DBT) under the Ministry of Science and Technology. Since then, DBT has been the principal research council for planning, funding, promoting and coordinating biotechnology R&D programmes in all the four sectors of modern biotechnology, medical/pharmaceutical, agricultural, industrial and environmental. DBT has established five specialist R&D institutions under its own financing umbrella, one each in immunology, cell research, DNA fingerprinting, brain research and plant genome research. DBT's work is guided by two expert committees, the Scientific Advisory Committee and the Standing Advisory Committee (Overseas), as well as by a number of taskforces. While the two committees provide advice on policy matters, priority setting and monitoring of special projects, it falls to the task forces to provide advice on how to promote R&D in specific areas and to assist in reviewing and assessing research proposals submitted by institutions from all over the country for funding by DBT. The first consolidated move to promote R&D work in GM-crops in India was made in 1990 by DBT, when it provided generous funding for the creation of six Centres of Plant Molecular Biology (CPMB), one each at the Bose Institute (in Kolkata/Calcutta, West Bengal), Jawaharlal Nehru University (New Delhi), Madurai Kamaraj University (in Madurai, Tamil Nadu), National Botanical Research Institute (in Lucknow, Uttar Pradesh), Osmania University (in Hyderabad, Andhra Pradesh) and Tamil Nadu. Agricultural University (in Coimbatore, Tamil Nadu). A seventh CPMB was established in 1997 in the University of Delhi South Campus (Sharma, Charak and Ramanaiah

2003). In addition to the work at the CPMBs, DBT supports a number of GM-crop projects in several national laboratories, specialist research institutes and centers, and 'elite' institutes of technology and universities (agricultural and general) that come under the aegis (financing umbrellas) of other large central national research Councils, such as the ICAR, CSIR, DST and UGC. The other main supporter of agricultural biotechnology R&D is the Indian Council for Agricultural Research (ICAR), which falls under the Ministry of Agriculture. Up until 2002, ICAR rendered its assistance indirectly by making the R&D and field cultivation infrastructure, which it funds in a number of agricultural universities and specialist research institutes, available to DBT funded projects. Since 2003, ICAR has committed itself to substantial direct funding of GM-crops research in the agricultural universities and institutes that come under its aegis. To further strengthen research in the area of crop biotechnology, a new institute, National Centre for Plant Genome Research (NCPGR) has been established in New Delhi in1997 with a mandate to strengthen plant biotechnology research in India. The Institute started to function in the year 1998 with the mandate to undertake, promote and co-ordinate research, train workers and to serve as information resource in identified aspects of plant genome to build a frontline plant genomics institution. NCPGR is contributing heavily towards frontier areas of Plant Biology such as, computational biology, genome analysis and molecular mapping, molecular mechanism of abiotic stress responses, nutritional genomics, plant development and architecture, plant immunity, molecular breeding, transgenic for crop improvement and other emerging areas based on plant genomics.

**2.24 Transgenic Rice Research in India**

Research into transgenic rice has had a late start in India. The early and continued emphasis placed by ICAR and the rice research groups on developing rice varieties that are resistant to abiotic stresses like drought and salinity was not regarded until recently by GM-researchers as interesting and appropriate topics for a transgenic approach. Resistance to biotic stresseslike attack by pests and diseases was considered to be the more relevant challenge for GM-research, as this would require the transfer of genes across species barriers, whereas abiotic stress could be handled by conventional, non-GM intra-species crossing and hybridization (Janaiah2002).

In addition to the substantial direct funding by the DBT, and the indirect infrastructural support by ICAR, the multi-faceted assistance provided by the Rockefeller Foundation through its International Program on Rice Biotechnology

(IPRB) has been pivotal and decisive in establishing transgenic rice research in India. The Rockefeller Foundation launched the IPRB in 1984 and ended it in 2000. Support was provided to a number of advanced public-sector research institutions in 12 industrialised countries (high-income countries, HICs, in Rockefeller terminology), three IARCs in the CGIAR system, 73 public-sector universities and research institutions in 12 Asian developing countries(low-income countries, LICs) and four institutions in Latin America. The strategy adopted was to focus the first half of the 17-year period on promoting basic research (i.e. into the fundamentals of the science of rice biotechnology) at the HIC institutions and IRRI, and the second half on transferring the know-how from, and the results of, the basic research to the LIC institutions. Periodic international meetings were held, which helped to develop collaborative research projects between the HIC institutions, the IARCs and the LIC institutions (Toole et al. 2000).

In addition to research, a major part of IPRB was devoted to the training of scientists from the HIC and LIC institutions to various levels (doctoral, post-doctoral, etc.). Over 400 scientists were provided training, most of them Asian, with China and India accounting for a big share The ‘trainees’ from the LICs were carefully matched with the ‘trainers’ in the HICs on the basis of shared research interests, as well as the present and future capacity needs of the trainees’ home institutions. Rockefeller financed the acquisition of some essential state-of the-art research equipment (including information technology) by participant institutions, the distribution of theses, reprints, books and patents’ information, and the publication and distribution of the newsletter "Rice Biotechnology Quarterly". All these activities were integral parts of a sustained effort by IPRB to build capacity in the participating LIC institutions in the field of rice biotechnology. A major stage was reached in 1988, when the international effort resulted in a molecular genetics map of rice. The map and its DNA markers were disseminated worldwide. As of the early 1990s, rice became the model plant for cereal genomic research. Rice genome sequencing projects began in Japan and the US, which were then combined and expanded to include a range of other countries, to become the International Rice Genome Sequencing Project. Within the framework of this project, India has successfully completed sequencing a part of chromosome. China and India have been the major beneficiaries of the IPRB, together accounting for about 60 percent of the training grants and research project funds. Twenty-four institutions in India participated in the IPRB and over 110 scientists from India with trained under various kinds of fellowships (doctoral, post-doctoral, career and short duration). The IPRB has also made a major contribution towards developing India's generic capacity in plant molecular biology research, in particular in the areas of GM- technology and marker assisted breeding in rice (Pental 1998). It has brought together plant molecular biologists and crop breeders who rarely interacted before.

One of the major outcomes of IPRB, which accelerated R & D in transgenic rice in India was establishment of Asian Biotechnology Network (ARBN). Rebecca Nelson formed ARBN in 1993 with funding from the Asian Development Bank, IPRB and by German government at its later stage with support from the Rockefeller foundation, DBT and ICAR, the Indian member institutions of the IPRB set up an Indian National Rice Biotechnology Network (INRBN) in 1989. Its stated aims are to coordinate the work going on in India into transgenic rice, avoid duplication, share research facilities, and promote inter-institutional exchange of information, literature, know-how and experience. The ARBN focused on biotechnology research and variety development in ten different institutes within National Agricultural Research and Extension System (NARES) of six Asian countries namely, PhilRic from Philippines; AGI from Vietnam; DRR, PAU, and CRRI from India; CNRI, GAAS, IGAU from China; DOA Thailand; ICABIOGRAD from Indonesia. Consequently, across the time, 18 training workshops were organized in which 630 researchers participated from NARES partner institutions, 3-9 months shuttle research werealso organized in which 39 researchers participated and 186 graduate students conducted thesis research. Eventually, ARBN ended in 2002.

Sustained effort of IPRB, which started in 1984, resulted in development of first DNA molecular marker map of rice in 1988. This milestone achievement paved the way for rice genomic research. Subsequently, from early 1990, efforts were made by scientists to have full structural information on rice genome and rice became the model plant for cereal genomic research. The rice genome sequencing project was initiated by Japan in 1997 and it got under way in 1998 with joining of USA. It expanded with participation of other countries and eventually transformed into International Rice Genome Sequencing Project (IRGSP).Within the framework of this project, India has successfully completed sequencing a part of chromosome. India joined the IRGSP in June 2000. It was joint effort of Department of Biotechnology (DBT) and Indian Council of Agricultural Research (ICAR), which led to the formation of the 'Indian Initiative for Rice Genome Sequencing' (IIRGS). IIRGS was carried out collaboratively by three institutes namely, Department of Plant Molecular Biology (DPMB), University of Delhi

South Campus (UDSC); the National Research Centre on Plant Biotechnology (NRCPB), New Delhi; and the Indian Agricultural Research Institute (IARI), New Delhi. About Rs. 48.83 crores (~ $10 million), two independent research facilities were established at UDSC and NRCPB for sequencing and detailed annotation of the generated data. (Frontline Magazine June 07, 2002).This project was completed in December 2004 and its results were published in Nature on August 11, 2005.

Another major event that provided impetus to the growth and development of transgenic rice research in India was formation of National Consortium for Functional Genomics of Rice (NCFGR). To explore the potentials of functional genomics in India, a meeting comprising of Indian rice scientists and IRRI scientists was organised in New Delhi in May 2002. Continuous discussions and deliberations for two days led to crystallization of the idea of establishing National Consortium for Functional Genomics of Rice (NCFGR). Consensus was also made to develop programs on the functional genomics of indica rice in few selected areas. With strategic approach, the main objective of NCFGR is to unfold and unravel the functioning of signal transduction and transcription components of genes from rice, which would be ultimately helpful in identification of several useful genes for improvement of rice and other related cereal crops as well as validation of their function for crop improvement.

NCFGR mainly comprises of five public institutions. Thirteen scientists having prior experience in rice genetics, transgenics and genomics were selected for working on this project. At least four scientists from Indian Institute of Science (IISc) and Delhi University South Campus (UDSC) would work together on procurement/design/development of a microarray system to analyze signal transduction (e.g. kinases, receptors) and transcription factor genes. It was also decided that selected crucial genes would be functionally validated in transgenics by methods of over-expression and functional knockout approaches, which would be carried out at IISc, UDSC, the Directorate of Rice Research (DRR), Madurai Kamraj University (MKU), and Osmania University (OU). It was expected that each group of scientists at UDSC, DRR, IISc, MKU and OU would work with about 20 gene constructs to generate at least 10-20 independent transgenic lines for each and analyze them in network mode at To and TI generations. Apart from IRRI collaboration, international cooperation was obtained with consent of scientists from Japan on advice and sharing of genomics resources and information's. A budget of Rs 670 millions has been approved for this project. This project is still under operation (www.genomindia.org, accessed on March 11, 2016).

**Table 2.8: Major Indian Developments in Transgenic Rice Research and Application in Public and Private Sector**

| Institution | Transgenes inserted | Aim of the project |
|---|---|---|
| Bose Institute, Kolkota | Sadenosyhlmethionine Decarboxylase | To generate plants tolerant to stress |
| Centre for Cellular and Molecular Biology, Hydrabad | Bar | To generate herbicide-tolerant plants |
| Central Rice Research Institute, Cuttack | Bt cry1A(b) Xa21 | To develop plants resistant to lepidopteranpests, bacterial blight/ disease |
| Delhi University, South Campus, New Delhi | Pyruvate decarboxylase and alcohol dehydrgenase<br><br>Coda, Cor47 | To generate plants tolerant to flooding<br><br>Resistance against biotic and abiotic stresses |
| Indian Agricultural Research Institute, New Delhi | Bt cry1A (b), chtinase | To generate plants resistant to lepidopteranpests |
| IARI sub-station, Shillong | Bt. Cry1A (b) | To generate plant resistant to yellowstem borer |
| International Centre for Genetic Engineering and Biotechnology, New Delhi | Gm2 | To generate plant resistant to gallmidge |
| Madurai Kamraj University, Madurai | Chitinase, b-1, 3-glucanase and osmotin genes | To develop plants resistant to fungal infection |
| Narendra Dev University of Agriculture, Faizabad | Cry 1A (b) gene | To generate plant resistant to fungal, lepidopteranpestsand bacterial diseases |
| Tamil Nadu Agricultureal University, Coimbatore | GNA gene | To generate plants resistance against pestsgall midge |
| MAHYCO Research Foundation, Hydrabad | Bacterial blight resistance conferring Xa-21 gene | To generate plant resistant to bacterial blight |

Source: Annual Report, Department of Biotechnology (2006)

It is quite evident from table 2.8 is that most of the R&D work in transgenic rice in India has been, conducted in the central government-funded public sector research institutes, universities and research centers. Agricultural universities receiving substantial financial and infrastructure support from respective state governments and Indian Council of Agricultural Research (ICAR) are also involved in conducting research in biotech crops. Total ten public sector institutes and one private institute are conducting research on transgenic rice till the year 2007 and two kinds of traits are being tackled, viz. resistance to attacks by insect pests, viral and fungal diseases (called 'biotic' stresses); tolerance of the 'abiotic' stresses of drought, water logging and salinity.

**Table 2.9: Transgenic Rice under Development and Field Trials Rice from 2007-2013**

| Institution | Year | No. of Transgene (s) selected for trial | Trial | Aim of the project |
|---|---|---|---|---|
| E.I. DuPont India Pvt. Ltd. | 2012 | 4 | Event Selection (Conducted) | Herbicide tolerance |
| | 2011 | 4 | Event Selection (Conducted) | Insect tolerance |
| | 2010 | 1 | Event Selection (Conducted) | Male sterile female inbred rice lines |
| BASF India Limited | 2011 | 1 | Seed production (Conducted) | Yield Enhancement |
| | 2010 | 1 | Event selection (Not conducted) | Yield Enhancement |
| Bayer Bioscience Pvt Ltd. | 2011 | 1 | Event selection under nethouse(Conducted) | Insect Resistance and Herbicide Tolerant |
| | 2010 | 1 | Event selection(Conducted) | Insect Resistance and Herbicide Tolerant |
| | 2009 | 1 | Event Selection (Conducted) | Insect Resistance |
| | 2008 | 1 | Event Selection (Conducted) | Insect Resistance |
| Metahelix Life Sciences Pvt. Ltd. | 2010 | 1 | Event selection(Conducted) | Insect Resistance |
| Department of Botany, University of Calcutta | 2010 | 1 | Event selection(Conducted) | Stress tolerance (Abiotic) |
| MAHYCO | 2009 | 1 | NA | Insect Resistance |
| | 2007 | 1 | Event selection(Conducted | |

Source: Data analyzed from Indian GMO Research Information System (IGMORIS). http://igmoris.nic.in/

From Table 2.9, it can be inferred that R&D work in transgenic rice in India which was earlier located in public sector research institutes has now shifted to private sector rice research institutes. Total five private sector research institutes and one public sector institute are involved in conducting field trials on transgenic rice from 2007 to 2013 and there is no change in traits tackled viz. resistance to attacks by insect pests, viral and fungal diseases (called 'biotic' stresses); tolerance of the 'abiotic' stresses of drought, water logging and salinity.

### 2.25 A Case of Golden Rice

Golden rice is a variety of rice (Oryza sativa), which has been produced through genetic engineering to biosynthesize beta-carotene, a precursor of vitamin A, in the edible parts of rice. In 1993, (Peter Beyer Applied Biosciences, University of Freiburg, Germany) and Ingo Potrykus (Institute for Plant Sciences of the Swiss Federal Institute of Technology (ETH, Zurich) began investigating how β-carotene is produced in daffodils (Narcissus pseudonarcissus). They isolated the biochemical steps that make the flower yellow and discovered that they could produce the vitamin A precursor in rice by the addition of three genes, the plant psy gene from daffodil, the crti gene from the bacterium (Erwinia uredovora) and the selective marker hygromycin phosphotransferase (aphIV) gene. The genes as well as the entire β-carotene biosynthetic pathway were introduced into rice endosperm in a single transformation effort through an Agrobacterium vector. The vector pB19hpc combined the sequences for the daffodil psy and bacterial crti placed under the control of endosperm-specific glutelin and constitutive cauliflower mosaic virus 35S promoter. This transgene construct constituted as a plasmid was expected to direct the formation of lycopene in the endosperm plastids (Ye et al. 2000). Pre-cultured immature rice embryos were inoculated with Agrobacterium, and hygromycin-resistance plants were analyzed for the presence of psy and crti genes. The antibiotic marker, hygromycin-resistance, was later replaced by the phosphomannose isomerase (plant cells lacking the marker are unable to survive on a synthetic mannose-a sugar monomer medium) (Privalle 2002) to avoid an antibiotic selection system which may slow a regulatory process (Hoa, Al-Babili, Schaub, Potrykus, and Beyer, 2003). The maximum carotenoid level in the transgenic lines was 1.6 μg/g, with about 50% of it as β-carotene (Ye et al. 2000). Although 0.8 μg/g of β-carotene was significantly higher than the level in white rice, it was unknown that this amount could make a meaningful dent on VAD. This allowed early critics of GR to diminish the results because children would have to consume unrealistic amounts of GR to achieve their recommended daily intakes of vitamin A equivalents (De Moura, Miloff, and Boy 2015). This study, nevertheless, provided the proof of concept that β-carotene could be produced in rice grain, also called the first generation of GR (Al-Babili and Beyer 2005). Unknown at this stage however was whether and to what extent the β-carotene would convert into usable vitamin A and prove bioavailable (Brooks 2013).

Furthermore, while japonica rice varieties were utilized for GR development, its target populations live where indica varieties are predominant. Therefore, transferring the β-carotene trait into indica varieties and ensuring stable trait expression became a critical issue (Brooks 2013). Eventually, the GR trait was transferred to indica type cultivars; a study reported two transformed elite indica varieties, which were considered highly valuable because of projected prompt approval (Hoa et al. 2003). The next logical approach to increase the β-carotene level in the first generation GR was to identify a rate-limiting step in the enzymatic pathway of the process and overcome it. This approach led to the development of the second generation GR (Al-Babili and Beyer 2005). Introduction of the maize (Zea mays) psy gene in place of one from the daffodil enabled the second generation GR to be developed under the hypothesis that the daffodil psy gene limited β-carotene accumulation (Paine et al. 2005). Through systematic testing, the psy gene from maize was identified to substantially increase β-carotene accumulation. The scheme used to generate the transgenic events involved the maize psy gene, bacterial crti gene, rice glutelin promoter, catalase gene from castor bean and a hygromycin-resistance marker. Subsequent analysis of the rice showed that the GR trait was stable and heritable. More importantly, a significant increase, up to 23-fold in comparison to the first generation, in total carotenoids was observed with a maximum of 37 μg/g of which 31 μg /g is β-carotene (Paine et al. 2005).

### 2.26 Entrance of 'Golden Rice' in India

There are two different versions about the beginning of golden rice research in India. According to first version, the major event that heralded the initiation of golden rice research in India occurred in 1999 at the big closure meeting of the Rockefeller IPRB held in Phuket, Thailand, where Ingo Portrykos, a co-inventor of golden rice offered India to conduct research on golden rice. This offer was embraced by DBT and ICAR. This event marks the beginning of golden rice research in agriculture history of India. Acting positively to the offer, DBT decided to import golden rice technology and trusted four institutes namely, Delhi University South Campus (DUSC) New Delhi; Tamil Nadu Agriculture University, Coimbatore (TNAU), Indian Agriculture Research Institute Pusa Campus New Delhi; and Directorate of Rice Research, Hyderabad to carry research on golden rice. DUSC was entrusted with the responsibility to obtain gene construct of golden rice and make available to other three above mentioned institutes. With the mutual consensus between institutes it was also decided that DUSC and TNAU will carry out the transformation work and IARI and DRR would do the necessary backcrossing into local cultivars (Indira et al. 2005).

According to second version, the golden rice entered into India through a collaborative network that was originally set up in 2002 and coordinated by Dr. Gerard Barry of the International Rice Research Institute (IRRI), Philippines. Main partners of this network were: Philippines Rice Research Institute (PhilRice); CUU Long Delta Rice Research Institute, Vietnam; Department of Biotechnology, Directorate of Rice Research, Indian Agricultural Research Institute, University of Delhi South Campus, Tamil Nadu Agricultural University, Agricultural University, Pantnagar and University of Agricultural Sciences, Bangalore, all in India; Chinsurah Rice Research Station and Bangladesh Rice Research Institute in Bangladesh; Huazhong Agricultural University, Chinese Academy of Science, Yunnan Academy of Agricultural Sciences, in China, and the Indonesia Agency for Agricultural Research and Development in Jakarta.

At present golden rice network in India is funded by the DBT and coordinated by Dr. S.R. Rao, Adviser, Department of Biotechnology (DBT). The network now comprises of just three public sector institutions namely, Indian Agriculture Research Institute (IARI), New Delhi, Directorate of Rice Research (DRR), Hyderabad and Tamil Nadu Agriculture University, Coimbatore. The first phase of the project started in 2002 and the second phase in 2006. At the very outset, genetic background of IR64 and Taipei 309 and SGR1 line in the cocodrie variety (javanica) were utilized as donors with the help of backcross breeding techniques and aphl1V as selectable marker. However, later it was found that these donors have low carotenoids content (6.0µg/g) and owing to this the programme was discontinued. Further, Syngenta, a leading seed giant, through HumBo, agreed to provide six SGR2 events (G1, R1, LI, T1 AND W1) to be used in public sector for research in breeding programme in different countries including India. The SGR2 has high carotenoids content with 37.0µg/g. Kaybonnet (javanica) background is used as donner and pmi as selectable marker. The method of transformation is called as agrobacterium mediated co-transformation (Haritha et al; 2014). An effort to develop Indica versions of golden rice using the transgenic kaybonnet variety as donor is under operation at all the three above mentioned institutes. At directorate of rice research, Hydrabad, work is under progress to make samba Mahsuri and MTU1010 Vitamin A enriched through transgenic techniques. Likewise, at the Indian Agriculture Research

Institute (IARI), New Delhi, all effort is made by scientists to transform the Swarna, a popular variety extensively grown in India into Indian version of golden rice. Whereas, a variety named ADT43 is used as recurrent parent for injecting Vitamin A trait at Tamil Nadu Agricultural University, Coimbatore (Haritha et al. 2014). However, the trajectory of golden rice development in India suggests that since its inception, the project golden rice was deliberately pushed into well-established institutes. These institutes are well-established in terms of infrastructure and scientific manpower particularly in field of rice research in India. This also further indicates that government is very much optimistic about the application of golden rice in India and did not want to take any risk pertaining to the project.

### 2.27 Application of Marker-Assisted Selection in Rice Research with Special Reference to Indian Context

MAS can be defined as selection for a trait based on genotype using associated markers rather than the phenotype of the trait (Foolad and Sharma 2005). Sometimes the term "Smart Breeding", an acronym for "Selection with Markers and Advanced Reproductive Technologies", which was first used in animal breeding (Davis et al. 1997), is used to describe marker supported breeding strategies.

In India, MAS in rice breeding has mainly started with being utilized for the pyramiding of disease resistances, namely bacterial blight and blast. The pyramided BB resistance genes, Xa4+xa5+Xa21, expressed strong resistance to virulent BB isolates of Korea compared with individual resistance genes that are moderately to completely susceptible (Jeung et al., 2006). The resistance genes xa5, xa13, and Xa21 have been pyramided into an indica rice cultivar (PR106) using MAS that expressed strong resistance to BB races of India (Singh et al. 2001). Hittalmani et al. (2000) pyramided three major genes (Pi1, Piz-5 and Pita) using RFLP markers from three parents for rice blast into a single cultivar Co-39. Two commercially cultivated rice cultivars (Angke and Conde) were released in 2002 for cultivation in Indonesia. They possess gene pyramids Xa4+xa5 and Xa4+Xa7, respectively (Bustamam et al. 2002). In the Philippines, two rice cultivars (NSIC Rc142 and NSIC Rc154) have the gene combination Xa4+xa5+Xa21. These genes have been integrated into the susceptible cultivar IR64 genetic background using MAS (Toenniessen et al. 2003) and in China the photosensitive genic male sterile line 3418s (Luo et al. 2003), restorer lines R8006 and R1176 (Cao et al. 2003) and Kang

4183 (Luo et al. 2005) were successfully developed with a high resistance to bacterial blight by using the bacterial blight resistant gene xa21.

Marker-Assisted Backcross Breeding (MABB) coupled with phenotypic selection for agronomic, grain and cooking quality traits has been used to incorporate BB resistance genes xa13 and Xa21 into 'Pusa Basmati 1' (Joseph et al. 2004). One of the improved lines was released as 'Improved Pusa Basmati 1' for commercial cultivation in 2007 (Gopalakrishnan et al. 2008), and this is one of the first product of MAS to be used in India. However, the susceptibility of 'Improved Pusa Basmati 1' and other Basmati rice varieties to rice blast and sheath blight (ShB) diseases remains a major concern. Later, Atul Singh et al. (2012), identified a blast resistance gene Pi54 and ShB resistance quantitative trait loci (QTL) - qSBR11-1 from a cultivar 'Tetep' to Improved Pusa Basmati 1 through MAS and the improved lines have desirable Basmati grain and cooking quality characteristics, in tandem with inbuilt resistance to BB, blast and ShB, and yield on par with 'Improved Pusa Basmati 1'.These multiple biotic stress-resistant lines will now be evaluated under multi-location trials for release to farmers as improved Basmati cultivars.

The achievements in rice blast resistant breeding program include the applications of the blast resistant genes, such as the Pid1, Pib and Pita pyramided to G46B (Chen et al. 2004), the Pi2 introduced into Zhenshan97B (Chen et al. 2004) and the Pi1, Pi2 and Pi33 introgressed to Jin23B (Chen et al. 2008). Parallel to these efforts, the resistance breeding team at Directorate of Rice Research (DRR), Hyderabad have introgressed three bacterial blight resistance genes Xa21, xa13 and xa5 into the elite, high yielding, fine-grain type rice variety, Samba Mahsuri through marker-assisted breeding (Sundaram et al. 2008).

A three-gene pyramid line, RPBio-226 (IET 19046) was identified to possess high yield, good level and broad-spectrum bacterial blight resistance and excellent grain quality. Recently, this line has been released for commercial cultivation as a new variety 'Improved Samba Mahsuri'. A sister line of Improved Samba Mahsuri, RPBio- 210 (IET 19045), which has high level of BB resistance, high yield, good grain quality has been recently registered with the National Bureau of Plant Genetic Resources (NBPGR) as a novel germplasm (Sundaram et al. 2010). Recently, Shanti et al. (2010) introgressed Xa4, xa13, xa5 and Xa21 genes into the hybrid rice parental lines KMR3, PRR78, IR58025B, Pusa 6B and the popular cv. Mahsuri. Whereas Zhan et al. (2012) developed an elite restorer line R8012 carrying multiple genes (Pi25/Xa21/xa13/xa5) through MAS, in which all the resistance genes can confer resistance to BB and blast.

The performance of the BB-resistant version of Pusa RH10 produced by intercrossing the improved parental lines was on par with or superior to the original Pusa RH10 (Basavaraj et al. 2010). Importantly, we now have BB-resistant Basmati breeding lines in the genetic background of Pusa Basmati-1 (Joseph et al. 2004), Pusa RH10 (an aromatic hybrid, Basavaraj et al. 2010) and a traditional Basmati, Type-3 (Rajpurohit et al. 2011). Pandey et al. (2013) improved the two traditional BB-susceptible Basmati varieties (Taraori Basmati and Basmati 386), through the strategy of limited marker-assisted backcrossing for introgression of two major BB resistance genes, Xa21 and xa13, coupled with phenotype-based selection for improvement of their plant type and yield. Table 2.10 given below demonstrates rice varieties released using MAS technique for commercial cultivation in India. Two varieties have namely Improved Pusa Basmati-1 and Swarna Sub1 have been released by by IARI and IRRI for commercial cultivation in India. Whereas one variety namely Improved Samba Mahsuri have been developed and released by the collaborative efforts of DRR (ICAR- sponsored institute) CCMB (CSIR-sponsored institutes). This variety is mainly released for the farmers of southern part of India. The utility ofPusa Basmati-1 and Improved Samba Mahsuri developed through molecular markers lies in resistant tobacterial blight disease (biotic stress resistance of rice). Swarna Sub 1 carries the potential of submergence tolerance (abiotic stress).

**Table 2.10: Products Developed through Marker Assisted Breeding in Rice in India**

| Name of Institute | Variety | Recurrent Parent | Trait / Genes |
|---|---|---|---|
| **IARI,New Delhi** | ImprovedPusa Basmati –1 | Pusa Basmati-1 | Bacterial Blight (xa-13 + Xa-21) |
| **DRR-CCMB, Hydrabad** | Improved Samba Mahsuri | Samba Mahsuri (BPT-5204) | Bacterial Blight ( xa-5 +xa-13+ Xa-21) |
| **IRRI** | Swarna Sub1 | Swarna | SubmergenceTolerance (Sub1) |

Source: Annual Report, ICAR (2012)

**Conclusion**

Agricultural research in India has an interesting history regarding its growth and development. It started during the colonial era and today India boosts of an agricultural research system, which has made the Indian agricultural research system one of the largest in the world. At present, ICAR plays a central role at the national level and it aids, promotes and coordinates re- search and education activities throughout the country. The research and education responsibilities at the state level rest with the State Agricultural Universities. In addition to these main streams of research, some general universities and other agencies like scientific organizations related to agriculture, Government departments, voluntary organizations, private institutions (private seed companies, poultry farms), etc. participate in the nation's research efforts. Hence, the role of the NARS in the development of agricultural research is of great importance, within which all these organizations come.

India has substantially increased its public funding of agricultural research since the late 1990s and this trend will likely continue in coming years. Nonetheless, India's research intensity ratio, measured as public agricultural R&D spending as a share of agricultural output, continues to be relatively low. In its upcoming twelfth five-year plan, the Indian Government seeks to address this deficiency by committing a significant percentage of agriculture GDP to agricultural R&D. ICAR and the SAU system are making a concerted effort to better target research and to improve coordination of programs across the various institutions. Deliberate efforts are also being made to foster partnership with the farming community and with other stakeholders to accelerate the diffusion of technology.

Evidence clearly indicates that an enabling policy environment and attractive market opportunities play important roles in the diversification of R&D through participation of the private sector. This is essential for enhancing research intensity and making the system more demand driven. At the same time, it is important to recognize the fact that private research is unlikely to bridge the gap in research intensity in the near future and whatever private funding will come will be mainly for in-house R&D. Therefore, the presence of strong public R&D is necessary.

Innovations in rice in India are almost a century old. Research into the history of rice cultivation reveals that it began with the endeavours of farming community in Tamil Nadu in 1911. Developing improved varieties has been one of the major thrusts of rice research since its beginning. The rice breeding programme finds its provenance in colonial India. Since then there has been continuous and consistent effort by Indian government to build a strong R&D in rice sector. This led to formation of a number of research institutes and organisations across the time and space. Indeed, the contribution of international agencies cannot be ignored. International agencies, such as IRRI, FAO, WARDA, IITA, and so forth have contributed substantially in development of strong rice R&D system in India. The journey of rice biotechnology research in India also suggests that introduction of new agricultural technologies have affected rice research in all dimensions. The credit is attributed to Rockefeller Foundation's International Program on Rice Biotechnology, which played pivotal and decisive role in establishing transgenic rice research in India. At present, various government and non-government institutes and organisations in India are contributing heavily towards frontier areas of rice biotechnology research such as, golden rice, MAS, computational Biology, genome analysis and molecular mapping, molecular mechanism of biotic and abiotic Stress Responses, and so forth based on plant genomics. However, the potential of new technology to contribute to sustainable agriculture would largely depend on policy finding a way of managing technological change in a way that provides a balanced outcome for society and environment.

In this chapter, an attempt was made to trace the evolution and organisation national agriculture system in India, with special reference to rice biotechnology research. The finding suggests that through the support of the national agencies such as DBT, ICAR, DST to name a few, rice biotechnology research has expanded massively, with mission-style programme funding new network of researchers working on particular trait, building of laboratory facilities and so forth. In addition to support from Indian government agencies through various mechanisms, international institutes have supported rice biotechnology research capacity. In the light of this, the next chapter attempts to capture the patterns of scientific collaboration occurring in the field of rice biotechnology research.

# Chapter III

## Mapping Scientific Collaboration: A Bibliometric Study of Rice Research in India

### Introduction

The changing nature of science from a solitary quest for knowledge to a group activity wherein scientists come together to share their resources and ideas to enhance the frontiers of knowledge, has given a fillip to collaboration. In this new culture of doing science, collaboration has come to occupy an important place. It is taking place in almost every discipline. Therefore, collaboration has become subject to considerable research effort and has generated considerable literature. However, in most of these studies collaboration is simply equated with the co-authored papers. Increase in multi-authored papers has become an evidence of increasing collaboration taking place (Katz and Martin 1997). Collaboration assumes greater significance in response to organization and professionalization of scientific knowledge (Beaver and Rosen 1978). During the 20$^{th}$ century, professionalization of science had a greater influence on the scientific community. However, the extent of collaboration and their rate of growth varied from one subject to another, one branch to another branch of the same subject and from one country to another country. The major impact of collaboration on scholarly research is the increase in productivity associated with multiple-authorship. Collaboration in research can take a variety of paths, based upon the type of participants, their position and location, etc.

Against this pretext, the present chapter analyses the patterns of scientific collaboration in terms of multi-authorship in the field of rice research in the context of India. The chapter identifies the type of co-authorship pattern to calculate co-authorship index and to measure the strength of co-authorship among rice scientists in India using the methods, such as collaborative index, degree of collaboration, collaboration coefficient, and modified collaborative coefficient. In the chapter, a collaboration profile has been constructed from two aspects: (1) co-authorship characteristics; (2) collaboration patterns according to collaborating institutions. Furthermore, an attempt is made in the chapter to quantify the magnitudes and pattern of local (intra-institutional,), domestic (inter-institutional at national level) and international collaboration for the country i.e. India.The Scopus International multidisciplinary bibliographical database has been used to identify the Indian contributions in the field of rice research.The retrieved data have been analyzed through bibliometric indicators and techniques. Bibliometrics involves the analysis of quantitative analysis of scientific documents. Bibliometric indicators can be considered as valid and useful tools in the assessment of research performance (Moed 2002). The number of publications is one of the indicators of scientific activities. Bibliometric analysis is used in science and technology policy arena to determine the knowledge outputs of national systems of innovations (Leydesdorff and Gauthier 1996). For comparative purpose, the study period (1995-2014) has been bifurcated into two different blocks viz. 1995-2004 and 2005-2014, each blocks consists a period of ten years.

### 3.1 Quantum of Indian Publications in Rice Research

In this section, we focus on the absolute counts of publications and growth pattern of publications in field of rice research. Total number of publications indexed by Scopus database during 1995-2014 has been selected in order to quantify the knowledge production in field of rice research.

**Table 3.1: Publication outputs in rice research during 1995-2014**

| Year | Publication | Percentage | Rate of growth |
|---|---|---|---|
| 1995 | 120 | 1.38 | |
| 1996 | 217 | 2.50 | 80.83 |
| 1997 | 264 | 3.05 | 21.65 |
| 1998 | 227 | 2.62 | -14.01 |
| 1999 | 314 | 3.62 | 38.32 |
| 2000 | 301 | 3.47 | -4.14 |
| 2001 | 292 | 3.37 | -2.99 |
| 2002 | 268 | 3.09 | -8.21 |
| 2003 | 320 | 3.69 | 19.40 |
| 2004 | 306 | 3.53 | -4.37 |
| 2005 | 363 | 4.19 | 18.63 |
| 2006 | 391 | 4.51 | 7.713 |
| 2007 | 492 | 5.68 | 25.83 |
| 2008 | 535 | 6.17 | 8.74 |
| 2009 | 519 | 5.99 | -2.99 |
| 2010 | 589 | 6.78 | 13.49 |
| 2011 | 678 | 7.83 | 15.11 |
| 2012 | 761 | 8.78 | 12.24 |
| 2013 | 831 | 9.59 | 9.198 |
| 2014 | 875 | 10.10 | 5.29 |
| Total | 8663 | 100 | - |

Table 3.1 indicates, Indian publication output in rice research during the period 1995-2014 consists of 8663 records, with an average publication per year 433.15 per year. The annual

publication output hovers around 1 to 3 percent during 1995-2004, which further increases to 5 to 10 percent during 2005-2014 (table 3.1).The publication output grew by 155 percent between 1995 and 2004 at rate of 15.5 percent annually. However, the growth rate of publication output decreases to 14.2 in next ten years (2005-2014). In rice research, the growth rate of publications have been fluctuating rather than remaining constant. Growth rate is negativein 1998, 2000, 2001, 2002, 2004, 2008 with -14.1, -4.14, 2.99, -8.21, -4.37, and -2.99 respectively. The year 1996 marks highest growth rate with 80.83, whereas 1998 records lowest growth rate with -14.01.

### 3.2 Relative Growth Rate and Doubling Time

The growth of literature in the field of rice research in India is being measured with the scientometrics indicators known as Relative Growth Rate (RGR) and Doubling time (Dt). The relative growth rate is the increase in number of articles/pages per unit of time. This definition is derived from the definition of relative growth rates in the study of growth analysis of individual plants and effectively applied in the field of botany (Blackman 1919), which in turn find its provenance from the study of the rate of interest in the financial investment (Hunt1978). The mean growth rate over the specific period of interval can be calculated from the following equation:

Relative growth Rate (RGR) $= \log_e W2 - \log_e W1 / T2 - T1$

Where:

RGR = relative growth of rate over the specific period of interval

Loge W1 = log of initial numbers of articles

Loge W2 = log of final number of articles after a specific period of interval

T2 – T1 = the unit difference between the initial time and the final time

The doubling time is the period of time required for a quantity to double in size or value. There also exists a direct equivalence between the relative growth rate and doubling time (Bradford 1934). If the number of articles/pages in a subject doubles during a given period, then the difference between the number at the beginning and at the end of this period must be logarithm of the number 2. If the natural logarithm is used, this difference has a value of 0.693. Thus the corresponding doubling time for each specific period of interval and for both articles and pages can be calculated by the following formula:

Doubling time (Dt) = 0.693/RGR

**Table 3.2: Relative growth rate and doubling time of rice publications in India**

| Year | Publications | Cummulative | $Log_e$ W1 | $Log_e$ W2 | RGR | Mean RGR | Dt | Mean Dt |
|---|---|---|---|---|---|---|---|---|
| 1995 | 120 | 120 | | 4.79 | | | | |
| 1996 | 217 | 337 | 4.79 | 5.82 | 1.03 | | 0.67 | |
| 1997 | 264 | 601 | 5.82 | 6.4 | 0.58 | | 1.19 | |
| 1998 | 227 | 828 | 6.4 | 6.72 | 0.32 | | 2.16 | |
| 1999 | 314 | 1142 | 6.72 | 7.04 | 0.32 | | 2.16 | |
| 2000 | 301 | 1443 | 7.04 | 7.27 | 0.23 | | 3.01 | |
| 2001 | 292 | 1735 | 7.27 | 7.46 | 0.19 | | 3.65 | |
| 2002 | 268 | 2003 | 7.46 | 7.6 | 0.14 | | 4.95 | |
| 2003 | 320 | 2323 | 7.6 | 7.75 | 0.15 | | 4.62 | |
| 2004 | 306 | 2629 | 7.75 | 7.87 | 0.12 | **0.34** | 5.77 | **3.13** |
| 2005 | 363 | 2992 | 7.87 | 8 | 0.13 | | 5.33 | |
| 2006 | 391 | 3383 | 8 | 8.13 | 0.13 | | 5.33 | |
| 2007 | 492 | 3875 | 8.13 | 8.26 | 0.13 | | 5.33 | |
| 2008 | 535 | 4410 | 8.26 | 8.39 | 0.13 | | 5.33 | |
| 2009 | 519 | 4929 | 8.39 | 8.5 | 0.11 | | 6.3 | |
| 2010 | 589 | 5518 | 8.5 | 8.61 | 0.11 | | 6.3 | |
| 2011 | 678 | 6196 | 8.61 | 8.73 | 0.12 | | 5.77 | |
| 2012 | 761 | 6957 | 8.73 | 8.85 | 0.12 | | 5.77 | |
| 2013 | 831 | 7788 | 8.85 | 8.96 | 0.11 | | 6.3 | |
| 2014 | 875 | 8663 | 8.96 | 9.06 | 0.1 | **0.11** | 6.93 | **5.87** |

The data pertaining to the growth of literature in the field of rice research in developing country like India has been presented in above-mentioned table 3.2. To calculate the mean RGR and mean Dt, the study period (1995-2014) has been divided into two block periods i.e, 1995-2004 and 2005- 2014. The publication output of Indian scientists in rice research has increased from 120 in 1995 to 8663 in 2014 with an average of 433 papers per year. It is observed from the table 3.2 that the mean RGR is decreased from 0.34 in the first block to 0.11 in the second block. On the contrary, mean Dt is increased from 3.13 in first block to 5.87 in second block. RGR is decreased from 1.03 in the year 1996 to 0.1 in the year 2014 and the corresponding Dt is gradually increased from 0.67 to 6.93. Therefore, the rate of growth of publications has decreased, the corresponding Dt has increased.

### 3.3 Collaboration Characteristics

Collaborative research has grown significantly in recent times and has come to be considered one of the main features of contemporary science. The trend in co-authorship can be interpreted in terms of a variety of factors, including the advent of “Big Science”, the increasing specialization of science, the degree of “advancement” of particular disciplines and, most recently, the professionalization of science (Price 1963; Gordon 1980). In this section of the study, the indicators of collaborations, such as co-authorship activity Index, collaborative index, degree of collaboration, collaborative coefficient, and modified collaborative coefficient have been first used to describe the co-authorship characteristics of the India in the field of rice research. Then, more attention is paid to the collaboration patterns from two aspects: domestic and international cooperation.

### 3.3.1 Authorship Pattern

Year-wise authorship pattern of India rice research is presented is presented in the table 3.3 below.

**Table 3.3: Year-wise authorship pattern of India in field of rice research**

| Year | Single Author | Double Author | Three Author | Four Author | Five and above | Total |
|---|---|---|---|---|---|---|
| 1995 | 12 | 47 | 38 | 10 | 13 | 120 |
| 1996 | 20 | 80 | 59 | 35 | 23 | 217 |
| 1997 | 26 | 89 | 77 | 32 | 40 | 264 |
| 1998 | 18 | 87 | 61 | 29 | 32 | 227 |
| 1999 | 28 | 106 | 88 | 46 | 46 | 314 |
| 2000 | 17 | 96 | 86 | 52 | 50 | 301 |
| 2001 | 23 | 71 | 94 | 50 | 54 | 292 |
| 2002 | 19 | 65 | 85 | 47 | 52 | 268 |
| 2003 | 17 | 87 | 74 | 62 | 80 | 320 |
| 2004 | 19 | 82 | 92 | 54 | 59 | 306 |
| 2005 | 23 | 100 | 96 | 67 | 77 | 363 |
| 2006 | 25 | 86 | 101 | 76 | 103 | 391 |
| 2007 | 24 | 116 | 131 | 84 | 137 | 492 |
| 2008 | 36 | 135 | 120 | 117 | 127 | 535 |
| 2009 | 32 | 108 | 141 | 94 | 144 | 519 |
| 2010 | 32 | 132 | 144 | 113 | 168 | 589 |
| 2011 | 35 | 144 | 153 | 137 | 209 | 678 |
| 2012 | 36 | 139 | 182 | 147 | 257 | 761 |
| 2013 | 36 | 157 | 192 | 143 | 303 | 831 |
| 2014 | 30 | 170 | 190 | 164 | 321 | 875 |
| Total | 508 | 2097 | 2204 | 1559 | 2295 | 8663 |

Among 8663 articles, 508(5.86 percent) articles are written by single author and 8155 (94.14%) articles are written by two or more authors. Five and above authored articles comprised highest percentage (26.49%), following three-authored articles (24.20%) of the total 8663 articles. The authorship pattern depicts a remarkable difference between the number of single author and multiple authors. Very less number of articles is written by single author. Thus, this suggests that multiple-authorship research is predominant as compare to solo in case of rice research in India. The co-authorship pattern indicates that collaborative research is favored in rice research in India.

### 3.3.2 Co-authorship Activity Index

Co-authorship Activity Index (CAI) has been suggested by Garg andPadhi (2001), and firstly elaborated by Schubert and Braun (1986). It is obtained by calculating the proportion of single, two, multi- and mega-authored papers during different periods.

$CAI = \{(N_j/N_0) / (N_{0j}/N_{00})\}*100$

Where:

$N_j$= number of publications co-authored by j authors in the country in a particular period,

$N_0$ = total publications in the country in a particular period,

$N_{0j}$ = number of publications co-authored by j authors in the country in a particular period,

$N_{00}$= total publication in the country, and

j = 1, 2, (3,4), and >5

CAI=100 indicates that the number of publications for a specific type authorship corresponds precisely to the average of all countries. CAI>100 reflects higher than the average, and CAI<100 indicates lower than the average.

Here, publications have been divided into four categories according to the number of authors, namely single authored papers, two authored papers, multi-authored and mega-authored papers. Papers completed by three or four authors are called as multi-authored papers, while these affiliated by five or more authors are named as mega-authored papers. Table 3.3 indicates the profiles of CAI for the year of 1995-2004 and 2005-2014, respectively.

**Table 3.4: Profiles of CAI from 1995-20014**

| Year | Single authored | Two authored | Multi-authored | Mega-authored |
|---|---|---|---|---|
| 1995-2004 | 120.14 | 118.46 | 95.44 | 60.00 |
| 2005-2014 | 81.28 | 82.01 | 92.04 | 107.48 |

As depicted in table 3.4, for two different research period the values of CAI for single authored and two-authored papers in 1995-2004 are all above 100, higher than the average level of the country. Contrary to these figures, CAI values for multi-authored and mega- authored papers are all less than 100, lower than country's average. However, the values of CAI in 2005-2014 for single authored, double authored, and multi-authored papers have dropped and goes below the country's average. Surprisingly, the CIA value of mega-authored papers has increased from 60.00 during 1995-2004 to 107.48 during 2005-2014. There is decreasing trend in case of single authored, double authored, and multi-authored papers and an increasing trend in case of mega- author papers. This suggests that the scientists engaged in rice research in the context of India are transforming their research from small groups to big groups with more collaborators. They are more interested to work with five and above scientists.

### 3.3.3 Measures of Collaboration

To show the trend towards multiple authorships in a discipline, many studies have used either the mean number of authors per paper, termed the Collaboration Index (CI) by Lawani (1980) or the proportion of multiple authored papers, called Degree of Collaboration (DC) by Subramanyam (1983) as a measure of the strength of collaboration in a discipline. Assuming that these two measures were seems to be inadequate, Ajiferuke et al. (1988), which derived a single measure that incorporates some of the merits of both of the above. Ideally, it is desired that a quantification of collaboration should have a value between 0 and 1, with 0 corresponding to single authored papers, and 1 for the case where all papers are maximally authored, i.e. every publication in the collection has all authors in the collection as co-authors.All the above mentioned formulas to find the Collaboration Coefficient (CC) value have one or other demerit. To overcome some of the demerits of previously explained measures, and propose a simple modification of CC, which is represented as the Modified Collaboration Coefficient (MCC), which improves its performance in this respect.

In this section, collaboration index, degree of collaboration, collaboration coefficient and modified collaboration coefficient was determined based on year-wise output of publications.

***Collaboration Index (CI)***

One of the early measures of collaboration is CI, which was propounded by Lawani in 1980.It is a measure of mean number of authors. Although it is easily computable, it is not easily interpretable as a degree, for it has no upper limit. Moreover, it gives a non-zero weight to single authored papers, which involve no collaboration.

Mathematically, Collaboration Index (CI) can be expressed as follows:

$$CI = \frac{\sum_{j=1}^{A} jf_j}{N}$$

Here, jfj is number of authors of total joint publications and N is total joint publications

**Table 3.5: Collaboration index of rice research in India**

| Year | 1995 | 1996 | 1997 | 1998 | 1999 | 2000 | 2001 | 2002 | 2003 | 2004 | **Mean** |
|---|---|---|---|---|---|---|---|---|---|---|---|
| CI | 0.44 | 0.43 | 0.42 | 0.42 | 0.42 | 0.39 | 0.39 | 0.38 | 0.36 | 0.38 | **0.4** |
| Year | 2005 | 2006 | 2007 | 2008 | 2009 | 2010 | 2011 | 2012 | 2013 | 2014 | **Mean** |
| CI | 0.38 | 0.36 | 0.35 | 0.37 | 0.36 | 0.35 | 0.34 | 0.33 | 0.33 | 0.32 | **0.35** |

In table 3.5, the mean value of CI manifests a decreasing trend. The mean value of CI has also decreasedfrom 0.4 during the first block period (1995-2004) to 0.35 during 2005-2014 second block period (2005-2014).

***Degree of Collaboration (DC)***

DC is easy to calculate and easily interpretable as a degree (for it lies between zero and one), gives zero weight to single-authored papers, and always ranks higher a discipline for period) with a higher percentage of multiple authored papers. However, DC does not differentiate among levels of multiple authorships. Here in this section the formula proposed by Subramanyam (1983) has been used to calculate degree of collaboration.

The degree of collaboration $C = N_m / N_m + N_s$

Where:

C = Degree of collaboration in a discipline

$N_m$ = number of multi authored papers in the discipline

Ns = number of single papers in the discipline

**Table 3.6: Degree of collaboration of rice research in India**

| Year | 1995 | 1996 | 1997 | 1998 | 1999 | 2000 | 2001 | 2002 | 2003 | 2004 | **Mean** |
|---|---|---|---|---|---|---|---|---|---|---|---|
| DC | 0.9 | 0.91 | 0.9 | 0.92 | 0.91 | 0.94 | 0.92 | 0.93 | 0.95 | 0.94 | **0.92** |
| Year | 2005 | 2006 | 2007 | 2008 | 2009 | 2010 | 2011 | 2012 | 2013 | 2014 | **Mean** |
| DC | 0.94 | 0.94 | 0.95 | 0.93 | 0.94 | 0.94 | 0.95 | 0.95 | 0.96 | 0.96 | **0.94** |

In table 3.6, the mean value of DC depicts a positive trend. The mean value of DC hasincreased from 0.92 during 1995-2004 (first block period) to 0.94 during 2005-2014 (second block period).This suggests that co-authorship pattern in rice research is in transition, moving from single authorship to multi-or mega-authorship.

