Agricultural R&D Policy in India

Edited by
Suresh Pal

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ICAR – NATIONAL INSTITUTE OF AGRICULTURAL ECONOMICS AND POLICY RESEARCH

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FOREWORD

Agricultural technology has been an important instrument for agricultural growth and poverty reduction in India. Therefore, the Government has made substantial investment for development of research capacity within the Indian Council of Agricultural Research (ICAR) and the State Agricultural Universities. ICAR provided leadership, resources and environment for development of a pluralistic system and also facilitated partnerships with the international organizations. The strategy paid rich dividends in terms of making the country self-sufficient in food production, diversifying the production and reducing rural poverty. Also, manpower contribution of the Indian system is immense which is appreciated world-wide.

The Indian agricultural research and development (R&D) system has evolved over time, but organizational growth has been phenomenal after the Independence. Public funding for agricultural R&D in real terms has increased six times since early 1980s. There is transformation of the public extension system also, which is now more diversified and decentralized. Management and institutional reforms have been undertaken by the R&D organizations to improve their effectiveness. At the same time, there have been significant changes in the regulations dealing with development, commercialization and use of new technology. This volume has discussed these institutional and policy developments in agricultural R&D since its inception in India and their outcomes in terms of meeting the development challenges.

The main feature of this volume is that it deals with all aspects of agricultural R&D in India—research, extension, commercialization of technology, intellectual property rights, regulatory reforms, and impact of technology. Trends in public investment and organizational development for research and extension have been discussed at length. The changing roles of centre, states and private sector in funding and provision of R&D services are also discussed. Recent topics like socio-economic considerations in biosafety assessment of genetically-modified organisms, and impact of intellectual property rights are probed in the context of their impact on Indian seed industry and farmers' access to improved material and technology.

The volume also provides an idea of emerging challenges in the management of agricultural R&D. The most important issue in this regard is monitoring of technology and input systems and taking measures to foster synergies between public and private sectors, so that there are no monopolistic tendencies in input markets and farmers have access to improved technology at a reasonable cost. The volume has drawn useful lessons from the Indian experience which can be applied for improving the performance of R&D systems in other developing countries. It is hoped that policy makers, researchers and students in India and abroad will find this useful.

Trilochan Mohapatra
Secretary,
Department of Agricultural Research and Education &
Director General,
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New Delhi

12th April, 2017

PREFACE

India has a history of more than one hundred years of organised research and development (R&D) for agriculture. It has grown from a few research organizations at the beginning of the 20th Century to one of the most productive national research systems in the world. This transformation could be attributed to stability of government support and research policy reforms to respond to the emerging R&D challenges for Indian agriculture. This volume deals with these changes and their outcomes. Public funding for agricultural research and extension are discussed at length. Institutional diversification and management reforms have attracted lot of attention during the last two decades or so, which are discussed in the context of responsiveness of the research system.

Strengthening of intellectual property rights (IPRs) has been subject to intense debate about their likely impacts on the Indian seed sector. Response of the seed industry to IPRs, pattern of plant variety protection and patents, and their implications for input markets like seed and agro-chemicals is another important theme of this volume. The discussion on socio-economic considerations in biosafety assessment of genetically-modified organism provides clarity on the scope of and approach to such an assessment. The chapter on productivity trends and research impact in the irrigated region addresses the question of research effectiveness and it reiterates the fact that investment in agricultural research and extension still pays high dividends.

This volume is an accumulation of research work done during the last two decades and it provides a holistic discussion on all aspects of agricultural R&D. A number of organizations and individuals have supported this work. I sincerely thank the Indian Council of Agricultural Research and National Institute of Agricultural Economics and Policy Research for providing necessary support to complete this work. I have immensely benefitted from the discussion with Derek Byerlee, Phillip G Pardey, Robert Tripp, Michael Morris, Mruthyunjaya, PK Joshi and Ramesh Chand while working on different programs. It will be unfair on my part if I don't acknowledge and appreciate the contributions of my family and all my colleagues for their encouragement and unstinted support. Special thanks are due to Mrs Swati Sanghi for her skills in editing the volume.

Although the volume is about agricultural R&D policy in India, examples of international experience have been drawn from the Consultative Group on International