***Collaboration Coefficient (CC)***

Suppose, if a paper has a single author, the author receives one credit; if two, each receives ½ credits. In general, if we have 'n'authors each receives 1/n credits. Hence, the average credit awarded to each author of a random paper is E [1/n], a value which lies between 0 and 1. If '0' is to correspond to single authorship, then the CC is defined as:

$$CC = 1 - \frac{\sum_{j=1}^{A} j f_j}{N}$$

Where, fjis the number of j-authors research papers published in a discipline during a certain period of time, N is the total number of research papers published in a discipline during a certain period of time (excluding anonymous authors) and Kis the greatest number of authors per paper in a discipline. Ajiferuke et al. (1988) were of the opinion that the CC incorporates the sum of the merits of both CI and DC. It lies between 0 and 1 (0<=cc>1). It tends to zero as single authored papers dominate and differentiates among levels of multiple authorship. In this section, collaboration coefficient was determined based on year-wise output of publications.

**Table 3.7: Collaboration coefficient of rice research in India**

| Year | 1995 | 1996 | 1997 | 1998 | 1999 | 2000 | 2001 | 2002 | 2003 | 2004 | **Mean** |
|---|---|---|---|---|---|---|---|---|---|---|---|
| CC | 0.56 | 0.57 | 0.57 | 0.58 | 0.58 | 0.61 | 0.61 | 0.62 | 0.64 | 0.62 | **0.6** |
| Year | 2005 | 2006 | 2007 | 2008 | 2009 | 2010 | 2011 | 2012 | 2013 | 2014 | **Mean** |
| CC | 0.62 | 0.64 | 0.65 | 0.63 | 0.64 | 0.65 | 0.65 | 0.66 | 0.67 | 0.67 | **0.65** |

Table 3.7 reveals that the average CC during 1995-2004 is 0.6. This figure has increased to 0.65 in next ten years (2005-2014). Overall, the value of CC has increased from 0.56 in 1995 to 0.67 in 2014. The CC is highest in 2013 and 2014 with 0.67. the CC is lowest in 1995 with 0.56. According to Ajiferuke (1988) collaboration coefficient tends to zero as single authored papers dominate and 1 for cases where all papers are maximally authored. This implies that higher the value of CC, higher the probability of multi-or mega-authored papers. Therefore, collaboration pattern in terms of co-authorship in field of rice research in context of India can be best characterized by the proportion of multi- and mega-authored papers accelerating steadily.

***Modified Collaboration Index***

The Modified Collaboration Index **(**MCC) was proposed by Savanur and Srikanth in 2010. The derivation of this new measure is almost the same as that of CC, as given in Ajiferuke et al. Imagine that each paper carries with it a single "credit", this credit being shared among the authors. Thus if a paper has a single author, the author receives one credit; with 2 authors, each receives 1/2 credits and, in general, if we have X authors, each receives 1/X credits (this is the same as the idea of fractional productivity defined by de Solla Price and Beaver as the score of an author when he is assigned 1/n of a unit for one item for which n authors have been credited.)

Hence,the average credit awarded to each author of a random paper is E[1/X], a value that lies between 0 and 1. Since we wish 0 to correspond to single authorship, we define the modified collaborative coefficient (MCC) as:

$$MCC = \frac{A}{A-1}\left\{1 - \frac{\sum_{j=1}^{A}(1/j)f_j}{N}\right\}$$

Where, A is a normalization constant to be determined. Setting A = 1 yields the measure CC. The requirement that j = 0 for single authorship does not restrict. The above equation is not defined for the trivial case when A = 1, which is not a problem since collaboration is meaningless unless at least two authors are available. CC approaches MCC only when A → ∞, but is otherwise strictly less than MCC by the factor 1-1/A.

**Table 3.8: Modified collaboration coefficient of rice research in India**

| Year | 1995 | 1996 | 1997 | 1998 | 1999 | 2000 | 2001 | 2002 | 2003 | 2004 | **Mean** |
|---|---|---|---|---|---|---|---|---|---|---|---|
| MCC | 0.58 | 0.58 | 0.59 | 0.59 | 0.61 | 0.62 | 0.62 | 0.63 | 0.64 | 0.63 | **0.61** |
| Year | 2005 | 2006 | 2007 | 2008 | 2009 | 2010 | 2011 | 2012 | 2013 | 2014 | **Mean** |
| MCC | 0.63 | 0.65 | 0.64 | 0.64 | 0.65 | 0.65 | 0.67 | 0.68 | 0.67 | 0.69 | **0.66** |

The mean values of MCC in two different block of the study (1995-2004; 2005-2014) are almost similar to the figure of CC mentioned above. There is very minute difference of 0.1 between the two measures. Therefore, the result of MCC (table 3.8) coincides with the findings of CC mentioned above in table 3.7.

### 3.3.4 Domestic and International Collaboration Profile

To study domestic and international collaboration profile of India in field of rice research, a short overview of the terminology and methodology used in the study is very important. The similar terminology and methodology were applied in their studies by Glänzel and Schubert (2001), Glänzel (2000), and MA and Guan (2005). According to different collaboration institutions, papers can be divided into four categories. Papers published in collaboration of at least two different countries can be called international papers; papers accomplished by several different institutions of the same country (here namely India) can be named domestic papers; papers finished by at least two authors of a single corporate address can be termed as local papers; and the left ones with only one author affiliated to one corporate address can be defined as non-collaborative papers. The last three collaboration patterns can also be called indigenous papers correspond to the foregoing international papers. It should be worth noting that the special case in which one author has affiliated to more than two different corporate addresses can be categorized into local or domestic collaboration papers (MA and Guan 2005).

The domestic collaborative index and international collaborative index suggested by (Garg and Padhi 2001) have been used to examine the domestic and international collaborative profile.Domestic Collaborative Index (DCI) has been obtained by calculating proportional output of domestically co-authored papers. For calculating DCI papers written in local and domestic collaboration have been added together.Likewise, International Collaborative Index (ICI) has been obtained by calculating proportional output of internationally co-authored papers. The two indicators are described below.

***Domestic Collaboration Index (DCI)***

Mathematically,

$DCI = \{(D_i / D_{io}) / (D_o / D_{oo})\} \times 100$

Where,

$D_i$ = Number of domestically co-authored publicationsin a particular time span,

$D_{io}$ = Total output of the country in that particular time span,

$D_o$ = Number of domestically co-authored publications,

$D_{oo}$ = Total publication of the country.

*International Collaboration Index (ICI)*

Mathematically,

$ICI = \{(I_i / I_{io}) / (I_o / I_{oo})\} \times 100$

Where,

$I_i$ = Number of domestically co-authored publicationsin a particular time span,

$I_{io}$ = Total output of the country in that particular time span,

$I_o$ = Number of domestically co-authored publications,

$I_{oo}$ = Total publication of the country.

The value of DCI or ICI=100 reflects that the collaborative efforts correspond to the average of a given country. DCI or ICI>100 indicates that the collaborative efforts are higher than the average and vice versa.

**Table 3.9: Domestic Collaborative Index (DCI) and International Collaborative Index (ICI) for rice research in India**

| Year | Domestic | Local | DCI | International | ICI |
|---|---|---|---|---|---|
| 1995-2004 | 422 | 1576 | 101.65 | 432 | 84.83 |
| 2005-2014 | 1638 | 2841 | 99.28 | 1246 | 106.60 |

The values of DCI and ICI, besides, the number of papers published by domestic, local, international collaboration in the two time spans are presented in table 3.9,exhibitsthat during 1995-2004 the value of DCI is slightly higher than 100 while during 2005-2014 it has decreased to 99, lower than 100. On the contrary, the value of ICI has increased from 84 to 106 during the above two time spans. It implies that the international collaboration has increased during 2005-2014 as compared to 1995-2004. It can be inferred that rice scientists in India have been gradually broaden the ambit of scientific collaboration and further integrated themselves into the international research community.

## 3.4 Collaboration Profiles according to Institutions

Research publications in the field of rice research come from a number of agencies.This section of the study examinesthe patterns of collaborationoccurring betweenthe various agencies. In later part, a metrics have been prepared to capture comprehensively the extent of collaboration between agencies that are active in the field of rice research in India.In order to understand the relationships among various agencies, institutional affiliations of all the authors, which were listed on their publications, were categorized broadlyinto following agencies:

- SAU: this category covers institutes coming under State Agricultural Universities;
- ICAR: this includes institutes sponsored by Indian Council of Agricultural Research;
- CUA: this consists of Central Universities having faculty of agriculture;
- OCU: this comprisesother Central Universities;
- INI: this constitutes Institutes of National Importance (IITs, NIITs, etc.);
- CSIR: this implies institutes sponsored by Council of Scientific and Industrial Research;
- CGIAR: this covers institutes coming under Consultative Group on International Agricultural Research, which are active in India;

- OII: this represents other International Institutes and Research Organizations;
- INDUSTRY**:** this consists of private research organizations;
- OTHERS: this covers other public and private institutions, research organizations, research foundations, and so forth.

The publication data in table 3.10 is higher than actually published as the collaborative papers were counted as many times as the number of collaborating institutions.

**Table 3.10: Publication output of different agencies during 1995-2004 and 2005-2014**

| **Agency** | **Year** | | **Year** | | **Year** | |
|---|---|---|---|---|---|---|
| | **1995-2004** | | **2005-20014** | | **1995-2014** | |
| | **Publication** | **Percentage** | **Publication** | **Percentage** | **Publication** | **Percentage** |
| SAU | 1243 | 30.93 | 2564 | 23.14 | 3807 | 25.22 |
| ICAR | 785 | 19.54 | 2060 | 18.59 | 2845 | 18.84 |
| CUA | 95 | 2.36 | 307 | 2.77 | 402 | 2.662 |
| OCU | 115 | 2.86 | 486 | 4.39 | 601 | 3.98 |
| CSIR | 190 | 4.73 | 504 | 4.55 | 694 | 4.6 |
| INI | 108 | 2.69 | 358 | 3.23 | 466 | 3.09 |
| CGIAR | 261 | 6.49 | 626 | 5.65 | 887 | 5.87 |
| OII | 590 | 14.68 | 1790 | 16.16 | 2380 | 15.76 |
| INDUSTRY | 67 | 1.67 | 191 | 1.72 | 258 | 1.71 |
| OTHERS | 564 | 14.04 | 2193 | 19.79 | 2757 | 18.26 |
| **Total** | 4018 | 100 | 11079 | 100 | 15097 | 100 |

Table 3.8 depicts that during 1995-2014, SAU and ICAR have contributed substantially in the field of rice research. The SAUs and ICAR contribute nearly 44 percent of the total publication output. Out of which SAUs contributed3807 (25.22 percent), followed by ICAR-sponsored institutes with 2845 (18.84). Other 56 percent of publication is shared by categoryOII (15.76 percent),others (18.26), CSIR (4.0 percent), CGIAR (5.87 percent), and so forth. The contribution of industry is the lowest with only 1.71 percent. This suggests that industries have less inclination towards publication activities in the field of rice research. Afurther analysis of the output of different agencies during 1995-2004 and 2005-2004 also indicates that the output of SAUs have declined considerably (by 5 percent)2005-2004 as compare to 1995-2004. The output of ICAR-sponsored also confronts a slight decrease (1 percent)in 2005-2014 as compared to earlier period (1995-2004). However, the contribution of the category ‘Others” has increased considerably by

almost 6 percent in second block (2005-2014) of the study. Except SAUs, ICAR, and CGIAR all other above-mentioned agencies depicts increase in publication output during 2005-2014.

### 3.4.1 Relative Research Effort

To compare a country's research performance with the world's research performance, Activity Index (AI) suggested by Frame (1977) and elaborated by Schubert andBraun (1986) had been made. Here we use Modified Activity Index(MAI) to see how a country's research activity changed during different years. This indicator suggested by Price (1981) characterizes the relative research effort of anagency country to a given subject field. However, in this section, we have used the same method to measure the research activities of different agencies active in rice research in India during 1995-2014. Mathematically, Modified Activity Index can be defined as follows:

MAI = $\{(C_i/C_0)/W_i/W_0\}*100$

Where:

$C_i$ = total publications of anagency for a given field during particular time span,

$C_0$ = total publications of anagency for a given field during research period,

$W_i$ = total publications of all the agencies for a given field during particular time span,

$W_0$ = total publications of all the agencies for a given field during research period.

**Table 3.11: Modified Activity Index of agencies during 1995-2014**

| Agencies | Modified Activity Index | |
|---|---|---|
| | Year (1995-2004) | Year (2005-2014) |
| SAU | 122.68 | 91.77 |
| ICAR | 103.67 | 98.67 |
| CUA | 88.79 | 104.06 |
| OCU | 71.89 | 110.19 |
| CSIR | 102.87 | 98.96 |
| INI | 87.08 | 104.68 |
| CGIAR | 110.56 | 96.17 |
| OII | 93.14 | 102.49 |
| INDUSTRY | 97.57 | 100.88 |
| OTHERS | 76.86 | 108.39 |

Table 3.11 indicates that the values of MAI for SAU (122.68), ICAR (103.67), CSIR (102.87), and CGIAR (110.56) are higher than country's average (100) during 1995-2004. It decreases and go below 100 in second block of study period (2005-2014) with 91.77(SAU), 98.67 (ICAR), 98.96(CSIR), and 96.17(CGIAR). SAU demonstrates

highest fall in MAI among all the other agencies from 122.68during 1995-2004 to 91.77during 2005-2014. Contrary to this, the MAI values of CUA (88.79), OCU (71.89), INI (87.08), OII (93.14), Industry (97.57), and others (76.86), which were trailing behind county's average (100) during first block (1995-2004), have increased drastically and is higher than 100 during second block. OCU takes the highest leap from 76.86 during 1995-2004 to 110.19 during 2005-2014.

### 3.4.2 Frequency of Research Collaboration

In this section, based on publication outputs, an adjacency matrix[1] has been constructed to examine the frequency of collaboration taking place between agencies in the field of rice research. Firstly, agencies were listed in both columns and rows. Then, number of collaborations between any pair of agencies were counted and inserted to form a symmetrical matrix. Table 3.12 and 3.13 indicates frequency of collaboration taking place between 1995-2004 and 2005-2014 respectively. However, table 3.13 manifests percentage change in the frequency of collaborations taking place between the agencies during the two blocks (1995-2004 and 2005-2014).

**Table 3.12: Matrix of research collaboration between agencies during 1995-2004**

| Agencies | SAU | ICAR | CUA | OCU | CSIR | INI | CGIAR | OII | INDUSTRY | OTHERS |
|---|---|---|---|---|---|---|---|---|---|---|
| **SAU** | 101 (4.42) | 127 (5.55) | 9 (0.39) | 4 (0.17) | 9 (0.39) | 20 (0.87) | 77 (3.37) | 157 (6.87) | 14 (0.61) | 31 (1.35) |
| **ICAR** | 127 (5.55) | 102 (4.46) | 4 (0.17) | 4 (0.17) | 10 (0.44) | 13 (0.57) | 45 (1.97) | 68 (2.97) | 6 (0.26) | 21 (0.92) |
| **CUA** | 9 (0.39) | 4 (0.17) | 1 (0.04) | 1 (0.04) | 1 (0.04) | 1 (0.04) | 3 (0.13) | 13 (0.57) | 0 | 3 (0.13) |
| **OCU** | 4 (0.17) | 4 (0.17) | 1 (0.04) | 4 (0.17) | 1 (0.04) | 2 (0.09) | 2 (0.09) | 22 (0.96) | 1 (0.04) | 10 (0.44) |
| **CSIR** | 9 (0.39) | 10 (0.44) | 1 (0.04) | 1 (0.04) | 4 (0.17) | 2 (0.09) | 2 (0.09) | 15 (0.66) | 3 (0.13) | 15 (0.66) |
| **INI** | 20 (0.87) | 13 (0.57) | 1 (0.04) | 2 (0.09) | 2 (0.08) | 4 (0.17) | 1 (0.04) | 11 (0.48) | 0 | 9 (0.39) |
| **CGIAR** | 77 (3.37) | 45 (1.97) | 3 (0.13) | 2 (0.09) | 2 (0.09) | 1 (0.04) | 8 (0.35) | 87 (3.80) | 8 (0.35) | 14 (0.61) |
| **OII** | 157 (6.87) | 68 (2.97) | 13 (0.56) | 22 (0.96) | 15 (0.66) | 11 (0.48) | 87 (3.80) | 124 (5.42) | 15 (0.66) | 71 (3.10) |
| **INDUSTRY** | 14 (0.61) | 6 (0.26) | 00 | 1 (0.04) | 3 (0.13) | 0 | 8 (0.35) | 15 (0.66) | 3 (0.13) | 10 (0.44) |
| **OTHERS** | 31 (1.36) | 21 (0.92) | 3 (0.13) | 10 (0.44 | 15 (0.66) | 9 (0.39) | 14 (0.61) | 71 (3.10) | 10 (0.13) | 51 (2.23) |
| **Total** | **549** | **400** | **36** | **51** | **62** | **63** | **247** | **583** | **60** | **235** |

[1] The adjacency matrix, sometimes also called as the connection matrix, of a simple labeled graph is a matrix with rows and columns labeled by graph vertices, with a 1 or 0 in position ($f_i$, $f_j$ )according to whether $f_i$, and $f_j$ are adjacent or not. For a simple graph with no self-loops, the adjacency matrix must have 0s on the diagonal. For an undirected graph, the adjacency matrix is symmetric (Chartrand 1985).

*Note: Values in the parenthesis represent percentage.

**Figure: 3.1: Research collaboration between agencies during 1995-2004**

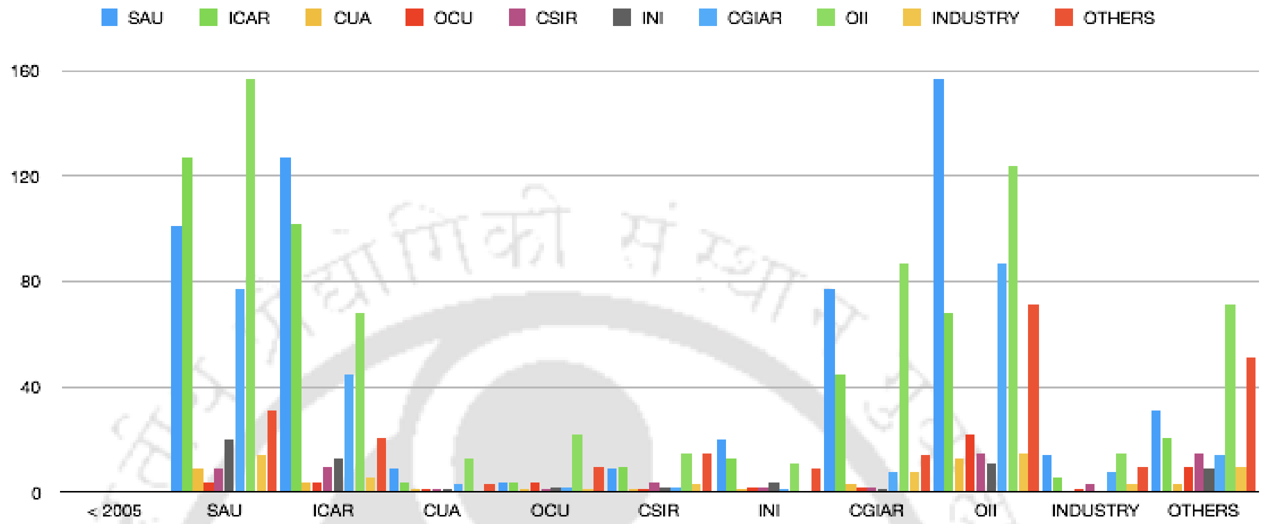



**Table 3.13: Matrix of research collaboration between agencies during 2005-2014**

| Agencies | SAU | ICAR | CUA | OCU | CSIR | INI | CGIAR | OII | INDUSTRY | OTHERS |
|---|---|---|---|---|---|---|---|---|---|---|
| **SAU** | 293 (3.69) | 380 (4.79) | 42 (0.52) | 33 (0.42) | 32 (0.40) | 33 (0.42) | 143 (1.80) | 291 (3.67) | 34 (0.43) | 225 (2.83) |
| **ICAR** | 380 (4.79) | 392 (4.94) | 39 (0.49) | 27 (0.34) | 31 (0.39) | 21 (0.26) | 111 (1.40) | 209 (2.64) | 28 (0.35) | 184 (2.32) |
| **CUA** | 42 (0.53) | 39 (0.49) | 4 (0.05) | 6 (0.07) | 8 (0.10) | 6 (0.07) | 8 (0.10) | 32 (0.40) | 2 (0.02) | 33 (0.42) |
| **OCU** | 33 (0.45) | 27 (0.34) | 6 (0.07) | 9 (0.11) | 19 (0.24) | 7 (0.09) | 9 (0.11) | 112 (1.4) | 3 (0.04) | 97 (1.22) |
| **CSIR** | 32 (0.40) | 31 (0.39) | 8 (0.10) | 19 (0.24) | 28 (0.35) | 10 (0.13) | 6 (0.07) | 58 (0.73) | 5 (0.06) | 85 (1.07) |
| **INI** | 33 (0.42) | 21 (0.26) | 6 (0.07) | 7 (0.09) | 10 (0.13) | 17 (0.21) | 7 (0.09) | 74 (0.93) | 5 (0.06) | 56 (0.70) |
| **CGIAR** | 143 (1.80) | 111 (1.34) | 8 (0.10) | 9 (0.11) | 6 (0.07) | 7 (0.09) | 72 (0.90) | 182 (2.29) | 17 (0.21) | 44 (0.55) |
| **OII** | 291 (3.67) | 209 (2.63) | 32 (0.40) | 112 (1.41) | 58 (0.73) | 74 (0.93) | 182 (2.29) | 400 (5.04) | 36 (0.45) | 352 (4.44) |
| **INDUSTRY** | 34 (0.43) | 28 (0.35) | 2 (0.02) | 3 (0.04) | 5 (0.06) | 5 (0.06) | 17 (0.21) | 36 (0.45) | 14 (0.18) | 27 (0.34) |
| **OTHERS** | 225 (2.83) | 184 (2.32) | 33 (0.42) | 97 (1.22) | 85 (1.07) | 56 (0.70) | 44 (0.55) | 352 (4.44) | 27 (0.34) | 365(4.60) |
| **Total** | **1506** | **1422** | **180** | **322** | **282** | **236** | **599** | **1746** | **171** | **1468** |

*Note: Values in the parenthesis represent percentage

**Figure 3.2: Research collaboration between agencies during 2005-2014**

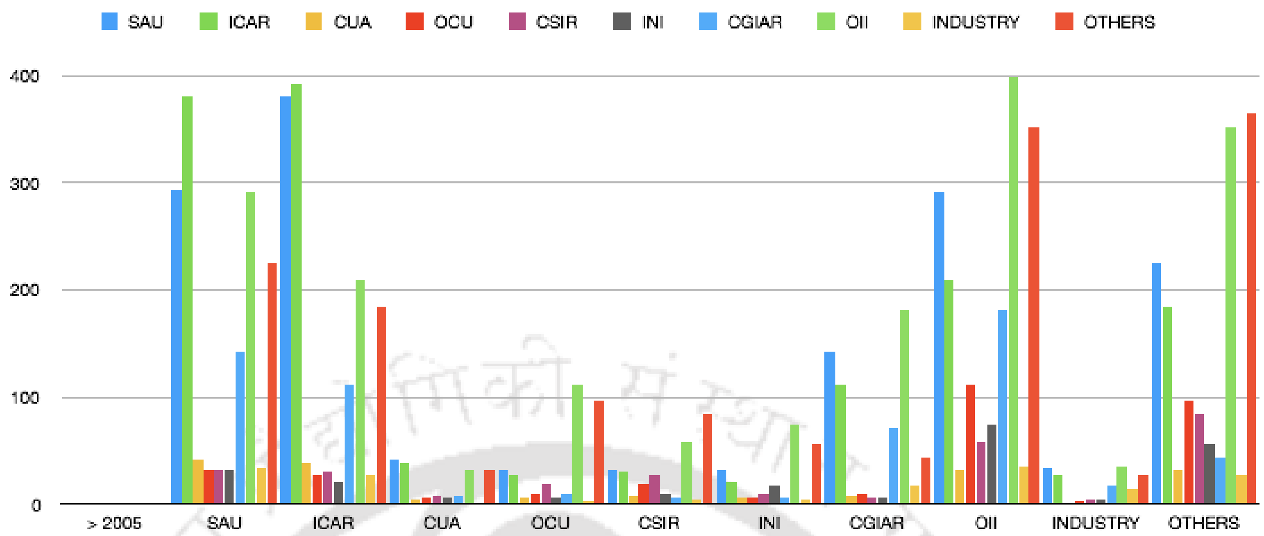
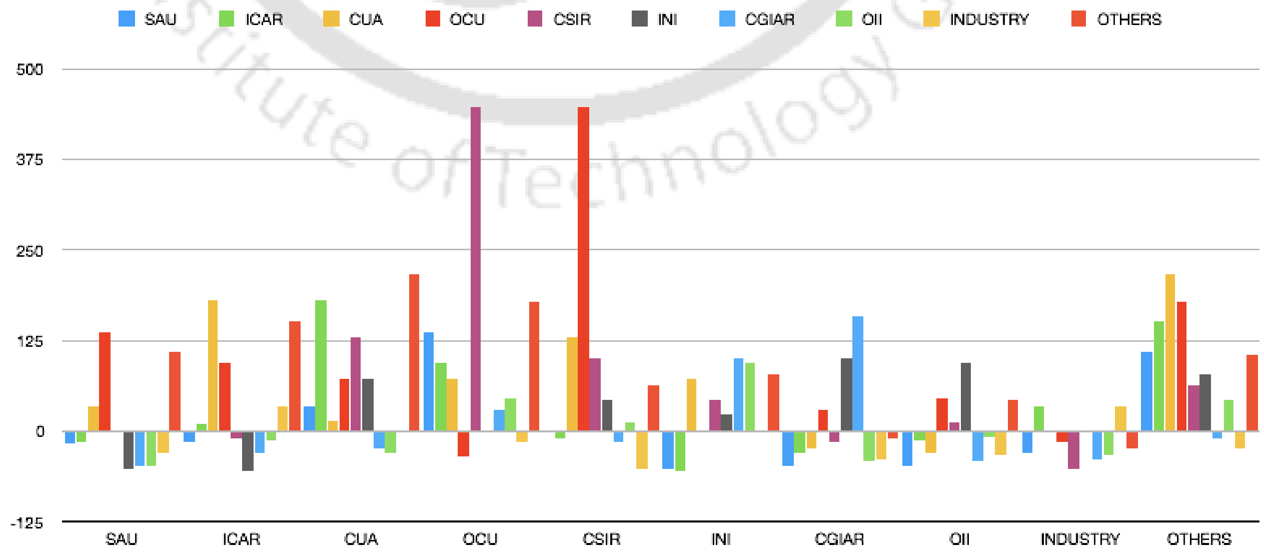



**Table 3.14 Percentage change in collaboration between agencies during two blocks**

| Agencies | SAU | ICAR | CUA | OCU | CSIR | INI | CGIAR | OII | INDUSTRY | OTHERS |
|---|---|---|---|---|---|---|---|---|---|---|
| **SAU** | -16.39 | -13.77 | 34.49 | 137.76 | 2.47 | -52.44 | -46.48 | -46.58 | -30.01 | 109.18 |
| **ICAR** | -13.77 | 10.76 | 180.99 | 94.53 | -10.66 | -53.44 | -28.91 | -11.42 | 34.49 | 152.52 |
| **CUA** | 34.49 | 180.99 | 15.28 | 72.92 | 130.56 | 72.92 | -23.15 | -29.06 | 0 | 217.01 |
| **OCU** | 137.76 | 94.53 | 72.92 | -35.15 | 447.58 | 0.87 | 29.69 | 46.72 | -13.54 | 179.55 |
| **CSIR** | 2.47 | -10.66 | 130.56 | 447.58 | 101.74 | 44.10 | -13.54 | 11.44 | -51.97 | 63.31 |
| **INI** | -52.44 | -53.44 | 72.92 | 0.87 | 44.10 | 22.48 | 101.74 | 93.88 | 0 | 79.32 |
| **CGIAR** | -46.48 | -28.91 | -23.146 | 29.69 | -13.54 | 101.74 | 159.38 | -39.71 | -38.75 | -9.42 |
| **OII** | -46.58 | -11.42 | -29.06 | 46.72 | 11.44 | 93.88 | -39.71 | -7.03 | -30.83 | 42.88 |
| **INDUSTRY** | -30.01 | 34.49 | 0 | -13.54 | -51.97 | 0 | -38.76 | -30.83 | 34.49 | -22.19 |
| **OTHERS** | 109.18 | 152.52 | 217.02 | 179.53 | 63.31 | 79.32 | -9.422 | 42.88 | 150.54 | 106.26 |

**Figure 3.3: Percentage change in collaboration between agencies during two blocks**



In the context of SAU, table 3.14 reveals that the SAU collaboration with OCU marks highest percentage increase with 137.76 percent, whereas collaboration with INI accounts highest decrease with 52.44 percent in the second block (2005-2014). Furthermore, the collaboration among SAUs has decreased by 16.39 percent in the subsequent block. From the perspective of ICAR, the collaboration metrics (table 3.12 and table 3.13) depicts that the collaboration of ICAR with CUA, OCU, INDUSTRY and OTHERS have increased, where collaborations with CUA accounts highest percentage increase (137.76 percent). Meanwhile, collaborations between ICAR and INI record highest percentage decrease with 52.44. Moreover, the collaboration frequency among ICAR indicates positive trend with one of the important findings of the study is that the collaboration between SAU and ICAR is negative with 13.77 percent decrease during the second block of the study period (2005-2014). In context of India, most of the agricultural research in general and rice in particular are carried out in these both institutional set ups. Moreover, these two institutional set ups are the main actors of National Agricultural Research System (NARS). Therefore, diminishing collaboration between ICAR and SAU highlights the coordination failure between ICAR-sponsored institutes and SAUs. Further, this also suggests that diminishing collaboration between ICAR and SAU may be a reason for poor performance of NARS in the area of rice research in terms of R&D outputs, such as publications, products, patents, and so forth.

One of the remarkable features of the above data set (table 3.12, 3.13 and 3.14) is that the collaboration between SAU and INDUSTRY decreases with 30.01pecrcentage in second block of the study period. Contrary to this, the collaborations between ICAR and INDUSTRY have been found to be positive with 34.49 percentage increase during 2005-2014 with respect to 1995-2004. Therefore, it can be inferred that triple helix model of innovations in context of SAUs and ICAR-sponsored institutes is in rudimentary phase. Moreover, public-private partnership found to be weak in field of rice research in the context of India.

The categories CGIAR and OII in above matrix (table 3.12, 3.13 and 3.14) covers international institutes and research organizations, hence indicates international collaboration in the context of India. The table 3.14 divulges that the collaborations of SAU with CGIAR and OII have decreased with 46.48 and 46.58 percentage decrease respectively during the 2005-2014. Likewise, the collaborations of ICAR with CGIAR and OII decreased with 28.91 and 11.42 percentage decrease during second block of the study period. Nevertheless, frequency of international collaboration has decreased in the context of both SAU and ICAR, but the position of the ICAR is relatively better with respect to SAU.

### 3.5 Collaboration Profile of State Agriculture Universities and ICAR-sponsored Institutes

As above finding indicates that SAU and ICAR are the two agencies that contributes substantially (around 44 percent) to the total publication outputs during 1995-2014 in the field of rice research. Therefore, in this section, collaborative profiles of SAUs and ICAR-sponsored institutes have been calculated in terms of non-collaborative papers, domestic papers, local papers, and international papers during 1995-2004 and 2005-2014. Moreover, In order to capture the changes in proportional output of domestically and internationally co-authored papers, DCI and ICI have been calculated separately for SAU and ICAR.

**Table 3.15: Collaboration patterns of State Agricultural Universities during 1995-2014**

| Collaboration characteristics | Year | | Percentage Change |
|---|---|---|---|
| | 1995-2004 | 2005-2014 | |
| | Number of Publications | Number of Publications | |
| Non-collaborative papers | 79 (6.35) | 100 (3.90) | -38.63 |
| Local | 615 (49.48) | 958 (37.36) | -24.48 |
| Domestic | 315 (25.34) | 1072 (41.81) | 64.98 |
| International | 234 (18.82) | 434 (16.93) | -10.09 |
| Total | 1243 (100) | 2564 (100) | 0 |

*Note: Values in parenthesis indicate percentage

Table 3.15 illustrates that during 1995-2004the percentage of non-collaborative papers are 6.35, which decreases to 3.90 percent during 2005-2014. The percentage decrease in non-collaborative papers within the two decades is 38.64 percent. During first block of the study period (1995-2004), local papers were found to be very dominant in collaboration pattern by contributing around 50 percent of total publication output. However, it shrinks to 37.36 percent in the second block (2005-2014). The percentage decrease within the two blocks of the study was found to be 24.48 percent. Contrary to this, the share of domestic papers, which was 25.34 percent during 1995-2004, has increased to 41.81 percent during 2005-2014.The domestic papers manifests highest percentage change with 64.98 percentage increase during the two decades of the study period (1995-2004 and 2005-2014). Therefore, this indicates that there is a shift in the preference of rice scientists located in SAUs, they are now more interested in collaborating with scientists located at distant institutes within the country. In context of SAU, the international collaborative papers have decreased from 18.8 2percent during 1995-2004 to 16.93 during 2005-2014 percent, percentage change being -10.09 percent during the second block of the study period.

***DCI and ICI of SAU***

**Table 3.16: DCI and ICI of SAU during 1995-2004 and 2005-2014**

| Year | Domestic | Local | DCI | International | ICI |
|---|---|---|---|---|---|
| 1995-2004 | 363 | 615 | 96.23 | 186 | 107.29 |
| 2005-2014 | 1135 | 958 | 101.83 | 371 | 96.47 |

The DCI value of SAU is 96.23, which is lower than average (100) during 1995-2004 (table 3.16). It increases to 101.83, slightly higher than 100 during 2005-2014. Contrary to this, the ICI value of SAU, which was higher (107.29) than country's average (100) in first block of the study (1995-2004) has decreased to 96.47 in second block of the study (2005-2014). Therefore, DCI values of SAU exhibits increasing trend, whereas ICI values demonstrates decreasing trend within the two blocks of the study.

*Collaboration patterns of ICAR*

**Table 3.17: Collaboration patterns of ICAR-sponsored institutes during 1995-2014**

| Collaboration Characteristics | Year | | Percentage Change |
|---|---|---|---|
| | 1995-2004 | 2005-2014 | |
| | Number of Publications | Number of Publications | |
| Single | 62<br>(7.90) | 70<br>(3.40) | -56.98 |
| Local | 323<br>(41.15) | 568<br>(27.57) | -32.99 |
| Domestic | 287<br>(36.56) | 1102<br>(53.49) | 46.32 |
| International | 113<br>(14.39) | 320<br>(15.53) | 7.91 |
| Total | 785<br>100 | 2060<br>(100) | 0 |

*Note: Values in parenthesis depict percentage

Table 3.17 depicts that during 1995-2004 the percentage of non-collaborative papers for ICAR are 7.90, which decreases to 3.40 percent during 2005-2014. Therefore, the percentage of collaborative papers is 92.1 percent during 1995-2004, which increases to 96.6 during 2005-2014. The percentage decrease of non-collaborative papers was found to be 56.98 within the two blocks. During first block of the study (1995-2004), local papers were found to be very dominant in collaboration pattern by contributing around 41.15 percent of total publication output. However, it decreases to 27.57 percent in the second block of the study (2005-2014) with 32.99 percentage decrease. Contrary to this, the share of domestic papers, which was 36.56 percent during 1995-2004, has increased to 53.27 percent during 2005-2014. Here, 46.32 percentage increases was recorded. Therefore, in the context of ICAR, local papers dominates in first block of the study, whereas in second block is dominated by domestic papers. In the context of international collaboration, ICI values of ICAR records a slight increase of 1.13 from 1995-2004 to 2005-2014.

*DCI and ICI of ICAR*

**Table 3.18: DCI and ICI of ICAR during 1995-2004 and 2005-2014**

| Year | Domestic | Local | DCI | International | ICI |
|---|---|---|---|---|---|
| 1995-2004 | 287 | 323 | 96.96 | 113 | 94.58 |
| 2005-2014 | 1102 | 568 | 101.16 | 320 | 102.06 |

Table 3.18 represents the DCI and ICI for ICAR during the two blocks of the study. The value of DCI (96.96) is lower than average (100) during 1995-2004. It increases to 101.19, slightly higher than 100 during 2005-2014. Contrary to this, the ICI values of ICAR, which was lower (94.58) than country's average (100) in first block of the study (1995-2004) has Increased to 102.06 in second block of the study (2005-2014). Therefore, DCI and ICI values of ICAR exhibits positive trend.

**Conclusion**

Based on the Scopus database, the data in the rice research literatures of the India were analyzed during the time span 1995-2005. Also various bibliometric indicators and techniques have been used to evaluate the pattern of collaboration of India in field of rice research. Some of the key findings suggest that he publication output in field of rice research in the context of India has decreased by 1.3 percent in second block of the study period. The multiple-authorship paper is predominant as compare to single author paper during the period of 1995-2014. The Co-authorship Index reflects decreasing trend in case of single authored, double authored, and multi-authored papers and an increasing trend in case of mega- author papers during the two blocks of the study period. The values of degree of collaboration, collaboration coefficient and modified collaboration coefficient indicates increasing trend in substantial years of 1995-2014. Hence, across the time, the multi- or mega-authorship pattern are dominating single authorship pattern. This shows positive trend towards collaborative research practices in field of rice research. In the context of India, domestic collaboration index values have decreased and have become less than country's average during 2005-2014, whereas international index collaboration, which was lagging behind in first block has increased during second block. The matrix of frequency of research collaboration among the agencies highlights that the collaboration between state agricultural universities and ICAR-sponsored institutes have decreased during second block with respect to first block of study period. The collaboration of state agricultural universities with industry has decreased, whereas

ICAR and industry collaboration has enhanced during second block. In the context of international collaboration, both SAU and ICAR exhibits decreasing trend in second block of study period.

Having explicated the evolution and organization of agricultural research in India, with special reference to rice biotechnology research in chapter II and the pattern of scientific collaboration occurring in the field of rice research through bibliometric study in this chapter, it would be pertinent to capture the socio-politics of formation and organization of scientific collaborations in field of rice biotechnology research in India vis-à-vis the response of the rice biotechnologists in India, which will be captured in the next chapter.

# Chapter IV

## Institutions, Structures and Organizations: Scientific Collaboration in Rice Biotechnology Research in India

### Introduction

During the last few decades, the life science research in India has grown by leaps and bounds. The quality and quantity of the science of biology today is increasing very fast and is making rapid strides on many fronts (Vale and Dell 2009). Experimental and lab-based biological scientists did not receive the same patronage and support as the breeders and agronomists. There were a number of groups that developed interesting research themes, but they did not get the exposure and funding of others. In the 1960s, and through much of the subsequent two decades, the lab-based scientists were the poor cousins of the breeders and agronomists (Sopory and Maheshwari 2001). It was only in the 1970s, with the emergence of recombinant DNA technology, that molecular biology and genetic engineering really took off. It heralded the beginning of biotechnology era in India. The new biology implies new relationships, different funding streams, changing ownership patterns, requirements for new skills and organizational arrangements. The new biology is more diffuse, hybrid and collaborative in nature, formed through multi-disciplinary and networked teams, making use of different instruments and very different methods and scientific approaches (Scoones 2005). Interdisciplinary in nature, the new biology not only interacted with the proliferating specializations but in practice expanded its network across labs, between institutes and through global connections. Collaborative research has taken a new meaning and shape in this context. At present, relationships between Indian public institutions and those with international universities and research institutes or private enterprises, both locally and abroad, have become necessary.

Against this backdrop, the objective of this chapter is to capture how collaborations are formed and organized in the field of rice biotechnology research in India. Further it explores the extent and ways R&D collaborations in rice biotechnology research are being shaped by new biotechnology regime and how rice biotechnologists located at SAUs and ICAR-sponsored research institutes are responding to it. Contingent upon empirical data, this chapter attempts to understand different attributes of collaborative networking practiced by rice biotechnology community in India. This chapter draws on a range of sociological insights that elicits what are the politics of project formation, what are the institutions involved, and researchers' perceptions about various facets of national and international collaboration taking place in the field of rice biotechnology research in the context of India. Based upon qualitative analysis, this chapter presents the dynamic picture of collaboration occurring in field of rice biotechnology in India.

### 4.1 Perceptions of Rice Biotechnologists about Research and Collaboration Activities

Based on the field data, results are presented in this section and following subsection manifests the perceptions of respondents about research and various dimensions of collaboration. The responses are measured at two point Likert scale of (1) important (2) not important according to the importance of the type of partners in the field of rice biotechnology research in India. Single percentage is calculated by adding the percentage of responses of very important and important.

#### 4.2.1 Different Activities Performed by Rice Biotechnologists within their Academic Area

The extent to which scientists performs a range of roles in their day-to-day academic life is of a paramount importance. They have to make a balance between teaching, research, administrative activities and outreach activities for attainment of academic goals. In this study, a very small portion of the respondents were concerned solely with teaching or solely with research.

**Table 4.1: Academic activities performed by rice biotechnologists**

| Academic Activities | Percentage |
|---|---|
| Research | 93 |
| Teaching | 84 |
| Administrative activities | 51 |
| Management responsibilities | 45 |
| Outreach activities | 34 |

Source: Field study

Table 4.1 exhibits that over 93% of the scientists reported that they are actively engaged in research activity and around 84% are found to be involved in teaching activity. Therefore, it is quite perceptible that a synergy of teaching and research is the central mode of academic activity in the field of rice biotechnology. Furthermore, nearly half rice biotechnologists are found to be part of administrative activities of some kind. This suggests that among scientists, there is some tendency to sacrifice research activity to gain administrative experiences. The proportion of respondents, who reported their involvement in outreach activities, is over 35%. The respondents were also asked whether they had any management responsibility apart from just partaking administrative activities. Around 47% of the scientists responded positively by accepting that they are entrusted with some kind of management responsibilities. Moreover, further analysis of field data suggests that this finding has significant positive relationship with the age of scientists included in the present study. Only 5% of scientists falling under age group of 30 have such responsibilities, whereas 40% of scientists falling under age group of 50 are found to be a part of management activity.

**Table 4.2: Scientists' perceptions about research-teaching nexus**

| Research and Teaching activities | Percentage |
|---|---|
| Teaching and research are equally important | 72 |
| Teaching should take priority over research | 17 |
| You can teach well without doing research | 21 |
| Research and teaching enhance each other | 83 |

Source: Field study

Based upon literature review four items were proposed to investigate respondents' perceptions about research-teaching relationships. The findings about research-teaching nexus are presented in table 4.2. According to the table 4.2, over 72 percent of the respondents preferred teaching and research are equally important by opting strongly agreed and agreed options. Contrary to this, only 21 percent of the respondents consider that teaching can be carried out without conducting research. Thus, a majority of the scientists engaged in rice research in India endorses the idea of teaching-research symbiosis, recognizes both teaching and research as complementary and inextricable to each other. This finding is further supported by the fact that 83 percent of the respondents are of the opinion that teaching and research enhances each other. Only 17 percent of respondents prioritize teaching over research. This indicates positive attitude of rice scientists towards teaching and research as an integral part of their role.

**Table 4.3: Scientists' perceptions about the importance of research**

| Value of Research | Percentage |
|---|---|
| Research allows to reflect on and improve my teaching | 82 |
| Research informs about latest theories and practices in the field | 85 |
| Research contributes to knowledge production | 86 |
| Research satisfies curiosity and creativity | 67 |
| Research increases professional status | 63 |
| Research gives job satisfaction | 66 |
| Research fosters promotion | 64 |
| Research inform policy | 61 |
| Research is a waste of time | 6 |
| Research is an extra burden on scientists | 9 |

Source: Field study

This section examines perceptions of rice scientists about the importance of research. Analysis of collected data indicates that overall respondents are optimistic about most research benefits mentioned in the item column of table 4.3. Over 82 percent of respondents hold that research allowed them to reflect on and improve their teaching. Around 85 percent of respondents agree that research keeps them updated about latest development in the area. More than 80 percent of respondents report that research increases their professional status, and contributes to disciplinary knowledge. Additionally, more than 60 percent of respondents also agree that research gives them job satisfaction, helps in promotion, enhances their professional status, and satisfies their curiosity and creativity. Maintaining consistency with their overall positive perception about research, less than 10 percent of respondents perceive research as an extra burden on rice scientists and waste of time. Thus, these results suggest that rice scientists emphasize the scholarly value of research instead of perceiving promotion as the most important driving forces behind conducting research. Moreover, these responses also points that propensity to carry research activities are not primarily driven by personal material gains rather it is motivated by values that research brought to production and sharing of knowledge, to the discipline and to the profession. For rice scientists research seems to be meaningful and productive activities rather than waste of time and an extra burden.

**Table 4.4: Scientists' self-reported individual characteristics**

| Individual Characteristics | Percentage |
|---|---|
| Research training allows to conduct research independently | 51 |
| Internally driven to conduct research | 56 |
| Well-developed network of communication with other researchers | 28 |
| Makes plans for research | 36 |
| In-depth knowledge about the field | 38 |
| Confidence in conducting research | 53 |

Source: Field study

This section measures perception of scientists about influences that have impact on their research productivity. Results regarding self-rated individual characteristics of rice scientists, which influence their research, are presented in table 4.4. Responding positively, more than 50 percent of respondents reported that their research training allows them to conduct research independently, they are internally driven to conduct research and that they are confident in conducting research. Contrary to this, the respondents rate all other proposed items less than 40 percent. Over 38 percent and 36 percent of respondents hold that they possess an in-depth knowledge about their field and always makes plan for research respectively. The weakest category in their self-reported characteristics was networking with other scientists in their particular field. Only 28 percent of respondents report positively on it. Thus, a large proportion of respondents in present study lack intrinsic motivation and confidence to conduct research activities. The low responses for networking and planning of research may be a reason for unsatisfactory research performance by scientists of ICAR-sponsored research institutes and SAUs in comparison to other public and private research institutes. Small responses for making research plans in particular also suggests that most of scientists does not have clarity of their interest area causing difficulties in formulating research plan. This inference is further supported by low responses in possessing in-depth knowledge in field. The Findings about rice researchers' individual characteristics coming under aegis of SAUs and ICAR-sponsored research institute indicate inclination towards research activities by majority of them, but lack of individual characteristics impede them from conducting research to their satisfaction level. Nevertheless, the positive perceptions can be utilize in motivating SAUs and ICAR scientists for developing desirable individual characteristics either through individually seeking opportunities or by optimizing institutional support for conducting research.

**Table 4.5: Perception of the scientists about institutional and departmental research environments**

| Research Environments | Percentage |
|---|---|
| Individual research (with no collaboration) | 6 |
| Management encourages research | 73 |
| Research is an important part of employment | 81 |
| The management invites scholars to talk about research | 42 |
| Guided by research leaders when engaged in research | 29 |
| Management organizes conferences/training/workshops | 30 |
| Management supports our attending conferences | 52 |
| Sufficient field facility to conduct research | 44 |
| Sufficient technical manpower support | 21 |
| Sufficient library facility | 46 |
| Sufficient ICT support | 38 |
| Sufficient in-house research grant | 43 |
| Sufficient laboratory support | 41 |

Source: Field study

The responses of scientists in this study suggest that SAUs and ICAR-sponsored research institute do not provide a conducive research environment, which further leads to low research productivity in terms of product and publications. As presented in table 4.5, it appears that SAUs and ICAR institutions promotes conducive research environment in mainly three areas: institutional encouragement for conducting research, supporting conference attendance and emphasis given to research activities, as these items are rated more than 70 percent of respondents. Indeed, lower responses were reported for research guidance and organization of conferences/training/workshops by management with 29 percent and 30 percent respectively. The findings about infrastructure support for conducting research suggests that SAUs and ICAR institutions suffers from poor infrastructure support for conducting research activities and for promoting research culture at the institution. Findings here shows that majority of rice researchers are not satisfied with infrastructure support by provided by their institutes. Less than 50 percent of respondents strongly agreed and agreed that they have sufficient infrastructure support in terms of field facility, laboratory facility, ICT support, library support, administrative and in-house research grant. Besides, figure for work force support is even worst with 21 percent of responses for sufficient work force support. However, collaborative research is reported by scientists in the study. Only 6 percent of respondent report that they do individual research without any collaboration. This indicates the extent of collaboration in plant science research in general and rice research in particular. To sum up, the finding suggests that rice scientists working under two different institutional setups (SAUs and

ICAR) are largely left to their own means for conducting research activities. Their institutions provide some support in terms of conference funding has but seriously lacked academic supports such as research guidance and conducting conferences, training and workshops, which help the research with hands-on experience. Additionally, SAUs and ICAR also suffers from poor basic infrastructural support for conducting research activities. This poses serious questions on the role of SAUs and ICAR as most of the agricultural activities in India are organized in these institutional set ups. In addition, result also suggests that these institutional set ups are plagued with inadequate technical personnel which directly hampers research work leading to under performance of scientists.

**Table 4.6: Relevance of research to external organisation in rice biotechnology**

| External Organisations | Percentage |
|---|---|
| Relevance for non-commercial external organisations | 77 |
| In general area of commercial interest to business | 36 |
| Applied in a commercial context | 20 |
| Non-relevance for external organisations | 3 |

Source: Field study

A current discussion focuses heavily on the relevance of research to external organisation in rice biotechnology, including both public and private sector. The data indicated in the table 4.6 illustrates the relevance of research to external organisation in terms of the kind of research that rice biotechnologists considered themselves to be carrying out. Respondents were asked to indicate that if the research they were undertaking whether it was in a general area of commercial interest to business and/or industry, it had commercial application, had relevance for non-commercial external organisations, including the public sector, or whether, in their view, it has no relevance for external organisations. Table 4.6 shows the responses to this question. Perhaps, the first most striking aspect that has emerged is that over 77% of rice biotechnologists answer that their research is relevant for non-commercial external organisations. These scientists are of the opinion that being a part of SAUs and ICAR-sponsored research institutes, which are public undertaking agricultural institutes and part of National Agricultural Research System and one of their primary mandates is to serve public sector. Their research outcomes are made available and accessible for other public institutes, which further utilises it for multipurpose application. Beside this, over 36% of respondents consider their research to be in a general area of commercial interest to business and around 20% feel that it has commercial application. These scientists are of the view that being a public institute, the primary objective of SAUs and ICAR-sponsored research institute is to serve farming community. Their target group constitutes farmers, not the private or business enterprise. Therefore, their research has limited commercial application. Research outcomes, such as a seed variety is registered under Protection of Plant Variety and Farmers' Rights (PPVFR) in order to protect the breeders' right, are further made available to the farmers either free or by charging very less for it. However, if any private enterprise shows its interest to acquire or access the variety or technology then it is transferred to them by charging a fixed amount of royalty. Contrary to this, only 3% of respondents are of the view that their research has no relevance for external organisations. These scientists are engaged in basic research and feel that it does not have any application for commercial or non-commercial external organisation.

The modes of interaction between the universities, research institutes and various external organisations are multi-dimensional and nuanced because interaction per se is a complex process. In seeking to identify different patterns of interaction exhibited by the rice biotechnologists in this study, possible modes of interaction have been classified into three broad categories: individual based, problem solving and community based activities. These are the aspects considered important, but neglected, "public space" role of universities (Cosh, Hughes and Lester 2006). These have been represented in several cases as the most common and fruitful avenues through which universities can foster development. The modes of interaction, such as informal and people exchange activities, are a rich set of interactions that may further result in deeper patterns of collaborative research and teaching based activity.

**Table 4.7: People based activities**

| Types of Activities | Percentage |
|---|---|
| Attending conferences | 91 |
| Participating in networks | 71 |
| Giving invited lectures | 67 |
| Sitting on advisory boards | 22 |
| Employ training | 27 |
| Standard setting forums | 34 |

Source: Field study

In table 4.7, we can see that there is a very high level of interactions taking place with external organisations through attendance of conferences, participating in networks, and giving invited lectures. Around 67% and 91% of rice biotechnologists are involved in these forms of interaction. This is followed by sitting on advisory boards, training employees and standard setting forums. A further 34% of scientists are involved in the activity of standard setting forums, which act as a crucial mechanism for shaping and developing pathways of research and innovation activities. Sitting on advisory board is least preferred as it involves external interactions just for 22% of respondents and employ training for external organisations included 27% of total respondents. Therefore, these responses indicate that the conventional modes of interaction in which rice biotechnologists are involved, such as disseminating and discussing their research results at conferences, participating in networks, and giving invited lectures lies at the core of external interactions by rice biotechnologists.

**Table 4.8: Problem-solving activities**

| Types of Activities | Percentage |
|---|---|
| Informal advice | 59 |
| Joint research | 46 |
| Joint publication | 42 |
| Consultancy services | 2 |
| Contract research | 4 |
| Research consortia | 35 |
| Prototyping and testing | 11 |
| External secondment | 9 |

Source: Field study

Table 4.8 displays the responses of scientists on the question of problem solving activities involving external organisations. The most important mechanism that involves external organisations in problem solving activities is the provision of informal advice. This is found to be nearly 59% of the total responses. Joint research and joint publications are also two common modes of problem solving interaction with 46% and 42% of total responses respectively. A research consortium also occurs in a significant number of cases with 35% of rice biotechnologists involved in this form of interaction. Consultancy services and contract research have got lowest responses with 2% and 4% respectively, whereas, prototyping and testing (11%) and external secondment (9%) are relatively infrequently used by rice biotechnologists as a mode of interaction for problem solving activities. Therefore, the role of informal advice has emerged in this study as a significant means through which contacts are established by rice biotechnologists and further may foster either problem solving interactions or people based exchange.

**Table 4.9: Community based activities**

| Types of Activities | Percentage |
|---|---|
| Lectures for the community | 64 |
| Training/workshop for the community | 86 |
| Public exhibitions | 89 |
| Community based sports | 3 |

Source: Field study

If we turn to different modes of interactions for community based activities as demonstrated in table 4.9, it is apparent that public exhibitions and training/workshops for the community have been rated high by rice biotechnologists with 89% and 86 % respectively. This is also followed by lectures for the community lectures, which achieves over 64 % of total responses. These forms of interaction have been rated highly because these activities are part of extension services, which is a separate department and part of curriculum for every agricultural institutes. The principal objective of extension services is to establish speedy and effective communication of new knowledge and technology to extension agents and to farming community. It involves a range of activities encompassing lectures, demonstration of technologies, refinement of technologies, public exhibition, capacity building programmes and so forth for the user of technology. Community based sports have emerged as a specialised activity related to a small number of rice biotechnologists with such specialised activities.

**Table 4.10: Ways through which external collaborations were initiated**

| Types of Initiatives | Percentage |
|---|---|
| Individuals associated with the external organisation | 83 |
| Mutual actions following up informal contacts | 79 |
| Your own actions in approaching the external organisation directly | 68 |
| Mutual actions following up a contact at a formal conference or meeting | 65 |
| Your institute department or administration | 19 |

Source: Field data

Table 4.10 indicates some of the ways used by rice biotechnologists to initiate external collaborations. In this study, individuals associated with the external organisation has emerged as the most frequently used initiator with83%. The least frequently reported initiator is the respective institutes department or administration (19%). However, it should be noted that scientists could identify multiple initiators in forging collaborations with external organisations. Furthermore, mutual actions following up informal contacts (79%) and rice biotechnologists own actions in approaching the external organization directly (68%) are also important means through which relationships are formed. Formal conferences or meetings (65%) are also important means through which rice biotechnologist build contacts and relationships with external organisations. To forge collaboration with external organisations, scientists do not depend upon the transactional and contractual inputs from their department or administration.

**Table 4.11: Collaborating partners according to geographic proximity**

| Types of Collaborations | Percentage |
|---|---|
| Collaboration with researchers within the institutes | 92 |
| Collaboration with researchers from other institutes within the country | 54 |
| Collaboration with researchers from other countries | 66 |

Source: Field study

As table 4.11 indicates, in terms of geographic proximity, perceptions of respondents are equally distributed over the proposed categories. Collaboration with researchers within the own institution is important as often as researchers from another institution within the country are or even as researchers from foreign institutions outside of the country. Respondents equally preferred all three categories. Whereas, collaboration with partners from other countries is ranked second as 66 percent respondents rate it as very important. Collaboration with partners within the institutes receives lowest preference as only 54 percent respondents ranked it as important. This is because for some respondents working together with researcher within the own institutions does not qualify as collaboration. For them collaboration means working together with partners located in some other institutions. Thus, only partners from other institutes within the India do better. The other categories are comparatively lower rated. Thus, it seems that to some extent collaboration in terms of (geographical) proximity is an important factor for some respondents, while to others it is not significant at all.

**Table 4.12: Collaboration with partners, in terms of arrangement**

| Types of Collaboration | Percentage |
|---|---|
| Formal collaboration | 73 |
| Informal collaboration | 39 |
| Established networks | 30 |
| Loosely coupled types of collaboration | 16 |

Source: Field study

The respondents are asked to indicate which type of collaboration, in terms of arrangement, they are mostly engaged in. The categories are formal collaboration, informal collaboration, established networks or other more 'loosely coupled' types of collaboration. Collaboration can be forged in the terms of formalized contracts or informal agreement and loosely coupled types of collaboration formats. The data presented in the table 4.12 reveals that collaboration between researchers seems to have both formal and an informal character. Around 39 percent and 30 percent of the respondents report informal collaboration and network contacts as important respectively. Yet collaboration among rice scientists also seems to have a relatively high level of formality, since 73 percent of the respondents held that working together on a formal/contractual basis to be important to them. However, 'loosely coupled' types of collaboration are rated lowest with 16 percent. One of the reasons for lower response is that most of the respondent could not understand the meaning of loosely coupled types of collaboration and mostly conceptualized collaboration arrangements in terms of formal, informal, and established networks. Thus, it can be inferred that for rice scientist's, collaboration in terms of arrangement is as much informal as formal in nature. According to scientists, no collaboration can exist without informal agreement and established networks. However, scientist also believes that there is substantial increase in formalization of contemporary collaborations due to rise of IPR regimes. Frequent occurrences of conflicts over ownership in terms of co-authorship and co-inventorship have compelled scientists to enter into formal contracts with their partners. Collaboration leading to co-patenting is mainly based on formal types of collaboration to prevent any type of disputes over ownership claiming future.

### 4.2.2 Motivations of Collaboration

In this section, we make an attempt to organize in terms of diverse themes under the category of motivations or what motivates the actors to participate in knowledge production. Collaboration grows historically as science gets institutionalized and professionalized and it becomes a mechanism for both gaining and sustaining access to recognition in the professional community (Beaver and Rosen 1978). Besides macro structural circumstances there are also individual reasons for collaboration. Even if the collaboration is between organizations or the institutions, the study of motivating factors for collaboration at the micro level is important because individuals also try to further their personal goals and aspirations through organizational goals (Melin 2000).

**Table 4.13: Scientists' perceptions about motivations for research collaboration**

| Motivations | Percentage |
|---|---|
| Access to instruments | 73 |
| Gaining expertise knowledge | 91 |
| Tacit knowledge | 17 |
| Time efficiency | 77 |
| Validation of New Techs/Methods | 84 |
| Funding | 62 |
| Social Reasons | 8 |

Source: Field study

Table 4.13 suggests that the motivations of research collaboration are manifold and range from personal networks to resource accesses. One reason may be for gaining access to sophisticated equipment. Most scientific knowledge is produced and tested with experiments. Instruments and equipment are an integral part of experimentation. Hence they play an important role in motivation for collaboration among practitioners of scientific knowledge. As science has progressed, it has become tool-oriented and more and more dependent on expensive instruments and equipment (Katz and Martin 1997). It is not possible for an individual scientist to own all necessary equipment required for his/her research. In such a situation, collaboration is a means through which a scientist can collaborate with someone who has better access to equipment for research. Empirical data collected in the present study does not show this trend. A substantial percentage (91 percent) of the respondents consider access to sophisticated instrumentation or technology as an important factor to promote collaborative research practices and as a major motivator. Around 73 percent of the scientists interviewed are of the opinion that access to sophisticated instruments is the main reason for pooling resources. Moreover, scientists also assert that most of the experiments in rice biotechnology are carried out and operated in laboratory, which requires access to sophisticated instruments. On the contrary, around 27 percent of scientists think that access to instruments is no longer a prime motivator for collaboration as these services can be easily franchised to many firms without taking them on board.

One of the prime motivations that has emerged from our study and is rated very highly by the majority of the scientists is to gain expert knowledge, which enriches their research. Around 91 percent of all rice biotechnologists are of the opinion that one of the most important reasons for collaboration is to gain expertise. To put it succinctly, it is the complementarities of expertise which in most of the cases leads to collaborative works. In order to sustain collaboration, there has to be a win-win situation for all. All the partners contributing to the project expect some gain from it. Each player tries to enhance their productivity and gain through it. In this way, many problems can be addressed through expertise from different areas, backgrounds, and disciplines.

Lee and Bozeman (2005) argue that collaboration takes place to gain a tacit component of knowledge. Furthermore, not all the details concerning new advances are necessarily documented. Much of the knowledge may be tacit (Collins 1974). The term "tacit knowing" or "tacit knowledge" was first introduced in philosophy by Michael Polanyi in 1958 in his magnum opus *Personal Knowledge*. He summarizes the idea in his later work, *The Tacit Dimension*, with the assertion that "we can know more than we can tell." According to him, not only is there knowledge that cannot be adequately articulated by verbal means, but also all knowledge is rooted in tacit knowledge in the strong sense of that term. With tacit knowledge, people are not often aware of the knowledge they possess or how it can be valuable to others. Effective transfer of tacit knowledge generally requires extensive personal contact, regular interaction, and trust. This kind of knowledge can only be revealed through practice in a particular context and transmitted through social networks. To some extent it is "captured" when the knowledge holder joins a network or a community of practitioners. Scientists included in the present study do not give a favourable opinion to the tacit component of scientific knowledge gained through collaboration. Only 17 percent of scientists opine that they collaborate for gaining tacit component of knowledge. Scientists are of the opinion that most of the collaborative projects are scattered in nature, which hinder diffusion of tacit knowledge because they are stored in research team which has generated it.

Efficient use of resources and time is another strong motivator for pooling resources. Around 77 percent of the scientists are of the view that efficiency in use of time is a strong reason for collaboration as many times there are different processes that a person can do but still one prefers to collaborate with a partner who is competent in that particular area in order to efficiently manage time and project as the collaborator has established competence for that area. So this is how rather than being repetitive and doing what others have already done, scientists tend to collaborate to complement expertise with others.

Other factor that has emerged to be major motivator for collaboration among scientists engaged in rice biotechnology is the testing of new processes and methods that need validation. Most of the plant breeders rank it as a major motivator. Around 84 percent of the scientists are in favour of the validation of new techniques and methods as one of the reasons of collaboration. In domain of science, recognition by peers group is given very high priority by the scientists. Through collaboration a newly developed process, pathway can be optimized under different systems and conditions. According to majorities of respondents, any variety or technology developed is subject to multiple field-trials at various locations across the country. Its effectiveness and efficiency is evaluated by peer group before its commercial utilization.

Funding is also specified as another motivational factor for collaboration. Government and non-government institutions are encouraging collaborative culture by providing various projects to scientists. Underscoring the importance of funding as a motivation for collaboration, a few scientists opine that many proposals are coming to them and also they are being approached by various government and non-government institutions. As these projects carry a decent funding, they often consider it. However, a few scientists are also of the view that certain norms of funding agency also provide important bases for collaboration. According to them, the norms in terms of eligibility criteria, experience, rank and status of scientist and institution, infrastructure requirements, material sharing, time limit, dissemination and ownership over the product vary across the funding agencies. The scientists included in the present study consider these norms before initiating any collaboration.

Melin (2000) finds that social reasons like collaborations with old colleagues and ex-supervisors are important for collaborative works. However, in our study, this factor is not rated high by the rice biotechnologists and dry responses are found on this factor as a motivation for collaboration. Around 92 percent of the scientist never considers social factors while collaborating, whereas 8 percent of the scientists give some degree of consideration to social reasons. More than 91 percent of scientists said that they seldom consider social reasons as the motivation for collaborative works. A Few scientists in the study strongly feel that it is only science and competence of the other partner that drives their collaborative research. Although they do agree that these social factors are occasionally considered and helps in sustaining collaboration as with old friends and colleagues the chance of finding common grounds and comfort zone increases. Knowing the collaborator before also reduces the chances of collapse of collaborative research. The reliability of data generated is an important reason for preferring collaborative works with known partners because collaborative projects have many links in the chain. If at one level some unethical ways are practiced, it gets carried to the entire chain and can lead to the collapse of complete project. However, social factors have pondered over at the time of collaboration with domestic partner as professionalism still lacks among the scientific community. While forging international collaboration social reasons are hardly considered, sometimes the collaborators do not even get a chance to meet each other. But the high level of professionalism in the scientific community of the west surpasses the need to consider social reasons. Therefore, it can be inferred that scientific collaboration is a merit-based activity and involves instrumental rationality.

### 4.2.3 Impact of Collaboration on Research

We have also asked the respondents about the impacts of such collaboration. And, with similar results, rice biotechnologists are not only primarily motivated to seek some kind of collaboration with others but also realise that such alliances help their research. Table 4.14 shows that 78% of scientists, who are engage with external organisations, believe that it has provided them new insights into their research work. This suggests that collaboration is a knowledge gaining activity. Around 70% of scientists believe that collaborations have expanded their networks by creating new contacts in the field. Thus, social capital has emerged as an important outcome of collaborative projects of rice biotechnologists, which enables more collective actions in future. Around 66% of respondents are of the opinion that working together in a collaborative project opens new avenues of research activities for them. This indicates that collaboration acts as a paradigm and promotes research activities. Meanwhile, around 60% of the respondents also believe that collaborations have strengthened their status and reputation in the field of rice biotechnology. This suggests that collaboration is also an important mean to acquire or achieve symbolic capital in rice biotechnology. However, only 8% of respondent consider that collaborations have very little or no impact on their research activities. It not only shapes the research activities of scientists but also determines the scope and ambit of further research.

**Table 4.14: Scientists' perceptions about impact of collaboration on research**

| Impact on Research | Percentage |
|---|---|
| It has given me new insights for my work | 78 |
| It has led to new contacts in the field | 70 |
| It has led to new research projects | 66 |
| It has strengthened my status and reputation in the field | 60 |
| It has had very little impact or no impact | 8 |

Source: Field Study

The process of collaboration is complex and is also affected by various factors. There are certain barriers to research collaboration, which hinder scientists to enter collaborative research practices. These barriers can range from high coordination costs to administrative ones like red tapism, extra time costs, and lack of funding, institutional and international treaties which set the norms of practicing science.

**Table 4.15: Scientists' perceptions about impediments of collaboration**

| Impediments of collaboration | Percentage |
|---|---|
| High coordination costs | 67 |
| Extra time costs | 74 |
| Irregularities in fund release | 57 |
| Administrative delays | 64 |

Source: Field study

Table 4.15 indicates that 67 percent of the respondents subscribe to the view that high coordination costs have affected their collaboration adversely. Here the coordination costs refer to as the costs mainly incurred on travel and communication. For inter-institutional, inter-sectoral and international collaborations, travel subsistence and communication costs incurred as researchers move from one location to another. Sometimes there is also a need to move equipment and material from one place to another for which transportation is required. Once moved, the instrument may need to be carefully set up again with the assistance of technicians incurring further costs. A majority of the scientists assert that coordination costs in terms of travel and communication affect collaborative research practices as it is not covered and taken care of by funding agencies. It is also evident that at present government institutions like SAUs and ICAR-sponsored research institutes do not promote research collaboration by providing travel and communication costs to the scientists. Thus, coordination costs of collaboration have become an insurmountable hurdle for the scientists

Collaboration also brings in time costs as a lot of time is spent on deciding the joint proposal and communicating it to others. A collaborative research consists of various parts and each part of the research would be done separately and it takes both time and resources to connect them (Heinz and Kuhlmann 2008). Table 4.15 shows that the most of the researchers find the extra time cost as a hurdle in forging research collaboration as 74 percent of the scientists agree that research collaboration entails extra time costs, and their collaboration is adversely affected by extra time cost. A majority of the scientists emphasize that research collaboration entails some extra time costs in terms of finding and selecting potential partner, preparing joint research proposal and research problem, planning the operation and also in accommodating various conflict of interests in terms of realization of outcome, distribution of credits and ownership over the product.

There is a mixed response on the constraints of funding from the scientific community engaged in rice biotechnology SAUs and ICAR-sponsored research institutes. This suggests that funding problem is not a simple one as there is a varying range of perceptions regarding it among the scientists. Around 57 percent of the collaborators opine that funding has always obstructed their collaborative practices. A majority of the scientists falling under this category are of the opinion that irregularity in timely release of fund is a common phenomenon, which they experience in handling collaborative projects. These irregularities have seriously jeopardized their projects. Contrary to this, around 43 percent of the respondents never find irregularities in fund release to be a problem in their collaboration. The pattern of funding is related to other factors such as the institutional research grant facility and also the mechanization of distribution of resources within the institute and concerned department.

Collaboration brings in certain costs in terms of increased administration. According to Katz and Martin (1997), collaboration results in increased administration in terms of more paper work and greater administrative checkup. This enhances bureaucracy and can delay the progress of many projects. There may be differences in the management culture, reward system, intellectual property rights regime, and financial norms of the collaborating partners. In addition, collaborative research brings in multiple researchers with distinctive and specialist perspectives in various institutional setups. It requires greater effort to manage research. It might need more formal management procedures which may create bureaucratic burden.

In this study it is also found that the administration cost of collaboration such as increased paper work and so on is almost evenly distributed. In this study 64 percent have always or mostly experienced and 36 percent have sometimes or never experienced administration costs adversely affecting their collaborative research. Hence, frequent delays in clearing and sanctioning the project are common problems which are confronted by the scientific community engaged in collaborative research practices in rice biotechnology. This can seriously affect the productivity, motivation, and credibility of the scientists.

### 4.3 Dimensions of Collaboration Formation in Rice Biotechnology Research

The institutional framework of modern science includes a host of organizational actors: funding agencies, academic departments, national laboratories, corporate laboratories, government laboratories, nongovernmental institutes, and private donors. Their interactions sometimes produce collaborations. Origins are intrinsically interesting. But stories of origins, what Knorr-Cetina (1995) calls "birth dramas". In this section, we examine the main contextual issues facing scientific collaboration and conceptualize the dimensions involved in forming projects. These include the degree of uncertainty in the acquisition of resources, the way projects fit into established programmes, their association with organizational changes, whether previous research provided a point of departure, and their institutional composition. Our goals in this section are to describe the logics that underlie the formation of collaboration and to analyze how the formation of collaboration shapes its evolution.

Contingent upon the major themes that have emerged in the interview with scientists, the impetus to form collaboration in the field of rice biotechnology may be construed as the interplay of factors arising from four broader dimensions of the environment: (1) the inter-personal context (the relations among independent scientists whose employment terms allow them to choose their research problems); (2) the funding context (the availability of government or private patrons); (3) the sectoral context (relations among academic, industrial, and governmental sectors, which traditionally have different goals and cultures); and (4) the context of participating organizations (relations among established, permanent organizations—university departments, government research laboratories, corporate research laboratories). Table 4.16, summarizes the distribution of project-formation characteristics of multi-organizational collaborations.

**Table 4.16: Distribution of project-formation dimensions (n=71)**

| Variables | Percentage |
|---|---|
| **Interpersonal context** | |
| Pre-existing relationships | 87 |
| Brokered relationships | 32 |
| **Donor/Funding context** | |
| High resource uncertainty | 17 |
| Reorganizations of funding agencies | 41 |
| **Sectoral context** | |
| University | 57 |
| Government research institutes | 73 |
| Industry | 14 |
| **Home organization context** | |
| Pressure from home organization | 82 |

Source: Field study

### 4.3.1 Interpersonal Context

Table 4.16 indicates that around 87 percent of rice biotechnologists form collaborations with pre-existing relationship. Pre-existing relationships among some or all of the participants are central to forming collaborations in rice biotechnology. This simple sociological hypothesis was confirmed by many of our informants. Narrating about the existence of pre-existing relationships in a project, a scientist from an ICAR-sponsored research institute shares:

> We are to known each other since a long time. We have never collaborated, but we're old friends. I'm not old friends with everybody, who are involved in the project but somehow I know them all. Mine friends are friends of theirs and their friends are friends of mine or something, the relationships are pretty close. Most of the collaborations are formed within social network or social capital of a scientist.

Another scientist from an SAU affirms:

> In my current project, probably one of the important things that really helped with myself working together with the other members of the research team was that we were known to each other. It became easier to communicate and create understanding. From the experiences of other projects that I have

> successfully completed, I would support that familiarization with one another in a project is very important. This provides much more flexibility in the uses of tools, or the ways you collaborate.

High response by rice biotechnologists for pre-existing relationships highlights the importance of social capital in the process of scientific collaboration. This also suggests, to what extent social factors are embedded in the process of project formation. Thus it can be inferred that scientific collaboration as an institution is as much social as scientific. Furthermore, high percentage rate for pre-existing relationships reveals the autonomy of scientists to choose desirable partners in collaborative projects. This indicates that scientific collaborations in rice biotechnology are shaped by agency function.

It should be worth mentioning here that this common approach (pre-existing relationship) is not the only standard process to form collaboration in rice biotechnology. Therefore, in addition to asking informants about their pre-existing relationships with participants, we also asked about "brokering", that is, cases where members of collaboration are brought together by other parties. These parties can be both internal and external. Emergence of collaboration via brokering and pre-existing relationships need not be mutually exclusive. Brokers can, in principle, bring together friends or even competitors in a scientific field. Around 32 percent of interviewees believe that formations of collaboration in rice biotechnology are based on brokered relationships. Describing the presence of brokered relationships in rice biotechnology, a scientist from an ICAR-sponsored research institute points:

> I have a proposal to the DBT for funding. There were other proposals in the same area and one of the competing proposals came from DRR, Hyderabad. When those two proposals were brought to the DBT review committee members, these people at the DBT recognized that instead of funding one of these centers or funding neither, they had an opportunity perhaps to talk to the leaders of these proposals and they made an attempt to merge the two proposals.

A scientist from an SAU mentions:

> In my opinion, there are two possible routes to collaboration in rice biotechnology. The first is to prepare a good individual proposal of national interest, hoping that a central puts you in mixing and matching of proposals in same research area. But in this case, you will have to work with whoever is selected, there is no choice. The second route is look for different kinds of experts (scientists) with whom you would like to work or your past

> collaborators, convince them that how collaboration will serve everyone's individual interests and create an appealing environment if they collaborate.

A scientist from an ICAR-sponsored research institute narrates:

> Contemporarily, there are huge numbers of institutes conducting research in field of rice biotechnology. But number of funding agencies does not equal this volume. It is beyond the capacity of government agencies to cater the need of economic resources of each and every institute. The best possible solution is to put together the research proposal of same research area. Moreover, nowadays funding agencies, ICAR in particular, attaches a low status institute with high status institute. The rationale behind this is to empower low status institute and make them competitive. They make them work with high status institute instead of diverting separate resources for each institute in the group.

Therefore, in our study, collaborations are more likely to form around preexisting relationships than around brokering by external authorities (table 4.16). Though pre-existing relationships are rated high by respondents, brokering is important, as a few scientists included in the present study endorse it. Here, brokering should not be viewed as an aberration, rather one of techniques for forming collaborations. In a few cases, both brokerage and preexisting relations were also reported by scientists, as when an authority insisted a single collaboration be formed from two collaborations that had each formed through pre-existing relationships. But in general, emergence through brokering and emergence through ongoing relationships are inversely related. Collaborations brokered through funding agencies are less likely to involve a group of participants with strong pre-existing ties.

### 4.3.2 Funding Context

Two features of the funding context constitute significant sources of variability for inter-institutional collaboration: resource uncertainty and agency reorganization. "Resource uncertainty" indicates whether or not collaboration has a "manifest" source for the resources it needs (Shrum et al. 2007). Here, resources have been used in terms of economic resources or funds. A "manifest" source indicates a funding agency with a program that readily fits collaboration objectives or a research facility with the capability to support the investigations. In this study, only 17 percent of the rice biotechnologists agree that there is high resource uncertainty in the field of rice biotechnology. Contrary to this, 83 percent of the scientists believe that sufficient manifest sources of funding are available in rice biotechnology. However, manifest does not mean easy, it is highly competitive. Dwelling upon the presence of manifest source of funding in rice biotechnology, a scientist from an ICAR-sponsored research institute emphasizes:

> We have adequate funds. Almost, all of the projects in rice biotechnology is being funded by ICAR, DBT and state government. We are directly supported by ICAR and DBT for our research. Apart from this, government agencies, such as ICMR,CSIR, DST, and UGC have special programmes to support R&D in rice biotechnology. The DRDO is latest to join the list. So, we have multiple choice to fund our project, the only thing required is an interesting proposal of national interest.

Another scientist from an SAU adds:

> Currently, funding does not seems a big deal in field of rice biotechnology, atleast not for the scientists of SAUs and ICAR-sponsored research institute. We have a continuous flow of funding from ICAR. ICAR is the primary source of funding for SAUs and ICAR-sponsored institute. Since the 1970s, ICAR has played a decisive role in Indian agricultural development through its initiation of, and sustained support to, multifarious components of public sector agricultural R&D throughout the country. The central government provides 52% of public funding for agricultural R&E in India, which almost entirely passes through ICAR. A significant proportion of the ICAR funds (30%) are made available for extramural funding and a large proportion of these funds (87%) is directed to the SAUs. Non-agricultural public research institutions and private research organizations (for profit and non-profit) obtain 7% and 6%, respectively, of ICAR's extramural funding through competitive research program and support to KVKs.

Contrary to this, around 41 percent of the scientists do not depend on the ICAR and DBT for funding their projects. These scientists reorganize their funding by exploring new avenues of funding in rice biotechnology. "Reorganization," usually of a funding agency, implies whether collaborations with manifest funding sources are predicated on the creation of new programmes or on arranging for support from multiple sources. For example, in the words of an experienced scientist from an ICAR-sponsored research institute:

> If you look at my profile, I have worked with various government and non-government funding agencies. You can't be dependent on one or two agencies to get your project funded, you have to keep on exploring new source of funding. Most importantly, choosing a funding agency also contingent on what you want to do. If I have to develop a variety using conventional biotechnological techniques, I would go for ICAR because these types of projects are being supported by ICAR under various rice breeding programs. Similarly, if my project contains aspects of modern biotechnological techniques, such as GM technology or Marker Assisted Selection (MAS) it would be better to approach DBT because it has been

established to promote agriculture biotechnology in country. Also, I want to work on abiotic stresses, I would look for international agencies such as CGIAR or IRRI because these agencies have various programs which focuses on impact of climate change on rice. You have to keep on switching funding agencies depending on nature of problem that you want to study.

A scientist from an SAU asserts:

> Currently, all the funds are being directed towards molecular biology and biotechnology programs. A plant molecular biologist has an upper hand in terms of funding as funds are available from both public and private sources to sponsor molecular research activities. And, this is due to advent of GM technology. We plant breeders don't have much choice rather than to search for new source of funding.

A scientist from an ICAR-sponsored institute opines:

> I want to make one thing clear that funding has become a prime necessity and motivation for a scientist to collaborate. In order to get the project funded, you have to look for various sources such as government agencies, non-government agencies, national and international agencies. The problem with government funding agencies are that you have to resort to much lobbying in New Delhi to counteract the pervasive Delhi-centric culture of the central authorities and extract enough funds. The government funding agencies such as ICAR, DST, DBT are that they prefer experienced scientists so that in case of failure of project they can justify that they have given project to an experienced scientists and junior scientist like me has no option rather than to look for other sources.

A scientist from an SAU adds:

> The field of breeding and genetics has become so large, it requires such continuous effort on projects running over many years that it obviously becomes difficult for governmental institutions to fund each and every project. Moreover, the increase in numbers also increases competition in the field. Therefore, we reorganizes our funding by keeping these factors in mind.

A scientist from an SAU points:

> Currently, applied research is being promoted in our country. There is substantial budget-cut in field of basic research. We don't have a hell of a lot of choice. We have to go where the money is available.

The level of resource uncertainty distinguishes collaborations that justified themselves by claiming to be superior within a recognized research niche from collaborations that went hunting for donors with arguments that their plans made novel or under-appreciated research possible. Funding agency reorganization also highlights the entrepreneurship aspect of scientists. Entrepreneurship, whether from the funding agency or the petitioning research scientists, is required for collaborations predicated on funding agency reorganization. According to Kloppenburg Jr. (1988) plant breeding is both a science and an art. As a science, it has a theoretical component, artifacts. And, the social organisation of breeding is a professional activity. As an art, it involves the deployment of skills and aesthetic considerations gained over time as part of the practice of breeding. If we add entrepreneurship aspect of scientists (reorganization of funding agencies) to Kloppenburg Jr.'s conceptualization of plan breeding then plant breeding can be conceptualized as a science, an art and a commerce.

### 4.3.3 Sectoral Context

The distinctiveness of modern collaborations lies partly in the inclusion not only of multiple organizations but also of multiple organizational firms, institutions, or sectors. Contingent upon the responses of rice biotechnologists, we have categorized a variety of institutions under three groups of collaborations: (1) university (2) government research institutes (3) industry. The respondents included in the present study report that most of R&D activities rice biotechnology are commanded by first two above-mentioned institutes. Around 64 percent of respondents are of the opinion that university collaboration is important in the field of rice biotechnology. The primary reason to collaborate with university was access to fundamental research. Accentuating the importance of university collaboration, a scientist from an ICAR-sponsored research institute expresses:

> Collaboration with university is very important because they devote their energies to the advancement of fundamental research, which would provide a foundation for future progress in technical and practical rice breeding. They are the dynamo of basic research. This would cater the active interest and cooperation of entire rice biotechnology community, which can rally and develop.

A scientist from an SAU points:

> Working with universities, we can get leverage from their existing knowledge and we can get enthusiastic people without building up a large, unwieldy team in-house. We want talent in the universities, and we want talent in our institute (ICAR) also, so we are looking to them for assistance in identifying good people for collaboration in all levels.

A scientist from an ICAR-sponsored research institute adds:

> The research in biotechnology cannot survive by categorizing basic as opposed to applied research and hence, favoring the latter and ignoring the former. The basic and applied research is not dichotomies rather they complement each other. A proper balance is required between basic and applied research foe overall prosperity of rice research in country. Therefore, active collaborations with SAUs becomes of paramount significance because they specializes in curiosity-driven research. If you have to understand how Mendels Law works, you need to go to university.

A scientist from an ICAR-sponsored research institute reflects:

> Working with universities, we can get leverage from their existing knowledge and we can get enthusiastic people without building up a large, unwieldy team in-house. We want talent in the universities, and we want talent in our institute (ICAR) also, so we are looking to them for assistance in identifying good people for collaboration in all levels.

Meanwhile, 73 percent of the respondents are of the opinion that collaboration with government research institutes is important. The first and foremost reason mentioned by a majority of the rice biotechnologists for collaborating with government research institutes is to access resources in terms of infrastructures, manpower and funds. A scientist from an SAU opines:

> The collaboration with government research institutes, such as ICAR, CSIR, DBT, and so forth are of critical importance. India has a strong network of state agricultural universities, but leaving a few, most of them are dormant due to various factors such as inadequate financing, poor infrastructure and lack of scientific and technical manpower. The universities have not got the focus it deserved. Contrary to this, we have large national agricultural research network with the Indian Council of Agricultural Research (ICAR) as the apex organization, which comprises modern laboratories, top-class scientist, ample genetic resources and sufficient funds. For an example, National Research Centre on Plant Biotechnology (NRCPB) is a premiere research institution of the Indian Council of Agricultural Research (ICAR), which has developed a world-class laboratory in terms of new tools and techniques to deliver breakthrough in biotechnology for crop improvement. Let me share one of my experiences, I am particularly interested to find out novel pathways, miRNAs and long non-coding RNAs that are responsible for salinity stress tolarence in rice. The goal is to transfer that important genes/miRNA from wild species to salinity sensative genotype of rice. To achieve these objectives, I have to collaborate with DBT and NRCPB. DBT is the funding body, whereas NRCPB has well-equipped lab for molecular mechanisms related to salinity stress tolerance of rice and it wild relatives such as Oryza coaratata and Oryza glaberrima.

A scientist from an ICAR-sponsored research institute asserts:

> You must have heard about Improved Samba Masuri. This new rice variety has been developed through traditional plant breeding and advanced

> biotechnology tools. It was developed by using MAS technology. It was result of 10 years joint effort of scientists at the Centre for Cellular and Molecular biology (CCMB) and the Directorate of Rice Research (DRR) in Hyderabad. We did molecular breeding in CCMB and actual traditional rice breeding at our institute (DRR). CCMB is a CSIR-sponsored agency. We collaborated with CCMB because CCMB is among one of the few institutes in India, which has established molecular breeding lab as well as top-class expertise in molecular breeding techniques.

A scientist from a SAU recalls:

> Since green revolution, we have successfully developed a multiplicity of new improved varieties of rice. But continuous infusions of germplasm were needed as crops spread to new areas or as disease or pest problems rendered other varieties obsolete. The reason and necessity for such things was removed when experiment stations were established by ICAR and SAUs in the several states. Those stations are in charge of scientists. They are therefore, particularly well equipped for trial, testing, and approval or condemnation of such new varieties as may be introduced from time to time. Collaborating with such research stations have made research easier and fast.

According to a majority of the scientists, the central government channels public funds into public sector R&D through seven large central national research councils. These are the Department of Science and Technology (DST), the Council for Scientific and Industrial Research (CSIR), the Department of Biotechnology (DBT), the Indian Council for Agricultural Research (ICAR), the Indian Council for Medical Research (ICMR), the Indian Council for Social Science Research (ICSSR) and the University Grants Commission (UGC). However, collaboration with DBT-funded labs, CSIR-sponsored research institutes and ICAR-sponsored research institute are found to be dominant in the field of rice biotechnology. Dwelling upon the prevalence of collaboration with government research institutes in rice biotechnology, a scientist from an SAU shares:

> Since last two and half years, I have been working with a theoretical botanist in the University of Delhi. I am also working with on a collaborating project under the CSIR-sponsored institute (Institute of Genomics Centre and integrative biology, New Delhi) to use gene chip technology to nitrate responsive genes in plant. I have also got a project with All India Institute of Medical Sciences (AIIMS), New Delhi for genetic diagnosis in which have some expertise in real time PCR, and they wanted to use our expertise. In my opinion, ICAR-sponsored research institutes DBT funded labs, CSIR-sponsor institutes, ICMR-sponsored institutes are the real instigators of collaboration in field of rice biotechnology.

A scientist from an SAU asserts:

> The R&D in rice biotechnology cannot prosper without collaboration with ICAR-sponsored research institutes. The ICAR-sponsored research institutes, such as IARI, DRR, and CRRI to name a few are the pioneer institutes in rice biotechnology. These institutes' commands rice research in India. For an example, green revolution in India emanated from the field of IARI, Pusa, New Delhi.

Contrary to this, only 14 percent of the rice biotechnologists endorse the important role of industry in promoting R&D in biotechnology in India. This suggests that triple helix model, which talks about active collaboration between university, industry and government do not seem to be working in the field of rice biotechnology. Reflecting upon university-industry collaboration in rice biotechnology, a scientist from an SAU shares:

> When the private sector has the ability to develop ideas and concepts into marketable products, then the private sector should take the responsibility to do it rather than the university. In this way, the university will continue to fulfill its role of conducting basic research and training graduate students but not to be in competition with the private sector.

Another scientist from an ICAR-sponsored research institute reacts:

> I am not against the idea of industry collaboration; I am concerned that the flow of new corporate money into the field (rice biotechnology) would have negative effect on government institutes. Free enterprises are wonderful things, but it should not harm the interest of farmers, which would be the possible outcome of public-private collaborations.

A scientist from an SAU adds:

> If you see the history of rice biotechnology, the contributions of private sector is marginal. But this doesn't mean that we should not have collaborations with industry. Private sector expertise should be fully utilized in efforts by the public sector to identify future research needs, estimate future demand for scientific and technical manpower, and define appropriate complementary roles and responsibilities for the various sectors and institutions involved in rice research. However, this is only possible when there is a proper mechanism to track the collaborations so that accountability should be fix in case of deviant, especially from the side industry collaborators.

### 4.3.4 Organizational Context

Each inter-institutional collaboration in our sample includes participants employed by two or more organizations. About 82 percent of respondents report about some form of pressure from parent institutions. In these cases, the individual scientists, who wish to participate in multi-organizational collaborations, need to secure approvals from parent organizations or experience similar constraints. Moreover, in the case of multi-institutional collaborations scientists have to convince their departments, a dean, or other officials to support the collaboration. However, there was wide variation in the extent to which organizational interests figure in the formation of the collaborations. In some instances, prospective collaborators need explicit, non-trivial approval from their organizations to participate. Occasionally, prospective members are unable to join the collaborations because of their failure to secure that approval. For an example, a scientist from an ICAR-sponsored research institute shares:

> I wanted to collaborate with a scientist of USA. I have met him in a conference at Mexico. We have been in touch since last three years. He has been helping me in my research area. We have common research interest. He has a well-established laboratory specialized in molecular technologies, the one we do not have here. I have decided to visit his lab and conduct some complex experiments, which is not possible here. So, we have written a good proposal and it got funded from IRRI. He got his approval from his institute, but my NOC was denied by authority with the reason that at the level of junior scientist, I cannot visit foreign countries for such a long period of time. Moreover, I was also reminded that I am still on probation. This is very frustrating and shows underdeveloped research culture in our country.

A scientist from an ICAR-sponsored research institute reacts:

> I have recently joined the institute (IARI, New Delhi). I am specialized in molecular biotechnology. I have worked in IRRI Philippines for three years. I have a few good publications including two of them in Nature (Journal). I want to continue my work in collaboration with IRRI. I have spoken to IRRI authority and they don't have any problem. They are ready to fund my work over here. But, I was not permitted by institute authority. Instead, I have been compelled to be a coinvestigator in an ICAR-sponsored project, as one of the coinvestigator has changed his job. Moreover, this project is all about developing a diseases resistant rice variety, which is not my research area. I don't know what to do.

The institutions remain embedded to collaborating projects and exert pressures, which guide and constrain subsequent actions of individual scientists. Furthermore, this suggests that collaborations in rice biotechnology are not only shaped by agency function but also by structure within which scientists operate.

### 4.4 Magnitude of Scientific Collaboration in Rice Biotechnology

"Magnitude" is preferred to size as a generalized concept because it conveys variations in a number of actors, project duration, and cost. This section examines the first two of these parameters. Although we are initially diligent in seeking information on the costs of collaboration, the unwillingness of rice biotechnologists to share data about the costs of project render the issue of cost too difficult to develop a comparative indicator of magnitude.

We make an attempt to analyse the number of participants, the number of teams, the number of organizations, the time needed to acquire funding for a collaboration, and the time needed to obtain scientific results once funding is obtained. The empirical data on current projects suggest that in total 187 projects have been undertaken by 71 respondents during 2010-2014. The average number of projects per scientists is 2.6. Tables 4.17, 4.18 and 4.19 represent individual participation, organization participation and duration of research projects undertaken by rice biotechnologists during 2010-2014.

**Table 4.17: Individual participation in research projects during 2010-2014**

| Individual Participation | | |
|---|---|---|
| **Range** | **Frequency** | **Percentage** |
| 1-3 | 7 | 3.74 |
| 4-7 | 85 | 45.45 |
| 8-11 | 71 | 37.98 |
| 12-15 | 14 | 7.48 |
| 16-19 | 6 | 3.21 |
| 20-23 | 3 | 1.60 |
| 24-27 | 1 | 0.53 |

Source: Field Study

**Table 4.18:Organization participationin research projects during 2010-2014**

| Organization participation | | |
|---|---|---|
| **Range** | **Frequency** | **Percentage** |
| 1-2 | 41 | 21.92 |
| 3-4 | 121 | 64.70 |
| 5-6 | 18 | 9.62 |
| 7-8 | 3 | 1.60 |
| 9-10 | 1 | 0.53 |
| 11-12 | 2 | 1.07 |
| 13-14 | 1 | 0.53 |

Source: Field Study

**Table 4.19: Duration of projects undertaken by scientists during 2010-2014**

| Duration of projects | | |
|---|---|---|
| **Range** | **Frequency** | **Percentage** |
| 1-2 | 31 | 16.58 |
| 3-4 | 101 | 54.01 |
| 5-6 | 51 | 27.27 |
| 7-8 | 3 | 1.60 |
| 9-10 | 1 | 0.53 |

Source: Field Study

The average number of individual participants in these collaborations are 8.2, ranging from 1 to 27. Nearly 50 percent of total projects consist of 3 to7 partners (table 4.17). Not included, as individual participants would have performed the same task had the collaboration not been conducted. For example, scientific staffs are the people they perform laboratory whether an experiment is for research, or for knowledge gathering. Similarly, we also have not included field evaluators as collaborating partners, who assist scientists in field trials, they carry out field works whether it is an individual project or collaborative project.

The number of organization participation ranged from 1 to 14, averaging more than 3 per collaboration (table 4.18). However, the number of individual participants, the number of organizational participants can vary during the course of collaboration. Additions are more common than losses, but there are occasional instances of organizations leaving collaborations. Collaborations involving only the university (between SAUs) sector typically involve a few participating organizations and teams. More than 85 percent (86.63 percent) of research projects involved only 1-4 organizations, versus 13.36 percent of collaborations with 5-10 organizations.

The second component of magnitude is duration, the temporal dimension that distinguishes short projects from the lengthy ones. Though actual termination cannot be accurately predicted, the fact that collaboration is generally designed to goals compels us to consider length as an aspect of magnitude. The average duration of project is 3.8 years per project ranging between 1 and 10 years. More than 70 percent of projects are of 3-4 years in duration. Collaborations that take a long time to acquire funding or to generate scientific results are generally seeking to mobilize many participants. The average length of time from the initial formulation of a project to the point of funding is 14 months. Minimally, collaborations require less than 6 months before resources are acquired. The longest wait in our sample was 24 months. More than half the collaborations in our sample wait 9 months or longer. Duration of publication indicates the amount of effort required before the project begins to yield scientific results. A majority of the scientists believe that no publication output related to research project is possible before 18 months or 24 months from the date of initiation of project. Nevertheless, scientists publish papers on techniques or instrumentations they are developing for the project, but these papers are not based on the results of projects and do not qualify as project outcomes.

**4.5 The Structure of Scientific Collaboration in Rice Biotechnology**

A social network is a collection of people, each of whom is acquainted with some subset of the others (Newman 2001: 404). Such a network can be represented as a set of points (or wrtices) denoting people, joined in pairs by lines (or edges) denoting acquaintance. One could, in principle, construct the social network for a company or firm, for a school or university, or for any other community up to and including the entire world. Social networks have been the subject of both empirical and theoretical study in the social sciences since I950s (Wasscrman and Faust 1994; Watts 1999; and Scott 2000), partly because of inherent interest in the patterns of human interaction, but also because their structure has important implications for the production of knowledge. It is clear, for example, that variation in just the average number of acquaintances that individuals have (also called the average degree of the network) might substantially influence at the level of policy framework.

In science studies, Derek J. dc Solla Price was the first notice that scientific collaboration “has been increasing steadily and ever more rapidly since the beginning of the ltwentieth] century”, a process he deemed “one of the most violent transitions that can be measured in recent trends of scientific manpower and literature", surmising that "if it continues at the present rate, by I980 the single-author will be extinct" (1963: 77, 79). The consequences he saw were more extensive and enduring than a mere shift in the practices or work habits of scientists:

> We tend now to communicate person to person instead of paper-to-paper. In the most active areas, we diffuse knowledge through collaboration. Through select groups, we seek prestige and the recognition of ourselves by our peers as approved and worthily collaborating colleagues. We publish for the small group, forcing the pace as fast as it will go in a process that will force it harder yet. Only secondarily, with the inertia born of tradition, do we publish for the world at large (Price 1963).

If we carefully examine the above statement of Price, it becomes clear that this powerful transformation of scientific practices continues in ways and with consequences that Price did not anticipate. Collaborators today communicate from different continents and cultures. synchronously or asynchronously, in the languages of different nations and disciplines, through a spectrum of technologies, using diverse forms of expertise to produce heterogeneous mixes of knowledge, products and solutions to problems (Walsh and Maloney 2002). The most notable technological gadget is the computer, which is used for processing data and text, and for communicating with peers across time zones. The "select group" that grants "prestige and recognition" accomplishes its collective purposes despite centrifugal forces. The published productivity of the group may not differ in quantity from that of an equal number of dissociated individuals, so the impetus to collaborate lies elsewhere]. In this context, Olson and Olson (2002) put it thus:

> The best technology must be complemented by activities that build trust and understanding through sustained, face-to-face social interaction. Tensions and paradoxes are essential features of collaboration, even within established, co- located research groups, so the mere occurrence of face-to-face interaction does not insure that understanding and solidarity will result.

Now it would be pertinent to begin our inquiry into the nature of scientific collaboration with the fundamental questions: What is collaboration? Why do scientists collaborate? What are the motivations underlying collaboration? These questions have elicited complex and quailed answers. 'Collaboration is a family of purposeful working relationship between two or more people, groups, organizations. Collaborations form to share expertise, credibility, material and technical resources, symbolic and social capital (Katz and Martin I997; Maicnschein 1997). The more emergent issues include: how do collaborations work? How productive are they'? What is collaboration becoming? What is driving the transformation? Hackett (2005) proposes that the landscape of scientific collaboration is changing in the following ways.

(a) *Social organization*: traditional small research groups are now complemented by episodic working groups; contractual agreements between organizations; international collaborations that strive to span the North- South divide; interactions amongst scientists, engineers, commercial ventures, and the university offices and experts that broker such agreements (Owen-Smith 2005).

(b) *Intellectual content and cultural reach:* interdisciplinary research has been rising for more than a decade, spurred by science policy and by the rising prevalence of fundamental research, that engages practical ends (Stokes 1997).

(c) *Technologies of collaboration*: the "invisible college" concerning oxidative phosphorylation described by Price (1963) was fueled by a mailing list through which researchers working in the area-circulated manuscripts. Today, e-journals, websites, digital libraries, blogs, collaboratories, and other applications of scientific cyber infrastructure accelerate research communication, with consequences for the process and products of research that are coming into focus.

(d) *Understandings of collaboration*: studies on collaboration that once equated it with co-authorship and explained it as a direct consequence of specialisation and access to research technologies have been supplanted by a distinction between collaboration and co-authorship, concern about the inherent paradoxes or tensions of collaboration, attention to the importance of place for the conduct of science (Gieryn 2002; Henke 2000), and awareness that scientists. students of science, and decision-makers are all embedded in scientific research and science policy.

In conceptual terms, these differences arc the dimensions that describe the transformation of collaboration (Hackett 2005): (a) *extent*, measured as a distribution over substantive, social, or geographic space, or over time; (b) *intensity*, measured as the frequency or significance of interaction among persons, places, or units of time; (c) *substance*, or the aims and content of collaborative work, which now include producing fundamental knowledge, developing technologies, guiding decisions, making things, training, and bonding; (d) heterogeneity, or the variety of participants, purposes, languages (ethnic. national. disciplinary. sectoral), and modalities of collaboration (face-to-face. electronically mediated in various ways, and episodic); (e) *velocity*, or the rate at which results are produced, analyzed, interpreted, and published; (D) *formality*, ranging from contractual arrangements among nations or organizations to handshake agreements and unstated understandings among friends and acquaintances.

**Table 4.20: Extent of collaborations in Rice Biotechnology (2010-2014)**

| Institutional Settings | SAUs | ICAR - sponsored research institute | Other Universities | DBT - sponsored institutes | Institute of national importance | CSIR - sponsored institutes | ICMR - sponsored institutes | International institutes (public) | Research Foundations (Private) | Industry | Total |
|---|---|---|---|---|---|---|---|---|---|---|---|
| SAUs | 20 | 11 | 6 | 1 | 2 | 2 | 0 | 28 | 1 | 0 | 71 |
| ICAR - sponsored research institute | 11 | 45 | 6 | 4 | 3 | 5 | 2 | 37 | 2 | 1 | 116 |
| Total | 31 | 56 | 12 | 5 | 5 | 7 | 2 | 65 | 3 | 1 | 187 |

Source: Field Study

Table 4.20 indicates the extent of scientific collaborations of SAUs and ICAR-sponsored research institute with the other institutional settings at national and international level. Out of 71 projects, 43 (61 percent) projects of SAUs are with national institutes, whereas 28 (39 percent) projects are with international institutes. Meanwhile, ICAR-sponsored research institute have 68 percent (79 out of 116) of projects with national institutes and 32 percent (37 out of 116) of projects with international institutes. This suggests that SAUs tend to collaborate more with international institutes (39 percent) in comparison to ICAR-sponsored research institute (31 percent). Further, collaboration between ICAR-sponsored research institute is strong accounting to 38 percent (45 out of 116) of total collaborative projects. Contrary to this, collaborations between SAUs and ICAR-sponsored research institutes are relatively weaker accounting to 9 percent (11 out of 187). However, if we combine the total project of SAUs and ICAR-sponsored research institutes, we find that 122 (65 percent) projects out of 187 projects are with national institutes and 65 (35 percent) projects out of 187 projects are with international institutes. This suggests that scientific collaborations in rice biotechnology are both national and international in character.

However, the study does not include the scientists located in industrial R&D organisations. Further, it is extremely difficult to calculate the intensity of scientific collaboration in the present study. Intensity shows the depth of scientific collaborations, which becomes difficult to be quantified. Similarly, it is difficult to aim at quantification in terms of substance, heterogeneity, formality and velocity.

**4.6 Patterns of Collaboration**

Different kinds of scientific research with different motives and different requirements are manifested in different patterns of collaboration. The different patterns of collaboration studied were:

1. Collaboration between different departments of the same institution
2. Collaboration between different universities within the same country
3. International collaboration
4. Collaboration with industry

Table 4.21 suggests that the collaborations of the first three kinds are predominant or preferred by the researchers. Eighty-five percent of the respondents have handled collaborative projects with different departments of the same institution in last five years. The high proportion of this type of collaborators suggests that this type of collaboration gives the advantage of physical proximity. As Kraut and Egido (1990) argued that physical proximity is an important driver of research collaboration. Collaboration is sustained by continuous and timely communication between collaborators and any lag or disturbance in the communication is bound to hinder the collaboration. As distance between the collaborators increases, it becomes increasingly difficult to have short and frequent communication. A project involves numerous small contentious aspects that require discussion and if the distance between the collaborators is considerable, these small problems are amplified by the communication gap, overall endangering the success of collaboration (Kraut and Egido 1990).

Though physical proximity is an important factor, it is not the only important factor in determining the short distance collaborative projects. Familiarity with the potential collaborator also plays an important role in determining whether the researchers would come together to collaborate or not. These two factors — physical proximity and familiarity — can also help to rationalize the high number of responses i.e. 84% (table 4.21) collaborating within the country with other universities. Even though the distance in the physical sense has increased as compared to collaboration between different departments of the institutions, the communication lag has not set in. That is to say, that communication is not a problem when collaborators are form the same country and different universities.

**Table 4.21: Types of collaborative projects undertaken by scientists (2010-2014)**

| Types of collaboration | Percentage |
|---|---|
| Inter-departmental | 85.3% |
| Inter-university | 84.4% |
| International | 83.3% |
| With Industry | 0.1% |

Source: Field study

When collaborators are from different academic cultures, different perceptions and views regarding the reward systems, management culture and other such considerations are likely to adversely affect collaboration. Conversely, if the collaborators are part of the same academic culture, it may ensure smooth functioning of the collaboration (Sonnewald 2007).

An interesting result revealed by the data is the fact that there is almost the same number of respondents 83% (table 4.21) with international collaborations as there were with inter institutional and inter country collaborations. Therefore, the loss of communication problem in long distance collaboration must be being offset by some other beneficial considerations. International collaborations become important in the view of access to expert knowledge and sophisticated instruments. These two factors are important because a high quality scientific research is impossible if either of the two is missing. Hence, we see a great deal of international collaborations, especially with technologically and scientifically advanced western countries where expert knowledge is readily available.

A remarkable feature of the data set is the remarkably negligible number of respondents with industry collaboration. Only 0.1 percent (table 4.21) of the respondents collaborated with industry. One reason as pointed out by Clarke and Preston can be that university and 'business organizations' like an industry have quite different research orientations. Mostly, universities have theoretical approach towards their research problems (Clarke and Preston 2002). They tend to do more research that is basic and are more concerned with the production of knowledge per se than with its application. On the other hand, industries have more applied focus in their research work. Their primary concern is regarding the applicability of the knowledge of their research work. This incompatibility in their perceptions towards their research work prevents any easy collaboration between them as also seen found in our study. Number of respondents who have collaborated with industry is very negligible. Primary reason that has come out from the discussion with the scientists for not having collaboration with industry is certain policies of the university. University system in our country is not very keen to collaborate with industry, as it is believed that universities are the centers of knowledge production, should focus on production of knowledge and its dissemination, and should not venture into commercialization of knowledge. Translating this basic knowledge to commercially viable forms mainly fall in the domain of research institutes and private firms. Triple helix is the new model of knowledge production that has emerged which is about bringing three different institutions — university or academia, which generates knowledge, industry, which makes the knowledge commercially viable and markets it and government, which prepares and regulates the policy and gives the overall direction towards which the research is directed. However, in the case of scientific community of rice biotechnology, this model has not stated to function.

### 4.7 Triple helix - Government-University-Private R&D Institutions Networking in Rice Biotechnology

Research and development in rice biotechnology that is based on plant molecular biology are situated at the intersection of two profoundly destabilizing changes: cognitive and political (Jasanoff 2005). This unique position makes the project of using the domain of life sciences to improve the human condition. On the cognitive front, the shift occurs from monovalent to polyvalent knowledge (Viale and Etzkowitz 2005). Moreover, on the political front, the shift is towards a fracturing of the authority of nation-states, with consequent pressures to rethink the forms of democratic governance. However, it is beyond the scope of present study to critically engage in mapping out the contours of the shift on the political front.

Viale and Etzkowitz (2005) trace the linkages between scientific and technical knowledge, on the one hand, and, the evolution of institutional and organizational forms, on the other, as a part of the process of innovation in scientific research pursuits. They argue that there is a reciprocal relationship between organizational and cognitive innovations, which enhance both the processes. They argue that historically one notices a transition from single helix model to triple helix through double helix that facilitates the collapse of barriers between university and industry. Polyvalent knowledge (triple helix model) supercedes both traditional disciplines and mode 2 knowledge (Gibbons et al. 1994) created in the context of application. The movement towards polyvalent knowledge system is accompanied by changes in institutions, organisations and roles of those involved in production of knowledge and its application. In this context, Viale and Etzowitz (2005) mention the "changing relationships of tacit to codified knowledge". Knowledge within this model is increasingly "polyvalent" as theoretical, practical and interdisciplinary implications from a common centre of gravity. The institutional spheresof industry and university are driven together on account of the changing nature of knowledge both in advanced industrialized societies and developing countries, which heralds the coming of the third Academic Revolution where the epicenter of innovation in the "entrepreneurial scientific role and an entrepreneurial university embedded in a triple helix of university-industry-government relations".

In triple helix, the first step usually involves collaboration among universities, firms and governments in a project to enhance a local cluster or create a technopole. To address the gap between the needs of industries 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. Understanding the view of the other calls for cognitive empathy (Haribabu 2000) and a language that aids in understanding both the tacit and codified elements of knowledge by the partners, which will be discussed later in chapter. Galison (1999), in his study of the interaction among theoreticians, experimentalists and instrumentationists in the discipline of physics, points out that although all the three specialists belong to the disciplines of physics they do not have a common idiom and they start interacting by deploying a 'pidgin' language. In today's context, industrial/applied research starts with a practical problem and in course of solving the real world problems, some basic research questions are addressed. Even in science, the growth of knowledge is punctuated by radical discontinuities over time (Kuhn 1970). One notices discontinuity across space-culture co-ordinates.

However, in context of rice biotechnology research in India, analysis of secondary data (see chapter III) as well as primary data reveals that triple helix model does not seem working. It is also evident from data that negligible amount of university-industry-government collaboration is taking place. Most of the collaborations are occurring between scientists located in SAUs and ICAR sponsored institutes. Even perception of scientists suggests that at times seems to have little apprehensions regarding the entry of private industries into the process of research and development.Scientists in interviews cited multiple reasons for not collaborating with private players in rice biotechnology research; sometimes they feel intimidated by the entry of big multi-national corporations into areas of agricultural biotechnology.

Highlighting one of the reasons for not collaborating with Industry a scientist from an ICAR- sponsored research institute asserts:

> We are part of ICAR sponsored institutes. The ICAR is the apex body for co-ordinating, guiding and managing research and education in the entire country. With more than 100 ICAR institutes and 70 agricultural universities spread across the country this is one of the largest national agricultural systems in the world. Its main objective is to provide free service to farmers. Whereas, main motive of industry is profit making. Moreover, for industrial collaboration government of India has a separate agency known as CSIR labs which works on industrial application of plant and seeks collaboration with industry.

According to a scientist from an SAU:

> Public institutes in agriculture are more concerned about delivering services to people without any interest. But private institutes don't work on philanthropic basis, their ultimate aim is to make profit. We do not collaborate with industry because they are much more interested in profit making and our priority is to serve farmer first. There is a conflict of interests and trade-off between two set ups.

According to a scientist from an ICAR-sponsored research institute:

> Private enterprises mandates are different from public institutions mandates. Prime mandates of the industry are to develop a product and put it in market for business. They want things to be done quickly. They are more concerned about the matters like, what are the chances of developing a product in stipulated time frame? What would be the market for the product in future? Whether their investment return is certain or not? Whether they will able to make profit from the product or not? Their math is completely different from us. Our prime objective is to see how science work and to what extent it can be harnessed to develop a product which is better than the existing one in catering the needs of farmers.

A scientist from an SAU opines:

> We have both public institutions and private companies in India. If collaboration takes place between them then the both agencies will go for publication of some research papers out of their collaborative research projects. They will also go for patenting their products. But, what happens in reality is that private agencies operate as a closed; they don't share information, equipment and research material. Further, sharing of the recognition and money has become a major casualty so far as private agencies are concerned. They are not interested in investing money in long term R&D.

A scientist from an ICAR-sponsored research institute stresses:

> To be specific, the collaboration between government, university, and private and public R&D institutions in India, I think, would be not able to solve the real-world problems. Any type of dialogue with the industry would directly hamper farmers. Farmers will have to face direct competition from private enterprises for which I think, farmers of India are not ready. I am against any form of collaboration with private agency even technology transfer. We are transferring technology to private companies. They multiply seeds and sell it to farmers at exorbitant price. In my opinion, generated technology should be directly transferred to farmers and farmers should be educated to use the technology through extension services.

According to a scientist from an ICAR-sponsored research institute:

> I think, a scientist collaborates with any agency mainly for funds. Being a part of premium institute, we do not have problem of funds. Different government funding agency like ICAR, DBT, DST, ICMR, CSIR and even DRDO has come up to fund plant science research. The only thing you require is a good research proposal, which should be in nations or in farmers Weil. Thus, if you are easily funded by government agencies than I think there is here is no compelling reason to collaborate with private enterprises.

A scientist form an SAU emphasizes:

> Indian seed agency except one or two like MAHYCO have very weak R&D unit. They are not engage in any serious research. They prefer taking consultancy for short period from scientists rather than funding and entering into collaboration for long period. I know number of scientist's even eminent scientists who are part of government institutes and simultaneously provides consultancy to private firms secretly. Thus, if private enterprises are getting easy access to required expertise at cheaper rate than there is no rationale for them to collaborate and invest in long term R&D projects with us.

A scientist from an ICAR-sponsored research institute reflects:

> We have a very weak collaboration with industry because industry is not interested in funding us. There are no Indian private agencies financially sound enough to fund long-term project of 3 years or 5 years. If you will talk about multinational companies like Monsanto and Syngenta they have strong research and development units comprising of world's top class plant scientists working for them. Even I know few Indian scientists who are working in USA for Monsanto and doing top class research. Their scientists are much ahead of our scientists in terms of quality and quantity of research work. They have good infrastructure in terms of well-equipped laboratory as well as financially sound enough to support their research activities. Thus, these MNCs do not require our expertise.

A scientist from an SAU expresses:

> The interaction between public sector and private sector in rice research is restricted to seed testing, field trials, pesticides testing's, technology transfer and to some extent in extension services for distribution of seeds. We don't want to have R&D collaboration with industry because they are not reliable. We can't trust them. Cases of fraudulent activities by private agencies are often reported in media. I want to share an incident that has occurred in our department. After a lot of deliberation and stringent administrative process we have entered into collaboration with a reputed Indian seed agency for developing a rice variety. I will not mention the names of scientists and agency because it is highly confidential. Initially, for few months everything was all well but later on the firm did not turn up. After sometime we discovered that we had been cheated by the firm. All the important data was scooped by the firm. Realizing the gravity of situation, we took legal action and a case of fraudulent was booked against the firm. The case is under subjuidice and ICAR legal department is looking after it.

A scientist from an ICAR-sponsored institute mentions:

> We do not collaborate with private agencies because of IPR issues associated with biotechnology. Private agencies are profit oriented and they look for patenting the developed product so that they can create monopoly in market and sell the product to the farmers at price of their will. They follow aggressive policy of patenting the product. This impedes access by poor farmers to the new technologies and products. The conflict of proprietorship over golden rice is famous case. To tackle these problems policy ofPlant Variety Protection (PVP) has been designed and introduced in our country. Under this policy breeder gain right for their varieties, but simultaneously farmers can save the seed and also it can be used by other breeders to develop new varieties. In my opinion, one of the main reasons for success of green revolution in India was that R&D activities were concentrated in public institutes and same model should be implemented in case of gene revolution. Thus focus should be more on collaboration between public institutes instead of public-private institutes.

A scientist from an SAU points:

> Multinational companies are mainly active in area of seed development and agricultural chemicals. The present status quo of these MNCs are that they have achieved full control over development of agriculture biotechnology in developed countries. They have invested heavily in in-house R&D facilities. They are collaborating with public research institutions and universities. They have more patents in comparison to public institutes. Today, in developed countries, agriculture biotechnology is organized by handful of MNCs and large farmers. To be very frank, we do not want same to be repeated with our country. Moreover, our country lacks strong regulatory policies and mechanisms, which can facilitate public-private partnership by protecting our interests and farmer's interests simultaneously. There are offers from private players for long-term R&D collaboration but we reject it

because we are very much aware of its consequences in long run. Our collaboration with private agencies are limited to testing and certifying them for commercial cultivation. Even, owing to reporting of few cases of malpractices in seed certification process ICAR is working on stringent regulation policies, which will be included in new seed policy act.

If we critically analyse the above viewpoints of scientists, we infer that there is conflict between public and private sector about mandates, willingness, interests, intentions, reliability, trust, goals and credibility of achievements, which further inhibits productive collaboration between public and private institutes. Another strong reason, which has emerged from the study, is consensus over accurate mapping of proprietary assets and liabilities or responsibilities it is conflict of interest and government policies that obstruct scientists to collaborate with industry. Scientists in India are mandated to do research with an application potential and the eventual commercialsation. However, in case of rice biotechnology collaboration involving private industrial R&D institutions and the public R&D institutions coming under aegis of SAUs and ICAR-sponsored research institutes, in the process of institutionalization of networking, there are still some issues that have to be resolved. One of the issues is related to differing perspectives on the functions of the SAUs in particular.

Broadly, there are two perspectives: first, the industry-sponsored research would enable universities to generate funds, to augment their resources for research, and as a corollary, scientists located in the university set-up have to shift their orientation towards more application-oriented problems. The second perspective is that the basic function of the university is to pursue basic research and provide comprehensive disciplinary education to the students. According to this perspective, the industry-sponsored research will affect the basic research orientation of the university researchers. Further, the industry-sponsored research would bring in commercial values thus entangling university research and researchers with proprietary interests and constraints thus changing the traditional image of the university (Nelkin and Nelson 1987). However, in present day context in areas like biotechnology, the culture of university research is moving towards applied research, even though in developing countries there are some reservations on the part of the scientists (Wagner1998). The conflict may rise due to values attached to research by the university scientists and industry as mentioned above. The papyrocentric culture of the university scientists may clash with the industry’s insistence of non-disclosure of research outputs. However, in case of ICAR –sponsored research institutes responses suggest that mandates and policies does not foster public-private R&D collaboration. Credit-sharing becomes a source of conflict in the absence of relevant norms (Price 1982, cited in Haribabu 2000).

The present study reflexively outlines that in the rice biotechnology context, the R&D institutions-public and private- will have to decipher the imperative to network for learning and generation of knowledge that has application potential and the eventual commercialization in the changing context of production of knowledge. The process of institutionalization of collaboration has to surmount barriers arising out of the interests and meaning that R&D scientists located in SAUs and ICAR sponsored institutes hold. However, there is a need to examine the dynamics of triple-helix model in the rice biotechnology by looking at the kinds of norms that government, and R&D institutions-public and private- evolve over time and for different kinds of activities relating to the process of innovation, and how they resolve clashes arising out of their interests and meanings.

**4.8 International collaboration**

Emergence of modern technology and frontier research are more complex, knowledge and resource intensive, and mostly boundary spanning. It has brought radical implications that have profound impact on governance of the sciences and knowledge creation simultaneously, now the context of discovery is not limited to local or institutionalized disciplinarily in university departments (Gibbons et al. 1994). Instead, it has become more globalized and internationalized in nature. Public research is now nationally and internationally linked and has become parts of huge knowledge networks. Research in public institutes is often decentralized with researchers at multiple locations within the same country and at different locations in different countries. The locations of knowledge production, competences and resources are driving the knowledge flows at national and supranational level. Consequently, the international collaboration of public research is playing a significant role in strengthening national competitiveness and production of new knowledge in general.

Across the time and space, various scholars to explain the growth of international collaborations have forwarded a number of reasons and theories. Within Centre-periphery paradigm, Schott (1998), following Ben-David (1974) and Shils (1983), captures growth in international collaborations as related to a succession of countries that are regarded or plays the role of “centres” for world science. Countries located at “periphery”, mostly small in size, emulate the scientific work model of the centre in terms of the organization, orientation and excellence of scientific work. Another theory approaches the escalation in international collaboration by stressing that the organization of international collaboration is highly influenced by disciplinary differentiation of science. This mainly includes Stichweh’s (1996) assertion by following Price (1963) that collaboration increases as scientific disciplines becomes more specialized. From financial perspective, a third reason explains that the financial demand of some scientific fields causes international linkages (Galison and Hevl,y eds. 1992). Crawford (1992) suggests that cross-border links occur when cost of a single project is too large to be afforded by a single nation. These collaborations often are carried out in form of “big science” or “megascience” projects. According to Beaver and Rosen (1978), collaboration grew historically as science become more “professionalized” occurring in dedicated institutions of science. However, Wagner and Leydesdorff (2004), suggests that neither of these reasons explains rise in international collaboration in absolute sense, international collaboration in science is complex, self-organizing network which operates in accordance with an internal social dynamic. Thus, there is need to investigate other reasons that have not been fully explored.

In the present study, an attempt is made to capture opinion of scientists regarding various dimensions of international collaboration in rice biotechnology in India. Keeping this objective in mind, in-depth personal interview was conducted with rice biotechnologists located in selected SAUs and ICAR-sponsored research institutes. Scientists profile was scrutinized and only those scientists who have experiences in international collaboration were approached for interviews. Different dimensions of international collaboration operating in rice biotechnology can be broadly classified into following categories:

- actors of international collaboration;
- the drivers and benefits of international collaboration;
- the process of finding international collaboration partners;
- possibilities for improving international collaboration.

### 4.8.1 Actors of International Collaboration

**Table 4.22: List of international collaborators in rice biotechnology research**

| International Agencies | Number of projects |
|---|---|
| **CGIAR agencies:** | **52** |
| IRRI | 31 |
| CIMMYT | 12 |
| Africa Rice | 4 |
| ICRISAT | 5 |
| Others | 4 |
| **National Government and Ministries** | **3** |
| **Inter-institutional ties (MoUs)** | **3** |
| **Other International Agencies** | **5** |
| Rockfellar foudation | 2 |
| World Bank | 2 |
| Others | 1 |

Source: Field Study

The scientists from SAUs and ICAR-sponsored research institutes are collaborating with multitudes of international institutes and agencies. The above mentioned table 4.22 depicts that around 80 per cent (52 out of 65) of international projects are forged with Consultative Group on International Agricultural Research (CGIAR) agencies. International Rice research Institute (IRRI) individually commands 48 percent of total international projects. The left 20 percent (11 out of 65) are shared by national government or ministries responsible for research activities in country concerning institutes, Inter-institutional ties (MoUs between institutes), charitable institutions such as Rockefeller and Ford foundation and other various International agencies such as FAO, UNDP, UNESCO, World bank etc. Therefore, various agencies of CGIAR have emerged as important avenues for rice biotechnogists to enter into international collaborations, which further enhance their international recognition and visibility. Respondents are in opinion that majority of international collaborative projects in rice biotechnology takes place with the initiatives of one or more above mentioned actors. However, this does not mean that all international collaboration occurring in area of rice biotechnology exhaust in terms of above mentioned agencies. There can be end numbers of collaborators at micro and macro level.

Consultative Group on International Agricultural Research (CGIAR) is a global partnership that unites various organizations which are engaged in research for a food secure future. CGIAR main objectives are to reducing rural poverty, increasing food security, improving human health and nutrition, and ensuring sustainable management of natural resources. India is an active member of CGIAR. It carries out its research activities through a network of 15 research centers known as the CGIAR Consortium of International Agricultural Research Centers located in different parts of world (see chapter II). Scientists in the study are in opinion that across the time CGIAR has evolved as an important source of international collaboration in agricultural research in context of India. According to scientists, currently sixteen different research programs is operating under CGIAR. And strategizes to realize these programs are based on partnerships, stakeholder's engagement and collaborative research practices. Rice is an important constituent of this program. Scientists in this study mentioned about the CGIAR research programe on rice, known as "Global Rice Science Partnership (GRiSP)". This is an ambitious project of CGIAR that has three main objectives. First, to increase rice productivity and value for the poor. Secondly, to foster more sustainable rice-based production and thirdly, to help rice farmers to adapt climate change. GRiSP was intiated in 2010.It is coordinated by three members of the CGIAR Consortium namely, the International Rice Research Institute (IRRI, the lead institute), Africa Rice Center (AfricaRice), the International Center for Tropical Agriculture (CIAT). This inclusive programe on rice align and bring to the table consortia, programs, platforms, networks, and collaborative projects with over 900 partners worldwide. Most of the respondent believes that CGIAR in general and GRiSP have created avenues for international collaborations in rice biotechnology in India.

Apart from CGIAR, most of the respondents in the study also emphasized on role of another international agency, known as International rice research institute (IRRI), which is part of CGIR for promoting international collaboration in rice research in India. According to scientists, IRRI has provided an important platform through which rice biotechnologists forge an alliance with many international scientists and international agencies. IRRI is a nonprofit autonomous international research and training organizations which was formed in 1960. Historically, India has a strong relationship with IRRI since 1967 (see chapter II). Most of the scientists in the interview believe that

IRRI has played a significant role in making India a major hub for rice research and development in South Asia. Respondents has mentioned about two mega project of IRRI, known as Stress-Tolerant Rice in Africa and South Asia (STRASA) and Cereal Systems Initiative for South Asia (CSISA)through which plenty of scientific and administrative talent both within the country and abroad came on single platform to work together. STRASA was initiated at the end of 2007 by IRRI in collaboration with AfricaRice (called WARDA at that time). Main objective of this project is to develop and deliver abiotic stresses tolerant rice varieties to the millions of farmers in the unfavorable rice-growing environments. STRASA is 10-year project which envisages delivering the developed improved varieties to farmers of the two continents namely, Asia and Africa.

Whereas the CSISA project was started in 2009, it envisages promoting durable change at scale in South Asia's cereal-based cropping systems. CSISA provides supports to regional and national efforts for improvement in cereal production growth in South Asia's Indo-Gangetic Plains which is home to the region's most important grain baskets. It operates in rural "innovation hubs" in India, Bangladesh and Nepal. This project involves more than 300 publics, civil society organizations and private sector partners. This project involves development and dissemination of improved cropping systems, new cereal varieties and hybrids, resource-conserving management technologies, livestock feeding strategies and feed value chains, aquaculture systems and policies and markets. According to the scientists in interview, most of the rice R&D institutions in India is part of this both networking project which is diffused across South Asia and Africa. Thus, IRRI continue to be a major actor and promoter of international collaboration in rice R&D institutions in India.

Besides, respondent also pointed that their respective institutes also act as a facilitator of international collaboration. According to scientists, their institutes have agreements and MoUs with various international institutes and agencies. Through these MoUs and agreement their respective institutes encourages them to develop and nurture academic and research collaboration with international institutes and organizations. These international agreements provide an opportunity for students, faculty, and researchers to visit international institutes and simultaneously, allow foreign student, faculty and researchers to visit their institutes and work together with them. These agreements include both short-term as well as long-term collaboration. According to a scientist from SAUs, *we have signed an MoU with Cornell University, USA. The Tamil Nadu Agricultural University (TNAU), Coimbatore, and Cornell University, Ithaca, NY,* *USA, an Ivy League university is offering students in India and USA a dual masters degree program that integrates Cornells Master of Professional Studies (MPS) and TNAUs Master of Technology (M.Tech).Cornell – TNAU dual degree program had provided the students a brainstorming exposure about education in US. The experience gained through this program is a big leap in their career in respect with all spheres*. Apart from this, scientists in interview also mentions that national government or ministries responsible for research activities in country, primarily Ministry of Science and Technology (DST), Department of Biotechnology (DBT) and Ministry of Agriculture and Farmers Welfare are creating ample opportunities for rice scientists to collaborate with scientists at international level. These government agencies have bilateral and multilateral cooperative agreements and partnerships with several countries. Moreover, these agencies are also part of regional cooperation such as SAARC, BIMSTEC and ASEAN. For an instance, currently, India has 83 bilateral cooperation out which 44 are active. These government agencies offer joint research collaboration between Indian research groups and other countries. It stimulates international research collaboration by funding joint research project which includes researchers from India and other countries. For an example, The Indo-Swiss Collaboration in Biotechnology (ISCB) is a bilateral research and product development programme, jointly funded and controlled by the Indian and Swiss Government (Department of Biotechnology, New Delhi and Swiss Agency for Development & Cooperation, Bern). The main goal of ISCB is to strengthen and enhance food security in the Indian context through the means of innovative biotechnology approaches and to support sustainable and climate resilient agriculture. Similarly, under Australia-India Strategic Research Fund, the International Center for Genetic Engineering and Biotechnology (ICGEB) in New Delhi, the Tamil Nadu Agriculture University (TNAU) in Coimbatore, Southern India and the Queensland University of Technology (QUT) in Australia are partnering to develop stress-tolerant rice based on a native Australian grass. This project is jointly funded by the Department of Biotechnology, India, and the Australian Government. *Here at TNAU we have already isolated genes from the Australian resurrection grass that would be used to enhance stress tolerance in rice. Now we will work to get a better molecular understanding of how the drought-tolerant gene works and prepare it for transfer into rice by our Indian partners (according to a scientist from SAUs).* Additionally, the Government of India has also authorized ICAR, assisted by the DARE, to make alliances and enter into bilateral agreements with various countries and agencies. This mode of collaboration particularly in agriculture area involves exchange of germplasm of plant and animal origin, exchange of scientific and technical information, infrastructure development, training of scientists, and visits of scientists and experts. Scientists in the interview believe that above-mentioned government agencies act as a bridge for rice researchers in India to collaborate with researchers from abroad and enhance their international linkages. According to Wagner (2004), policymaker's interest in international collaboration has a political and an epistemic perspective. The political perspectives primarily consist of using International collaboration to cater a range of goals, including security, cost savings, capacity building in developing nations, and political goodwill (Crawford 1992; Skolnikoff 1994; Wagner 1997). Whereas, epistemic perspective involves formulation of policies which supports large-scale research activities and promotes mobility of researchers by encouraging researchers to travel to international conferences and projects (Wagner 2004).

Apart from this, scientists in this study also pointed that charitable institutions such as Rockefeller, and Ford foundations; other several international agencies such as FAO, UNDP, World bank etc. through its various funding's, projects, technical support, training and capacity building program is playing a significant role in strengthening international collaboration in rice research in India. A scientist from SAUs points: *Rockefeller Foundation funded a research project on "large scale germplasm characterization for drought resistance in rice" during 2003-2008. The project was completed with fulfillment of technical commitments, which was certified as good. Under this project, a state of the art infrastructure facility, "Rain Out Shelter" in area of 10,000 sq.ft was established at Paddy Breeding Station. The facility is continuously used for screening rice varieties for drought resistance without interference from the rains which has empowered our capacity to carry out research to find technologies for mitigation of climate change* This conforms the findings of Wagner's (2006) which suggest that the international collaboration in science and technology is funded by governments (through various agencies, institutes, universities and special programmes), by quasi- governmental bodies (such as the World Bank), and by non-governmental organizations (such as philanthropic groups). These three set of actor's finance R&D for multiple reasons. This includes the need to cater larger policy goals (national defense, foreign relations), to fulfill specific public missions (energy, health), and also to promote knowledge production (basic science or engineering), which is often profoundly tied to theultimate objective of enabling economic growth. However, respondents in the study believes that international collaboration has accelerated the pace of growth of rice R&D in context of India and the reciprocity and mutuality of interests between partners at micro and macro level are the essence of international collaborations.

### 4.8.2 Drivers and Benefits of International Collaboration

International collaboration is manifested in growing share of scientific and technical activities (Wagner 2006). Obviously, various studies have demonstrated upon various opportunities emanating from international collaboration, this includes ease of travels for researchers, meeting and connecting diverse groups of people from differing cultures and assimilating themselves in those cultures.

Every scientist interviewed in the study had collaborated nationally and internationally and perceives collaboration as an indispensable part of research for developing hypotheses and publishing. They affirmed about citation benefits as an outcome of such collaboration and crystallize about the wider benefits which come in different forms from working with talented and best minds in the world. Few benefits are seen as improving in quality of result; extending impact value; benchmarking progress and success and providing inspiration.

Additionally, the respondents talked about some practical benefits of international collaboration. Field trials need to be international in scale and large scale networking research projects often need access to special technology, equipment as well as expert's research skills. In agriculture biotechnology, some projects are too expensive for every nation to carry out its own individual experiments and the only sensible way to solve this problem isto collaborate across border.

A scientist from an SAU emphasizes:

> Having collaboration with international agencies such as CGIAR, IRRI etc. leads to strengthening of the current structure and institutional capacity of the national breeding system for rice. These international agencies are stable, efficient which comprises of many partner institutions each having broad ambit of research activities. Collaboration with international agencies, the regular exchange of knowledge and technology, and open access to key findings of research are the hallmark of any agriculture biotechnology research.

A scientist from an ICAR-sponsored research institute points:

> I would like to highlight the advantages of collaboration between International Agriculture Research Sytem (IARC) centers and National Agriculture Research System (NARS) in India. IARC centers coordinates

field trials for international screening and testing of advanced breeding materials in the area of rice crop. This is an indispensable component for cultivar development programsconducted by all NARSs. IARC activities also includesadministration of multi-site international nurseries which are responsible for distributing promising lines for testing among all interested countries. Thesenursery networks across the world have created massive efficiency gains particularly for NARSs testing programs in rice crops. Even NARSs that has various successful crossing programsdepends heavily on cultivarsacquired from these IARC administered nurseries for supplying their pre-breeding material and for finished varieties.

A scientist from an SAU opines:

> The most important factor in any form of collaboration is always to find the appropriate partners to collaborate with, and international collaboration gives you access to a wider set of researchers than is available in the India alone. Currently, there are various global challenges such as sustainability, poverty, food security, where the issues transcend national specific programmes, thus it is natural that your peers will be international.

Another scientist from an ICAR-sponsored research institute expresses:

> Our focus is to collaborate with top universities. We look to find some universities, which are stronger than we are because collaboration with such universities improves our level and reputation at national and international level. In my opinion, one should be a passive recipient as well as a positive builder.

A scientist from an SAU reflects:

> Practically speaking, international collaboration helps to solve complex problems more efficiently and effectively. It gives you the opportunity to access wide range of researchers with different expertise and resources. It brings multiple ways of thinking and multiple approaches. Sometimes, one approach or one idea can give you the success.

A scientist from an ICAR-sponsored research institute acknowledges:

> One of the benefits of international collaboration is that you get the best person for the work. When you are grappling with a problem, you have to rely on your previous experience and try to solve it.However, through international collaboration you get to access someone with different training, perspective, and approaches, whichbring a completely different angle to the research.

Another scientist from an ICAR-sponsored research institute shares:

> NRCPB institute hasmany collaborative partners throughout the world with most of them inAmerica and Europe. When we select partners for collaboration, we usually look for first-class institutes that could contribute

substantial exchanges with NRCPB in concrete collaborative projects. There is another perspective; students are sent for training which develop their global vision. The institutes in USA are priorities for our collaboration. We have signed MoUs and cooperative agreements with the UC Davis, California, Max-Planck institutes, Germany.

A scientist from an SAU mentions:

When I was doing my research in IRRI Philippines, I got the opportunity to work with researchers from Spain, France, Holland, Italy, US, Canada, Germany as well as other countries. It was a global project on rice crop. More specifically, we were trying to understand impact of the climate change over rice crop and ultimate impact upon human communities. It was a project, which involved biotechnologists, environmentalists, geographers and climatologists, but the focus was to strengthen the food security in world.

A scientist from an ICAR-sponsored research institute adds:

In my opinion, international collaboration in rice biotechnology is nothing if not bridging multiple scientific communities or disciplines in accordance with nature of the problem about which you are inquiring or investigating. International collaboration is something that I always thought to be very important for making use of knowledge generated aboutagriculture biotechnology at international level. Today, agriculture biotechnology research is much more situated in global scientific community.

A scientist from an SAU explains:

One of the main objectives of our institute is to have a global partnershipand to have an interdisciplinary portfolio. The driver for international collaboration is contingent upon this the research questions you are trying to investigate and whether it require expertise, equipment's and other resources from outside your own institute and discipline.

A scientist from an ICAR-sponsored institute annotates:

Multidisciplinary approaches in rice biotechnology are very much valuable, whether those are domestically funded, or internationally funded. In my opinion, agriculture biotechnology research in general and rice biotechnology in particular is all about working together of faculty from multiple departments, divisions and even institutes for an organized research unit. I believe that it will help to break down few common silos that emanatesduring technical stage of research.

A scientist from an SAU explicates:

International collaboration facilitates working with researchers having multiple expertises in order to accomplish something that would otherwise difficult to accomplish in isolation. International collaboration gives you

> access to pool of scientists scattered throughout the world. Internationalization of research helps you in identifying model problem as well as possible range of solutions to solve those particular problems.Apart from faculty, we also encourage our students to interact with foreign scientists and researchers. It means that you should be open enoughto work with many scientists to produce the desired results. A healthy discussion always results in knowledge production. This will inevitably broaden their horizons, enrich their careers and provide them with social capital networks for a lifetime.

A scientist from an ICAR-sponsored research institute summarizes:

> Over the last ten or twelve years, I've been working with a number of international agencies such as IRRI, CIMMYT, ICRISAT and other charitable organizations Rockefeller foundation, Ford foundation etc. to name a few. I attend series of conferences and I am working with many scientists who met me at the various conferences. In my opinion, international collaborationfosters mobility of researchers,research activities from institutions and organizations abroad, collaboration between researchers from different countries, formal and informal knowledge exchange, and systematic exploitation and application of foreign knowledge. For an example, by working in other countries you acquiretechnical know-how and strengthen your networking.

If we critically analyze above viewpoints of respondents, three concrete propositions can be drawn from it. Firstly, desire of rice researchers to work with best scientists and institutes in the world to produce high quality and high impact research are one of primary drivers of international collaboration. Secondly, cross-disciplinary nature of agriculture biotechnology is playing a significant in accelerating international collaboration in rice research in context of India. Cross-disciplinary collaboration has become inevitable as scientific community recognizes its role in solving complex research problems. The key advantage of cross-disciplinary collaboration was perceived by respondents as the means to bring new perspectives into a research team and identification of appropriate journal to publish the interdisciplinary work. Further, peers within that particular discipline are acknowledging the value and importance of the work. Thirdly, the definition of "partners" has become now broader for many respondents, which includes universities, institutes as well as third sector bodies such as, charitable trusts and organizations. Thus, researchers engaged in rice biotechnology in context of India are accessing wide range of experts, expertise, perspectives, resources, and facilities through forging collaboration across the geographical boundary. To put it succinctly, the above mentioned views of rice scientists over international collaboration corresponds with Wagner's (2004) hypothesis that international collaboration operates as a factor internal to science at subfield level, and there is growth in international collaboration owing to the mechanisms of preferential attachment premised on reputations and rewards found within scientific collaboration which is fastened more closely to the intellectual and social organization of science.

### 4.8.3 The Process of Finding International Collaborating Partners

Understanding partner's similarities and differences, and identifying the right partners plays a critical role in the success of international collaboration. An attempt was made in this study to understand howa rice researcher establishes contacts with international partners and how they sustained and embedded relationships with their identified partners. Most of the respondents believes that collaborative networks are formed early in research career. Mostly, respondents in interview talked about the relationships, which they established when they were doing doctorate research. These early contacts with multiple researchers provided the platform for future collaboration and networking. Consequently, they succeeded in building aprofound link with various institutes and with its research agendasat international level. The process for identifying and selecting potential international partners was seen, by respondents, as being very specific. They mention that identification of partners is based oncommunication channelsintroduced by their colleagues, seniors and faculties. Meeting and discussing with peoples at conferences and seminarsis also an important avenue to build collaborations and networks.

A scientist from an ICAR-sponsored research institute opines:

> Attending and actively taking part ininternationally renowned programme, conferences, seminars, colloquium etc. provides you the opportunity to build up contacts with researchers who you know are visiting places and conducting interesting research in your area. They arethe people with whom I have kept constant touch. Theyhave gone off and nowhold important positions in various Universities, Institutes and Organizations.

Another scientist from an SAU reflects:

> International conferences not only improve your skills and knowledge's about your own field but also makes you aware about researcher working and contributing in your area of research. By attending their seminars, you engage yourself with their work, ask questions and might see them after the presentation. In my opinion, networking is very important in field of agriculture biotechnology. This is one of the ways for inviting and being invited to form collaboration such as edited books, funding application for joint project, and special issues in peer-reviewed journals.

Another scientist from an ICAR-sponsored research institute mentions:

> Attending international conferences provides you the opportunities to establish your international networks and to enhance your awareness about new developments and happenings especially in your area of interest. You meet and speak to scholars representing dozens of universities and in this way, your professional network expands accordingly. You have better chances of collaborating with them in future because now you are known to each other.

For many respondents, quest for finding right international partners to work with and knowing partner's competency in the field was not a big problem. Nevertheless, they acknowledged that occasionally they need assistance to build relationship and enter into research collaboration with researcher having foreign nationality. Several respondents referred to the importance of various international networks such as Universitas and the World Wide University Network to be fruitful in identifying a potential international partner. While, others also mentioned about different discipline-specific networks and online professional groups to be very helpful in finding partners and sharing information's. Respondents also spoke about using online communication tools such as Skype, Research Gate, Academia.edu and social networks such as Facebook, LinkedIn, Twitter, Instagram as an important means for sharing of ideas, opening up discussion and connecting with researchers around the world. Thus, noble ways of establishing and maintaining contacts with scientists across the world are emerging in field of rice biotechnology in India, it appears that information and communication technology is playing a major role in establishing new contacts, enriching existing relationships and making it easier to exchange ideas and information with scientists located across the world.

A scientist from an ICAR-sponsored research institute asserts:

> People comes to know about you and your work through outlets such as Academia.edu, Research Gate and having profile on social networking sites such as, LinkedIn, Twitter and Facebook generates new contacts and a new degree of awareness because most often people searches for information germane to their own discipline and work. These modes of communication are still very new and evolving, so it would be pre-mature to judge its long-term value.

Most of the scientists agree that although they could see multiple benefits from using online tools and portals to identify potential international partners and support their research networks, but they are of the opinion that still there is no substitute for personal networks and contacts. Constant references are made to the reach and cement strong personal relationships which underpin high quality international collaborative research projects. It has also emerged from few interviews that different research cultures operate in different countries. This is perceived by scientific community as strengthening the research process. Additionally, respondents believe that it enhances the necessity for investment to support scientists in to come together, spend time, and getting to know each other.

A scientist from an ICAR-sponsored research institute shares:

> Today, owing to transnational nature of agriculture biotechnology research, every scientist has equal chances to collaborate worldwide and to become globally recognized. For every scientist forging a meaningful and sustainable collaboration especially international collaboration has become a corner stone of success. Identifying, selecting and finally working with international partners is subject of multi-year process. There are multiple ways to establish contacts with international scientists who are working in your research area. However, in my opinion if there are no references or personal contacts you can't use online stuffs such as video call .Nobody wants to interact with a stranger. People entertain you only when they know you either through personal contacts or by somebody's references. Personal interactions are required before you enter into any form of partnership.

A scientist from an SAU accentuates:

> International collaboration is not just about working with international scientists but it has multiple dimensions. From an academic perspective, building personal relationships are very important. For instances, you had collaborated with researchers who is located at other countries. If they move to other institutions or countries then your goodwill and allegiance might well move with them to the other institutions and countries, because you built a strong relationship through past collaboration and likewise your academic moves.

Moreover, the present study suggests that a few SAUs and ICAR-sponsored research institutes already have separate department or sections to look after foreign affairs, collaborations and international linkages, whereas others are now opening them. Many rice research institutions coming under the aegis of SAUs and ICAR are using networks of individual scientists to make international collaboration as an integral part of their long-term strategies and also to enter into formal partnership agreements with international institutes for driving research forward in particular areas by mutual sharing of resources, expertise, knowledge, and supporting teaching and learning. Indeed, this is an attempt to hold, embed and sustain international relationships so that they do not get lost with the researcher mobility to another institute. However, it would be pre-mature to judge whether these strategies adopted by institutes results in establishing new or different types of relationships. Several respondents also spoke about the need to ensure that, as institutes look forward to develop a more strategic approach to international collaboration, they avoid "matching" or "pairing" researchers or partners who are not comfortable and willing to work with each other. Respondents in the interview advocated for researchers or faculty driven collaboration, to let faculty, researchers and students make decisions about their partnerships, especially in case of international collaboration which is strongly tied with country's image.

A scientist from an ICAR-sponsored research institute stresses:

> Today, no doubt, India is an active member of various international networks which operates to promote R&D in agricultural sector at global level and as a corollary; we have active collaboration with multiple institutes across the world. However, we are also taking individual initiatives to have R&D collaboration with few South East Asian countries such as China and Philippines. In my opinion, these two countries are world's leading rice producing and consuming countries. Moreover, we share more or less common climatic conditions that play an important role in cultivation of rice crops. Thus, any R&D collaboration with these countries particularly in rice crop would benefit all the countries. In order to realize this idea, we have contacted Philippines Rice Research Institute (Philippines) and China National Rice Research Institute (China). With mutual consensus, we are looking forward to work out a common R&D exchange program, which would promote exchange of students and scientists every year between these three institutes. In this context, a very eminent rice scientist of our institute is helping us because he has very strong relationships with these institutes as he had collaborated with the scientists of PRRI and CNRRI in a project coordinated by IRRI. This is one of very good example of various strategies that our institute is taking to identify foreign partners apart from individual researcher contacts.

A scientist from an SAU reflects:

> In contemporary agriculture sphere, if an institute does not go international it is not perceived as a good school. In order to internationalize our institute, we have initiated many measures. We encourage our faculty and student to participate in International fellowship program such as Nehru Fulbright Scholarship, DAAD, Erasmus Mundus and so forth. We have setup a separate section namely, External and Foreign Affairs to assist faculties and students who wish to visit foreign. Besides, by using contacts of some faculties we have entered into MoUs with few international institutes and organizations. We are also working out for offering scholarships for students

> and faculties. We have screened and selected seven or eight institutes and organizations mainly in USA and Europe with whom we can have student exchange programmes and faculty exchange programmes. We are in deliberations with these institutes and trying hard to start this particular program by next year.

Another scientist from an ICAR-sponsored research institute elucidates:

> I am not great believers in MoUs and other collaboration agreements to forge an alliance with scientists and researchers who are located abroad. These cooperative agreements exist mostly at institute level. In my opinion, any collaboration is established at the instigation of a partner which is directly proportional to mutual research interest and willingness to collaborate between the partners. Few partners look for formalization of relationships at individual level and many feels more comfortable with a written MoUs and collaboration agreements at institute level, which is renewed every year or after an agreed fixed period of time. For me, it is content which drives collaboration but not the form.

### 4.8.4 Possibilities for Improving International Collaboration

As most of the respondents understand and recognize the various benefits of international collaboration, they also share their views about possibilities for improving international collaboration in field of rice biotechnology in context of India. Administrative matters related to visa applications for visiting foreign institutes are often identified by all respondents as a significant factor which restricts researcher mobility and further, long-term international research collaborations. Almost all respondents had encountered this common problem, with the majority emphasizing that issues related to visa grant had deterred them from working with the best mind in the world, impeded or seriously delayed their research, and eventually, hampered their longer-term collaborations with international researchers. The long-term impact of this was raised in several interviews: the view was that post-graduate students should be seen as future collaborators and regarded as a “cherished investment”. Interviewees also talked about the personal and research benefits which come from taking sabbaticals or moving to work for a period in a different country, and of the need to ensure that visa issues don’t obstruct this or prevent it from happening. Interviewees felt that 2 years was an ideal length of time for a sabbatical or placement, arguing that partnerships are more impactful and have better outputs if they last for at least 2 years.

A scientist from an SAU opines:

> The administrative delays that impede mobility of students, particularly postgraduate students, are proving detrimental for any kind of collaboration. Postgraduate students are young dynamic scientists and greatest champions of our country. They should be considered as a cherished investment, not as some sort of official work burden and back door immigration.

A scientist from an ICAR-sponsored research institute asserts:

> Since its inception, ICAR has played a prominent role in promoting research, education and extension in agriculture sector. Now, in order to function as a one of the globally leading, agriculture research-intensive institute we need to attract students and researchers from around the world. There are few complexities and mutability related to visa issues, which needs to be worked out as soon as possible because it can seriously delay any kind of international venture. We are grateful to ICAR administration and Ministry of External Affairs (GoI) for consulting and working with us. Emphasis is on clarifying regulations as well as simplifying administrative processes to promote international research activity.

Another scientist from an SAU underscores:

> In my opinion, India needs to decide whether they want to be open in field of R&D or close by being more bureaucratic and costly for research, but everything apart special attention is required in this direction.

An equally important point discussed in all interviews was increasing national funding to develop contacts and support collaboration. Respondents pointed to various USA and European Union framework program as a reference model to support international collaboration and partnerships in field of agriculture sector in India. Respondents talked about the advantages of collaborating with one University, institute or organisation, the greater ease and comfort of going for one application and getting one decision. Other international collaborations are affected by the individual funding application process each participant goes through. Many interviewees mentioned the situation where each partner needs to succeed in their distinct local funding proposals, each with their own timetable and outcomes before a collaborative project could commence. The general view was that differing funding cycles can make it more difficult to collaborate with research nations outside India and restrict potentially fruitful research collaborations. Problems associated with the short-term nature and the uncertainties of many funding mechanisms were also discussed by respondents. They are seen as making it a challenge to attract and keep the best candidates for a role. Whilst interviewees recognised and referenced the efforts being made in India to support international collaboration, all felt that more could still be done to promote awareness of existing schemes to support tri-partite or multilateral and non-Indian research programmes and to make them more problem-focused and more flexible. The feeling was that to attract the very best to a particular project; there needs to be as much stability as possible in the funding streams and they need to recognise the importance of supporting personal contact.

A scientist from an SAU expresses:

> My money cannot go to you and your money cannot come to me… It is a problem worldwide…. Governments are not willing to let their money go abroad …. Only the money offered by private foundations, such as Bill Gates' foundation… can cross the border… government has to consider its own benefits, like intellectual property and so on and so forth. There are many legal issues.

A scientist from an ICAR-sponsored research institute points:

> A lot of the difficulty in internationalizing our own research is actually finding the sources of funding that we need in order to do it effectively. If there were, a United Nations Research Council then that would be a remarkably good thing for the internationalisation of research.

Another scientist from ICAR-sponsored research institute explicates:

> There are few international programmes hosted by India in which international partners collaborates on projects in a formal way. The partner's institution has to say: "yes, we're committing this to the project in such and such a way, and we have an interest in the success of the project". This is great and it helps to support international collaboration. However, Project Partners cannot receive funds from the grant to help support the collaborative research. Therefore, it is a little strange that even if the reviewers and panel find the case for collaboration compelling, one cannot support it with India's funding. Of course, some other means might be found within a programme, but the Project Partner route requires a commitment from an international collaborator with no reciprocal support from our end beyond an agreement to collaborate. I think we could be more supportive if we want to internationalize our R&D agriculture sector.

Besides, most of the respondents in the interview also discussed that how active, sustained recognition and demonstration of the quality of research produced by Indian researchers could help to foster international collaboration. Recognition of high quality work by scientific community was seen as playing a crucial role in attracting potential collaborations both at the personal level of researchers proposing research collaborations, and at the broader level of institutions mapping out future partnerships. Scientists as an important way of attracting further international collaborations also proposed hosting workshops, brain storming, colloquium, seminars, conferences and other scientific events to exhibit research to the public, as well as to Industry and the international community.

**Conclusion**

We have discussed various dimensions of scientific collaborations – in terms formations of scientific collaborations, magnitudes of scientific collaborations, structures of scientific collaborations, patterns of scientific collaborations, government-university-private R&D networking, various facets of international collaborations, in the field of rice biotechnology research. The findings of this chapter suggest that the research project formation process is influenced by the inter-personal context. Majority of scientists form collaborations with pre-existing relationships. The second dominant factor that shapes project formation is pressure from home organizations. Parent institutions exert some kind of pressure on collaborations, which enables or constrains the actions of scientists.

The extent of collaborations suggests that collaborative projects are both national and international in nature. There is also an increasing emphasis on scientific collaborations cutting across disciplines and institutions in India engaged in research in rice biotechnology. The empirical data on the patterns of collaboration suggests that the collaborations of the three kind's collaboration between different departments, collaboration between different universities within the same country of the same institution, and international collaboration – are found to be predominant or preferred by the researchers in rice biotechnology. The empirical data exhibits that triple helix model does not appears to be working in field of rice biotechnology. It is also evident from data that negligible amount of university-industry-government collaboration is taking place. Most of the collaborations are occurring between scientists located in SAUs and ICAR-sponsored research institute. Scientists in interviews reported multiple reasons for not collaborating with private players in rice biotechnology research.

A few actors which are playing major role in organization of international collaboration in rice biotechnology in context of India are: (a) Consultative Group on International Agricultural Research (CGIAR); (b) national government or ministries responsible for research activities in country; (c) concerning institutes; (d) charitable institutions such as Rockefeller and Ford foundation; (e) other various International agencies such as FAO, UNDP, UNESCO, World bank etc. In this study, desire to work with best scientists and institutes in the world to produce high quality and high impact research has emerged as one of primary drivers of international collaboration. The cross-disciplinary nature of agriculture biotechnology is playing a significant in accelerating international collaboration in rice biotechnology research in context of India.

Scientific collaborations are profoundly influenced by sociotechnical factors. The ways collaboration is organized cannot be understood without understanding how that particular collaboration is shaped by sociotechnical characteristics of partners or collaborators local working environment. In the light of this, Chapter V dwells upon the scientists' views on different influences of sociotechnical factors, such as the nature of work, common ground, different aspects of collaboration readiness, management and leadership style, and technology readiness – on collaborations in rice biotechnology research in India.

# Chapter V

## Sociotechnical Influences on Research Collaboration in Rice Biotechnology Research in India

### Introduction

Collaboration provides a platform where researchers from various institutes and organization can work closely. It enables people located at distant places to work interactively and effectively on a common project. In collaboration, each participant is an important stakeholder who brings in required knowledge, skills, resources, funding, social capital, cultural capital, etc. Each collaborator aligns his/her interests with the interests of other partners and contributes to the project. Any form of collaboration is profoundly influenced by sociotechnical factors. The ways collaboration is organized cannot be understood without understanding how that particular collaboration is shaped by sociotechnical characteristics of partners or collaborators in locally working environment. Collaboration is never location-neutral and involves a complex interplay of sociotechnical factors. Therefore, a deeper understanding of these factors is required to analyze any form of collaboration.

In this chapter, an attempt has been made to present a sociotechnical analysis to demonstrate the ways in which various sociotechnical aspects are embedded in locally working conditions and how it enables or restrains the collaboration process at various stages such as foundation, formulation, sustenance, and conclusion or completion. This chapter finds its theoretical or analytical framework in actor-network theory in general, and Olson et al.'s (2008) theory of remote scientific collaboration (TORSC) in particular. The, TORSC per se is a theoretical and empirical adaptation of actor-network theory. TORSC delineates various sociotechnical aspects that are important in the success or failure of remote collaboration in science. In their seminal work, Olson et al. (2008) pinpoint five main key elements that shape distributed collaborations and are vital to collocated projects. These factors constitute the nature of work, the quantum of common ground among partners, partners' readiness to collaborate, collaborators' management style and leadership, and technology readiness. The main argument of TORSC is that groundbreaking thinking can occur because collaboration involves working together of scientists from diverse backgrounds, which brings in multiple perspectives to carry on a common objective or problem. Technology fosters smooth functioning of collaboration.

It enables distant and diverse scientists to carry and coordinate their collaborative project.

Through sociotechnical analysis, this chapter attempts to extend the TORSC to the context of multidisciplinary and large-scale distributed inter-institutional collaborations between academicians and researchers in the field of rice biotechnology coming under the aegis of SAUs and ICAR. The main objective of this sociotechnical analysis is to indicate patterns and utilize them for a better understanding of organization of R&D collaborations among scientists engaged in rice biotechnology research.

## 5.1 Nature of Work

Nature of work implies coupling of work with division of labour. The concept of coupling of work refers to the amount and frequency of communication needed to complete a task (Olson and Olson 2000; Birnholtz 2004), and division of labour as possibility of a task being broken down into small components (Olson and Olson, 2000). Tightly coupled work is non-routine, can be ambiguous, and requires greater interdependence. The communication necessary to perform this kind of work can be complex and needs frequent and prompt feedback and rich information. On the contrary, a loosely coupled work has fewer dependencies, is more routinized, and tasks and procedures are clear. As a result, less amount and frequency of communication are needed to complete the task (Chompalov et al. 2002).

**Table: 5.1: Nature of work**

| Nature of Work | Responses (in percentage) |
|---|---|
| Coupling of work | 13 |
| Division of labour | 93 |

Source: Field study

Table 5.1 depicts that only 13 percent of the scientists believe that coupling of work influences research collaboration in rice biotechnology research. Contrary to this, around 93 percent of rice biotechnologists are of the opinion that research collaboration is profoundly influenced by division of tasks among collaborators in a project. A majority of the scientists are of the opinion that small, large, mega, interdisciplinary, inter-institutional, and distributed collaborative R&D projects in rice biotechnology are organized and managed independent of physical proximity and coupling of works. This would be realized only when problems of project are clearly defined and the work is separated into discrete pieces that can be handled alone by individual partners. Same research interest of partners and their willingness to join or contribute to project establishes some common ground, which further enhances reliability among partners, whereas clear division of labour among collaborators enables them to work independently for the most part of the project. According to a majority of the scientists, works are separated in discrete pieces and then are allocated to partners according to their expertise and resources. Additionally, factors such as number of partners, amount of funds, and duration of projects along with division of labour are considered. If works are divided among partners formally, it becomes easy to fix the accountability. Furthermore, it decreases the chances of conflict due to overlapping of the same task. Nevertheless, according to the scientists, if the nature of problem of the proposed study is clearly defined, unambiguous, and tasks are divided among partners meticulously, the frequency of face-to-face communication is less. In these cases different forms of technology-driven modes of communication, such as email, are mostly used to reach other partners. Therefore, coupling of work and division of labour are reciprocally interdependent on each other.

A scientist of an SAU mentions:

> Agricultural biotechnology is global in nature. Consequently, most of projects in rice biotechnology are multidisciplinary and multi institutional. Partners are distributed and the locations of the research group are a long away, often transcends national boundary. It is not always possible to have face-to-face interaction. It incurs extra cost in terms of time, money, and other resources. Therefore, most of the proposed projects are designed accordingly with the communication factor keeping in mind. Moreover, clear and organized division of tasks among the partners according to their expertise minimizes the chances of face-to-face communication in such projects. Most of the interactions among partners take place via email.

A scientist from an ICAR-sponsored research institute opines:

> I am part of a large multi-institutional project namely, "From QTL to variety: marker-assisted breeding of abiotic stress tolerant rice varieties with major QTLs for drought, submergence and salt tolerance". This project was initiated in 2010. It is funded by Department of Biotechnology, Government of India, in collaboration with International Rice Research Institute, Philippines. The main objective of this project is to improve productivity of rice in eastern, northeastern and southern region of the country, which bear the adverse impact of one or the other forms of abiotic stresses frequently. Consequently, various institutes located in these above-mentioned regions are partners in this project. Aims, objectives, problems and methodologies are clearly defined and work has been divided among the institutes according to available experts and resources. Our institute (DRR) has well-equipped

biotechnology laboratory. Thus, we have been given the task of transferring seven consistent drought tolerant QTLs, namely, qDTY1.1, qDTY2.1, qDTY2.2, qDTY3.1, qDTY3.2, qDTY9.1 and qDTY12.1 into submergence tolerant versions, namely, Samba Mahsuri-Sub1, Swarna-Sub1, and IR 64-Sub1. If you ask me, I do not know about other scientists working in this project. I am responsible for the task, which has been allocated to me. This project is successfully operating within country. We have our yearly meetings, where we meet face-to-face with each other to reviews progress of the project and future course of action to be taken. Besides, we are in constant touch with project coordinators via email and follow the direction and instruction given by them.

A scientist from an SAU stresses:

> I am handling a mega project, namely, Stress-Tolerant Rice in Africa and South Asia (STRASA). This began in the year 2007 with International Rice Research Institute (IRRI) in collaboration with Africa Rice (called WARDA at that time). The main objective of this project is to develop and deliver rice varieties, which is tolerant of abiotic stresses. Initially, STRASA was conceived as a 10-year project. This project envisages delivering the improved varieties of rice to at least 18 million farmers of Asia and Africa. This is a networking project. There are thousands of scientists, who are collaborating partners and working under same project in above two mentioned continents since 7 years. Even one of my colleague is working under same project. We possess different expertise, she is an agronomists and I am a plant breeder. Therefore, we have been assigned different tasks depending upon our expertise and resources. Her work is completely different from mine. Her work is field based whereas my work is laboratory based. Moreover, we report to different coordinators. Although, we are contributing to same project but independently. It is same like e adding separate bricks in the wall. This is possible only when problems of the proposed study is clear and focused. Clarity in research question and objectives of study enables formal division of tasks. Therefore, objectives of study and division of labour are interrelated and complement each other.

A scientist from an ICAR-sponsored research institute acknowledges:

> Being a principal scientist, I am used to work in networked or multi institutional projects of various kinds. Here, I must admit that in most of cases we all work as a team, we share data, and there is often real discussion among us through different modes of ICT. There are situations when you are stuck, have doubts and you post it to discussion forum. The very next morning, you have something really interesting on your email oh, look at how nice this thing is, here is the solution, somebody from research group has share it" I have experienced that formal division of labour brings individualism in the work. However, it is effective only when you have updates about the progress of project via ICT tools. Therefore, I recommend that you should have habit to work with these kinds of tools, at least in your professional environment.

A scientist from an SAU elaborates:

> Last year, I have successfully completed one networking project under The Cereal Systems Initiative for South Asia (CSISA). The main objective of this mega program is to promote durable change at scale in South Asia's cereal-based cropping systems. This program operates in India, Bangladesh and Nepal. I was having collaborating partners from Bangladesh and Nepal. Our project coordinator was from Mexico. We never met with each other. We use to communicate via email. It was almost our daily affair to keep updating each other about progress of work. We were sharing our data related to project by mailing each other. Therefore, mailing supported information sharing about the project. It enabled us to make other partners aware about what others were talking about at every point in time. It also provided a platform where partners can meet and concentrate on the specific issues when they emerged.

Besides, a few scientists also report that sometimes they find the task vague, ambiguous, complex and abstract. In these cases, they need either to meet face-to-face or to talk to other partners in real time through (e.g. phone) to understand and decide future course of action.

### 5.2 Common Ground

Common ground implies mutual trust, knowledge, beliefs and assumptions that collaborators shares with each other. In order to achieve collective progress, it is imperative for people engaged in collaboration to have mutual knowledge, beliefs, and/or assumptions, and know that they have this (Clark 1996; Clark and Brennan 1991). The absence of one or more of these aspects of common ground can seriously arrest the progress of any collaborative project. According to Olson and Olson (2000), it is tough to establish and maintain common ground among different partners having different expertise, subject domain knowledge, work practices, professional values, special vocabularies, and so forth. Corresponding to this finding of Olson and Olson, in this study, the analysis of interview suggests that in field of rice biotechnology common ground is relatively easy to establish when research project is homogenous, intradisciplinary, and intra-institutional in nature.

A scientist from an ICAR-sponsored research institute opines:

> Frequent communication is very important within a research team for understanding your partner and making yourself understood to others. Intra departmental and institutional collaboration facilitates more face-to-face interaction between partners in comparison to inter disciplinary and inter institutional collaboration. This foster trust building. In my opinion, physical proximity generates social proximity.

A scientist from an SAU interprets:

> Having in-house or internal project enables conversation, which further provides you an unplanned bonding opportunity that helps members to trust each other, believe in teamwork, look forward to spending more time together, and even explore additional opportunities to collaborate. I have succeeded in building a strong bonding with some of my colleague in our department. We are working as a team since last ten years. We meet regularly to discuss the nuances of the research, and we have written more than a dozen research proposals for future collaborations.

A scientist from an ICAR-sponsored research institute points:

> If partners are collocated, it becomes easy for partners to schedule their social time for mingling and building relationships. These socializing activities can relieve stress, underpins common values and team goals, and integrate ideas. Additionally, it possesses potentials to diffuse problems before they grow. Mutual trust and beliefs brings cohesiveness within a team. Researchers are more motivated to participate in collaborative project if professional rewards accompany social benefits.

A scientist from an SAU reflects:

> Building common ground in inter disciplinary task is difficult. Interdisciplinary work involves partners from multiple disciplines. Each discipline has its own language, jargons, terms, and definitions, and this often inflicts miscommunication in a research team. Partners from various disciplines may have different meanings for the same words, or sometimes may not even recognize some terminologies used by other members with different expertise in a research team. For example, the term, 'desertification'. It has multiple definitions. Ecologists utilize it to describe loss of productive agricultural land — the shift from fertile soil and arable land to a desert-like landscape. However, scientists of all disciplines do not share this definition. Agricultural scientists emphasizes on over-grazing practices to describe desertification, while economists often uses 'desertification' to describe the vicious circle of poverty in developing countries.

A scientist from an ICAR-sponsored research institute asserts:

> I have worked with partners from various countries in an IRRI coordinated project, which was an interdisciplinary study to assess impact of climate change on rice crop in Asia in general and Philippines in particular. Surprisingly, our cultural differences in terms of native languages were less problematic as compare to differences in our specialized, disciplinary language. In most interdisciplinary projects, you do not get opportunity to understand each other's work intimately.

Therefore, the above excerpts from the interview demonstrate the effect of establishing or not establishing common ground in the field of rice biotechnology. When research teams are fully collocated (within the institute), it becomes relatively easy for rice biotechnologists to establish the common ground. They share not only local and cultural context, but also more subtle and micro context in terms of who is doing what at present and what remains to be done. It fosters both awareness and familiarity, which further makes communication easier.

Furthermore, existing literature also suggests that aspects, such as previous ties, shared experiences of collaboration, transfer of tacit knowledge, transfer of transactive knowledge, similar disciplinary background, and compatible work styles play an important role in achieving the common ground when they work remotely (Sonnenwald 2007; Thune 2007; Hara et al. 2003; Nardi and Whittaker 2002; Olson and Olson 2000; Haythornthwaite et al. 2006).

**Table 5.2: Common Ground**

| Common Ground | Responses (in percentage) |
|---|---|
| Role of previous ties | 87 |
| Tacit knowledge and transactive knowledge | 22 |

Source: Field study

### 5.2.1 The Role of Previous Ties in Collaboration Network

Table 5.2 shows that the history of collaboration among individuals/organizations has a major impact on collaboration. Around 87 percent of the rice biotechnologists agree that it influences their collaborative projects and plays an important role in achieving the common ground. The importance of previous ties, working experiences or relationships is an important factor for the successful development of collaboration among rice biotechnologists. Scientists reflect on various advantages of previous experiences, which are the outcomes of working together for example in form of past joint projects, publications, patents, grants, and other collaborative activities. This enhances the potential collaborative partner's willingness to commit to project and makes them trust the decisions and the collaborative processes.

According to a scientist from an ICAR-sponsored institute:

> In my opinion, most of collaboration are forged with partners with whom you have has successful experiences in the past. In cases of successful collaborations, you would find members have some histories of relationships

> and trusts. Collaborative relationships between institutions and individuals always have a history, even if it can be a history of limited interaction. The prior relationships, conduct, and attitudes of the partners are significant in collaboration because it is capable of influencing the degree to which partners engage in or resist the collaborative process.

A scientist from an ICAR-sponsored research institute mentions:

> I have a DBT funded project, namely, 'From QTL to Variety: Marker assisted breeding of abiotic stress tolerant rice'. Apart from formal partners, three volunteer external rice scientists also participated in this project. They come from different institutions in different locations, but we had previously established ties and relationships. All of three has given their personal time and effort to this project. Their contribution to the project took different forms, from doing the lab work to fieldwork. They participated actively at the foundation phase of the project. These persons were involved because we know each other very well. Previously, we have collaborated in few national and international projects. We share good rapport. We often help each other and have developed substantial amount of trust gradually. Recently, we have met each other in a national conference and decided to set up a project.

A scientist from an SAU opines:

> When human and economic resources are scarce, the question becomes how to do the job economically and efficiently, while making the best use of the limited resources. In this situation, previously established ties and existing common ground influenced positively the achievement of a stable alignment of interests throughout the project, facilitating communication and understanding and supporting faster and smoother decision-making process.

A scientist from an ICAR-sponsored research institute expresses:

> I am principal investigator of a project, namely, 'Identification and functional analysis related to yield and biotic stresses of rice'. It is an interdisciplinary, ICAR networking project. The partners involved in this project shares different disciplinary knowledge and previous collaborative experiences. Role of previous ties or relationship has profound implication on a collaborative project. It enhances smooth functioning of project. It helps you to establish a common understanding about task to be done, which includes experimentation, data collection, data analysis techniques, and realization of outputs in terms of publications and patents. One advantage of having previous ties or relationships with partners is that you need not have to spend much time and efforts in building common understanding. It enables division of work, as you would know from past collaboration who is capable of what. This further makes management of task simple and project moves forward quickly and easily.

The present study indicates that for scientists located in both SAUs and ICAR, the role of previous ties and relationships are a crucial component of collaboration. This has emerged as a prerequisite for initiating the collaborative project. This finding suggests that other things being equal, any collaborative initiative is likely to succeed only when individuals/organizations share some positive history of collaboration. Scientists, by working together in the past, they establish work practices, and common understanding. They become familiar with the respective cultures, norms and knowledge precisely what to expect mutually (Mattessich et al. 2001). Indeed, they establish substantial compatibility, which is much needed for sustenance of a collaborative project (Hara, Solomon, Kim and Sonnenwald 2003).

### 5.2.2 Tacit Knowledge and Transactive Knowledge

As mentioned in chapter IV, the term "tacit knowing" or "tacit knowledge" was first introduced in philosophy by Michael Polyani in 1958 in his magnum opus *Personal Knowledge*. He summarizes the idea in his later work *The Tacit Dimension* (1967) with the assertion that "we can know more than we can tell." According to him, not only is there knowledge that cannot be adequately articulated by verbal means, but also all knowledge is rooted in tacit knowledge in the strong sense of that term. With tacit knowledge, people are not often aware of the knowledge they possess or how it can be valuable to others. Effective transfer of tacit knowledge generally requires extensive personal contact, regular interaction and trust. This kind of knowledge can only be revealed through practice in a particular context and transmitted through social networks. To some extent it is "captured" when the knowledge holder joins a network or a community of practitioners. Daniel Wegner (1985) has developed a theory of transactive knowledge. Transactive knowledge means knowledge that is somehow available or possible because of transactions between people. According to Wegner, transactive memory system is a mechanism through which groups collectively encode, store, and retrieve knowledge. A transactive memory system consists of the knowledge stored in each individual's memory combined with metamemory containing information regarding the different teammate's domains of expertise. Table 5.2 indicates that only 22 percent of the rice biotechnologists believe that the tacit and transactive component of knowledge can be transferred among collaborators in a collaborative project. According to a rice biotechnologist from an ICAR-sponsored institute:

> In the field of agriculture biotechnology, there are certain limits to what extent one actually can make knowledge explicit. Not all forms of knowledge are recordable and transferrable, such as GM technology. The plants are not programmed with a genetic code by using a common terms. It

> is not possible to reread that code, rewrite the program, and transfer useful bits of that program.

Another scientist from an SAU asserts:

> The science concerned with the determination of new varieties is complex and abstruse. It has yet to unravel all the mystery of biological force and of adaptation to new environment. Hence, it is not possible that the complete and exact knowledge generated, such as characteristics of new variety can be transferred at the will of investigator. The science of agriculture biotechnology is highly context-specific.

Furthermore, scientists included in the present study report that the outcome is adversely affected in the case of dispersed collaboration pertaining to transfer of tacit and transactive knowledge. Rice biotechnologists are of the opinion that long-distance collaboration circumspect the flow of tacit and transactive component of knowledge between the research teams, primarily because it is stored in the research group that has generated it. Moreover, it is not possible to communicate every pocket of knowledge through ICTs. Describing the difficulties confronted in transferring tacit and transactive knowledge, a scientist from an SAU mentions:

> In order to transfer knowledge i.e. 'implicit' or 'transactive' knowledge through ICTs first needs to be captured explicitly and then transformed into certain formats. For this you have co-create scientific data, which requires developing elaborate rules annotation and metadata. By doing so, a scientist can transfer only some component of dataset and hope that it would improve interpretation of data by their collaborators. This system is laborious and time consuming and nobody knows whether these extra efforts produce extra benefits or not. If you ask me, I believe that there is no end to metadata. There is no single and unique set of metadata for any given set of scientific data set, because sufficiency is contingent upon the uses to which data are put.

### 5.3: Collaboration Readiness

**Table 5.3: various dimensions of collaboration readiness**

| Dimensions of Collaboration Readiness | Responses (in percentage) |
|---|---|
| Incentives and rewards | 64 |
| Goals and imperatives of collaboration | 93 |
| Knowledge sharing culture | 24 |
| Mutual trust | 81 |

Source: Field study

#### 5.3.1 Incentives and Rewards

An aspect of rewards and incentives is important because it develops a positive attitude towards knowledge sharing and collaboration. It makes collaborators feel that collaboration is in their interest (Olson and Olson 2000; Arzberger and Finholt 2002; Hara et al. 2003; Barrett et al. 2004; Corley et al. 2006).

Table 5.3 indicates that around 64 percent of the rice biotechnologists believe that incentives and rewards play a pivotal role in shaping their collaborative projects. The rice biotechnologists acknowledge that intrinsic rewards as well as extrinsic rewards are the main drivers of any collaborative effort. For instance, a scientist from an SAU recalls**:**

> I have been doing many projects over the years and you cannot expect rewards from each piece of work. You are aware that you are not going to get them, concrete rewards I mean. I have regular meetings with my head of departments, and every study that has taken place I tell her and she responds well done and keep it up, but that's really enough about it. In my opinion rewards are for yourself, I mean to say is that you are helping the cause.

A scientist from an ICAR-sponsored research institute asserts:

> I always enjoy being able to have accomplish goal and update the outcomes of the research. Now, it attracts the attentions of researchers worldwide and you are praised for the work. Further, it get some researchers involved, researchers who shows their interest and try to sustain their interest. It is the sheer satisfaction that you earn from a piece of scientific work.

A scientist from an SAU affirms:

> I enjoy the fact that I am trusted with some kind of responsibility (in the project), but other team members are very good in attitude and behaviors. They are very good with the other members of the team. They uses your initiatives, give you a challenge, but they are always there to support and advice you, so it is enjoyable.

A scientist from an ICAR-sponsored research institute stresses:

> The sense of achievement is the ultimate reward that you get from your work. As a professional person in rice biotechnology, I feel that if people are conducting research you need to support them because agriculture biotechnology is multidisciplinary and requires expertise from various disciplines. Moreover, they are doing research in interest of farmers and nation. If everybody says, I am least bothered to do it, nothing would have ever been done and plant science would have perished. I am firm believer of partaking in these things to improve. When, obviously, the results of research are published, they automatically enhance the profile of researcher and the institute.

A scientist from an SAU mentions:

> Last year I collaborated with a research team of CRRI, Bhubaneshwar. When I decided to apply for funding at that time, I had a big conflict or a big

> friction with my department and institute, because of some projects that we were carrying out at the university. At that moment, I told myself, my university does not deserve and better to go for external projects. At least it involves interesting things. I had no particular wish, but to learn new things, to strengthen my network a bit, to broaden horizons I do not think this is applicable only to me, there are others also.

A scientist from an ICAR-sponsored research institute shares:

> What ultimately matters is a publication in the end. In fact, if any publication comes out, I include it to the list of publications I update it every year to the synthesis of my scientific output which I do it after every three years. However, I must honestly accept that I do not just do it to receive funding. If I have to do a blunt cost-benefit analysis, I could have easily written three articles by myself in the quantum of time consumed in setting up a collaborative project, which involves management and organization and produces journal articles coauthored by all the collaborators.

A scientist from an SAU explicates:

> I must tell you that in the university where I am now, my university would not even notice about it. If I publish something or not. Absolutely not, never. Indeed, there surely are some responsive scientists, who are doing good work and are linked to the national and international networking projects. To whom I could say, "Look, I am involved in a collaborative project and I published this". They would simply congratulate me and say how good it is, but could not support me even if they wish.

A scientist from an ICAR-sponsored research institute asserts:

> I have a project with IRRI. Under this project, I am evaluating abiotic stress tolerant variety of rice, which has been developed by IRRI. To be honest, I don't think that these kinds of project are praised but are voluntary. I think institutions do not value this type of work. There are individual interest, but definitely not always compatible with interest of institute.

The above responses indicate that intrinsic reward is more valued than the extrinsic rewards while forging collaboration. Intrinsic rewards, such as professional interests, altruistic and personal values, giving something back, helping each other out, and enjoyment are the primary factors, which motivate scientists to volunteer a collaborative project. Intrinsic rewards, such as self-satisfaction or a feeling of accomplishment, play an important role. Scientists feel intrinsically motivated to work in collaborative projects. Nevertheless, scientists' responses also indicate a lack of extrinsic reward, such as wages, bonuses or any other monetary rewards from their institutes. However, they agree that publications derived from the project are a reward per se. Their employing institutes recognize them by promoting them in their professional careers.

### 5.3.2 Goals and Imperatives of Collaboration

Scientific collaboration can be successful, provided there is a combination of factors contributing to its formation. The collaboration among scientists in research activity has become the norm (Beaver and Rosen 1979). Then the question arises: why to collaborate? This question requires a direct and qualified answer. Collaboration is perceived as the best or perhaps the only means to achieve one's objective.

Table 5. 3 depicts that around 93 percent of the rice biotechnologists endorse that goals and imperatives of collaboration are the most important factors, which play a decisive role in any R&D collaborative initiative. Scientists are of the opinion that collaborations have become the nature of rice biotechnology. It has become prominent in day-to-day research activities because individual scientists or organizations cannot manage the fund, facilities, and expertise required to acquire the kind of result that scientists find meaningful. For example, a scientist from an SAU shares:

> In terms of what really spurs collaboration, we are more driven by problems that we are addressing. So, in order to find solutions, if we know somebody who has a specialized resource, like I am looking for a mutant which somebody else has developed for some other purpose, but I need that mutant to answer any questions. I enter into collaboration with him. I can access that mutant. I work with it or I bring it back to me, and thereby we keep continuing these things.

A scientist from an ICAR-sponsored research institute asserts:

> The increasingly interdisciplinary, complex and expensive nature of modern plant science create conditions for scientists to enter into a collaborative research. Complementarities of expertise, sharing materials for research, physical assets and nature of funding bodies determine the basis of scientific collaboration. There are various funding agencies, particularly government agencies, facilitate active research collaboration as part of their funding conditions. For example, the CSIR, the DST, the DBT, the ICAR, etc. have initiated many technology transferpolicies that enhance interaction among researchers throughout R&D organizations. In particular, some technology programmes require inter-organisational collaboration for funding and research.

A scientist from an SAU mentions:

> The imperatives of collaboration are twofold: (a) need of the expertise; (b) as a corollary, the demands of the agriculture institutes (problems related to agriculture). To be very precise, Ii would like to mention that complementarities of expertise as well as seeking solutions to challenging problems related to agriculture and agriculture institutes like the NARS have become main bases of my collaborations always.

A scientist from an ICAR-sponsored research institute points:

> I have always prioritized complementarities of expertise and material for research as the basis of my collaboration. These two factors are extremely important in today's rice biotechnology. M collaborator has expertise on biochemistry, plant sciences and nutritional genomics. And, my collaboration with him has reached the stage of plant molecular biology. My students are also extremely bright in collaborating with me, and our collaboration has resulted in several novel things.

A scientist from an SAU affirms:

> Everything [complementarities of expertise, sharing of materials for research and physical assets] is required including funding to pursue research in the area of rice biotechnology. Today research in this area is very expensive. So, funding is need definitely. But, it is not just funding – actually, in the university, I say at least my perception is in the university system the research we have taken up at least in India – if you see all over country – it is not that commanding, I would say in general. I do not say there are no good laboratories. There are, of course, good laboratories, but at least in general, I am trying to address this problem. Now at least, the university should focus on, say, I have taken a PhD student – he may not be able to turn out with a wonderful thesis where the research will lead to discovery. But, at least, now we are exposing [the student] to the research area – how really it should be done and what are the basic techniques that the student really requires to learn and the expertise s/he can get, and those are the things we have inculcated – the research interest in the student. Once s/he joins a national laboratory or some other institute, s/he will be able to turn out good.

Culling out from the responses of scientists coming under aegis of ICAR-sponsored institutes and SAUs, it is obvious that complementarities of expertise, sharing of materials for research, physical assets and nature of funding bodies determine the bases of scientific collaboration. Further, this suggests that it is the lack of human and non-human resources that spurs collaboration in rice biotechnology. Therefore, this can be appropriately described as "technoscientific" which emphasizes the fuzzy boundaries between practices, equipment, inscriptions, and claims in the local context where knowledge is created. (Bijker et al. 1989). Collaborations are technoscientific in nature because concept, formation, design and organization revolve around the technological practices, which are required to collect the data.

In addition, the responses of the scientists suggest that rice biotechnologists co-construct collaboration goals and align their interests during the formulation stage. They hesitate to collaborate, if their goals and ideologies do not match. None of the examined scientists spoke about projects to be dominated by either team or group. On the contrary, the principal investigator of projects considers the potential contribution of each member and resource that each of them brings to the project. They also negotiate shared goals, such as goals for cooperation, shared decision-making, and shared benefits to name a few at the very outset of the project for mutual participation.

### 5.3.3 Knowledge Sharing Culture

A working culture that values knowledge sharing and learning from sources internal and external to the organization is another important component of readiness to collaborate (Olson and Olson 2000; Barrett et al. 2004). However, this culture is more valuable when people share the values of a collaborative effort, rather than simply accepting collaborative work practices (Karsten 1999). When sharing the values of collaboration, people feel ownership of both.

In table 5.3, only 24 percent of the scientists are of the opinion that knowledge sharing culture characterizes R&D collaboration in rice biotechnology. They are skeptical about knowledge sharing culture, which fosters free flow of knowledge among all the partners in a collaborative project. Scientists report that a lack of shared collaborative culture is not only found in dispersed collaborative projects but also in collaborative projects where partners are collocated. Reflecting upon the aspects of shared collaborative culture, a scientist from an ICAR-sponsored research institute mentions:

> The field of agriculture biotechnology is highly competitive and commercialized. A a huge work force as well as economic forces is involved in agricultural biotechnological field, making the data or information highly valuable and precious. Hiding of data or information has become common practice in this field. In a collaborative project, scientists or institutes are reluctant to share data because in agriculture biotechnology research individual scientists and laboratories tended to be very competitive and work hard to be the first to achieve some breakthrough. They do this for their personal and commercial benefits.

A scientist from an SAU points:

> Among the rice biotechnologists and other scientists of rice, a tendency seems to be developing to regard of sharing of information or research outcome they have on their piece of work in a collaborative project. They are reluctant to divulge it. This seems to be an extremely shortsighted vision, and one that probably needs to address quickly if a scientist want to progress in their research area and strengthen their social capital in area of rice biotechnology.

A scientist from an ICAR-sponsored research institute reacts:

> The real problem in any collaborative project is of sharing of data. This is very much prevalent in the field of rice biotechnology. It is a common phenomenon in day-to-day research practices. Scientists in a collaborative project tend to hide data in the pursuit of personal and commercial success. If the results of same research program are widely disseminated and the other may be kept secret the essence of research is lost. Further, this can mislead the whole research program. The hiding of information is very common and is even practiced by responsible faculty members and scientists**.**

A scientist from an SAU asserts:

> To make a collaborative effort successful, there is no way, besides from sharing of information and finding of the study to other collaborators without hiding or concealing even a word of it. The point is that scientists in a collaborative project believe that those who have more data or information are valued more in science. But this a wrong perception, science does not work like this. Scientific communities that practice research that is more transparent are likely to be more coherent and successful. This is era of multidisciplinary research, which is not possible without collaborating with other experts. Such practices are against the ethos of research collaboration and can hinder the future collaborating prospect of a scientist.

The above responses suggest that R&D collaborations in rice biotechnology lack shared collaborative culture. Collaborative practices in rice biotechnology research are plagued with hiding, concealing, and misrepresentations of data or information's. Lack of knowledge-sharing culture in collaborative practices is against the ethos of disinterestedness. Merton (1973) constructed four ethos of science namely, universalism, disinterestedness, communism and organized skepticism. Ethos of science is the norms of behaviour that guide appropriate scientific practices. Ethos of disinterestedness is a form of integrity that demands that scientists should disengage their personal interests from their actions and judgement. They are expected to report results fully, no matter what theory those results support. Disinterestedness rules out any form of fraudulent practices, such as not sharing data, reporting fabricated data, because fraudulent behaviour typically represents intrusion of interests.

### 5.3.4 Mutual Trust

Cotemporary scholarship perceives trust as an important premise required in all systems of knowledge production, primarily where actors work together toward a common goal. As Steven Shapin (1994) in his study of the progress and development of modern science argues, the recognition of "trustworthy persons" is an indispensable component in building research networks. As collaboration involves complex social interactions and formations, it acquires immense importance in an era when individualistic and utilitarian practices of science are popular and prioritized. Social tie reinforces a culture of trust, which in turn fosters cooperation in organization (Alter and Hage 1993).

Table 5.3 depicts that around 82 percent of rice the biotechnologists accept that mutual trust shapes their collaborative initiatives. They considered the existence of trust as a prerequisite of a collaborative project. A majority of the rice biotechnologists are of the opinion that trust is necessary for any collaborative enterprise and it is the trust that characterizes modern scientific organization of rice biotechnology. They recognize trust as a constitutive component of their successful collaborative projects. A scientist from an ICAR-sponsored institute, trusting that other scientists have something to contribute mentions:

> They understand the behavior of plants at phenotype level pretty well, too. I understand the behavior of plant (genes) genotype level pretty well. . . . In my opinion, we all trust and value each other, not just trust but also value the input of that other partner. Because you recognize that they have expertise in plant breeding and know more than you do. I believe that is the basis of any collaboration. Any form of collaboration would not work without establishing mutual trust.

A scientist from an SAU opines:

> I believe that any scientific strives with high degree of trust among collaborators are always better in some sense. Trust allows researchers to achieve their goals while projects riffed with mistrust carries greater risk of failures. For an instance, I was handling a project in collaboration with DRR, Hyderabad. Initially, we suspected that the research team at DRR has some hidden agendas that we were unable see. However, later we started trusting them more and more but as time went on passed on I think we have trusted them less. This trust-deficit has delayed the whole project for almost one year. I still regret about my miscalculation about my counterparts at DRR.

### 5.4 Management and Leadership

The way in which the work of a distributed collaboration is organized and carried out is critical to its success. The skills that leaders possess and the time they have to devote to running the collaboration, the effectiveness and timeliness of communication, the mechanisms for decision making, and the clarity of institutional and individual roles as well as responsibilities are all critical aspects of management. The larger the collaboration, the more significant these elements become (Cummings and Kiesler

2005). Those projects left loose suffer when the participants' directions begin to diverge; if they have not assigned someone to take leadership to get the group back on track, or have not bought in to that person having that authority, failure is likely. Projects should designate a point person at each location who will be responsible for making sure that all participants there are informed and contributing. One business strategy that may work in collaboratories is including a ''rotator'' at each location, someone from the other location(s) to serve as the eyes and ears for the remote people (Olson and Olson 2000).

In this study, majority of rice biotechnologists, over 90 percent (66 out of 71), believes that efficient and effective project management is precondition of collaborative projects in rice biotechnology. According to scientists, project management determines the fate of projects. Improper or loose project management can seriously jeopardize a project and sometimes even can cause failure of a project. A majority of the scientists report the uses of a structured approach to project management for governing collaborative projects. They follow structured project management approach because they are part of public funded institutes (SAUs and ICAR), where they are accountable to various administrative departments. As structured project management approach involves recording and documenting of all formal activities in projects, it enables them to produce reports on the request of their concerned departments and pinpoint the lapses in accountability of actors if something goes wrong. Therefore, rice biotechnologists are using a structured project management approach to govern a collaborative project, which entails the use of conventional project management. Reflecting upon management aspect of collaborations, a scientist from an ICAR-sponsored research institute shares:

> Any collaboration, when it first starts there are a lot of enthusiasm for {the project} and it seems it is going to be done almost in half {time}. Then, one of the people is retired, one changes their job, one is transferred, one go to foreign, and somebody takes sabbatical. These types of operational problems create trouble for other peoples in project. Strong management is very important for stability and continuity of projects. If you manage a project, you need somebody who is possesses human resource management skills, who is going to keep very tight reins on everything because people changes roles.

A scientist from an ICAR-sponsored research institute points:

> It was my management technique, I've used it on a bunch of projects, where you start the meeting the first day, maybe there's 20 people there, and you get everybody together and tell them for two hours what's happened since the last meeting. And, they meet in parallel sessions and talk about their particular works. Then, I get two groups together, which have some issues

> between then and then, finally, we all get back together, and I have each one of those groups stand up and report what happened with the major assigned work, what the major action items were, what they expect to come out of it before the next meeting.

A scientist from an SAU expresses:

> I am happy with the structured approach. It works in a very mechanical and unhelpful way. However, this structured approach requires a strict implementation through the project, especially when there is reorganization in project. Also, this approach usually has recording and documenting culture so it keeps check on everyone.

A scientist from an SAU mentions:

> I am using structured management approach in my current project. As the PI of the project, I conduct regular meetings and updates and ask my collaborators "how is it going?" and so forth. Feedbacks from your collaborators are very important in collaborative projects. It works quite well. I think both myself and the team are keen to do the work and to get the work done. I think it has gone reasonably well. The principal investigator (PI) is the individual with appropriate level of authority and responsibility to lead the project. There number of PIs varies depending upon the nature of project. If a project is large or multi institutional, two or more PIs can be designated to the project.

Such responses suggest that an effective project management is required for a stable and smooth functioning of collaborative projects. A few dimensions of collaborative management such as system of leadership, decision-making, and degree of formalization, which has emerged during the interview of scientists, have been discussed in following sub-sections.

### 5.4.1 System of Leadership

The strong leadership is required in collaborative research practices to integrate interests and competencies, manage their relationships, and keep the project headed in the right direction with minimal delay and conflict. In this study, it is found that Principal Investigator (PI) is main leader in collaborative projects. The principal investigator (PI) is the individual with appropriate level of authority and responsibility to lead the project. There number of PIs varies depending upon the nature of project. If a project is large or multi institutional, two or more PIs can be designated to the project. In our study, 68 percent of the projects, there were more than one PIs and most of these projects involved scientists from two or more institutes. Reflecting on system of leadership in collaborative projects, a scientist from an SAU reacts:

> The Principal Investigators(s) is the real boss of a project. Although, some tasks may be delegated, the principal investigator is the accountable person and bears responsibility for all scientific, fiscal and administrative conduct of the project and meeting terms and conditions of the funding agency. They initiate the personnel hiring or assignment process and approve the selection or appointments of individuals. They allocate tasks and budgets among partners.

A scientist from an ICAR-sponsored research institute points:

> I am one of the PIs in a DBT funded project. I am leading the project at my institute. Basically, what I have to do is look over the whole project time line and track that somebody is falling not off. I have to talk to everybody to make sure everybody fits together . . . and that no one is violating the conduct, and that basically they work as coherent. So far, I assume I am doing a good job.

A scientist from a SAU mentions:

> You need powerful principal investigators [in this collaboration], who can lead the project. On one hand, in [collaborative projects] you have a young, relatively inexperienced scientist, on the other hand, you have senior scientists, relatively more experienced and then you cannot expect the young, relatively inexperienced scientist to be more dominant than [these PIs]. There are possibilities that the two groups are in conflict with each other. In my opinion, PIs should also posses administrative skills along with scientific skills.

Usually in multi-institutional projects, there is a system of appointing a project manager, who manages the collaboration's resources, or who oversees the assembly and integration of its instrumentation. However, this system does not seem to operate in the case of collaborative projects in rice biotechnology. In the field of rice biotechnology, there is no separate and distinct administrative leader such as project manager. A scientist from an ICAR-sponsored research institute adds:

> We don't have system of hiring project manager. We are never comfortable with the idea of having a real project manager for the project. The primary reason behind this is that single person would then have to be given control over resources of the other institutions, and scientists are never really comfortable with this. Moreover, if you're going to hire a project manager, such people aren't cheap, and that would just take away from resources which might go directly to the [research and development].

In the field of rice biotechnology, the administrative responsibilities are carried out by PIs accompanied by project coordinators. A project coordinator is the member of a project management team responsible for keeping the project organized and for running the project smoothly. The project coordinator works alongside the project manager to track and dispense all of the information that the various team members need to do their jobs effectively. Therefore, PIs in collaboration exhibit both types of authority, scientific as well as administrative.

### 5.4.2 Decision-making

One of the important aspects of project management is decision making, ranging from hierarchical to consensual and centralize to decentralize. Reflecting on R&D collaborations in rice biotechnology, what appears to be clear that decision-making is hierarchal and highly centralized. It is leadership subgroups (PIs), which dominate decisions concerning scientific, engineering, and administrative matters, whereas other members are not included in decision-making process. According to a scientist from an SAU:

> PI is the person, who takes the last call. S/he decides who should be rewarded and who should be punished. The power of PIs can be understood by fact that they can terminate or recruit any partner during the course of project by taking funding agency into confidence. They are the supreme body to decide what duties should be allocated to whom and accordingly distributes resources among the partners, including financial resources. Moreover, where will the results be presented and/or published? Who will be included as authors? What will be the order of co-authors? The final approving authority for these decisions is PI of project. Hence, the decision-making process is top to bottom, which is presided by PIs. We are restricted to executing body.

On the contrary, informants also report that decision-making is consensual when a project constitutes of more than one PI. When they have to make a decision that involves the entire collaboration, it is done mostly amongst the PIs. There is no single PI, who makes the final decision. It is a consensus among the PIs. However, this is applicable only in the case of multi-institutional collaborations where there is more than one PI. Therefore, decision-making practices might, at best, be characterized as a blend of hierarchical and consensual, where consensual decision-making operates at the top level while a more hierarchical structure characterizes the organization itself. This hierarchy may be called two-tiered hierarchy.

### 5.4.3 Degree of Formalization

The findings of study suggest that formally organized collaborations are prevalent in the field of rice biotechnology. More than 90 percent (65 out of 71) of the scientists report that the collaborative projects accomplished in the last 5 years are formal in nature. Inter-institutional collaborations, whether viewed in terms of number of participants, organizations, or teams are more likely to have formal contracts, more levels of authority, systems of rules and regulations. However, the degree of formalization increases with the increase in size of number of participants, organizations, or research teams. Large, multi-institutional collaborations tend to be more formal in nature in comparison to small collaborations. Therefore, the magnitude of inter-institutional collaborations is positively related to the degree of formal organization and management of collaborative project. Moreover, a majority of the scientists report that international collaboration is more formal than national collaboration. Describing the degree of formalization in collaborative projects, a scientist from an SAU mentions:

> The formal contracts are not only drawn up between the scientists, institutes, and research teams, but also for sharing of equipments and sharing of materials, of course, at the beginning of the collaboration. Nowadays, even formal agreements are done for credit-sharing (plant variety, publications) and resolving of conflict if one arises during the course of collaboration. So what that tells you is the very informal nature of this project. People honor these legal binding rules and it's basically done in written mode. There is nothing verbal in collaboration.

A scientist from an ICAR-sponsored research institute points out:

> In my opinion, there are two primary reasons for formal nature of collaborative projects in rice biotechnology. The first is that we are part of government funded institutes and secondly, we mostly deals with government funding agencies. Thus, in order to maintain accountability to these government agencies, we choose to formalize the relations through numerous agreements, contracts, subcontracts, and other form of legally binding documents. In our field, informal does not qualify for collaborations.

A scientist from an SAU asserts:

> The degree of formalization is directly proportional to the size of project in terms of participants, organizations, or research teams. For an example, we are part of DBT coordinated project, namely Molecular Breeding in Rice for Biotic Stress Resistance in India. This project is a multi-institutional project involving five institutes, namely Directorate of Rice Research (DRR), Hyderabad, IARI, New Delhi, Punjab Agricultural University (PAU), Ludhiana, ANGRAU, Hyderabad, Tamil Nadu Agricultural University

> (TNAU), Coimbatore, and VPKAS, Almora. What I have observed is that this project is highly formalized in comparison to my other inter-institutional projects. Everything is written in agreement, what is going to done what and how it is going to be done? In my opinion, formalization enables better control, when collaboration is large and crystallizes accountability in project.

A scientist from an ICAR-sponsored research institute stresses:

> If you talk about the degree of formalization in collaborative projects, I think International collaborations will top the hierarchy. Today, if you wish to enter into collaboration you need to take approval from department, institute, ICAR, DBT, DST, Ministry of Agriculture and Ministry of External Affairs. This involves submitting a lot of legally binding documents. Apart from this, you also need take certain approval from your collaborating institute's country. This is very tedious and time taking process.

The above responses suggest that R&D collaborations in rice biotechnology are highly formalized. It involves high incidences of written rules and regulations and formalized responsibilities. The agreements among participants in the projects are formal and written, with legal implications in the case of withdrawal or non-completion of the assigned task. However, the degree of formalization changes with the change in size and types of collaboration.

## 5.5 Technology Readiness

### Integrated Use of Information and Communication Technologies

In the present study, more than 80 percent (59 out of 72) of the rice biotechnologists resort to different modes of ICTs to interact with other partners in collaborating project. The scientists report that they are comfortable with general-purpose technologies, such as email, word processing, spreadsheet, and online searching. However, scientists emphasize over the use of email, videoconferencing and phone to communicate with each other. In this study, email-based interactions are found to be more prominent among scientists. Nevertheless, scientists subscribe to phoning their partners only when there is a pressing need. In general, they avoid making phone calls for project-related issues. Project participants in rice biotechnology share the characteristics of a virtual team distributed across space and organizational boundaries and connected by email, videoconferencing and phone, depending on the need. Even when the research groups are formed at the intra-institutional level, researchers tend to work mostly in a distributed fashion, although they are collocated at the same institute. Scientists in the study report that they set up a mailing list, where all the evaluators can communicate with each other, raise doubt, seek clarifications, and ask questions related to the project. The interactive communication among rice biotechnologists in collaborative projects are primarily supported by the internet. By communicating via email, they feel that they have the opportunity to respond in detail to a question or topic that they might have answered completely in a real-time conversation. Reflecting on the use of emails in collaborative projects, a scientist from an ICAR-sponsored research institute shares:

> I think that I have not yet developed the habit to work with this kind of technological tools, at least in my professional environment. I think this is negative point in me and causes trouble, where it is critical to interact via computer. I should try to make full use of the mailing list.

A scientist from an SAU adds:

> It is difficult to set up a web site for each project. I have my own website but I just use it to put research reports on that. The main difficulty is to try to get a website. It is difficult to set up one in the department, because we have to feed materials to somebody else to put materials up. That doesn't work. We paid for the web site for another project. That worked all right, but we have ceased to pay the subscription so the web page no longer exists.

A scientist from an ICAR-sponsored research institute affirms:

> We (the research group) collected the experiment data, and mostly I use SPSS to analyse the data. When I do the research work, I work mainly from home, especially the analysis part, so I do more processing of my research data at home. This is only possible through integrated use of ICT. We also shares information regarding the project through mailing list on the request of partners.

A scientist from an SAU stresses:

> The mailing list makes your work easier. We could upload an excel file and then each evaluator download it and fill it in with the data about his or her assigned work. It enables sharing of data.

A scientist from an ICAR-sponsored research institute emphasizes:

> Earlier, I was not use to the email and it was very little in practice, I had this resistance. Nevertheless, now I think it is very effective tool to manage any kind of collaboration. At one hand it makes collaboration easy and, simultaneously, it gives you opportunity to clarify aspects that probably, if you had a handbook, you couldn't do because there isn't this interaction that allows you to respond to something you read, is it?

A scientist from an ICAR-sponsored research institute mentions:

> Under National Consortium for Functional genomics of Rice, we have a multi institutional project. It involves scientists from institutes, such as Indian Institute of Science (IISc) and Delhi University South Campus (UDSC), the Directorate of Rice Research (DRR), Madurai Kamraj University (MKU), and Osmania University (OU).Given that project participants were distributed and arranging face-to-face meetings were difficult, we have created a mailing list for the project based on Yahoo Groups!to connect and communicate with each other. Yahoo! Groups is a piece of server software, which provided the project with free email and web based online group. It is very effective and fosters smooth functioning of project. It played an instrumental role, linking distributed project evaluators and providing them with a convenient way to connect and communicate with each other. It is simple and easy-to-use application that project participants learned quickly. Some scientists used this collaborative technology for the first time but they became comfortable with it quickly.

A scientist from an ICAR-sponsored institutes points:

> In my opinion, meeting in person might not be productive, because most of the time one ends up talking about something else. I also would like to add that I teach my students to communicate and work as a group in this kind of environment.

When the evaluators interact with others, they do it through the emails primarily when they encounter problems. The mailing list is a crossroad where people discuss problems, exchange information, and provide solutions. Messages are archived so that the individual evaluators could access messages, retrieve them, and refer to them at any point during and after the end of the project. Therefore, emails are the primary and common means that evaluators use for interaction during the collaborative project. Furthermore, interaction among collaborators in rice biotechnology is internet-based.

While the interviewed participants acknowledge the usefulness of email when people are distributed and the timescale for the completion of the project is tight, they think that occasional face-to-face meetings also help. Reflecting on the importance of face-to-face interaction in a collaborative project, a scientist from an SAU reacts:

> I think I would have liked another face-to-face meeting somewhere with research group, which we did not have earlier. Indeed, it would be very good to discuss progress periodically. Also, it is very effective to resolve the interpersonal conflicts in group and fix accountability if something goes amiss in project.

A scientist from an ICAR-sponsored research institute points:

> I think email works quit well. However, I think there are some advantages, sometimes, to have a face-to-face discussion rather than doing everything by email and feedback. This probably a better way to get consensus than collating individual feedback. In addition, it can help if there are any issues of clarification or explanation. If the people you are working with closely on the project are there, then they can clarify and explain what everyone is discussing. I think that is actually a little bit more difficult by email.

A scientist from an SAU asserts:

> Yes, indeed, sometimes face-to-face meeting becomes necessary. Probably, it is useful for someone to win his or her fear, for someone else to overcome the coldness. It allows you to share more obscure points. We always organize a meeting, maybe an initial one, to explain what we are required to do precisely, a one-day meeting, or half a day, well, may be, it has been good.

Therefore, while most of scientists accept that most of the communications take place through ICT-driven modes such as email a few evaluators are also of the opinion that a face-to-face meeting would have helped disentangle emerging issues and explore concepts. Furthermore, since most of the project participants have never met and do not know each other personally, a collocated meeting at the start of the must be organized to "break the ice", be acquainted, establish personal relationships, and develop trust.

### 5.6 Problematic of Scientific Collaboration in Rice Biotechnology

The present study recognizes the problematic of the conceptualization and measurement of collaboration. More specifically, does one focus on the productivity increments related to particular scientific outputs, such as publications, or take a much broader view of increments to scientific capacity? And, if one examines increments in the capacity to do scientific work, does one focus on the individual, the research group, or some concepts of a scientific field? We have to consider the impact of collaboration strategies on "scientific and technical human capital" (Bozeman, el al. 2001; Bozeman and Rogers 2002). Scientific and technical human capital is the sum of scientific, technical and social knowledge, skills and resources embodied in a particular individual (scientist). It is both human capital endowments such as formal education and training, and social relations and network ties that bind scientists and the users of science together. Scientific and technical human capital is the unique set of resources that the individual brings to her/his own work and to collaborative efforts. Scientific and technical human capital can be understood at the level of the individual scientist or research group, and it is possible to measure the individual scientists training, skills and even tacit knowledge, as mentioned above in the excerpts from the interviews with the scientists engaged in research in rice biotechnology coming under the aegis of ICAR and SAUs. Further, it is possible to measure the individual scientist's ties to networks and transactions with others in those networks. Examining collaboration from the standpoint of a multi-level scientific and human capital model shows that productivity implications are part and parcel of the analytic focus. Thus, for example, any particular collaboration may be a productivity decrement for specific individuals but a productivity increment for a field, educational cohort, or "knowledge value collective" (Lee and Bozeman 2005). As a scientist from an SAU puts it:

> A senior researcher choosing to collaborate with- a graduate student may, from one perspective, not be making the most productive use of her/his time. Working alone or with another senior scholar would perhaps result in equal or higher quality achieved in less time. But, the same activity may be quite productive from the standpoint of the work group or the scientific field, because the collaboration is likely to lead to greater increment in scientific and human capital than would work performed alone.

Funding in India is not so lucrative today so far as basic research is concerned. Perhaps, the decision-making bodies and the scientific elite in the country tend to lose sight of the essence of pursuing research in basic sciences. As a scientist from an ICAR-sponsored research institute mentions:

> For basic research, funding bodies are less. If I go for or if there is a chance for patent or if there is a chance of business-oriented activities having commercial potential, in such cases, funding organisations are more. So, that is what is. Then, basically, most of the time we want our quick results or quick reputation. So, we do not want to put much of our time on these things [basic sciences]. That is another reason. Then, we go for certain international programmes. Sometimes we do specific research. People are often interested in participating in these activities. Certain research as such is not very much important — you are not doing something preliminary activity or extra-ordinary thing, or others have done it and you are doing just a routine type of job because of other interests, say for money or foreign tour or other things, etc. So, that is one reason. These are the basic reasons for this, I feel. But, some of the people are there who crave for basic research. However, the problem of basic research is that you may not get success. After putting a huge amount of labour, you may not be able to succeed. Very often do I not get the necessary funding from the funding organisations, as more and more basic components have characterised my research thrust. The less I reflect upon the nature and functioning of fundingagencies to support basic research, the better. I do not want to be drawn into unnecessary and avoidable troubles by disclosing everything before you. Today the scientific

community in India has to devote its time, energy and money for basic research, if it wants India to be a leader in scientific achievements in the world. Having said this, l do not intend to say that there should not be any support for applied research. Obviously, more and more funding should come in support of applied research. However, the scientific community in India cannot afford to lose sight of the domain of basic research.

### 5.6.1 Cognitive Empathy: Understanding the Needs of the Laboratory and the Field

The term "cognitive empathy" has been borrowed from Max Weber (1964). Cognitive empathy essentially implies understanding phenomena from the point of view of the other by one's imaginative identification with the other or simply by putting oneself in the shoes of the other (Haribabu 1997, 2000). This is the first step in transcending one's disciplinary boundaries. As collaboration in rice biotechnology involves expertise from multiple disciplines, cognitive empathy paves the way for viewing phenomena from a mutually shared perspective, construction of the objects of research, development of concepts and arriving at a consensus regarding the meaning of concepts, and shared norms of communication and collaboration. These create conditions for the formulation of interrelated research problems and division of labour to execute them in order to generate knowledge and solutions that transcend disciplinary and institutional boundaries. Thus, cognitive empathy can facilitate interaction in situations where the individuals involved in the interaction have shared interests, albeit with different disciplinary and institutional orientations and approaches. Out of 71 scientists included in the study, 32 scientists are plant molecular biologists and 39 scientists are plant breeders. Perhaps, the tools used by plant molecular biologists and plant breeders demarcate the two disciplines. On the one hand, plant molecular biologists use sophisticated tools to carry out their research in their laboratories. Genetic engineering is an example of this. On the other, plant breeders are not much in tune with the contemporary sophisticated tools and they mostly operate their research on the field.

The differing perceptions of plant molecular biologists and plant breeders on a specific plant and the subsequent stratagems of intervention by plant molecular biologists and plant breeders may be attributed to their disciplinary orientation and the mandates of the institutions/organisations to which the plant molecular biologists and plant breeders belong. Further, the culture and mandates of various institutional settings along with the intellectual antecedents of the individual scientists resulting in their motivations very often define the extent of collaboration between scientists engaged in research in plant molecular biology and those engaged in research in plant breeding.

In the context of scientific research pursuits, the scientists in the present study are quite anxious about collaborative research projects. The anxieties are borne out of the perspective that a particular scientist, whether plant molecular biologist or plant breeder, adopts. Whereas laboratory characterizes the world view of plant molecular biologists, field-based research defines the worldview of plant breeders. This kind of situation calls for cognitive empathy that good result in bridging the gap between two domains – plant molecular biology and plant breeding rather than aiming at desired consensus. When different actors – scientists/inventors, decision/policy-making agencies and funding bodies – aim at desired consensus, scientific research pursuit and the associated practices very often get manipulated.

The present study conforms to an earlier study on collaboration between molecular biologists and plant breeders (Haribabu 2000) in the sense that in the case of collaborative research project(s) between two or more scientist(s) drawn from different institutional settings with varying resource endowments may gain disproportionately out of such collaborative research project(s). In addition, these values and related attitudes have to be altered through a process of negotiation to arrive at a consensus over division of labour and credit-sharing. Of course, credit-sharing occurs through the Memorandum of Understanding (MoU). As, a plant breeder from an ICAR-sponsored research institute reflects:

> Though the IPRs regime not only in India but also outside places much emphasis on research output in the form of publication in peer-reviewed international journals, I, as plant breeder, feel the beauty of research does not lie in publication, rather developing a [plant] variety that would help the farmer[s] and the country as well. But, molecular biologists tend to place much emphasis on publication in international journals and often and often lose sight of the need of field-based research.

In this context, it would be pertinent to note that the mandates and protocols of specific institutional settings may direct the pursuit of research collaboration in specific dimensions. As mentioned in chapter IV, the scientists engaged in rice biotechnology research collaborates with scientists drawn from a variety of institutional settings – national research institutes and international research institutes such as universities (central, deemed and state), institutes of national importance and mission-oriented research institutes/organisations (public sector), and research foundations (private sector). Organisational mandates and norms affect the interdisciplinary exchange required for transcending the disciplinary and institutional boundaries. In the university set-up, the general tendency is to emphasise basic research and subsequent publications in addition to training. On the contrary. mission-oriented organization sare mandated to carry out applied research and development of products. This kind of difference creates anxieties amongst plant molecular biologists and plant breeders. In the absence of a set of mutually accepted norms, the problem can be especially serious in the case of a collaboration between a scientist in a publicly funded research institute and one in a privately funded research institute. On the one hand, the interests of: privately funded research institutes are directed towards the development of patentable products with delays in research disclosure and accessibility. On the other, the mission of publicly funded research institutes is directed towards distribution of scientific knowledge on a huge scale without any private ownership. It implies that problems can arise regarding the publication of scientific results and credit- sharing. Further, organisational mandates and norms are also subject to changes contingent upon the changes in scientific practices in the IPRs regime. More specifically, various research institutes not only evolve but also revise and update their mandates and norms from time to time depending upon the changes in the pursuits of scientific research.

### 5.6.2 Intellectual Property Rights Issues in Research Collaboration

The scientists interviewed for the present study are aware of the issues related to IPR and seem to collaborate with other scientists or institutes to cater their objectives. In this study majority of scientists (57 out of 71 scientists) see the problematic of IPRs regime. They firmly believe that patenting a product would have adverse effect on scientific collaboration. However, few scientists (14 out of 71) do not seem to bother about impact of these institutional changes over R&D collaboration in rice biotechnology. Being a part of public funded institutes, scientists drawn from ICAR-sponsored institutes and SAUs pays more emphasis on getting their research papers published rather than patenting their products. Moreover, if they develop a product (plant variety), it is registered under PPVFR act, 2001 with full legal ownership claim of institute or university. In the case of collaborative research projects, the only IPR issue that has come into any of the discussions prior to and after initiating the project directly or indirectly in terms of credit-sharing or authorship, mostly in publications. For majority of the scientists in the study, authorship is a large IPR issue than patent. In other words, they seem to be ambivalent on reorienting their research practices under the gamut of changed and changing protocols. As mentioned earlier, differences in the organisational protocols influence the worldviews of scientists. Scientists' perception on scientific research and the associated practices in the age of IPRs very often do diverge contingent upon a variety of factors — social, economic, political, disciplinary, institutional, aesthetic, organisational mandates, and so forth. Though scientists pursue research keeping the protocols of the IPRs in mind, a plant breeder from an ICAR-sponsored research institute immediately reacts:

> Presence of intellectual property makes ownership and documentation in a collaborative project more complex. Let me give you an example. I was part of an in-house project. The main objective of this project was to identify genetic variability of major and emerging diseases of rice. It involved mating type's analysis of Magnaportheoryzae populations by molecular markers. Forty-six isolates of M. oryza ewere collected from leaf blast lesions of rice from various ecosystems of coastal Odisha, India and mating type analysis using molecular markers was carried out. The results were astonishing. But, the main problem aroused, when there was a conflict between researchers regarding data ownership and disclosure. Few scientists were in favour that all researchers owned the data and it should be released to all. For them, it was the most logical choice to release the data and all other document in the public domain. Because, they thought that it would be beneficial to the rice biotechnologist's community. Contrary to this, few scientists were against the disclosing of data and keeping it in public domain. Although, number of times open discussions among all the project participants took place but consensus was not achieved and making project result openly accessible never occur. Even we could not produce a single publication from this project. In my opinion, IPRs regime is obstructing the smooth functioning of collaborative projects.

Another scientist from an SAU points:

> Patent obstructs scientific collaboration. It is against ethos of sharing. But, I am not against the idea of patents. In Italy, one of the few countries in the world enacting a "professor's privilege" system, in which university employees are generally sole owners of their intellectual property and are not pressured by the university to protect intellectual property through copyright, licenses, patents, or other agreements. Professor's privilege allows flexibility for individuals to greatly determine the creation and fate of their intellectual property, which can be important in collaborative projects.

A scientist from an ICAR-sponsored research institute mentions:

> The advent of IPR regime has made research activities more complex. Disputes related to ownership claim in publication, product, and other form of inventions are rampant especially in academics. It is adversely affecting the outcome of project by seriously delaying it. I want to share one experience related to this matter. We were having a bi-lateral project on development of a hybrid variety of rice. An agronomist from project team took help of a statistician for analysis of data about the performance of new variety in the field. Afterwards, when we were looking to publish the result,

the statistician claimed his authorship in proposed article, which was objected by other partners with the explanation that project does not talk anything about the ownership claims through any kind of informal collaboration. Consequently, until now forget publishing, we are not even able to send that article for conferences or poster presentation. My concern is that being an academician, we are here to generate knowledge for society, but I am sorry to say that new institutional regime such as IPR not only obstruct production of knowledge but also circumspect sharing of knowledge.

Another scientist from an SAU shares:

IPR regime has brought many changes in research activities and researchers attitudes, which ultimately have colossal impact on collaborative projects. It has various aspects and it is legally binding. I have contacted institutes legal adviser to understand clearly the legal domain of IPR. University has given me the responsibility to conduct few classes on IPR especially for faculties of the institute. Notwithstanding its negative effects, IPR gives us right to protect our product, publications and other form of inventions. Even after patenting, one can still keep his/her inventions free for public. I want to tell you one thing that IPR is recent phenomena and most of the scientists are not aware about its ambit, limitations, and scope. There is need for some workshop, training on the IPR for the scientists by trained professionals or from any consultancy agency, specialized in IPR issues.

One of a senior scientist of an ICAR-sponsored research institute expresses:

I do not have any patent on my research. Moreover, I do not want to file any patent on my research. Basically, patenting is a business policy. Competition, intellectual development, etc. are only ornamental to the policy and to hide the basic unfair business. This policy does not allow competitive development of any R&D. Sometimes fair amount of resources is wasted due to multi-corner competition without information of similar developments. Besides, the final product becomes costlier to the end-users or sometimes they are not affordable. In a country like India, which is still struggling for sustenance, natural resources should be easily accessible to the people. Whatever research or development we do, fundamentally we are not creating new things in the worlds. Only we are trying to explain the understanding of the basics of the naturally available materials. Therefore, in any condition, natural products in any form should be easily available or accessible to world beings. However, the developer has his/her right to get the benefit of his/her efforts, but for that, there should be no hindrance for others to get the benefit of otherwise natural resources.

A scientist from a SAU asserts:

IPR regime has led to commodification of research in India. Scientists have become entrepreneur and marketing guru. Earlier scientists look for producing knowledge in terms of product and publications for the free use of general populace. Now they look for commercializing their knowledge through IPR for generating revenues. Scientists now have direct commercial

> interest with outcome of their research. IPR has made academic science more commercialized. The outcome of academic research at government-funded universities are privately appropriated through the mean of IPR. IPR has polluted academia in India, which will have detrimental effects on coming generation.

The above responses suggest that rice biotechnologist perceives IPRs as an obstruction to R&D collaboration and they are resisting to such institutional regime. Furthermore, this study also conforms the theory of remote scientific collaboration (TORSC),which suggests that intellectual property issues can create serious problems for the collaborative scientists related to full legal ownership or control of disclosure, including publications, of their results (Olson et al. 2008). Therefore, it is recommended that scientists discuss and negotiate issues concerning IP rights at the formulation stage to avoid conflicts later on (Sonnenwald 2007).

### 5.6.3 Inequalities in Research Collaboration

Merton (1968) developed the argument of “Matthew effect” in the sociology of science. He posited that small differences in initial status amplify over time to generate cumulative advantages. In Merton’s classic account, not only does status itself influence perceptions of quality, but high status scientists are more likely to attract tangible resources, such as research funding and outstanding graduate students, which are parlayed into scientific outputs of higher quality.Merton observed that those better-known scientists tend to get more credit than less well-known scientists for the same achievements (Merton 1968).

Here we examine the presence of Matthew effect in R&D collaboration in field of rice biotechnology in India. In the interview, more than eighty percent (57out of 71) of scientists talked about presence of Matthew effect in research collaboration. These strong voices accepted that they have confronted status-based discrimination in one or many forms since the formulation to conclusion phase of research collaboration. However, there were also few respondents (14 out of 71), whose chose not to comment on this topic. This minor group of scientists believe that status-based discriminations is embedded in system, which is beyond their control, and theyare not the right person to comment or reflect on this topic. Highlighting the status-based discrimination in research collaboration, a scientist from a SAU vehemently puts it:

> In rice biotechnology, projects are not funded on the basis of merit-based factors but rather status-based factors. Your eligibility for a project is

> assessed from the lens of status-based factors such as your status in research area, status of your mentor, status of your past collaborators, status of your team members, status of your department, status of your institute in which you are employed and so forth. R&D collaboration in rice biotechnology is the terrain of elite scientists, who gets more project and consequently produces more in terms of product and publication.

A scientist from an ICAR-sponsored research institute shares:

> Most of the international projects are allocated to popular and famous scientists, especially in plant biotechnology. Last year, I had submitted a research project to DBT for funding under Indo-Australian biotechnology fund. The overall objective of this research project was to strengthen food security in India and Australia by developing salt tolerant rice through the means of modern biotechnological tools. Currently, I am doing good work in stress tolerant rice. Gradually, I have established a well-equipped biotechnology laboratory to carry out required experiments. I have a good research team, which is working on this particular topic since last six years and have contributed immensely in the area of abiotic stress tolerant rice. In spite of having all these advantages, this research proposal was turned down. Afterwards, I have discovered that this opportunity was conferred to a renowned scientist...... from M. S. Swaminathan Research Foundation, Chennai. The main problem in research is that very often equal talents and accomplishments are turned into unequal when it is evaluated through the lens of status, recognition, and popularity of a scientist.

A scientist from a SAU asserts:

> It seems foolish to waste more time on discussing role of status of a scientist in research collaboration. Scientist's status is often used as yardstick to judge about his/her quality and competitiveness. Over the years, what I have definitely learned is to have reputable scientists as a part of your research project, if you want to get your project funded. For flourishing in this field, you need to have strong connections and social ties especially with eminent scientists.

A scientist from an ICAR-sponsored research institute reflects:

> I do not want to work with famous or renowned scientists because finally all the credit of work is attributed to them. I have collaborated with an eminent scientist to develop a hybrid variety of rice. I have worked hard for almost 7 years to produce this variety of rice, which was unique in terms of high yield and high diseases resistant than its parent variety. Butall the credit was given to the eminent scientist. He was awarded by ICAR for this achievement and other team members including me were ignored. Your contribution's in a project is overshadowed with status of other scientists due to your low status. This is a common practice in India. I believe this is a dark side of any collaborative project. Misappropriation of credit is not there, when you work independently without any collaboration. But this is not possible in science. This a paradox of research collaboration.

A scientist from an ICAR-sponsored research institute mentions:

> You can crosscheck the publication list on our department site. You will be surprised to know that most of the publications consists the name of our HoD and even director of our institute as coauthor. Do you think s/he has contributed in all publication?

The above responses indicate the prevalence of inequalities in research collaboration in the field of rice biotechnology. It is obvious that status-based factors are dominant than academic-based factor while allocating project to scientists. The scientists of higher status win highly desired collaborative projects, whereas, it is converse for those scientists who are on the lower rungs of the status ladder. Moreover, status-based discrimination is confined not only to the project allotment but also to the credit-sharing between researchers in a collaborative project. The contributions to the project are evaluated based on status. When a more and a less well-known scientist together make a contribution while collaborating as equals, the scientist with high status gets larger share of credit for her/his contribution to the project. Contrary to this, the contribution of the less known scientist is undervalued. Therefore, the prevalence of the status-based discrimination in rice biotechnology poses serious questions on the ethos of equality in scientific practices. Therefore, it can be inferred that R&D collaborations in rice biotechnology are highly stratified.

**Conclusion**

We have discussed the way sociotechnical factors influences scientific collaborations in rice biotechnology. Moreover, this chapter is focused on scientists' responses to the problematic of scientific collaborations. The findings of the chapter suggest that clear division of labour among collaborators enables them to work independently for the most part of the project. Similar research interests of partners and their willingness to join or contribute to project establish some common ground, which further enhances reliability among partners. The analysis suggests that in the field of rice biotechnology common ground is relatively easy to establish when research project is homogeneous, intra-disciplinary, and intra-institutional in nature. History of collaboration among individuals/organizations influences collaborative projects profoundly and plays an important role in achieving the common ground. Long-distance collaboration circumspect the flow of tacit and transactive component of knowledge between the research teams. Incentives and rewards play a pivotal role in shaping collaborative projects in rice biotechnology. Intrinsic rewards, such as self-satisfaction or a feeling of accomplishment – are more valued by scientists. The scientists use structured approach of project management to manage collaborative projects in rice biotechnology. In the field of rice biotechnology, the scientific and administrative responsibilities are carried out by PIs accompanied by project coordinators. The decision-making practices in collaborative projects might, at best, be characterized as a blend of hierarchical and consensual. The R&D collaborations in rice biotechnology are highly formalized, The communications in collaborative projects take place through the ICT-driven modes such as email but a few evaluators are of the opinion that a face-to-face meeting is necessary. The rice biotechnologists perceive IPR as an obstruction to R&D collaboration. The findings indicate dominance of Matthew effect in research collaboration in the field of rice biotechnology.

This chapter demonstrates how the sociotechnical aspects of one or many forms can affect the foundation, formulation and sustenance of collaborative research projects. In the context of this, Chapter VI discusses social and political construal of rice biotechnology in India, reflecting on the scientists' responses on the questions surrounding genetically modified crops, political imperatives, policy implications, intellectual property rights and other contextual issues related to new agricultural technologies.

# Chapter VI

## Conflicting Narratives on Innovations in Rice Biotechnology in India

### Introduction

Plant biotechnology has been one of the most fundamental of humanity's productive organs. Whatever the historical period, whatever the mode of production, plants and their products have been necessary components of the material base on which the structures of human societies have been raised (Klopenburg Jr. 2005). In the last decade, with the advent of a set of new and uniquely powerful genetic technologies, a new kind of scientific practices has emerged that has altered the modes, means and relationships of agricultural production in India. The introduction of thes new genetic technologies in India was championed as 'Gene Revolution. This narrow view is reproduced by interpretations that subsume the gene revolution under agricultural history. Agrarian environments have to be comprehended as being part of a biophysical and social environment that always includes the urban and the non-urban, the arable and the non-arable, and other areas that are integrally linked to the world of agriculture and environment and their allied social-economic relations (Agrawal and Sivaramakrishnan 2000). Scientific research and knowledge production do not take place in a vacuum but are part of the social world and thus subject to a variety of 'non-scientific' influences (Latour and Woolgar 1979; Jasanoff 2004). Hence, it is necessary to conceptualise the phenomenon more broadly and to understand the gene revolution less as an isolated agricultural event and more as a result of a multilayered political, economic, technological, and social phenomenon made possible by a variety of actors and interests.

It is against this backdrop that the present chapter captures the transformations that are occurring in rice research with the emergence of new agriculture biotechnologies and how it is conceived and practiced by scientific community in different institutional setups coming under the aegis of SAUs and ICAR-sponsored institutes in agricultural dependent country like India. By focusing on galaxy of scientists engaged in rice biotechnology research, the present chapter shed light on the response of scientific community on the questions surrounding genetically modified crops, intellectual property rights and other contextual issues related to new agricultural technology. The attention of the chapter is focused on the culture and practice of agriculture biotechnology, because these have major implications for both how agriculture biotechnology is perceived in policy terms and for its ability to deliver the goods to farmer community. This chapter explores what are the new discourses about the role of biotechnology and rice biotechnologists? What are new forms of practices and what are new institutional and organizational arrangements emerging in rice biotechnology in India? The objective of this chapter is to understand how rice biotechnology in India is experientially constituted and politically negotiated along the contours and at the boundaries of national and international development operations, policies, extension agents, and the everyday lives, livelihoods, and aspirations of farmers.

### 6.1 Traits Tackled by Scientists in their Current Research Activities

Plant traits are morphological, anatomical, biochemical, physiological or phenological features that can be measured at the individual level (Violle et al. 2007). It is the result of evolutionary and community assembly processes in response to abiotic and biotic environmental stresses (Valladares et al. 2007). Additionally, plant trait is an important link between species richness and functional diversity in an ecosystem (Díaz et al. 2007). A focus on traits provides a promising premises for scientists to be more quantitative and predictive ecology and global change science (McGill et al. 2006; Westoby and Wright 2006). In this study, scientists were asked about the traits that they are tackling in their current research activities. Responses suggest that traits that are being studied by scientists are mainly consists of yield enhancements. biotic stresses, abiotic stresses and quality enhancement (biofortification). As indicated in table 6.1, 21.3 percent of the respondents are engaged in tackling traits responsible for yield enhancement, 76.6 for biotic stresses, 72.1 percent for abiotic stresses and 41.4 percent of scientists are involved in research pertaining to biofortification traits.

**Table 6.1: Types of traits tackled by scientists in their current research**.

| **Types of traits** | **Responses (in percentage)** |
|---|---|
| Yield traits | 21.3 |
| Biotic stressses | 76.6 |
| Abiotic stresses | 72.1 |
| Nutritional Traits | 53..4 |

Source: Field Study

It is obvious from table 6.1 that only 21.3 percent of the researchers affirm that their research focuses on traits that are directly responsible for the increase in the productivity of rice crop. Scientists are of the view that genetic yield potential of rice crop in India has reached a plateau owing to limited genetic diversity of HYV rice germplasm which impedes further improvement in production in crop. Discussing the reasons for low priority for yield enhancement research, according to a scientist from an ICAR-sponsored research institute, *rice consists of complex agronomic traits that is controlled by multiple genes known as QTL (quantitative traits loci) which normally exhibits a continuous phenotype distribution in separating population that is obtained by crossing a pair of inbred lines. In rice QTL of yield enhancing traits manifest small genetic effect and are difficult to identify*. A majority of the scientists are of the opinion that new strategies involving genetic improvements are urgently required in the country to overcome the bottlenecks of yield potential of current varieties that largely depends on the elucidation and exploitation of genetic and molecular basis for yield traits. According to a scientist from an SAU, *efforts are being made to incorporate genes from wild ancestors of rice into improved genotypes for enhancing productivity traits.* Scientists in the interview also advocated that conventional plant breeding program and hybrid-rice technology are viable option for tackling yield enhancement traits. Therefore, new molecular technologies like GM have very limited scope in the area of yield enhancement. *These technologies are not yield enhancing mechanisms but yield loss preventing mechanism which fosters controlling of biotic and abiotic stresses that indirectly causes yield loss*, according to a scientist from an ICAR-sponsored research institute. However, the respondents highlight the potentials of plant breeding supplemented by MAS techniques as one of the most efficient and effective tools to tackle the problem.

Table 6.1 also indicates that biotic stresses (76 percent) and biotic stresses (72.1 percent) are the most researched traits among scientific community in the realm of rice research. Biotic stresses refer to stresses that occurs as an outcome of damage caused to plants by other living organisms, such as bacteria, viruses, fungi, parasites, insects, pests weeds, and cultivated or native plants, whereas, abiotic stresses are stresses that occurs as an outcome of damage afflicted on plants by non-living factors, such as sunlight, wind, salinity, flood and drought to name a few, in a specific environment.

A majority of the rice biotechnologists in the study are in opinion thatone of the primary reasons for shift in their research priority from yield enhancement to biotic stresses are mainly yield losses inflicted by diseases and pests. According to a scientist from an SAU, *rice crop is susceptible to various pathogens and pests. These biotic strains are very detrimental to rice plant causing 40 to 50 percent yield losses. Thus, to* *combat this crisis there was serious need for reorientation of research priority from yield enhancement to biotic stresses.* Dwelling upon abiotic stresses, biotechnologists emphasized on climate change as main reason for transition of their research area towards abiotic stresses. According to a scientist from an ICAR-sponsored research institute, *climate change has exacerbated the frequency and severity of many abiotic stresses, particularly droughts and high temperatures*. Falling on the same ground, a scientist from an SAU mentions: *In India, rice is grown in rainfed areas. Owing to global warming, in many parts of India, monsoon has become more unpredictable and more intense. Water for irrigation is becoming increasingly scarce. Thus, there was need to enhance resilience of rice crop to climate change and climate vulnerability.*

In the study, 53.4 percent of the scientists are found to be engaged in tackling nutritional traits or biofortification. Biofortication is a crop improvement process which aim to enhance nutritional (proteins, fats, vitamins, minerals etc.) value of crops. Golden rice is one of best example of it. According to a scientist from an ICAR-sponsored research institute, *people are now more concerned about quality of rice grains in terms of size, taste, and nutrition's. People have become more health conscious. There is shift in market demand of rice from quantity to quality rice. Thus, these factors are responsible for shift in the research priority and more focuses on quality enhancements by scientific community engaged in rice research in India.* However, the emergence of modern agriculture biotechnology tools and escalation in funding from government agencies are two common and consistent factors that has emerged from discussions with scientists as main reasons for transition of research priority from yield enhancement to biotic stress, abiotic stress and nutritional enhancement. From the respondents' perspective, new agriculture biotechnologies have widened the ambit of rice research in India. According to a scientist from an SAU, *new agriculture biotechnology tools such as GM technology, MAS to name a few, offered solution to certain complex diseases and pests which were not possible to combat with the help of conventional biotechnology tools. Now with the help of these new technologies rice plant could be modified to enhance its micronutrient contents such as vitamin, tolerate herbicides,accelerate photosynthesis,resist insects and pests, increase size of grain, generate multi-nutrients, flavor and proteins. Molecular technologies have great potentials especially in field rice crops.* Additionally, now government R&D policies in rice crop are more oriented towards stress tolerance and biofortification. Consequently, projects involving stress tolerance and biofortification are getting easily funded by government agencies.

## 6.2 Basic and Applied: Changing Relations

Scientific endeavour is not as undifferentiated in character as it is conceived. It is often disaggregated on the basis of basic, applied and development. However, these categories require some critical examination. The question of how to distinguish between basic and applied work has been frequent and a recurring theme of debate in scientific domain. There has been a continuous and consistent effort across the time and space to classify scientific research either on the basis of the scientist's motives or on the nature of the work itself. Basic research is mostly conceptualized as a scientific research directed toward a fuller understanding of the subject under study rather than focusing on practical application. Major objective of basic research is to satisfy need to know and advancement of knowledge without any commercial interest. On the contrary, applied research is widely acknowledged as a scientific activity which is directed toward practical applications of knowledge. Development research is the systematic use of knowledge from research directed toward the production of useful materials, devices, systems or methods, including design and processes. Scientists in the study were asked to characterize their research thrust in terms of basic, applied and development research. Table 6.2 provides the pattern of responses to the questions.

**Table 6.2: Scientists' Responses to their own Research**

| Institutes | Only basic research | Only applied research | Only development research | Both basic and applied research |
|---|---|---|---|---|
| ICAR-sponsored institutes | 0 | 1 | 0 | 33 |
| State agricultural universities | 1 | 3 | 0 | 33 |
| Total | 1 | 4 | 0 | 71 |

Source: Field Study

Table 6.2 indicates that most of the scientists (66 out of 71) drawn from both institutional set up characterize their research thrust as a combination of both basic and applied research, whereas only three scientists from state sponsored institutes and four scientists from ICAR- sponsored research institute has classified their research thrust as applied research. Moreover, one scientist from state sponsored institutes characterizes his research practice as only basic research. Besides, none of scientists in study characterizes their research thrust as development research. Thus, a majority of the scientists in the study do not accept the classification of their research in terms of mutually exclusive terms.

A scientist from an ICAR- sponsored research institute, based on his experiences, puts it thus:

> Whether one's research is basic or applied depends on the programme of the particular scientist. One's research comes under the domain of basic science when it is interested in broadening the horizon of knowledge, that is, it is not used for industry or society. On the other hand, applied science is need based. It is meant to earn money herein research has got potential for commercial application. Applied research is basically driven by the market forces and government programmes. So, the distinction between basic and applied science is blurred. However, I will characterize my research thrust as both basic and applied. The research in which I am engaged attempts to generate new plant type or a new product or a good material. You see, we all start from basic research, but most often, we lose sight of its commercial application. I always try to have an applied goal for my basic research.

Similarly, a scientist from an SAU expresses:

> Basic science is doing something out of curiosity whereas applied science begins with clear motive of application. Commercial and market-oriented motives are often the driving forces in the case of applied science. I would like to characterize my current research thrust as both basic and applied. Though my research thrust aimed at solving the real-world problems-problems relating to our agriculture, farming community and the country, as a whole, it takes inputs from the fundamental properties of basic sciences. In this sense, you may term my current research thrust to be both basic and applied.

On equal measure, a scientist from an ICAR-sponsored research institute mentions:

> Both basic and applied components have characterized my current research thrust on genetic study of rice. We develop new technologies by doing basic research and applying molecular techniques. We apply the technique to achieve the results. As we are put in the ICAR set-up, my research is basically oriented towards applied research. Seed production has more applied components that benefits not only farmers but also industrial R&D organizations.

A plant breeder from an SAU asserts:

> I would like to characterize my current research thrust as bothbasic and applied. Basically, we are trying to see how rice crop interact with a particular insect. This plant-insect interaction comes under basic research. But my ultimate objectives are to develop pest resistant rice variety that could be used and beneficial to farmers. Hence, my research has also application component. I have been working in this area since last 15 years.

> Some of my outcomes of research are currently used to develop biotic resistant rice by various ICAR-sponsored and SAUs in the country.

According to a scientist from an ICAR-sponsored research institute:

> There should be no distinction between basic and applied science. Principally, in any research, one should realize that there would not be any applied research without basic research. Therefore, only when basic research finds application it turns into applied research. Even in applied research, there has to be a component of basic research; science has to be there. Without science, neither applied nor basic research will work. Therefore, I think the line between basic and applied research is very thin. Only for the sake of certain conveniences, these distinctions are made.

Another scientist from an SAU states:

> My current research is both basic and applied. Like, I generate mutations in rice- that is basic work. However, when I use these mutations in breeding programmes, then it becomes applied. Basic research basically means identification genes which confers resistance to certain stresses of plants. Whereas, transferring of identified genes to genes of a target plant through conventional or modern biotechnology tools are application side of research. Thus, basic and applied research cannot be demarcated. In contemporary plant science, they both are complementary and cannot exist independent of each other in any research activities.

From the above responses, drawn from multitude of institutes, it is apparent that for majority of scientists, the distinction between basic and applied sciences is getting blurred. However, responses of scientists also suggested that no research works are being carried out under the category of development research. Tools, equipment's and other instruments required for research are either outsourced to private enterprises or shared by collaborating with other institutes consisting required laboratory facilities.

### 6.3 Scientists' Opinions on the Development of New Agriculture Technologies

If agriculture is considered a deliberate domestication of plants and animals than technology is a human artefact developed across the time and space that act as a means to achieve the objectives of former. Technology development in agriculture is an on-going process where scientific knowledge is utilized to cater the changing requirements of society. This human achievement had, and continues to, shape society and the environment. New technology in agriculture can be attributed to all those innovations and developments made in the field of agriculture including technological, biological, agronomic, chemical, biotechnological information's and risk subsiding innovations that are introduced with keeping certain objectives in mind. Generation of new technology is considered to be important to upgrade existing technology. Thus, a profound and focused research program is considered as prerequisites of any technology development.

In this study, an attempt is made to capture the scientists' responses on the nature of technologies that are being developed in rice crop research in India. Scientist's responses suggest that they are engaged in myriads of technology development, demonstration, assessment, and refinement within the realm of rice crops. They are in views that technologies are developed in the responses to the needs of farmers, consumers, community, country and international trade. Scientists also asserted that sometime improved technology may not be innovative, but could be reallocations of available resources and realignments extant practices.

A scientist from an SAU expresses:

> Today, agriculture activities rest on scientific and technological advancement. Crop science in particular, is flying high by sitting on the shoulder of new technological developments. Some of the new techniques in rice crop such as alternate wetting and drying method, SRI Method, Aerobic Rice Technology, and so forth will be worth mentioning here. Aerobic rice is the one of the latest technology that reduces water consumption by growing rice crop like any other irrigated upland crop. Using molecular technology physiological traits of aerobic rice can be selected which would be helpful in enhancing water use efficiency sustaining the productivity. Presently, our research priorities are development of varieties for abiotic stress tolerance. At present our institution in collaboration with TRPI and National Research Centre for Biotechnology has launched a project for development of varieties for abiotic stress tolerance that is for submergence tolerance, drought tolerance and sodality tolerance. The purpose of this research is to utilize the untapped and unutilized land resources which will ultimately result in increase in overall rice production.

A scientist from an ICAR-sponsored research institute asserts:

> We here at CRRI have developed an environment safer technology to tackle leaf blast diseases in rice. This technology involves aqueous extract of Bael leaf @ 25 g/litre of water and steamed aqueous extract of Tulsi leaf @ 25 g/litre of water which was sprayed in the diseases infected field. The spray was repeated after 10 days. Subsquently, after 15 days, it was found that the spray was very much effective in controlling blast disease. The yield recovery was up to 80% to 85% as compared to 45% recovery in field sprayed by pesticide named ediphenphos (Hinosan).

A scientist from an SAU mentions:

> Our main objective is to develop new technologies that provides a yield advantage and increase the productivity. In fact, we are engaged in development of such new varieties that has high yield, high biotic and abiotic

tolerance than the old varieties. Our priorities are mainly focused on implementation of such technologies that are cost effective, labour effective, time effective and resource effective in practice. At present we are working on technologies such as SRI, DSR (Direct Sown Rice), Zero—Tillage System, mechanical transplanting of rice, Rice Fish Culture in Lowland Rice— wheat system, optimization of Rice Transplanting Date, Integrated farming system, Resource Conservation technologies, conservation agriculture and so forth. We are sure and confident that implementation of these technologies will help farmers by augmenting their farm production.

A scientist from an ICAR-sponsored research institute stresses:

> Our research team here at DRR have developed an eight drum seeder. This technology had been designed and fabricated to maintain crop geometry, spacing and crop establishment. It has been popularized by collaborating with IRRI under CREMET program. This equipment is cost effective, easily adaptable, user friendly and capable of being easily fabricated by local artisans. The device helps to maintain intercultural operations in the field by maintain plant and row spacing by utilizing cono-weeder. It saves 30 percent of total labour requirements, 20 percent of seed and 25 percent of water. It is effective during delayed monsoon and in scarce water and labor conditions. No negative impact on overall yields have been noticed by using drum seeder visa-vi manual mechanical and transplanting methods. It costs only Rs 2000/- the farmers can afford to buy this equipment's.

A scientist from an SAU shares:

> Despite substantial yield advantage over inbred rice, the adoption rate of hybrid rice in India is poor. To surmount this problem, we are working on a doubled haploid (DH) breeding technique. A doubled haploid (DH) is a technique in which genotype is formed when haploid cells go through the chromosome doubling. Artificial productions of doubled haploids possess great potential in plant breeding. Haploid cells are produced from pollen or egg cells or from other cells of the gametophyte, and then by induced or spontaneous chromosome doubling, a doubled haploid cell is produced, which can be grown into a doubled haploid plant. DH is a time effective technique as it saves a lot of time for the plant breeders by producing homozygous lines after a single round recombination. The variety developed by DH technique is expected to better yield and grain quality, can efficiently handle the problems associated with hybrid rice technology.

According to a scientist from an ICAR-sponsored research institute:

> We are working on trap crop technology. The use of trap crop technology is the planting of a trap crop to protect the main crop from a certain pest or several pests. It is being tested in several of the AICRIP locations throughout the country. The use of trap crop reduced the damage by half in the main crop caused by various pests.

A scientist from an SAU mentions:

> The benefits of the new techniques over the older one is that new techniques helps in conservation of soil health and water for suitable use of these precious resources in future. For example, at present we are working on Aerobic rice, which reduce the water requirement of the crop by 50 per cent without sacrificing production and productivity of the crop and be able to conserve tremendous amount of energy. At the same time, it also reduces methane gas emission, as it reduces the water consumption which caused decomposition of organic matter in the absence of oxygen and this process generates methane. So it is eco-friendly. Similarly, SRI involves certain management practices for plant, soil, water and nutrients. It saves water, compose is used instead of chemical fertilizer hence it is good for soil, environment, water and health.

A scientist from an ICAR-sponsored research institute points:

> All new techniques on which they are working whether it is SRI, DSR, ZTS, Mechanical Transplanting (MT) of rice. Conservation agriculture etc. one of the main objectives of these techniques iis to reduce the water consumption as it is required for production of one KG rice. Secondly, improving soil health through eliminated puddling (SRI, DSR, ZTS, MT). as puddling is reduced it reduces methane gas emission. Thirdly, our main objective is also to reduce the use fertilizer, chemical and pesticides and emphasis on organic farming by using burmicompost and other organic materials which are ecofriendly and health friendly.

Scientists in the study mention that technological innovations in rice research primarily have two main objectives: (i) to develop technologies that can increase the productivity of rice in general and to better-endowed areas in particular, where production of rice has stagnated owing to losses in soil fertility and water scarcity; and (ii) to focus on developing technologies that are free from environment externalities and effective in areas where green revolution remains elusive, particularly in rainfed areas. According to a majority of the respondents, the process of new technology development involves identifying production constraints at the farmer's field and to work out an appropriate solution to surmount them. The involvement of target group plays a crucial role in the development of technology. There have been gradual shifts in the technology development programmes. In traditional technology development programmes the principal objective was to enhance the productivity of crops. But now the focuses are on biodiversity and biosafety. Contemporary technology development programmes give due consideration to sustainability of natural resources and environment issues. It emphasizes maintaining harmony with farmers and natures. These dimensions have given a new trajectory to the technology development by making it human and environment friendly.

Efforts are now being directed towards developing technologies that maintains equilibrium with nature, makes agriculture self-sustainable and increases productivity of crops. However, it is also conspicuous from the responses of scientists that they are much more interested in speaking about technical relations of technologies and social relations of technologies are lacking from their narratives. Social dimensions of technologies, such as accessibility, equity, acceptability, and social viability of technologies are seriously missing from the dialogues of the scientists. They insist more on the nature of technologies instead of farmers, who ultimately uses the technologies. Attention is more on characteristics and functional aspects of technologies rather than the social conditions in which expression of technologies are possible.

## 6.4 Scientists' Opinions on Slow Adoption of New Agricultural Technologies among Farmers

Scientists engaged in agricultural research and development promote new technologies, such as new varieties, farm inputs and management practices. The success and failure of any new technology in agriculture depends on the rate and volume of adoption of that particular technology among the farmers. The rate of adoption of technologies among farmers indicates the efficiency of technology generated and effectiveness of technology transfer. By adopting technologies farmers provide critical inputs to the process of technology development. It is the farmer, who is real integrator of scientific, economic and social aspects of technology. The process and result of adoption of any new technology by farmers ensures how much a technology is socially embedded. The dissemination and training of farmers to adopt any novel technologies and techniques are an integral part of agricultural research and development work. However, the common experience is that the adoption of an apparently useful agricultural technology is slower than predicted, or desired, by extension agents (Röling 1988).

In the context of India, studies carried out by various researchers show that the adoption of new technologies among farmers is very poor. What are the factors that govern the adoption or non-adoption of any technology generated by scientists? In developing countries like India, small and marginal farmers do not adopt even a low cost technology in some regions. Thus, scientists in this study reflect on the issues of low rate of adoption of technology by farmers cultivating rice crops. Scientists not only develop and promote technologies but also follow the results as it demonstrates how much efforts and understanding about the technology that they promote to fit into the complex pattern of agricultural change in which all farmers participate. Forwarding reasons for low adoption of new technologies among rice-growing farmers, a scientist from an ICAR-sponsored research institute expresses:

> Even in advanced agricultural countries farmers don't make changes easily. Technology adoptions are slow. In my opinion, it can be due to establishment costs, the way that the changes fit with the broader farming system, belief systems, other pressures from people associated with the farm business, habit, family and community expectations, etc. I don't know much about farmers of other countries, but in India they are small farmers, who are risk averse. They don't necessarily appreciate someone coming and challenging their established perception about cultivation and suggesting them how to run their farm.

A scientist from an SAU emphasizes:

> I believe that reasons for poor adoption of technology by farmers are culturally-driven rather scientifically-driven. Farmers feel very comfortable with their cultural practices and very reluctant to come out from this comfort zone. Sometimes it might also be possible that the processes required to adopt the technology is more cumbersome or unwieldy than what they practice. Researchers would have to go the extra mile to find out what are reasons for non-adoption of technologies by farmers. Another problem in my view is the gap between extension and research. The extension agents act as a bridge between researchers and farmers and if this link is weak then any technology fails. Currently, most of agricultural institutes in our country has weak extension services. Even KVKs which had been started by center mainly to combat this problem suffers from technical manpower scarcity and management problems.

A scientist from an ICAR-sponsored research institute points:

> Indian farmers have a set of perceptions about their ways of farming and trust only themselves. Instinctively, they wish to continue with same production process that has been in practice for decades unless they are paid or forced by an employer. Mostly farmers are of orthodox mentality. You will not believe their intention is not produce with scientifically sound techniques – this is the dream of any scientist in India. To change their perceptions and make it scientific will require study, time, money, trust building and also ability to cope with change.

A scientist from an SAU mentions:

> If we speak of Indian context, there are multiple reasons for slow or non-adoption of a technology in rice farming. The first is the cost of technology and ability of farmers to pay for that. My personal experiences are that even if there is technology awareness among farmers, they lack the capacity to purchase it and hence the adoption remains limited to selected few big farmers who can afford it. Second reason is lack of timely availability of technology. Even if the technology is cheaper in comparison to current

technology in use and farmers are ready to adopt it technologies are often not available there. Thirdly, awareness of technology is also an important reason, i.e. they may not be aware about it, its utilization, potential benefits and so forth. The extension systems in the country have to make sure that they not fail in creating awareness, and the responsibility of government and other agencies is to ensure that a particular technology is available and equally distributed among common farmers for its adoption.

A scientist an ICAR-sponsored research institute stresses:

For me reasons behind failure of technology transfer to farmer are multifaceted. There is big linkage gap between researcher, extension personnel and farmers. Our extension personnel's are directed to transfer all type of technologies developed by scientists. They are not very much conversant with each of the technology and lack confidence while interacting with farmers about the details of technology. In my opinion, there is need of subject wise extension specialists; i.e. practical experienced people who can persuade and trained farmers for adoption of novel technologies. Thus, I wish to say that our extension personnel's should be subject matter specialist with good practical experience. Good extension personnel should be duly credited and also motivated with monetary and non-monetary incentives for popularizing technologies among farmers.

A scientist from an SAU mentions:

Farmers are accustomed to the farming techniques that they have practiced for centuries and learned from their forefathers. They don't want to take risk. Additionally, controversies surrounding agriculture biotechnology have made farmers highly suspicious about the sustainability of the new technology. Generally, this problem is multifaceted and requires comprehensive study.

A scientist from an ICAR-sponsored research institute affirms:

Education status of farmer is an important reason that affects the adoption of scientific technologies. There are various technologies which are profitable in long term, immediate or short term gain may not be visible. Every technologies requires some incubation period before producing desired outcome. Thus, especially technologies having long term impact are adopted mostly by farmers with good education background. This is more applicable in case of developing and under-developed countries. The technologies with less incubation period are labeled as trustworthy by farmers and yes also, in poor countries adoption/non-adoption of technologies are also determined by government policies. Additionally, more emphasis is given to generation of technologies instead of diffusion and adoption of technologies as these countries are often seen as technological scarce countries.

A scientist from an SAU elaborates:

Apart from SAUs and ICAR-sponsored institutes, there are three main public players for agricultural technology dissemination in our country. These institutions are Krishi Vigyan Kendras (KVKs), government departments

> and the Agricultural Technology Management Agency (ATMA) but among these the performance of KVKs is very poor. Lack of infrastructure in KVKs and block offices, lack of technical personals, and lack of proper planning and regular monitoring of their activities by a high level committee. So the extension machinery in the State is still very weak and inadequately staffed. As the State machinery for supply of seeds, fertilizers, pesticides, etc., is almost crippled, the private agencies have penetrated into the villages and there are often allegations of selling spurious seeds/ pesticides by few of them in the absence of any effective quality control mechanism. Further, markets are unorganized and the farmers are exploited by the unscrupulous traders.

A scientist from an ICAR-sponsored research institute mentions:

> In my opinion, various bottlenecks in extension services are main reasons for non-adoption of a technology by farmers in rice cultivation. There are various flaws in extension policies of our agricultural institutes governed by center and state. There is no common classification who is involved in extension. Most importantly, extension policies of institutes are dissemination-centric instead of problem-centric. Moreover, extension services in India is subject to a set of norms which extension agent has to follow or accomplishes by disseminating technology to the farmers. Synergies between research, extension agent and farmers are lacking. There is a complete coordination failure between SAUs and ICAR sponsored institutes. Farmers need a broad range of support including organization, technical and marketing aspects. And lack of these integrated supports impedes practical application of new knowledge restricting it to theoretical or rhetorical application.

Now it can be inferred that scientists are of the opinion that when farmers approach a technology, weak extension services in the country are the primary reasons for low adoption of new technology by farmers. In India, for scientists, farming practices are culturally organized. Farmers attach cultivation with their culture and follow traditional practices. Indian farmers lack scientific approach and attitude. Additionally, they make compromises even if the traditional technology in uses is less productive in comparison to an available new technology but do not take risk of shifting and adopting new technology. Therefore, farmers are risk averse. The second reason that emerges from this study is weak extension services delivered to farming community by public institutions in India. Agricultural research is limited to an academic endeavor. It is loosely linked with farmers owing to weak extension services. Extension system is a bridge between researchers and farmers. Owing to weak extension services research and farmers continue to be two separate domains that is not functionally linked to each other. Research is not supported by real problems faced by farmers at grass-root level unless there is a strong link between research and farmers which is only possible by establishing efficient and effective extension services. However, the success of any technology depends upon its wider cultural acceptance. Cultural acceptance is based on rule-governed shared culture (Weber 1920). It is based on indirect or explanatory understanding of social action which is related to interpretative understanding of social action. Therefore, adoption of any technology invites multiple interpretations.

### 6.5 Scientists' Perceptions about Genetically Modified Technology

The discovery of the molecular nature of genetic material in 1944 has enabled geneticists and capitalists to put consistent and concerted effort for utilizing DNA to modify the characteristics of living organisms; a process otherwise called as transgenics. Although biotechnology and genetic modification commonly are used interchangeably, GM is a special set of modern biotechnological tools that alter the genetic makeup of organisms such as animals, plants, or bacteria. The principle underlying the production of genetically modified (GM) involves identifying individual genes of interest that control particular characteristics, separate them from original source and transferring them directly into another cells of an organism or a plant. GM seed production is based on knowledge of traits at the genotype or molecular level.

Like all new technologies, GM crops also poses some risks both known and unknown. Controversies surroundings GM technologies mainly revolves around social, political, economic, cultural, technical, legal, ethical, human health and environmental concerns. This has generated an intense debate among the major stakeholders.

During the field study three out of 12 SAUs viz. Tamil Nadu Agricultural University, Coimbatore; University of Agricultural sciences, Bangalore; and Punjab Agricultural University, Ludhiana are empirically found to be engaged in GMOs research. Among ICAR-sponsored institutes, four out of nine viz. Indian Agricultural Research Institute, Pusa (New Delhi); National Research Centre on Plant Biotechnology, New Delhi; Indian Institute of Rice Research, Hyderabad; and National Rice Research Institute, Cuttack are empirically found to be carrying out research on GMOs.

The debate surrounding development and application of new agricultural technology is mostly centers around the claims of scientists, policy makers and representatives of the biotechnology industry. The general public is dubious about the motives of scientists, political institutions and industries involved. The dilemmas posed are nested, embracing value questions, scientific uncertainty, and contextual issues which have occasioned extensive discussion and debate among major stakeholders. Within this picture, open questions concerning GMOs were posed to the scientists with an objective to know their opinion regarding the development and implementation of GMOs in Indian agriculture sector. Obviously, this study is not aimed at reaching any conclusion on this controversial matter. However, an attempt is made to empirically capture the central claims made by scientists on GMOs issues that can further contribute to the discussions related to this delicate aspect of GM technology. An attempt is made in this study understand the socio politics of agriculture biotechnology operating in context of India in general and rice research in particular.

Presenting his opinions on GMOs a scientist from an ICAR-sponsored research institute asserts:

> Today GM has become heritage of handful developed nations and Industries. Few countries and Industry are dictating at the global level in field of agriculture biotechnology. It is us who are responsible for this situation. There have been continuous and consistent efforts to obstruct GM research in India. We have not allowed our scientists to work freely on GMOs. Today multiple public institutions are working on GMOs and I am confident enough that they will break the ice and come up with effective GM products. India has best brains in area of biotechnology. Medical-biotechnology is doing well and there is no reason that agriculture biotechnology will not do well if scientists are given autonomy and conducive environment. GM technology holds great potential for transferring genes across species, genera, and perhaps family barriers. For an example, with the help of GM Technology the resistance of maize to wheat stem rust diseases might be used to make wheat resistant to this disease. Thus I am in favor of introducing GM seeds because it has bright and promising future in developing country like India. GM technology can turn arid land into arable land.

Highlighting the benefits of GMOs, a scientist from an SAU advocates:

> The benefits of GM crops will outweigh all the controversies once it will find its place in farmer's field. GM crops has great potential in poverty and hunger ridden country like India. Its introduction will have lowered the price of food and will increase the farmer safety by enabling them to use less pesticide. It will raise the output of food grains by 30 to 40 percent, helping some people to survive who would not have without it. If it is more widely adopted around the world, the price of food would go lower, and fewer people would die of hunger. In the future, the contribution of GMOs will become all the more significant. More food grains will be required to feed the bourgeoning population. Additionally, climate change will make much impact on flora and fauna. GM crops could produce higher yields, grow in dry and salty land, withstand high and low temperatures, and tolerate insects, disease and herbicides.

Emphasizing on the changes brought by GM technology at molecular level, scientists from an ICAR-sponsored research institute argues:

> I would like to share my experience on matter of substantial equivalence regarding GM product. On question of equivalence there are lobbies and they use multiple vocabulary to convince. In breeding technique two genomes interact with each other and thousands of changes occurs. When a single gene is transferred, then also it influences the activities of other genes. In molecular sense certainly they will be never equal. In my opinion equivalence should be checked at the overall utility level of product and tests are to be conducted for the other human needs. I know these changes are there. I have transferred one gene into rice plants. It affected 600 other genes but result is that the plant develops tolerance and performs well in water-deficit conditions.

Reflecting upon the technical complexities concerning GMOs a scientist from an ICAR-sponsored research institute points:

> Main controversy surrounding GMOs is all about human health and environment. Antagonist's talks about that altering of genes in crops through GM technique would cause to unpredicted and unintended results. Let me tell you, since inception of human civilization we have been critically engaged in selectively crop breeding which involves manipulation of plant genome. For an example, wheat has long been strictly a human engineered crop. It could not survive outside farms as it seeds do not scatter. Triticale is a very old hybrid of wheat and rye found in some flours and breakfast cereals. In this sense, wheat itself is a cross hybrid. This demonstrates that nature is involved in this process and so do scientist. Thus, if conventional plant breeding is widely accepted and has caused no known human and environmental problems then why not GM technology? Conventional plant breeding and GM technique, which is a form of modern biotechnology are the two sides of same coin.

Showing concerned about the adverse effects of GMOs on environment, a scientist from an ICAR-sponsored research institute emphasizes:

> GMOs debates are based on wrong assumption that GM foods are an ultimate solution to hunger and poverty. In fact, reality is that GMOs are a menace to our biodiversity, threat to our agriculture, inimical to our farmers, detrimental to our people's health, and deleterious to consumers' choice. GMOs are a false solution to climate change. It is myth cultivated by few industry and developed nations for their vested interests. Many countries, such as France, Austria, Italy, and countries like Vietnam and Thailand have banned GM crops at the policy level. In India, situation is very chaotic. The current GMOs modified regulatory system in the country is inherently flawed. Our public research institutes are plagued with poor infrastructure, finance and manpower. Our current agricultural paradigm is input-intensive and based on corporate control inflicting destruction of farmland and farmers' livelihood. Hence, I don't find any one good reason to implement GM technology in India.

Opposing the introduction of GMOs in Indian context, a scientist from an SAU opines:

> I don't wish to comment on the prospect of introducing GMOs and about possible future of GMOs in India. Rather, I would like to comment on the status quo of GM research in India. After pumping a huge amount of money and manpower in agricultural biotechnology research by government of India, since last two decades what is the outcome? I am not aware about the research intensity of private enterprises. But being a part of government institution I know that not a single GM variety has been developed by any government institute. Nor there has been any land mark achievement or innovation in the field of GMOs by public institutes in country. To put it succinctly, the project GMOs has failed in India. Thus, instead of wasting money, time and energy on a controversial alien technology we should focus on other alternative technology that has promising future in biodiversity rich country such as India.

Whereas, according to one of the senior scientists of an ICAR-sponsored research institute:

> Past experiences about the performance of industry in this area are intimidating. They exploit farmers by charging exorbitant rates for GMOs. This is the experience in the case of Bt. Cotton. The cotton seeds used to only cost RS. 5 or RS. 6 per kilogram unto seeds were produced by public sector. Now, from RS. 5 seed cost has jumped with GMOs to RS. 3600 per kilogram. When Bt. Brinjal discussion was going on, the company already started booking seed at Rs.50000 a kilo. You can imagine to what extent the prices will go up. Owing to patent regime they had monopoly over genetic resources. The common farmers are not benefitted from the use of GM. Even after introduction of Bt. Cotton situation has become worst in western India. Seven years after Bt cotton came in, there has been an increase of 60 percent in the average annual number of suicides of farmers in Maharashtra as per the National Crime Bureau records. This is the data shared by Mr. P. Sainath. The Indian institutions have not made adequate advances in using this technology for meeting the national needs. GM seeds are suitable for developed countries. Thus, there are chances of domination of world food production by a few companies, increasing dependence on developed nation and also Bio-piracy, or foreign exploitation of natural resources.

Divulging the dilemma of researchers to express on GMOs issue, a scientist from an SAU asserts:

> GMOs are not the best or only possible solution to a set of problems. There are other efficient tools and techniques available which would be very effective in Indian agricultural context. Researchers or scientist knows everything but they refrain to speak. We have orders from the institute that on GM issues, only director can speak and we are instructed to not entertain media or any type of interviews especially on GMOs. More scientists could speak up about the truth of genetic modification but doing so might result to their excoriation in academics and media. This could seriously jeopardize their funding of ongoing projects and for future projects. Speaking against

> GM technology makes, you subject of coordinated attacks by your colleagues. It can cost your reputation. Even there may be chances of being thrashed. Theses all fears restrict researchers to speak and write about GMOs in public domain.

A Few respondents in the study also prefer to take a middle ground on the question concerning GMO issues. These moderate voices talk about stepping up and setting up of infrastructures for the risk assessments and safety testing on GM technologies. They mainly advocate for keeping a close eye on health and environment risks related to GMOs. However, they do not rule out GM crops for special scrutiny before implementing into the farmer's field. According to one of the senior scientist from an ICAR-sponsored research institute:

> Before introduction there is need of certain infrastructures so that its consequences, long tern effects, should be studied, it should be properly tested and experimented. There is need for setting up of certain laboratories so that we can carry same works (produce GM seeds) in our country that are carried out in foreign countries. So GM seeds should be introduced with proper cautions and safety rather than a blanket.

Another scientist from an ICAR-sponsored research institute opines:

> I wish to tell you one thing that even established plant breeders are not trained enough in GM technology and they do not understand molecular biology well enough. There is no doubt that GM technology has a great potential in poverty and hunger ridden state like India. But before implementing GM seeds in India there is need of proper infrastructure development and proper training should be given to scientists. Otherwise, it will lead to serious repercussions.

A scientist from an SAU mentions:

> For me it is not the excellent time to introduce GM seeds in India. Although rigorous efforts are going on across the globe to assess the pros and cons of GM seeds but I still believe we need more time because GM seeds have been not subjected to all the risk factors. At present, the prudent course of action for developing country like India is to establish the risk factors, properly evaluate it. In addition to this, there is also need for a strong regulatory mechanism to control the GM research in India.

If we critically examine these responses, diversity of viewpoints among scientific community is quite palpable. On the questions of GM technology, the scientific community is split into three groups. First consists of scientists who are vehemently advocating for the application of GMOs in Indian agricultural sector without any delay. Secondly, comprises the scientists, who are resisting the implementation of GMOs in

Indian agricultural context, and thirdly, includes scientists who prefer to take a middle ground on the questions concerning GMOs. These moderate voices talked about stepping up and setting up of infrastructure for the risk assessments and safety testing on GM technologies. They mainly advocate for keeping a close eye on health and environment risks related to GMOs. However, they do not single out GM crops for special scrutiny before implementing into the farmer's field. However, it is obvious from the above responses that there is a complete lack of consensus among the scientific communities on the issue of GM technology. The conflicting nature of responses is apparent, which can be better understood in the wide variety of meanings attached to GMOs. The GMO issues have been construed with different meanings by the scientists. Collective representation is replaced by individual interests and meanings.

### 6.6 Development of Indian Version of Golden Rice: A Case of Swarna

Golden rice has become one of the most controversial grains in the world. Since its discovery (2002) it has generated a lot of controversies. In context of India, since 1999, after a long journey of struggle (see chapter II for details) finally an attempt was made at the Indian Agriculture Research Institute (IARI), New Delhi, to develop Indian version of golden rice. This attempt was carried out under second phase (2006 to till present) of golden rice project in India. At theIndian Agriculture Research Institute (IARI), New Delhi, the variety of Swarna and its flash flood resistant variety Swarna Sub1 were selected for introgression of provitamin A trait. Marker assisted backcross breeding (MABB) technique was deployed for incorporation of provitamin A traits into genetic background of Swarna. Initially, researchers subscribed to SGR2-G1 event as an event for deregulation. However, later this event was withdrawn and discontinued owing to certain regulatory issues. Currently, SGR2 R1 event is being widely used as donor under public sector breeding programs and advanced backcross derived lines ($BC_3F_4$ and $BC_4F_4$). It has total carotenoid content within the range of 6.5 to 26.7 µg/g of endosperm in the freshly harvested samples. Moreover,it's recurrent parent genome recovery is within the range of 89.47 to 96.42% are available. For stability of transgene inheritance and expression, the pattern of transgene inheritance were studied thoroughly with the help of PCR analysis in$F_2$, $BC_1F_2$, reciprocal $BC_1F_1$and $BC_2F_2$ populations derived by crossing a pCaCar event of golden rice line developed in the genetic background of IR64 with Swarna. Scientists also analyzed the transgene inheritance in$F_2$ and $BC_1F_1$ and $BC_1F_2$, which were derived through utilizing SGR2 events in the background of Swarna .

For the transgene in$F_2$ and $BC_1F_1$ (Swarna × $F_1$) populations,segregationdistortion was observed.whereas the transgenein the reciprocal $BC_1F_1$ ($F_1$ × Swarna) cross, demonstrated normal Mendelian segregation ratio of 1:1. Similarly, same trend was also observed in the case $BC_2F_2$, where the transgene exhibited an expected segregation ratio of 3:1. Talking about transgene inheritance, segregation distortion was observed for transgene in $BC_1F_2$ and $BC_2F_2$ families derived utilizing SGR2 G1, T1 and R1 events.

Since, SGR2R1 event was prioritized by plant scientists as most appropriate candidate event for deregulation, a comprehensive phenotype characterization of backcross derived lines in Swarna background utilizing SGR2R1 event as donor was carried out. However, outcome of the experiments was not convincing. The outcome revealed that the transgene homozygous plants visa-vi to their hemizygous and null siblings, explicit reduction in height of the plant, shortened internodes, pale green leaves shaped in form of whorls, elongated nodal buds causing to short panicles that remain partially within the leaf sheath. This type of phenotype is considered as serious limitation in the development of a product with commercially viability. This resulted in urgency for the researchers to explore the reasons behind unexpected behavior of plant or altered phenotype of transgene homozygotes. Through nucleotide blast analysis,scientists found that transgene integration on chromosome 1 in kaybonnet (donor) had disrupted the exon 1 of endogamous OsAux1 gene causing disruption in its overall coding system and disturbing its function. Likewise, time expression analysis also confirmed the absence of the expression of OsAux1in homozygous lines. The β-carotene content of the transgene homozygous line was to be found in the range of 6.5 to 260μg/g. Further, seeds were harvested at physiological maturity and were stored under the observation of scientists. It was duly quantified through high-performance liquid chromatography. After analysis scientists found that there was gradual decrease in carotenoid content upon storage to an amount of 70 percent in four to five months. This prompted a long discussions and deliberations among the scientists about the experiment results of Swarna. Finally, it was declared that it is not viable for cultivation. Sharing its opinion about the commercial release of golden rice in India, a scientist from IARI, New Delhi, points out:

> We are in no hurry! Golden rice will be made available to farmers and consumers of country only if it is: (a) successfully technologically advanced into varieties that retain the quality of its original variety 'Swarna' in terms of the same yield, grain qualitypest resistance; (b) meets the safety standards of GMOs; (c)tested and approved by national regulators; and (d) demonstrates to improve vitamin A level not only under laboratory

> conditions but also under community conditions. Far from a blind and premature rush to market, we are taking an extremely cautious approach towards Golden Rice research and development. We are keeping a close eye on the behavior of gene in the laboratory and plants in the field simultaneously. We are continually examining the data generated from experiment and refining the methodology accordingly, before reaching to any finale conclusion and giving consent for its commercial release. In other words, we are scrupulously following the safety and precautionary principles.

Substantiating his argument for the undesirable outcomes of experiment conducted on Swarna, a scientist from IARI, New Delhi asserts:

> Yes, I would like to inform you that the results of experiment conducted on Swarna are not convincing. There is nothing to worry about it. Failures in research are frequent and inevitable. In my opinion, we should talk more about failures because it always motivates you to do better. Plant science has its own secret. It takes effort and time to unlock the secret of gene expressions. Moreover, transgenic technology is a complex process, where an alien gene is integrated into plants original gene. Owing to some human or technical errors, sometimes, it might give you unexpected and undesired results. But this doesn't mean that it can't be fixed and we should forget about it and bury them simply by saying that it has failed. We are re-examining the data of Swarna and trying to find out what and where it went wrong. Once it would be identified, I can assure you that we will have our desired result.

Falling on same ground, another scientist from IARI, New Delhi emphasizes:

> Not only us, simultaneously, IRRI is also working on beta-carotene-enriched golden rice. IRRI has conducted series of Multi-location Field Trials (MLTs) of golden rice in Phillipines. MLTs of golden rice have been also scheduled in Indonesia and Bangladesh. Like us, after the thorough analysis of the data captured from the series of MLTs conducted in the Philippines, IRRI admitted that there are certain shortcomings. The first round of MLTs was conducted by using GR2 event 'R' (GR2-R), which is considered to be one of the most advanced versions of golden rice. This first round was carried out in 2012/13. The main objective of this round was to assess the performance of this version of Golden Rice in different locations in the Philippines. But IRRI admitted openly that preliminary results of the tests were mixed. Test results exhibits explicitly that beta-carotene content in the grain was up to the target level, but average yield was unfortunately found to be lower in comparison to the local varieties, which are already preferred by farmers. In my opinion, some more research is required before the golden rice to reaches the plates of common people.

Optimistic about the future of golden rice in India, a scientist from IARI, New Delhi, stresses:

> The attempt to develop Indian version of golden rice so far in the genetic background of Swarna has several shortcomings. We are not concealing anything and are very much open to these short comings. Our analysis shows that characterization and selection of the transgenic events must be carried out with utmost care. The analysis should not only be restricted to transgenic events for the target trait but their overall phenotype and agronomic performance should also be assessed. We hope that one day the dreams of golden rice will become true and it will be in use by farmers and consumers shortly.

Empirical evidences of the experiment carried on Swarna at the IARI, New Delhi, pose serious questions on the claims of scientific community about the universal applicability of GM technology in general and application of golden rice in Asian context in particular. It also questions the scientific assertion that the product development (golden rice) is ready to be used since its invention in 2002. The result of tests conducted at IARI reflects that like any other technology GM technology is also contextual in terms of natural settings, geographical location, climate, soil, environment, and ecological-social habitat. The case of Swarna can be best understood in terms of Feenberg's paradox of complexity. According to Feenberg's (2010) When a technology is decontextualized either by abstracting the useful aspects of materials from their natural connections or by removing it from their natural context and transferring to alien locales, needs recontexutalisation in a new technological niche which is not always successful. Likewise, Swarna was decontextualised from its natural setting by disturbing its natural genetic setting through injecting an alien gene into it. It was transformed to enrich with a new trait so that it becomes useful in a new context. Also, this indicates that golden rice that had been designed especially for Asian people to surmount Vitamin A deficiency has been uncritically imported and any attempt to introduce it as blanket without thorough rigorous testing might fetch unprecedented results. Holistically, it has casted doubt on the safety and predictability of golden rice in Indian context.

### 6.7 Policy Imperatives

The GM technology has become arena of struggle between politics, science and public. GM controversy is not situated solely in the agriculture space but also in political space of India. The controversies mainly involve critical issues such as application of GM technology in India, orientation of public institute research, field trials, the independence of research on industrial sector, its public accountability and other interests. The important characteristics of the controversies, struggles and tensions over GMOs are not limited to scientist's laboratory and farmer's field but also are closely linked with multiple political actors, institutions and their practices. Frequent changing role of political institutions regarding social and technical regulations of agriculture biotechnology are profoundly connected with the series of events occurring in field of agriculture biotechnology in India. A degree of regional politicization has occurred in India prior to official release of the Bt cotton in India. Currently, In India there are nine states namely Punjab, Haryana, Rajasthan, Madhya Pradesh, Gujarat, Maharashtra, Andhra Pradesh, Karnataka and Tamil Nadu where Bt. Cotton is commercially cultivated. On Bt brinjal, the state goverments of Chhattisgarh, Andhra Pradesh, Karnataka, West Bengal,Bihar, Orissa,Madhya Pradesh and Uttarakhand have expressed apprehensions on the safety of Bt brinjal and have called for extreme caution as Bt brinjal is the first GM food crop to be introduced in the country. The Governments of Kerala and Uttarakhand have informed that they have taken a decision to prohibit environmental release of all GM seeds and keep the State totally GM free. State Governments of Bihar, Kerala and Madhya Pradesh have informed that GM crop field trials will not be allowed in the State. The Supreme Court is hearing a public interest litigation that has sought a ban on open field trials. Thus, stance of state governments varies from state to state. A scientist from an ICAR-sponsored research institute mentions:

> The stance of government on GMOs is confusing. Congress government has put ban on field trials of GMOs. But current BJP governments are optimistic about GMOs. In recent development the environment ministry has allowed field trials of two varieties of genetically modified (GM) brinjal and mustard, almost 18 months after the previous government ordered a freeze on such tests. Ministry permitted the Delhi University to hold trials for a mustard variety and Maharashtra-based Bejo Seeds Pvt Ltd to test Bt brinjal.

Another scientist an SAU expresses:

> Due to some political issues government is not promoting the genetically modified seeds. In 2011 state government (Bihar) assigned us a 68 lakh rupees' project on Golden rice seeds. It was solely state funded project and the infrastructure required for the project such as laboratory is full-fledged ready for the test to be conducted but government has put hold on this project and is not giving no objection certificate.

A scientist from an ICAR-sponsored research institute stresses:

> Government's role is dubious on the issue of GMOs in India. It was BJP government that cleared first GM crop Bt cotton for commercial cultivation in 2002. Contrary to this, UPA government imposed a moratorium on

> commercial release of Bt brinjal in 2010. Again in 2014 after regaining power BJP led government is looking to promote GMOs. Hence, GMOs related decision-making process has been on Achilles heel for Indian governments. Frequent changes in policies has killed the pace and vigor of scientific research in India.

A scientist from an SAU points:

> On the decision-making regarding GMOs, Indian government is playing a dangerous game. State governments are divided on implementation of GMOs in India. Few selected ICAR- sponsored research institutes, SAUs are allowed to conduct field trials but others not. Moreover, there is no check on researches and field trials carried out by private enterprises. From 2011 it has become mandatory to take NOCs from state government. The role of government which represents largest democracy of world has been undemocratic in context of GMOs in India. GMOs controversy in India is outcome of dirty politics and there is no social and technical problem associated with GMOs.

A scientist from an SAU asserts:

> Development and success of any technology is based on free political will of a country. Unfortunately, in India decisions regarding GMOs are still in hands of government and bureaucrats in power. An enhanced conflict of interest of central government, state government, political party, political ideology, and various pressure groups has contributed to the down fall of agriculture biotechnology research in India. The role of political institutions is questionable in context of GM technology. For an example, recently the Maharashtra government cleared 'no objection certificate' to conduct field trial of five GM crops namely maize, rice, brinjal, cotton and chickpea in the state.The Maharashtra government has permitted to conduct field trial of BT rice and two abiotic stress tolerant rice varieties that are drought resistant and nitrogen efficient. But ban on rubber remains. Beside this, states such as Punjab, Haryana, Delhi, and Andhra Pradesh have cleared NOCs to conduct field trials of few biotech crops. But contrary to this, instates like Rajasthan and Madhya Pradesh ban on such research activities continues.

It is evident that few states are promoting, few are neutral and few states have imposed restriction on GMOs research activities. Differences between state and central government on the issue of regulation of GMOs have altered the politics of India. National politics is being replaced by state and regional politics. These changes have brought with them a new discourse in terms political geography of the country. It has created a new political geography in India. This new political geography is not stable and unified. In spite, it is being reformed, redefined, reorganized, strengthened and weakened. National interest is less important and regional interest has become more prominent.

## 6.8 Complexities of GM Policies: A Case of Calcutta University

India's policy regulation over agriculture biotechnology field covers a broad spectrum of discourses, topics, actors and institutions. Currently, regulatory mechanisms in the country constitutes of Genetic Engineering Appraisal Committee (GEAC); Review Committee on Genetic Manipulation (RCGM); Recombinant DNA Advisory Committee (RDAC); State Biotechnology Coordination Committees (SBCC's); District Level Committees (DLCs) and Institutional Biosafety Committee (IBSC) that has been established across the time at state and central level to regulate GMOs activities. Apart from this, these institutional mechanisms are also supported by bio-safety guidelines such as Recombinant DNA Safety Guidelines, 1990; Revised Guidelines for Research in Transgenic Plants and Guidelines for Toxicity and Allergenicity Evaluation, 1998; Guidelines and SOPs for the conduct of Confined Field Trials of Transgenic Plants, 2008; Guidelines for the Safety Assessment of GM Foods, 2008 and Protocol for Safety Assessment of Genetically Engineered Plants /crops, 2008. These guidelines are updated at regular intervals keeping in tune with biotechnology practices and development at national and international level. Additionally, India is also signatory to 17 different international conventions/agreement/protocols such as Convention on Biological Diversity (CBD),Cartagena Protocol on Biosafety (CPB),Nagoya Protocol on Access and Benefit Sharing and so forth pertaining to biodiversity and biosafety. Albeit, this enormous wide policy framework has gradually evolved in last three decades but in practice it has failed to mark its existence. Therefore, India's policy- making and policy-implementation related to GMOs varies across actors and institutions. GM technology in India suffers from multi-level governance structure. There is lack of single and uniform policy. Single policy framework and its universal execution within country are absent.

In 2010, scientists from the department of botany, Calcutta University approached Review committee on genetic manipulation (RCGM) for conducting event selection trials with 10-meter isolation distance on seven transgenic rice (Orzya Sativa L) which contains gene for high iron content. Trials were to be conducted in two seasons at rice research station, Chinsura, in Hooghly district of West Bengal. In November 2010, the RCGM recommended the proposal of Calcutta University to Genetic Engineering Appraisal Committee (GEAC) for approbation. A meeting of GEAC committee members was held and matter was deliberated. The GEAC committee observed that the proposal of Calcutta university about isolation distance of 10 meters is not in the compliance with Indian Minimum Seeds Standard Certification,1988 (IMSCS), which authorizes 200 m isolation distance to prevent genetic contamination of germplasm of other crop or plant. Consequently, the GEAC committee ratified the proposal with subject to implementation of 200-meter isolation distance. Accordingly, RCGM was directed to issue the permit letter to the university. Subsequently, resisting the GEAC decision, the botany department appealed to the member secretary, GEAC, by referring that as per guidelines of Indian Minimum Seeds Standard Certification,1988 (IMSCS), the requirement of 200-meter isolation distance is for hybrid rice and 3 meter is for inbred lines. Their proposal is for transgenic rice which falls under the category of inbred rice.The matter was reconsidered and a GEAC meeting was held in January, 2011. In this meeting committee found that the claim of Calcutta University was valid. IMSCS, 1988, prescribes 3-meter isolation distance for inbred lines and 200 meter for hybrid lines. Consequently, GEAC overturned its earlier decision and issued no objection certificate to university for conducting event selection trials with 10 meter of isolation distance.

Meanwhile, RCGM directed Calcutta University to obtain no objection certificate from state government. As under rules of 1989 act clause 4 (4) suggests that GEAC is the apex authority in the country for approval of activities relating to GM crops into the environment including experimental field trials. Whereas, as per Clause 4 (5 & 6) under Rules 1989 also suggests that it is responsibility of the State Government through the State Biotechnology Coordination Committee (SBCC’s) and District Level Committees is to monitor the compliance of the safety guidelines and conditions stipulated by the GEAC during the field trials. It also confers powers state government to investigate, inspect, and take punitive action in case or violations of statutory provisions. Therefore, prior approval of the State Government is not necessary. However, objections were made on this clause by few state governments. Thus, GEAC considering the matter has mandatory for applicant to acquire NOC from state government in which field trial has to be conducted. In 2011, Supreme Court has made NOC mandatory from state government in case of GMOs trials. Following the order of RCGM Calcutta University approached state government (West Bengal) to obtain NOC for field trial. Later, it was found that GMOs regulatory bodies were absolutely non-functional in state. The West Bengal government was yet to initiate the statutory bodies falling under the Environment Protection Act, 1986, the state biotechnology coordination committee under the chief secretary and the district-level committee under the district magistrate. However, in March, 2011 directorate of agriculture (government of West Bengal) issued NOC with a condition that plastic barriers should be placed around GM rice field trial site.

Next twist in the event occurred when media reports emerged alleging that GEAC has flouted the supreme court decision (2007) which prescribes maintenance of 200-meter isolation distance is mandatory in case of GMOs trials. Moreover, conflict of interest were reported by media as one of the PI of the project was member of GEAC. Taking the cognizance another meeting was conducted by GEAC in July, 2011. The case was reconsidered and GEAC uphold its earlier decision and allowed the Calcutta University to carry out event selection trial in the light of fact that 10-meter isolation distance is adequate and under the compliance of law. GEAC by defending its decision explained that the Supreme Court's order dated 08.05.2007 which enforces maintenance of 200-meter isolation distance for all GM crop field trials were waived through an order dated 08.04.2008 which prescribes that the isolation distance to be maintained should be crop-specific. It is accepted that some crops may requires 200 meters and some may require less than 200 meters. The court confers authority to GEAC to examine this issue and prescribes the isolation distance to the applicant contingent upon nature of crop. Thus, no law has been violated in the case of Calcutta University. Ultimately, the final approval letter was issued to the university by DBT (RCGM). However, field trials were not initiated till August, 2012.

This case illustrates the repercussions of multi-level governing structure of agriculture biotechnology in India. It had seriously delayed and jeopardized project for two years. Calcutta University was victim of complex policy structure operating at state and central level to regulate agriculture biotechnology in India. The role of state government and central government are overlapping. Even policy designed by central authority is not implemented by states with same intensity. There is lack of single cohesive policy

Therefore, agriculture biotechnology regulation policies have become juggernautin India. It possesses power to curb and direct GM activities but also threatens to run out of control. It has made great leaps in the pace, scope and profoundness of changes taking place in area of agriculture biotechnology at national and international level. But if it is not controlled efficiently it could be pernicious and case of Calcutta University substantiates this proposition.

**6.9 Scientists' Views on IPR**

Today developing countries, as a whole, and, India, in particular, are rapidly experiencing the change in scientific research and the associated practices in the new institutional regime. This new institutional regime is marked by the Intellectual Property Rights (IPR) of the World Trade Organization (WTO). The IPR regime is something, which is not just influencing the economic context of science and technology but has also brought about a new set of interests and values, which tend to transform the social institution of science and the research system. The advancement of systematic knowledge, prominence attached to open publications to claim priority, high premium placed on professional rewards and constitution of reference groups from the discipline-base scientific elite, which not only remained the hallmark of academic science but also governed the scientific communities in the pot-world War II era, is undergoing changes. In the present study an effort is made to capture the shift made in the views, attitudes, values, interests, and ideologies of scientific community engage in rice research owing to emergence of IPR regime. As mentioned in chapter V, the scientists engage in rice biotechnology research coming under the aegis SAUs and ICAR-sponsored institutes in India is resisting IPR regime.

### 6.10 Intricacies of the IPR Regime: An Enquiry into the Scramble for Geographic Indication (GI) Rights over Basmati Rice

Analogous to copyright, patent or trademark, geographic indication (GI) is also a mechanism of intellectual property right that assigns a particular tag to a product, enhancing both its value as well as its export potential. GI is also a requirement under the 1994 Trade-Related Aspects of Intellectual Property Rights (TRIPS) agreement. According to TRIPS(Article 22(1)), geographical indications are defined as “indications which identify a good as originating in the territory of a member, or a region or locality in that territory, where a given quality, reputation or other characteristic of the good is essentially attributable to its geographical origin”. India, being a member of the World Trade Organisation (WTO), enacted the Geographical Indications of Goods (Registration & Protection) Act, in 1999, which became into force from 15 September 2003. As per Geographical Indications of Goods (Registration & Protection) Act 1999, geographic indication implies an indication which identifies such goods as agricultural goods, natural goods or manufactured goods as originating or manufacturing in the territory of country, or a region or locality in that territory, where given quality, reputation or other characteristic of such goods is essentially attributable to its geographical origin and in case where such goods are manufactured goods one of the activities of either the production or of processing or preparation of the goods concerned takes place in such territory, region or locality, as the case may be. A GI registration impedes others from passing off their products as the genuine article. Any association of persons, organisations or authority can apply for a GI tag with the Registrar of Geographical Indications, after specifying why their product qualifies for the tag. After a preliminary scrutiny, the application is published in the GI journal. If there is no objection, approval is granted for the particular GI tag. Appeals against any decision are referred to the Intellectual Property Appellate Board (IPAB) in Chennai.

The concept of geographic indication came into fora in India after the Basmati Rice controversy. Basmati Rice became talk of the world after RiceTech, a USA based rice company, in 1997, patented certain types of rice which they developed as “American Basmati”. They had been striving to penetrate the international Basmati market, through introduction of brands such as ‘Texmati’ (American style Basmati Rice) and ‘Kasmati’ (Indian style Basmati Rice). They claimed to have developed a new strain of aromatic rice through interbreeding basmati with another variety. They called this new variety as Texmati or American Basmati. In 1997, Texmati was granted patent (5663484) by the United States Patent and Trademark Office (USPTO). Reacting to this, government of India, taking into confidence the All India Rice Exporters Association (AIREA) and the Agricultural & Processed Food Products Export Development Authority (APEDA) officially challenged this the patent in 2000.India argued that Basmati Rice plant varieties and grains are already in existence and hence cannot be patented. India furnished various evidences in support of their arguments. Finally, in 2001, the patent (Texmati-5663484) was held to be null and void. Taking a lesson from this incident, India, becoming serious and cautious towards protecting its intellectual property pushed implementation of geographic indication protocols in the country in 1999.

Apart from international disputes, Basmati Rice has also faced national barriers. The Agriculture and Processed Food Products Export Development (APEDA) in Delhi, a statutory body responsible for export promotion and development of certain scheduled products, had sought a GI tag 2008 for seven states namely Punjab, Haryana, Delhi, Western Uttar Pradesh, Jammu and Kashmir, and Himachal Pradesh. However, Madhya Pradesh (MP) was left out from this list, where the farmers are growing long-grained rice in large quantities. Perturbed, the Madhya Pradesh government, taking organizations such as the Central Regional Basmati Growers’ Association, the central Region Basmati Exports’ Association, and a fewricemilling companies into confidence appealed at the GI registry office in 2010. Three years later, the GI registry upheld the claims of Madhya

Pradesh and asked for it to be included as a basmati-growing areas. Subsequently, APEDA challenged the decision at IPAB. Later, in February 2016, IPAB rejected MP'S claims and directed the GI registry to reexamine the matter afresh. Meanwhile, the Madhya Pradesh government moved the issue to Chennai High Court. Consequently, the Chennai High Court asked APEDA not to take any precipitative action against basmati-producers from Madhya Pradesh until the dispute is settled, which gave a temporary reprieve to the famers of Madhya Pradesh. The matter is hitherto subjudice. Taking cognizance of the matter a senior scientist from an ICAR-sponsored research institute asserts:

> Denying GI tag to the long-grained rice produced in Madhya Pradesh would have colossal impact. If GI tag is not granted many farmers will lose their employment, which would further precipitate economic crisis in the state because it will have detrimental effect on the interest of the producers and growers.

Another scientist from an SAU opines:

> The scuffle between APEDA and Madhya Pradesh government over the issue of Basmati Rice have triggered a huge controversy in the country. Punjab and Haryana are the two states, which are vehemently opposing the move of Madhya Pradesh government, arguing that basmati cultivation in Madhya Pradesh is of recent origin and any step to include it in basmati-producing states will tarnish the quality of the long-grained aromatic rice that is widely recognized as basmati at the global level. Contrary to this, Madhya Pradesh, on its part, insists Basmati Rice cultivation has been an integral part of its culture and farmers in the state have been traditionally cultivating basmati, marshalling historical evidence to substantiate their claim. It would be very interesting to see what will the final verdict as it would display how India interprets the TRIPS agreement.

Madhya Pradesh government is grappling with this issue since the last eight years. However, ignorant to these controversies, farmers of the state are shifting to Basmati Rice cultivation because it fetches them more profit, which has resulted in swift enlarging of the area under basmati cultivation and tremendous increase in Basmati Rice production in the state. According to the data (2016) released by Department of Agriculture, Madhya Pradesh, the total area under paddy cultivation in MP has escalated substantially from 8,094 hectares in 2006-07, to about 5 lakh hectares in 2015-16. The production of Basmati Rice accounted for approximately 10 lakh tonnes of MP'S total paddy production of 54.38 lakh tonnes in 2014-15. Currently, long-grained rice is cultivated mainly in the northern and central parts of the state comprising Bhind, Morena, Gwalior, Sheourpur, Datia, Shivapuri, Guna, Vidisha, Raisen, Sehore, hoshangabad, Narsinghpur, and Jabalpur districts. Describing the current status of Basmati Ricecultivation in Madhya Pradesh, a scientist from an SAU mentions:

> Farmers of MP have been lured by Basmati Rice cultivation. They are adopting it uncritically. It is proving more profitable to farmers. If a farmer grows Soybean as his main kharif crop on the 25 acres of his farms. It fetches him Rs 7,000 to Rs 8,000 per acre. Whereas, if he takes Basmati Rice cultivation profit soars to RS 40,000 per acre. Currently, two varieties of basmati, namely PB1 and P1121, are primarily grown in Madhya Pradesh. The state contributes for 30-40 percent of the total basmati exports from the country. Across the time, the crop has become a crucial factor in the agricultural growth of Madhya Pradesh. Over 20 percent agricultural growth rate has been recorded in Madhya Pradesh in last five years, prompting a long leap in farm incomes and rise in consumption in the rural economy.

Reflecting on reasons for increase in Basmati Rice cultivation in Madhya Pradesh, a scientist from an SAU stresses:

> One of the principal reasons why there is transition in MP towards basmati cultivation is that many farmers in north India, particularly Punjab, Haryana, and western UP, sold substantial land back at home because holdings were getting fragmented and therefore less remunerative. Furthermore, they invested in MP by purchasing much bigger holding at lower rates. They brought with them their advanced agricultural techniques and profitable crops such as basmati rice. Looking at the newcomers' success, local farmers shifted to basmati cultivation in the state.

Forwarding another reason for Basmati Rice cultivation in Madhya Pradesh, a scientist from an SAU emphasizes:

> Through holding demonstrations, field trials and distributing high quality seeds, various branded rice companies introduced the Basmati Rice cultivation in many areas of Madhya Pradesh. The product has a huge oversees demand, especially in Gulf countries, Europe and the Americas. Therefore, these branded rice industries started procuring paddy in Madhya Pradesh and simultaneously established several plants in the states, where raw rice could be processed for export. The export potential of the product ensured that in certain years' basmati paddy sold for almost Rs 4,000 per quintal, giving the sort of returns farmers, which farmers couldn't get from any other regular crop. Prices are now down to about Rs 2,100 per quintal but it's still the best bet in the kharif season if water is available.

Highlighting crop breeding advancement as one of the main reason for spread of Basmati Rice cultivation in Madhya Pradesh, a scientist from an ICAR-sponsored research institute firmly puts:

> The spread of Basmati Rice cultivation India, beyond its traditional confines can be credited to a single phenomenon i.e. advances in crop breeding. The traditional basmati varieties required short day length for flowering. The

> plants would flower only when the sunshine hours fell to 12 or less. This bottleneck was removed through advancement in plant breeding techniques. In late 1980's,the Indian Agricultural Research Institute (IARI)developed and the release certain improved basmati varieties such as Pusa Basmati-1, Pusa-1121 and Pusa-1509, which were not merely a HYV variety, but also relatively less susceptible to photoperiod or day length variations, which further enhanced the planting time flexibility. Now they could flower even when day (sunshine hours) is long, which enabled farmers from states such as Madhya Pradesh to adopt basmati cultivation, where the day length are 14 hours or more during October.

Now the question that intrigues is why APEDA and other states are opposing MP's entry to GI rights. Their principal argument is that MP never had tradition of basmati cultivation. Moreover, their another contention is that the state does not has the specific agro-climatic conditions conducive for basmati cultivation, which is a prerequisite for grant of GI. Contrary to these arguments, various evidences have been produced by MP to prove that basmati cultivation has been in practice in the state since very long period of time. These evidences constitute of literary works, manuscripts, historical artifacts, government records, weather reports, and so forth, which tend to substantiate that the Basmati Rice was historically cultivated in the state. However, the opinion of agricultural communities suggests that they are not very much optimistic about the success of Madhya Pradesh over Basmati Rice battle. Explaining the complicacies involved in the matter, as scientist from an ICAR-sponsored research institute expresses:

> In my understanding, geographic indication is a poor people's intellectual property rights. It is meant for a community rather than an individual or an enterprise. The characteristics which are examined while registering of geographic indication are place of origin, uniqueness of the product, method of production, geographic area of production, and climatic conditions. However, one of the utmost important factors to be kept in mind is the perspective of people i.e. whether people, who purchases and uses Basmati Rice knows that it is also produced in Madhya Pradesh. As you know, there is a common perception among people that Basmati Rice is the sole production of Indo-Gangetic plains, which includes mainly Punjab regions and few northern states. Therefore, I am little skeptical about the success of Madhya Pradesh over the GI issue.

Another scientist from an ICAR-sponsored research institute explicates:

> As name itself suggests, geographical Indication is a phenomenon of international trade that attaches a particular product to a specific location which identify its character of originality and uniqueness. Conferring geographic indication to any product means to differentiate it from the rest of the product which are of same kind therefore fetching superiority to its value. Historically evident, the basmati rice, which is famous for its aroma

throughout the world has confronted many obstacles, but has finally emerged victorious every time, elbowing out all the contenders and pretenders to the throne. Any old rice cannot be called as Basmati. In order to get GI tag it has to be the variety that especially grows in the Indo-Gangetic plains.

Pessimistic about the prospect of granting GI right to Madhya Pradesh, a scientist from an SAU mentions:

> The ultimate objective of granting GI tag to a product is to protect the interest of the producers of basmati rice. Therefore, if the demand of Madhya Pradesh is accepted by Geographic Indication Registry it will set a wrong precedent. Following MP other states too might demand for their inclusion. The states such as Rajasthan and Tamil Nadu, which even claims cultivation of Basmati Rice will be in question. These type of decisions should not be influenced by market deliberations, rather it should be taken with the motive to conserve heritage of the country.

Describing about national and international barriers confronted by Basmati Rice over the issue of ownership claims, a scientist from an SAU affirms:

> Basmati has a long history of controversies. It has been a controversial commodity. Not only national but it has also faced international aggressions. When APEDA sought the coveted GI tag in 2015 for 77 districts of Punjab, Haryana, Delhi, Western Uttar Pradesh, Uttarakhand, and Jammu and Kashmir. Basmati Growers Association (BGA), Lahore, Pakistan, challenged the registry order by making an appeal to the Intellectual Property Appellate Board (IPAB). In March 2015, the IPAB, without making any discrimination admitted BGA's appeal. It gave BGA's an equal opportunity of being heard. Finally, in 2016, the IPAB upheld the decision (Registry's order) thereby granting a GI status for Basmati Ric eto APEDA. IPAB further held Basmati growing areas in India does not come under jurisdiction of BGA. Further, it directed the BGA to appeal before the High Court of Sindh. Talking of national barriers, if MP succeeds in getting the GI tag, then the other states such as Maharashtra, Andhra Pradesh and Tamil Nadu might also join the race and the ultimate beneficiary from this all will be Pakistan. Their case will become stronger.

Dwelling upon quality issues of Basmati Rice grown in Madhya Pradesh, a senior scientist from an ICAR-sponsored research institute, who is recognized as one of the pioneers of Basmati Rice research in India, points:

> The grains of the Basmati Rice that is cultivated in the non-traditional belts such as Madhya Pradesh suffers from certain quality issues. Basmati Rice has a unique and distinctive trait i.e.it has long kernel length, linear elongation of kernel on cooking, and fluffiness and most importantly it is aromatic, which is derived from a compound called 2-Acetyl-1-Pyrroline. The accumulation of this highly volatile compound gets accumulated in the grain and it contributes to basmati's characteristic fragrance. But this accumulation is largely a function of environmental conditions. The characteristics of aroma, courtesy 2-Acetyl-1-Pyrroline, could be retained

> only when the physiological process i.e. flowering and grain-filling phase takes place within a cool climate. During the daytime, the temperatures should be below 30 degrees Celsius and at night, it should be just over 20 degrees Celsius. These conducive conditions areobtained during the month of October only in the traditional basmati belt. Moreover, apart from aromatic issues, higher temperatures can also affect the texture and milling quality of the grain. Therefore, all this means that Pusa-1121 basmati can be grown in MP. But the aroma, appearance, and quality of the grain produced from Madhya Pradesh are inferior to the basmati grown in traditional basmati areas.

The GI brawl over Basmati Rice between APEDA and Madhya Pradesh government foregrounds the practical implications which could flow out from this intellectual property right. The collective nature of geographic indications also brings to the fore significant collective action related problems across various stages of organization and governance (Das, 2009). Now, there are two major challenges before the law-makers. First is to ascertain or define, which community is the real producer. Secondly, to assess the precise geographic boundary, where Basmati Rice was cultivated traditionally. Hence, the most important puzzle that needs to be solved is which region is the legitimate one that qualifies for GI rights. The decision regarding GI rights over Basmati Rice is pending in the High Court of Madras. Regardless of the decision, double-edged outcome is expected. If the judgment comes in favour of Madhya Pradesh, in one hand, it will foster continued growth and prosperity for the farmers of the states, but contrary to this, on the other hand, it might prompt national or international dispute, owing to failure in protecting various products and producers, which is the main rationale behind establishing Geographical Indication Registry in the country. Whereas, if decision turns out to be against Madhya Pradesh, it would lead to a crash in value, as the premium long-grained aromatic rice grown in Madhya Pradesh would no longer be recognized in the market as basmati afflicting deleterious effect on the interest of the growers and producers in the state. The decision would be a landmark decision because it would reflect how India theorizes IP protocols and protects the interest of different stakeholders. Thus, this decision will not only shape the future of the forthcoming products but also the products which already have been registered under GI rights. In nutshell, the case of Basmati Rice highlights the intricacies of IPR regimes and questions the assumption that among all the other forms of intellectual property rights, GI may be more amenable in the context of developing countries.

### 6.11 Scientists' Views on Marker-Assisted Selection (MAS) Technology

MAS is a modern biotechnology tools which involves transfer of desired genes from one variety to another variety of a seed within domain of primary genepool of a given crop. It is different from genetic engineering technology which involves transfer of genes across the taxonomic barriers. In this study, respondents pointed about the extensive application of MAS in field of rice research in India. An intensive discussion was carried out with experts about the ambit and scopes of MAS technology in field of rice biotechnology research. Few themes have emerged from discussions that have been analyzed below within the purview of discourses about socio-politics of modem biotechnology in rice research in context of India.

***MAS and Plant Breeding***

When asked about the application of MAS in breeding programme of rice crop, most of scientists in the study accept that currently they are using MAS as an effective tool to breed rice crop. A scientist, who was part of Pusa Basmati 1 project, a variety developed through MAS technique affirms:

> Earlier, Basmati rice breeding program in India was solely dependent on conventional breeding technique contingent upon phenotype selection. MAS has provided us an alternative technology that can be effectively utilized to cases which cannot be solved through conventional breeding techniques. MAS is capable of producing result in short duration. Pusa Basmati 1 is a living example of it which has become a paradigm in rice breeding program operating throughout the nation.

Accentuating the importance of MAS in breeding rice crop, another scientist from an SAU mentions:

> A high-yielding rice variety which are resistant to biotic and abiotic stresses has been developed through plant breeding methods assisted by MAS techniques. MAS approach could be useful to plant breeders in developing more productive cultivars of rice crop without use of genetic modification technology. Breeding short, sturdy and high yield cereal crops were hallmark of the green revolution in the 1960s. These seeds are often credited as salvation seeds. Recently, plant scientists have begun to unfold the genetics of these salvation seeds, which possess a huge potential further and faster. Generally speaking, it takes almost 10 years at stretch to breed a new variety through conventional selective breeding techniques. However, if molecular markers are linked with the particular gene controlling the trait, we can dramatically reduce time and laborious human work.

Most of the scientists in study are in opinion that MAS is not applied in all breeding programs, but it has become an important part of the breeding program in rice research.

A MAS is predominantly used in hybrid breeding of rice crop. The application of MAS is seen as especially significant as it carries potential to accelerate the breeding process and deliver the result in short period. It allows attaining certain breeding aims which normally are very difficult to achieve through conventional breeding methods. Almost all scientists expect the impact of molecular markers in plant breeding to escalate in the future. According to respondents the decision for applying MAS is based upon the nature of problem of research and availability of resources. However, few scientists from SAUs also pointed out that application of MAS technology is still very limited owing to economic considerations. Respondent's opinion found to be inconsistent regarding the breeding progress in rice crop that has been achieved through MAS during the past 10-15 years. For some scientists MAS has not contributed significantly to the progress of breeding program in rice crop owing to late start of MAS at larger scale by rice scientists in India. For other scientists believe that MAS is only one set of tools amongst many available biotechnological tools capable enough to contribute breeding program in rice research. However, few scientists gave examples of varieties (Pusa Basmati-1, Swarna Sub1, and Samba Mahsuri) developed through MAS in support of their arguments that MAS has contributed immensely to attain certain breeding objectives in rice crop which were not possible earlier with conventional breeding technique.

***MAS and Genetic Engineering***

MAS and genetic engineering are two different forms of modern biotechnology. Former being non-controversial technology with wider public acceptance and later being a controversial technology with lesser public acceptance. Thus, it is of paramount importance to capture the opinions of scientists on MAS vis-a-vis transgenic technology. The respondents were asked about the potentials of MAS technology as compared to transgenic technology. They were also asked if MAS technology could substitute some transgenic approaches. The responses were relatively consistent. It was pointed out that MAS and genetic engineering cannot be seen as competing technology. Rather they are complementary to each other to a greater extent. Currently working on golden rice project, a scientist from an ICAR-sponsored research institute opines:

> We have adopted marker assisted backcross breeding (MABB), which is a type of molecular breeding to introgress the Vitamin A gene in Swarna and its flash flood tolerant version Swarna Sub 1. It was successful and proved to be very useful to us by producing the desired result in quick time. Therefore, MAS and genetic engineering are complementing technology rather than competing technology.

Another scientist from an SAU mentions:

> Both GMO's and MAS technology, if combined together, can play a prominent role in solving some complex questions which is still to be answered by scientific community in domain of rice research. No doubt, conventionally we have identified many genes for many of traits through applying either conventional or modern biotechnology methods. However, there are few genes which are still beyond our reach. For example, stem borer is a common disease found in rice crop. Till now we are not able to find a suitable tolerant donor for it. In my opinion this can be easily done by combining MAS and genetic technology. As, with GM crops, the MAS technology is being continuously refined and upgraded new developments and methods.

Another scientist from an ICAR-sponsored research institute expresses:

> Few goals can be achieved effectively through combination of a transgenic approach and MAS. The best example is experiment conducted at IARI, New Delhi to develop so called Indian version of golden Rice (Swarna and Swarna Sub1), and a genetically modified rice variety containing high carotene levels to control dietary vitamin A deficiency in the India. Marker technologies are very effective in identifying and locating transgenes within GMOs. Most of the scientists accepted that decisions for using MAS or GM technology largely depend on case-by-case basis. MAS can be apt in some cases whereas GM cannot and vice-versa. It is impossible to blindly substitute the two technologies with each other.

A scientist from an ICAR-sponsored research institute reflects:

> MAS technology can be more effective where genes from the primary, secondary or tertiary gene pool are utilized. Provided that genetic variation for the desired trait can be found in the breeding material available, markers can be used for selection purposes. If this variation is not available, transgenic approaches cannot be substituted. Thus, the choice of using technology is problem driven.

Another scientist from an SAU points:

> Practically, the ambit of GM technology is more as compare to MAS. MAS technology is not effective when it is applied to breed crops that have long generation period for example citrus. Thus it would be naïve to say that any set of technologies including MAS and GM technology are universally applicable in all plant research. Rather, application of any set of technology is case dependent.

Thus, MAS and genetic engineering has to be understood as entirely two different set of methods having independent approaches. MAS always include new crossing and selection from the progeny while transgenic approaches allow for the improvement of an existing variety, e.g. in terms of resistance characteristics. Breeding methods are considered by the scientists as a time and space consuming technique Time is an important factor in plant breeding. Various aims and objectives, which can be achieved through applying MAS might be achieved faster by means of transgenic approaches. Contrary to this, in case of some minor crops even transgenic approaches can prove to be very time consuming. Thus, scientists clearly refused to integrate MAS and GMO strategies, as the decision regarding application of these set of modern biotechnology tools is often made as the case arises.

***MAS as a Sustainable Technology***

Technologies are mostly identified with problems and solutions that are closely linked with objectives of sustainable developments. Sustainability focuses on the need to satisfy the needs of present generations but avoid compromising the interests of future generations by degrading the resource base. However, in agriculture domain it is defined as an approach to agriculture that focuses on food in a way that does not degrade the environment and contributes to the livelihood of communities. The economic, environmental, and social goals of sustainable agriculture are mainly served as a useful yardstick for measuring performance and progress of any technology in the field of agriculture. The impacts of new technologies on agriculture sectors affect various interests and domains. In this study, most of scientists are in view that MAS promotes economic, environmental, and social goals of sustainable agriculture. Feedbacks from farmers regarding MAS-derived product that had been already released for cultivations are positive. Laboratory reports also does not confirm about any externalities caused owing to use of MAS technology in rice research. MAS cater all parameters of a sustainable technology and possess a huge potential in field of rice research in India.

A scientist from an SAU opines:

> MAS is an ecological sound technology. It does not pose threat to environment. Recently in 2013, researchers from Japan and IRRI found a unique gene, named Spike, from an Indonesian landrace, capable enough to boost rice yields up to 36%. By integrating molecular identification of the Spike gene and conventional breeding, the rice scientist's transferred Spike gene into popular rice varieties of such as IR64, BR11, Swarna, Ciherang and PSBRc18 to name few. The resulting lines are under multi-locational field trials. If it becomes successful it would contribute immensely to food security in south and south-east Asia.

Another scientist from an ICAR-sponsored research institute stresses:

> Biotic and abiotic stresses, e.g., plant pathogens, drought and salinity, pose significant challenges to yield. These challenges are expected to increase with the effects of urbanization, the conversion of more marginal lands to agricultural use and climate change. Adapting new cultivars to these conditions is difficult and slow, but it is again plant breeding perhaps complemented with MAS, that is expected to make the most substantial contribution. In addition, breeding supplemented with the use of MAS can speed up crop development, especially for simple traits. It could also significantly accelerate the development of traits that depend on multiple genes. Breeding technique combined with MAS remains viable options for meeting development and sustainability goals.

According to experts the new molecular techniques (MAS) that are being implemented extensively in rice research to tackle biotic stresses, abiotic stresses, yield and quality enhancement has boost up the rice production in India. MAS is ecologically sound, human health friendly, economically viable, socially justified, humane, adaptable, easily available and accessible by the farming community.

***MAS as a Participatory Technology***

There has been consistent and continuous demand for participatory technology development in agriculture sector. On the questions of MAS as a participatory technology, responses from the scientists were found to be consistent. Scientists in the interviews asserted that MAS promotes participatory plant breeding approach to rice crop. According to scientists, developing any variety or population through MAS by engaging farmers directly into research process has many advantages. It promotes learning from each other's experiences especially the tacit component of knowledge which can be shared only through socializations. Moreover, such participatory practices could also make varieties or populations easily available to the farmers outside the immediate field in which they were developed and this can directly benefit the farmers. Scientists in interview have mentioned few examples of successful application of MAS in participatory plant breeding program in rice crop in India. Few of them would be worth mentioning here. According to a scientist from an SAU:

> First example is from eastern India where to develop drought tolerant rice, MAS was used to introgress four QTLs for root traits into the variety Kalinga III. The Philippines cultivar Azucena (Oryza Sativa L. spp. japonica) was the donor of the positive effect QTLs. In India experiments for selected for agronomic traits were conducted at Birsa Agricultural University (BAU), Jharkhand, upland research stations and farmers' fields. Following MAS, farmers compared the lines with different combinations of root QTLs in their fields and assessed them for traits including maturity, yield and grain

> shape. Trials were conducted in farmer's field in the kharif season which is the main rice growing season in eastern India. The selected subsistence farmers were dwellers of 32 villages participating in development programmes coordinated across Jharkhand, Odisha, and West Bengal by the Gramin Vikas Trust. Data collected from more than 60 field trials carried out in farmers' fields in eastern part of India over 6 years demonstrated the introgression into Kalinga III of four roots QTLs has improved grain yield by 1.0 t ha-1 in these environments. This strategy was used further to develop a novel upland rice variety that has been released in India as Birsa Vikas Dhan 111.

According to another scientist at an SAU:

> Second example is from southern part of India, where, a study was conducted based upon participatory selection through DNA markers for enhanced drought resistance and productivity in rice crop. In this study, MAS and participatory techniques were combined together to develop drought-tolerant rice varieties exploiting more efficiently and specific adaptation to the farmers own conditions and needs. A F2 population derived from the cross between deep-rooted variety ''Moroberekan'' with shallow-rooted variety ''IR20'' were used to identify and validate of SSR markers associated with root morphological traits. The F2, F3, F4, F5, F6 and F7 materials derived from crossing divergent parents viz, Moroberekan and IR20 were used in experiments. While, the female parent Moroberekan was an African japonica processing a deep and thick root and is tolerant to drought but relatively low yielding, the male parent is IR20, an indica type, having short stature, a shallow root system and high yielding but susceptible to drought. Field experiments for the present study were conducted during 2004–2007 in the experimental field of Hebbal Research Campus, University of Agricultural Sciences, Bangalore, India and farmer's field at the Shettigere village 20 km North of Bangalore. The laboratory experiment was carried out in the Marker-Assisted Selection laboratory, Department of Genetics and Plant Breeding, University of Agricultural Sciences, GKVK, Bangalore, India.

Indeed, above examples and responses of scientists indicates that several projects had been carried out, few are in progress comprising MAS as part of participatory breeding programs, and few varieties such as Birsa Vikas Dhan 111, a drought tolerant rice, had already been released for cultivation. These examples not only explicit efficiency of MAS as an effective technology to harness farmers' knowledge and experiences, but also indicates that molecular biotechnology could benefit resource-poor farmers if implemented appropriately. Enlisting the participation of farmers through molecular breeding programme is helpful in identifying the stresses that a rice crop is exposed in a given area. It generates knowledge from the field that is utilized to develop varieties by using genomic data of rice crop. Thus, incorporation of MAS in participatory plant breeding program has initiated the necessary knowledge required to provide innovative solutions in collaboration with the local communities. The knowledge and solutions produced in this participatory programme will enhance access to knowledge thus generated and enable collaborators to share the knowledge and add to the knowledge. It leads to merging of science with farmer's knowledge that has emerged as a paradigm for participatory innovation in rice research in context of India. It makes innovations in rice breeding programme more participatory involving the farmers who conserved germplasm in situ over time, and sustainable, which requires the democratization of the process of innovations.

***MAS as a Non-Controversial Technology***

Technology controversies have become an integral parts of society in general and agriculture sector in particular. Recent application of modern agriculture biotechnologies such as GM technology has raised social, economic, political, technical, cultural, legal and ethical debates at the national and international arena. GMOs are facing several legislative constraints due to biosafety and ethical concerns. On the questions of controversies surrounding MAS, most of the scientists are in opinion that MAS is a non-controversial technology. According to the respondents the introduction of varieties obtained through MAS is not subject to such restrictions. All genes that are transferred in to targeted crops through MAS exist within the natural gene pool of a particular crop and reside at the natural chromosomal locations. Therefore, MAS heeds a special attention to species barriers and unlike transgenic technology no environment, human health and ethical issues related to flora and fauna is attached with MAS. A scientist from an ICAR-sponsored research institute stresses:

> MAS technology is being looked at with increasing interest within the nation. In country like India, where public opposition to GM food has remained resolute. In recent years, MAS technology is attracting considerable attention and emerged as upgraded conventional technology as an alternative to GM technology. Unlike GM crops, MAS driven varieties do not raise health and environment concerns as they do not involve introduction of alien genes. It has been widely accepted by farmers, scientific community, policy makers, activists, populists, media, and other groups opposing GMOs. Thus, MAS has emerged as non-controversial modern agriculture biotechnology that enables plant breeding without genetic engineering.

Another scientist from an SAU opines:

> Wider acceptance of MAS in society can be seen as the new beginning of agriculture sector which was in deep financial trouble in the country. A huge scarcity of public and private funding has occurred in field of crop science research owing to GMOs controversies in country. Currently, numbers of project under MAS are funded by public sector institutes such as DBT, ICAR to name a few. Not only rice but some other crops such as wheat, maize, chickpea, linseeds, mustard and groundnuts are being engineered under public sector MAS breeding programme this indicates the acceptance of MAS in the society in general and policy makers in particular.

Thus, experts are in opinion that MAS is not subject to public distrust as are GMOs. Society seems to accept MAS to a large extent. MAS also seem to be free from public debates. Unlike GMOs, MAS is free from image problem. Being a non-invasive biotechnology approach, MAS is not subject of public concerns and has wider public acceptance along with farmers, policy makers, media, activists, NGOs and populists. MAS has provided an opportunity to the scientists to make seismic shift away from the GMOs controversies. Scientists are in opinion that with adoption of MAS, public criticism of modern agriculture biotechnology as a whole are expected to subside. Modern agriculture biotechnology possesses larger domains of applications and MAS is one of them. Scientists are in views that MAS is likely to be more popular than GMOs as varieties developed through MAS do not require additional tests for food safety that GM crops require. MAS offer a positive alternative to extremes.

***MAS as a non-propriety Technology***

The importance of molecular marker analyses for different applications was recognized very early, resulting in the filing of many patents in the last 10-15 years (Jorasch 2004). However, at least in case of rice biotechnology research in India, till now not a single case of ownership claim was reported about MAS-derived. To date, whatever products that have been developed through MAS technology have been registered under PPVFR act. According to a scientist from an ICAR-sponsored research institute:

> We have developed a disease (Bacterial Blast) resistant variety, namely 'Improved Samba Mashuri' through the innovative use of MAS. This product is outcome of the active partnership between the Centre for Cellular and Molecular Biology (CCMB) Hyderabad, which is one of the constituent R&D organisation of the Indian Council of Scientific Research (CSIR) and the Directorate of Rice Research, a constituent R&D organisation of the Indian Council of Agricultural Research (ICAR).This variety has been duly registered with the PPVFR act (Registration No.: REG/2009/240). In

> addition, this unique variety has been licensed to a Private Seed Agency (M/s Sri Biotech, Hyderabad on non-exclusive basis) on licensing fee of Rs 6,00,000/-.

### 6.12 A Case of Swarna Sub 1: Application of MAS-derived Product in India

In India there has been at least one instance in which MAS have been used to confer resistance to a popular rice variety of eastern India against flood and submergence (abiotic stress). Scientists in the interview discussed enthusiastically about the project that adopted MAS as non-gene pool to make one of the rice varieties resistant to abiotic stresses.

The development of flood-tolerant rice variety through genetic improvements facilitated by marker-assisted selection. Swarna-Sub1 is the flood-tolerant version of the popular mega-variety Swarna (MTU 7029) in eastern India. Technically, two alternative paths were followed to develop this variety. One comprises of introducing into modern rice varieties quantitative trait loci that contain the SNORKEL 1 and SNORKEL 2 genes, which induce elongation in traditional deep-water rice varieties, allowing them to survive during periods of prolonged flooding. The second path involves the SUB 1 quantitative trait locus that responds to ethylene buildup by restricting elongation, the natural response of the rice plant. A particular advancement is the introduction of the SUB 1 locus in Swarna (IRTP12715), which is India's most popular variety. Swarna-Sub1 is almost identical to its counterpart Swarna in terms of grain yield and grain quality, but it has an added advantage that it can withstand to flooding of up to 17 days while retaining the desirable traits of the original variety. Swarna-Sub1 out yields Swarna and other popular varieties under submerged conditions.

It was developed by scientists from the International Rice Research Institute (IRRI), evaluated and released in India by Central Rice Research Institute (CRRI), and disseminated by IRRI in collaboration with the national agricultural research systems, government organizations, nongovernment organizations, and public and private seed companies in India. It was released in August 2009. Highlighting the advantages of Swarna- Sub1, a scientist from an ICAR-sponsored research institute mentions:

> Swarna-Sub1 is a climate-smart rice variety, which was released in August 2009. It is the first submergence-tolerant, high-yielding rice variety of India. It was released for commercial cultivation in record time and is spreading at a great speed. It took around 25 years for Swarna after its release to be cultivated on six million hectares, giving its current "mega" rice variety status in India. We are very much sure that Swarna-Sub1 will achieve the

> same status in coming five years. It could entirely substitute Swarna and permeate to other flood-prone areas throughout the country.

According to a scientist from an SAU:

> The flood-tolerant rice, Swarna-Sub1, is a major innovation in field of rice research. It holds great potential for the farmers in the flood-prone lowlands areas, especially of eastern India. Swarna-Sub1 has been technologically advanced to survive under water for more than two weeks and without the flood-tolerant gene, gives higher yields than the same variety. Farmers are taking full advantage of this variety in their flood-prone fields, which often suffers from water lodging during the rainy season owing to flash floods.

A scientist from an ICAR-sponsored research institute reflects:

> Swarna-Sub1 integrates the SUB1 gene into the Swarna, which is a mega-variety in India. It has been transformed technologically to be resilient to flooding of up to 17 days and retains the desirable traits of the original variety simultaneously. Under submergence condition, Swarna-Sub1is very effective as well as very efficient. It has a yield advantage of about 1 ton per hectare over its original variety 'Swarna'. Since Swarna Sub 1 is an improved form of Swarna, an existing variety, scientists only tested its tolerance of submergence, which lessened the time for field-testing by a year.

A scientist from an SAU stresses:

> Swarna-Sub1 has yield advantage over Swarna and other popular varieties under submerged conditions. This makes Swarna most suitable for cultivation in flood-prone rice areas in the country. It is replacing Swarna and other varieties, which are non-flood-tolerant. It can make flooded areas flourish with rice. Earlier, these areas were normally not cultivated and left fallow during the kharif season. Moreover, Swarna-Sub1 is not limited only to flood-prone rice areas rather it carries potentials to take a slice also of non-flood-prone areas because it is being accepted by farmers for cultural and religious uses.

A scientist from CRRI, Cuttack recalls:

> In October 2013, we made a visit to Jajpur District, Orissa, which is considered as a stronghold of Swarna, where Swarna is grown on 65% of the total rice area. We stopped at several places throughout the day and interacted with farmers. We tried to know about the performance of Swarna-Sub1 in that particular locality. I still remember our trip took place just 2 days before cyclone Phailin was expected to hit the state. We were surprised by feedbacks from farmers. Most of the farmers have a good experience with Swarna-Sub1. Their responses were quite positive. Nevertheless, there were a few complaints pertaining to seed (Swarna- Sub1) shattering mainly during harvest and transportation. But, maximum farmers who cultivated Swarna-

> Sub1just for the trial for the first time on some parts of their land have resolved to expand it to their entire landholding.

Just after field trials, Swarna Sub 1 lines were transferred to national agencies to conduct further research and multiply seeds without any condition. Immediately after release, seeds were distributed to other channels for large-scale multiplication, and were also made available free to the farmers in target areas. IRRI and its collaborator have not claimed any form of proprietorship over Swarna-Sub 1. It was made available free for public use. This suggests, Swarna-Sub 1 is free from any institutions including rules governing the production, distribution and organizational mechanisms that are required to commercialize the molecular- driven variety especially in era of increasing privatization of seed production. The seed distribution of Swarna-Sub 1 expanded significantly when the national food security mission included Swarna-Sub 1 in its eastern India programs in 2010. About 38000 tons of seeds were distributed, reaching an estimated 1.3 million farmers in 2012 alone. This indicates the popularity and wider acceptance of Sub 1 by farmer's community in India. Describing about activities to promote seed distribution of Swarna-Sub1 among farmers, a scientist from an ICAR-sponsored research institute accentuates:

> Normally, it takes 4-5 years for field-testing of a rice variety before it is released and also another 2 to 3 years to reach in the hands of farmers. By subscribing targeted dissemination, we are assisting state governments in identifying specific flood-prone areas, where seeds of the Swarna-Sub1can be distributed, without having waiting period for farmers until the seeds are multiplied and distributed en masse.

A scientist from an SAU mentions:

> In case of Swarna-Sub1, before the seeds were released in the field, its seeds were transferred to different research institutions for multiplications. Furthermore, once it was released for cultivation, we encouraged different state governments to distribute the seeds to other various channels for large-scale multiplication and also ensured that the seeds are disseminated directly to farmers in target areas. Now, farmers have to not wait for 2 to 3 years for receiving the seeds.

A scientist from an ICAR-sponsored research institute shares:

> We have identified areas that are flood-prone and low agricultural productivity. Moreover, areas with slow technology diffusion have been also identified. State governments are distributing "minikits" or 5-kg packets of Swarna-Sub1 seeds to farmers in these areas. Till now, 70,000 minikits, which is an equivalent of 350 tons of seeds, have already been distributed

during kharif or monsoon. This variety has reached in the hands of more than 100,000 farmers in India, within one year of release.

Researchers from the International Rice Research Institute (IRRI) and the University of California, Berkeley, US, conducted randomised field trials in 128 villages in the eastern Indian state of Odisha, on Swarna-Sub1. They used a randomized field experiment in 128 villages of Orissa, India to capture the performance of Swarna-Sub 1 in the field. The analysis of field data indicated significant positive impacts on rice yield when fields are submerged for 7 to 14 days with no yield loss without flooding. It was estimated that Swarna-Sub 1 offers an approximately 45 percent yield increase over the current popular variety (Swarna) when fields are submerged. Additionally, they found that the average duration of flooding on plots cultivated by SC or ST farmers is longer by 1.83 days, when compared to farmers that belong to the highest caste group. Their results show that universal replacement of Swarna with Swarna-Sub 1 during the 2011 floods in their sample of farmers in Bhadrak district of Orissa have resulted in a predicted increase in total rice production of 24.8 percent for higher caste farmers and 39.6 percent for SC/ST farmers. Thus, Swarna-Sub 1 has deliverd both efficiency gains, through increase in overall yield, and equity gains in benefiting the most marginal group of farmers. It is the technology that helps socially disadvantaged groups. Thus, Swarna-Sub 1 has emerged as a non-proprietary technology and inclusive technology for the farmers cultivating rice crops. Case of Swarna-Sub 1 exemplifies what kind of institutional and organizational arrangements for knowledge production, application, and large-scale production and deployment by farmers are necessary in the innovation system in agriculture in country.

### 6.13 Future Prospect of MAS in Rice Research in India

When asked about expected future for the next five years regarding the application of molecular markers, scientists did not point out precise aims. Altogether an increase in application of markers is assumed, maybe also covering complex traits to a higher extent. Regarding the impact of MAS on breeding in ten years' time an increase in relevance and application is unanimously expected by all respondents. Especially the increased application of SNPs and improved technologies for sequencing will contribute to an increasing impact of MAS. Some respondents also expect that MABC strategies will gain importance and that field trials will not be replaced but complemented by the application of markers. Respondents admitted that a substantial technological breakthrough in the field of rice biotechnology research especially case of increasing rice productivity would take at least another decade. Here, major technological breakthrough means to escalate the photosynthesis process of rice plant and bring to the level of that in wheat, maize and other productive cereals.

However, experts pointed that the increase in importance of MAS is not expected to be the same for all crops. For high value cereal crops such as rice, wheat, maize, are expected to have more application of MAS as compared to other crops. Moreover, respondents were skeptical about the implementation of MAS in non-food crops. In contrast, for food crops it is very unlikely that such developments will gain any relevance in the breeding process.

**Conclusion**

We have delved into the social and political construal of rice biotechnology by reflecting on agricultural innovations in India, traits tackled by scientists, technology development, and slow adoption of new technologies by farmers, scientist's reflections on GM technology, IPR issues, political imperatives, policy implications and Marker Assisted Technology (MAS). The findings of this study suggest: Scientist's responses suggest that they are engaged in myriads of technology development, demonstration, assessment, and refinement within the realm of rice crops. Contemporary technology development programs give due consideration to sustainability of natural resources and environment issues. It emphasizes maintaining harmony with farmers and natures. Farmers approach towards new technology and weak extension services in the country are the primary reasons for slow adoptions of new technology by farmers. In India, few states are promoting, few are neutral and few states have imposed restriction on GMOs research activities. There is a complete lack of consensus among the scientific communities on the issue of GM technology. The conflicting nature of responses is apparent, which can be better understood in the wide variety of meaning attached to GMOs. India policy-making and policy-implementation related to GMOs varies across space and institutions. GM technology in India suffers from multi-level governance structure. There is lack of single and uniform policy. Single policy framework and its universal execution within country are absent. The new molecular techniques (MAS) has emerged as an alternative technology that are being implemented extensively in rice biotechnology research to tackle biotic stresses, abiotic stresses, yield and quality enhancement has boost up the rice production in India.

# Chapter VII

## Conclusion

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

### 7.1 Summary of the Findings

The present study has been divided into seven chapters. The first chapter has introduced various facets of the thesis attempting to capture review of the literature, research gaps, rationale for the topic, research questions, objectives of the study, method of analysis, structure of the study, and so forth. The second chapter provided a socio-historical analysis of agricultural research and development with special reference to rice biotechnology research in India.

The third chapter encapsulated bibliometric study of the knowledge base of Indian rice research community, based on the bibliometric information in the field of rice research from Scopus database during the period of 1995-2014. The bibliometric study suggests that the multiple-authorship paper is predominant as compared to single author paper during the period of 1995-2014. The Co-authorship Index reflects decreasing trend in case of single-authored, double authored, and multi-authored papers and an increasing trend in case of mega-author papers during the two blocks of the study period (1995-2004 and 2005-2014). Similarly, the mean values of degree of collaboration, collaboration coefficient and modified collaboration coefficient indicate increasing trend, when two blocks of the study period are compared. Thus rice scientists have transformed their collaboration patterns from their initial small groups with one collaborator to big groups with more collaborators. Indian rice scientists show a preference for mega-authored patterns.

In the context of domestic collaboration, DCI values have decreased and have become less than country's average during the first block, whereas international index collaboration, which was trailing in the first block has increased and surpassed the country's average during the second block. Thus collaboration pattern according to collaboration institutions changes from local (intra-institutional) papers via domestic papers ((inter-institutional (national)) to international papers. Besides, the international collaboration has been increasingly strengthened. This has enhanced the international visibility of Indian rice scientists.

The frequency matrix of research collaboration among the agencies highlights that the collaboration between state agricultural universities and ICAR-sponsored institutes have decreased during the second block with respect to the first block of the study period. The collaboration of state agricultural universities with industry has decreased, whereas ICAR and industry collaboration has enhanced during the second block. In the context of international collaboration, both SAU and ICAR exhibits decreasing trend in the second block of the study period.

The fourth chapter has captured how scientific collaborations are formed and organized in the field of rice biotechnology research and what are the underlying process of such formation, organization, and outcomes. By highlighting the socio-politics of project formation and organization, the chapter has focused on the internal dynamics of scientific collaboration. Our survey of rice biotechnologists reveals that they have several motives for seeking collaborative partners. Some of these motives were: access to instruments, expertise, tacit knowledge, validation of new technologies/methods, etc. The data shows that there is a considerable difference in the role played by different factors. For instance, accesses to sophisticated instruments, expert knowledge, time efficiency, validation of new technologies/methods are strong motivational factors for scientists to collaborate. The motivations reflect the broad structural and institutional milieu which the scientists work as well as preferences of the scientist at the individual level. Therefore, on a macro level access to instruments and expert knowledge become important because nature of modern biotechnology is multi-disciplinary and laboratory-based (tool-oriented). It requires access to experts from various disciplines and access to sophisticated instruments to conduct research and hence scientists are dependent on them.

Although collaboration increases productivity and brings in many benefits, there are some undesirable costs that have to be borne by a collaborator. The main bottleneck that has come up from our study is the administrative delays. Funding as such was not considered a major impediment. But delays in disbursements of the funds and periodic reviews mainly dealing with how the money assigned is spent, impedes the scientific research. Co-ordination cost in terms of extra resources spent on travel and communication in more a major hurdle. Even time cost was not considered a major setback as it is offset by proper planning that saves time. For that research, tasks are clearly defined and modalities chalked out properly among individual scientists. This is particularly important when the collaboration occurs across distance.

The pre-existing relationships among some or all of the participants have emerged as central to forming collaborations in rice biotechnology. This implies the significance of social capital in the process of scientific collaboration. Furthermore, this also indicates the autonomy of scientists (agency function) to choose their collaborating partners. Besides, although there are multiple sources of funding that supports R&D collaborations in rice biotechnology, substantial scientists reorganizes their funding by exploring new avenues of funding in rice biotechnology. This indicates entrepreneurship aspect of scientists. A majority of the scientists (57 percent) wants to collaborate with university set up in order to access to fundamental research. Whereas, 73 percent of scientists want to collaborate with government research institute primarily for funding and access to technical and manpower resources. Thus through scientific collaboration, scientists get access to a new source of funding, expertise knowledge, and sophisticated equipment leading to scientists-entrepreneur relations. Further, this also implies the departure from traditional ways of producing and organizing knowledge at Indian scientific institutions. Meanwhile, pressure from parent institutions has also emerged as a dominant factor, which influences the formation of scientific collaboration in rice biotechnology research. Institute guides and constrains subsequent actions of individual scientists in collaborative projects. Therefore, the project formation in rice biotechnology research is not only shaped by agency function of scientists but also by the structure within which they operate. However, in this study, the role of the structure was found to be more dominant in comparison to the agency function.

The analysis of research projects undertaken by rice biotechnologists during 2010-2014 reflects that ICAR-sponsored institutes have the maximum number of collaborative projects with other institutional settings in India. Rice biotechnologists at the ICAR-sponsored institutes are engaged in 116 collaborative projects with other institutions in India out of which 32 percent are with international institutes (public) and 68 percent are with national institutes. Scientists at SAUs commands 61 percent of collaborative projects with national institutes and 39 percent with international institutes (public). Thus, ICAR-sponsored agencies dominate in collaboration with national agencies, whereas the collaboration of SAUs with international agencies are more than ICAR-sponsored institutes If we integrate the collaborative projects of scientists located at SAUs and ICAR-sponsored institutes out of 187 projects 65 percent are with national agencies and 35 percent are with international agencies. However, this study indicates weak collaboration between SAUs and ICAR-sponsored agencies accounting for just nine percent. The variations pertaining to scientific collaboration may be attributed to infrastructure facilities available at the respective institutes, the selection of research problem and use of novel techniques (for example, genetic engineering). However, the study does not include scientists from other institutional settings.

The pattern of scientific collaborations measured in terms of research projects exhibits that the collaborations of the three kinds - collaboration between different departments of the same institution, collaboration between different institutes within the same country, and international collaboration – are found to be predominant or preferred by the researchers in rice biotechnology research. Therefore, the quantitative and qualitative analysis both indicates that collaborative ambits of rice research are transcending boundaries of organizations, regions and nation as well. Furthermore, the research activities in the field of rice crop are in a transition phase, making a shift from "little science" to "big science" environment.

One of the concrete findings of the study is a weak collaboration between SAUs, ICAR-sponsored institutes, and Industry. The bibliometric study and, the analysis of research projects indicate that industries have very less amount of collaboration with SAUs and ICAR-sponsored institutes. The lack of university-industry collaboration should be understood in the context of frequent debates that take place in India regarding lack of innovation and commercialization of research. The university-industry linkage, a phenomenon quite common and established in the developed countries is rare in India. This has hampered the research from producing innovative products. Collaboration between university, industry, and government sectors contributes to industrial development. It suggests the bringing of three agencies on a single platform viz. government, regulating the research; universities, engaged in the production of knowledge and Industry commercializing the knowledge. The triple helix theory pays attention to improving collaboration between the three sectors in order to enhance the practical implications of academic research because the theory focuses on the industrial use of knowledge. Certainly, the collaborative research between sectors enhances the practical implications of research. Therefore, the triple helix model which advocates for bringing university, industry, and government sectors on a common platform through collaboration, is yet to evolve in the field of rice biotechnology research.

The analysis of research projects indicates that scientists coming under the aegis of SAUs and ICAR-sponsored agencies. However, by commanding 76 percent of total international collaborations, CGIAR has emerged as one of the important avenues and the most preferable agency for forging international collaboration in rice biotechnology. International Rice Research Institute (IRRI) has emerged as a key player in the organization of international collaboration by 48 percent to total international projects. The desire to work with best scientists in the world to produce high quality and high impact research has emerged as one of the primary drivers of international collaboration. The cross-disciplinary nature of agriculture biotechnology is also playing a pivotal role in accelerating international collaboration in rice research in the context of India. This study reflects that collaborative networks are formed early in the research career. Meeting and discussing with peoples at conferences and seminars is also an important avenue to build international collaborations and networks. However, it was found that there was no substitute for personal networks and contacts to reach an international collaborator. Administrative delays and lack of national funding to develop contacts and support international collaboration were the two major challenges to international collaboration.

The fifth chapter has examined various sociotechnical factors that are embedded in local working conditions and how they influence the collaboration process at initiation, development, and conclusion of collaboration between rice biotechnologists in distributed/inter-institutional projects. The present study finds that collaborative practices in rice biotechnology appear to be influenced by various sociotechnical factors that are embedded in the local working condition of a scientist. With high percentage (93 percent) of response from scientists, the division of labour has emerged as a dominant factor that influences scientific collaboration in rice biotechnology research. Clear division of labour among collaborators enables them to work independently for the most part of the project and pinpoint accountability if something goes wrong in a project. The same research interest of partners and their willingness to join or contribute to project establishes some common ground, which further enhances reliability among partners. Furthermore, in the field of rice biotechnology research common ground is relatively easy to establish when a research project is homogenous, intra-disciplinary, and intra-institutional in nature. Therefore, dispersed collaboration hinders the formation of common ground among partners.

The history of collaboration among individuals/organizations was another factor highly rated (87 percent) by the scientists, shapes collaborative projects profoundly and plays an important role in achieving common ground. The scientists prefer to collaborate with past collaborators. This suggests that compatibility over competency is preferred by rice biotechnologists while making alliances with other scientists. The intrinsic rewards, as well as extrinsic rewards, have emerged as the main driver of any collaborative efforts. However, intrinsic rewards, such as self-satisfaction or a feeling of accomplishment were more valued by rice biotechnologists in comparison to extrinsic rewards. Furthermore, it is obvious from the study that collaborative practices do not facilitate the transfer of tacit and transactive components of knowledge.

The presents study finds that complementarities of expertise, sharing materials for research, physical assets and nature of funding bodies determine the basis of scientific collaboration. Therefore, it is the lack of human and non-human resources that spur collaboration in rice biotechnology research. Further, a majority of scientists believes that R&D collaborations in rice biotechnology research are not characterized by knowledge sharing culture. Rather, collaborative practices are plagued with hiding, concealing, and misrepresentations of data or information.

The communications in collaborative projects are technology dependent and ICT driven. Majority of the rice biotechnologist's uses internet-based email to reach their partner regardless of physical and social proximity. Email has emerged as a dominant mode of communication between partners. It has enabled practices of data acquisition, manipulations, and analysis. The email provides a platform where partners discussed problems, exchanged information, cross-check results, and provided solutions. Therefore, an ICT-driven technology does not only shape the relationships between partners but also plays a critical role in the organization of collaborative projects.

This study indicates that rice biotechnologists located at SAUs and ICAR-sponsored institutes adopt structured (conventional) approach to project management to manage collaborative projects in rice biotechnology research. In the field of rice biotechnology research, the scientific and administrative responsibilities are carried out by PIs accompanied by project coordinators. The decision-making practices might, at best, be characterized as a blend hierarchical and consensual, where consensual decision-making operates at the top level while a more hierarchical structure characterizes the organization itself. The R&D collaborations in rice biotechnology are highly formalized, involves high incidences of written rules, regulations and formalized responsibilities. Therefore, the organisation of scientific collaboration in rice biotechnology research can be best characterized by a high incidence of the classical Weberian features: hierarchy of authority, written rules and regulations, formalized responsibilities, and a specialized division of labour (Weber 1964). However, these features should not be understood as impediments to scientific collaborations. Their principal objective is to protect organizational interests as any form of collaboration is, by definition, an intendedly ephemeral joining of partners.

The study finds that there is need to understand the problem faced by plant molecular biologists and plant breeder for the smooth function of R&D collaboration in rice biotechnology research. The differences between plant molecular biologists and plant breeders may be seen through the differences in their emphasis on laboratory research and field research and the techniques associated with the respective approaches.

The present study infers that the mandates and protocols of specific institutional settings may direct the pursuit of research collaboration in specific dimensions. Differences in the mandates of the institutes create anxieties amongst plant molecular biologists and plant breeders. An absence of mutually accepted norms carries the potentials to create tensions among partners.

The present study indicates that the rice biotechnologist perceives IPRs as an obstruction to R&D collaboration and they are resisting to such institutional regime. Merton (1973) outlines three responses to the institution (norms): (a) conformity, (b) deviance, and (c) ambivalence. Here, norms can be understood as a set of rules used by the scientific group for appropriation and inappropriation of beliefs, values, attitudes and behaviour. Putting the responses of the scientists in the present study to the institutions (norms) in terms of Merton's classification, the responses of the scientists suggests that though the scientific community in India at times resists the protocol of the IPRs regime keeping in view the spirit of democratization of scientific knowledge. However, resistance from the scientific community in India is not very often seen in its practice. Their profiles of scientists mentioned in chapter IV suggests that they are much interested in shielding their innovations in terms of publication, patents, plant variety protection and other various forms of inventions. Instead, their resistance to IPR regime is associated with the earlier value system of communitarian ownership over scientific knowledge. As a corollary, the scientific community in India subscribes, to a great extent, to the value system of the restricted accessibility to scientific knowledge.

The presence of Matthew effect in research collaboration was found to be very rampant in the field of rice biotechnology. It is obvious that status-based factors are dominant than the academic-based factors while allocating project and credit to scientists. The scientists' of higher status wins highly desired collaborative projects than the scientists of lower status. Inequalities are also found in credit allocation, scientists with high status get larger credit vis-à-vis scientists with low status while collaborating and contributing as equals. Therefore, scientific collaboration is not based on the ethos of equality.

The sixth chapter emphasized on the transformations that have occurred in the field of rice biotechnology research due to the advent of new agricultural biotechnology tools. The presents study observes that there is a reorientation of research thrust among rice biotechnologists. Their research priorities have shifted from yield enhancement to control of biotic stresses, abiotic stresses and nutritional enhancement or biofortification of rice crop. However, control of biotic and abiotic stresses indirectly contributes to the yield enhancement. Furthermore, a shift in research priorities also indicates the transition of rice biotechnology research from green revolution era to gene revolution era, as green revolution focused on yield enhancement and genetic revolution concentrates on controlling biotic and abiotic stresses. The emergence of modern biotechnological tools and escalation in funding from government and non-government agencies are the two common and consistent reasons forwarded by majority scientists for the reorganization of their research area. The introduction of new biotechnological tools has enabled rice scientists to tackle complex traits which were not possible with the conventional biotechnological tools. Therefore, applications of modern biotechnologies have positive implications, at least in the laboratory, especially on methods of knowing and doing science.

Majority of the practitioners of rice biotechnology research in the study, drawn from selected scientific institutions coming under the aegis of SAU and ICAR, do not dichotomise between basic and applied research; rather, they see it as a continuum. Besides, none of the scientists in study characterizes their research thrust as development research. This group of scientists tends to collaborate with a variety of research institutes and universities across continents.

The present study reflects that contemporary technology development programs in rice biotechnology research are concentrated on biodiversity and biosafety. This implies that rice biotechnology research is being carried out in SAUs and ICAR-sponsored within the goals and ethos of sustainable agriculture. However, scientists in the interview were more interested in discussing the scientific aspect technologies. Social aspect technologies, such as accessibility, equity, acceptability, and social viability of technologies were found to be missing from the dialogue of the scientists.

The present study empirically finds 3 out of 12 SAUs, viz. Tamil Nadu Agricultural University, Coimbatore; University of Agricultural Sciences, Bangalore; and Punjab Agricultural University, Ludhiana. Whereas 4 out of 9 among ICAR-sponsored institutes, viz. Indian Agricultural Research Institute, Pusa (New Delhi); National Research Centre on Plant Biotechnology, New Delhi; Indian Institute of Rice Research, Hyderabad; and National Rice Research Institute, Cuttack to be engaged in research pertaining to GMOs. All these institutes are well-established in terms of scientific, technical, and manpower resources. Therefore, GM research programmes are being deliberately pushed into well-established institutes.

The opinion of the rice biotechnologists on GM technology is fragmented. On the questions of GM technology, the scientific community is split into three groups. First consists of scientists who are vehemently advocating for the application of GMOs in Indian agricultural sector without any delay. Secondly, comprises of the scientists, who are resisting implementation of GMOs in Indian agricultural context and thirdly, includes scientists who chose to take a middle ground on the questions concerning GMOs. There is a complete lack of consensus among the scientific communities on the issue of GM technology. This suggests that the paradigm shift from green revolution to gene revolution has occurred in the context of Indian agriculture by forging an alliance between political power and scientific authority. Moreover, it also appears from the study that internal critic for GMOs has generated among the rice biotechnologists. The discontent of scientists is now beginning to coalesce into more organized viewpoints that might turn into the reformation of the vitality of a public plant science community to public services.

In the context of golden rice, the case study of Swarna suggests that the initial attempt to develop an Indian version of golden rice at IARI, New Delhi has failed. The occurrence of anomalies such as the withdrawal of G1 event, Aux1 disruption in R1 event causing unexpected phenotype and gradual degradation of carotenoid content in stored grains questions the scientific and technical soundness of GM technology. These multiple undesirable and unexpected outcome of the experiment also suggests that GM technology is still poorly understood phenomenon in terms of scientific and technical knowledge. The case of Swarna rejects the claims of the scientific community that golden rice is ready to use since its invention and it is not in the plates of targeted groups owing to lack of social and political will. Therefore, golden rice suffers from certain scientific and technical flaws, which need to be fixed within the rigour of science before its implementation in the field for cultivation.

The scientist's response over policy implications indicates that there are frequent changes in the stance of political actors and institutions over the social and technical regulations of GM technologies. India's policy-making and policy-implementation related to GMOs varies across actors and institutions. There is lack of single-cohesive policy over the technical regulations of GM technologies. These highlight design gaps present within the structure to regulate the technical aspect of GM technologies in India. The function and ambit of various regulating agencies are not well-defined leading to conflict between the agencies. The overlapping of the policies is quite palpable. Moreover, not only single policy framework but its universal execution within the country is also absent. The stance of government varies across the state in the country. Some states are promoting GM technologies and a few have imposed restrictions on GM technology. There are differences in the stance of central and state government on implementation of GMOs. This might be called as operator failures. The case study of Calcutta University elicits the design faults and operator failure present within technical regulation policies of GM technology. At Calcutta University, the field trial of seven transgenic rice (Oryza Sativa L), which contained the gene for high iron content was seriously delayed and jeopardized for two years owing to ambiguous and multi-structure technical regulations for GM technologies in India. Thus, existing policy framework pertaining to GM technology suffers from design faults (structural problem) and operator failure (agency failure). The GM regulation policies in India have made great progress in pace, scope and profoundness, but it has failed to effectively reach its goals or deliver services. Consequently, it has colossal implications on the pace and vigour of rice biotechnology research. Therefore, current rice biotechnology research cannot be characterized as normal science but rather it can be called as post-normal science, where both science and the scientific community is in crisis.

The present study demonstrates that genomic-based Marker Assisted Technology (MAS) is being extensively implemented by scientists in rice biotechnology research to tackle biotic stresses, abiotic stresses, yield and quality enhancement has boost up the rice production in India. MAS technology, based on moving genetic material between on variety to another variety (within the crop gene pool) of a species is a molecular technique but different from GM technology, where the transfer of genetic material takes place across the taxonomic barriers. Amid controversies surrounding the GM technology, MAS technology has emerged as a non-controversial technology with wider public acceptance. Thus MAS technology offers an alternative to GM technology. In the context of India, to date, whatever products that have been developed through MAS technology have been registered under PPVFR act. This characterizes MAS as a non-propriety technology.

The case study of Swarna Sub 1, a MAS-derived flood-tolerant variety of rice developed by IRRI, is benefiting marginal farmers and helping social disadvantageous groups. Moreover, after its invention, Swarna- SUB 1 was made available free for farmers use. It is free from any institutions including rules governing the production, distribution and organizational mechanisms that are required to commercialize the molecular- driven variety especially in an era of increasing privatization of seed production. Therefore, the case study of Swarna-Sub 1 exemplifies what kind of institutional and organizational arrangements for knowledge production, application, and large-scale production and deployment by farmers is necessary for the innovation system in agriculture in the country.

Finally, the present study concludes that although the process of collaboration is ubiquitous in scientific research, its understanding is very ambiguous. There are various levels at which a person can contribute in the research work. For instance, a person who does the data collection work is defineatly making a contribution in the overall scheme of the research work. However, this kind of contribution is fundamentally different from that of scientists. The contribution of a scientist is on an intellectual level but that of a technician or a data collector is extra-intellectual. This fundamental confusion has not been paid much attention to. Thus, collaboration is mostly analyzed in the scientometric framework with co-authorship being the predominant criteria for evaluating the existence and extent of collaboration. There is another aspect of collaboration which does not render itself amenable to be studied easily. There is a considerable amount of sharing of ideas and views, discussions in platforms like conferences, seminars etc. The views and ideas obtained at these forums are of significant value to a scientist and may even sometimes provide a breakthrough. In this sense, the contribution obtained in this way is no less than the contribution obtained through formal collaborative channels. The problem lies in the research tools to map informal contributions. Since these contributions are not recorded, it becomes difficult to identify and measure this assistance either qualitatively and quantitatively. Thus a research work highlighting the importance of informal collaborative channels is conspicuous by its absence. Even in the present work, the author many times, during the course of personal interviews of the scientists, felt that scientists appreciate the sharing of ideas at the informal level and benefit from them. Yet due to difficulties mentioned above, it was not possible for the author to analyze that informal contribution in the present work. Therefore one important direction in the collaboration studies would be towards the contribution of informal channels.

### 7.2 Limitations of the Study

The present study is limited in terms of its scope. The present study is limited to public agricultural institutes coming under the aegis of SAU and ICAR. The study could not accommodate other public institutes sponsored by DBT, ICMR, CSIR, DRDO and so forth. Moreover, industry and research foundations, to a larger extent, could not be accommodated in this study. The study could not include the perspectives of funding agencies and policy-makers, which plays a significant role in the formation and organization any form of collaborations. However, the finding of this study may provide an indication of various forms and levels of scientific collaborations occurring in the field of rice biotechnology research in the context of India.

### 7.3 Scope for Further Research

A large number of participants from diverse institutional setups especially industry may be incorporated to examine the intricacies of scientific collaboration operating in the field of rice biotechnology research. Multiple-case studies could be conducted that requires much ethnographic delineation though.

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 with the 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 the 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 the 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

**Indian Institute of Technology Guwahati**
**Department of Humanities and Social Sciences**

**Dynamics of Scientific Collaboration: A Study of Rice Biotechnology Research in Selected Scientific Institutions in India**

**<u>INTERVIEW SCHEDULE</u>**

*Data obtained through the interview schedule will be used for research purpose only. Strict confidentiality will be made.*

1. What are the major areas of research which you are engaged in?
2. How do you locate your research in relation to your peer group in your institute and elsewhere?
3. How do you collaborate with your peer group? In other words, how do you identify your peer/ research group?
4. According to you what is research/scientific collaboration?
5. What are the prerequisites of research collaboration?
6. How do you select a potential partner in collaborative research practices and what is the cement that binds partners in research collaboration?
7. What according to you is an appropriate size for research collaboration and what role does it play in collaborative research practices?
8. What are the issues associated with division of labour in collaborative research practices and how is work allocated among the partners in research collaboration?
9. Would you kindly dwell upon the importance of time in collaborative research projects?
10. Would you kindly elaborate on the processes by which research collaboration is carried out?
11. Why do you think that scientific collaboration is important for research in plant biotechnology?
12. What are the factors that encourage research collaborative practices in plant biotechnology?
13. Would you kindly reflect on the types of scientific collaboration which you're engaged in?
14. What are your experiences regarding the institutional mandates in carrying out research collaboration?
15. Do your collaborating partners have conflicting interests with your set of institutional mandates?
16. What are the concrete deliverables or innovations that you often expect to get out of such collaborative networking with other disciplines and institutions?
17. As practitioners of plant biotechnology research in India, would you kindly reflect on the ways in which you may very often resist as well as accommodate various contentious issues in plant biotechnology?
18. What, according to you, are the social dimensions of innovation in plant biotechnology research in India?
19. Would you please reflect upon the role of research collaboration taking place in genetically modified technology?
20. What are the major issues of contention in research collaboration against the international framework of genetically modified seeds?
21. What are the proprietary issues in research collaboration and how it is being addressed in collaborative research practices?
22. To what extent and in what ways funding plays an important role in research collaboration?

23. How does success or failures of a collaborative research work affect the probability of future funding?
24. What are the outcomes of research collaboration which you are part of?
25. Can research collaboration be measured? If yes, what are the indicators? If no, what are the problems if we attempt to measure scientific collaboration?
26. How does a collaborative research practice enhance research productivity and quality of research? Comment?
27. What are the advantages and disadvantages of co-publication?
28. Explain what according to you are the benefits and limitations of co-patenting?
29. What are the complexities involved in benefit-sharing in research collaboration in terms of publication, patenting, awards, grants, fellowships, research mobility, etc.?
30. Kindly elaborate on the bottlenecks that you may often confront with so far as collaborative networking with other disciplines and institutions?
31. What are the shared responsibilities associated with the collaborative research practices?
32. How are risks of research collaboration covered and how failures are treated and negotiated in all categories of research collaboration?
33. Do you agree that there is need of setting up a mechanism for systematic central monitoring and evaluation of collaborative activities? Elucidate.
34. To what extent and in what ways ICT promotes collaborative research practices in plant biotechnology?
35. Please name the special plant biotechnology software (if any) that you are currently using in your research activities and explain its potentials and constraints?
36. Have you ever used germplasm from the national and international gene banks? Please explain the advantages and disadvantages of germplasm use from gene banks.
37. What are the constraints which limit the access to and utility of germplasm from gene banks?
38. What are the reasons for gene erosion in India and how new agricultural technology being developed addresses the question of gene erosion in India?
39. Would you please reflect on genetic exchange taking place at international level?
40. In what areas collaboration should be promoted and how it should be most effectively promoted?
41. What do you think measuring research collaboration in terms of co-publication and co-patenting is an appropriate method to measure collaborative research practices? Comment.
42. Do collaborative research practices enhance research productivity and quality of research? Comment.
43. What are the IPR issues in research collaboration and how it is being addressed in collaborative research practices?
44. What are the advantages and disadvantages of co-publication?
45. Explain what according to you are the benefits and limitations of co-patenting?
46. To what extent and in what ways individual motivations (reward, recognition, publication, patent, scholar generation, to gain expertise and tacit knowledge etc.) of a scientist influences propensity to collaborate?
47. What are the risks associated with the collaborative research practices?
48. How risks of research collaboration are are covered and how failures are treated and managed in all categories of research collaboration?

49. Do you agree that there is need of setting up a mechanism for systematic central monitoring and evaluation of collaborative activities? Elucidate.
50. To what extent and in what ways ICT promotes collaborative research practices in plant biotechnology?
51. Please name the special plant biotechnology software that you are currently using in your research activities and explain its potentials and constraints?
52. Have you ever used germplasm from the national and international gene banks? Please explain the advantages and disadvantages of germplasm use from gene banks.
53. What are the constraints which limit the access to and utility of germplasm from gene banks?
54. What are the reasons for gene erosion in India and how new agricultural technology being developed addresses the question of gene erosion in India?
55. Could you please reflect your views on genetic exchange taking place at international level?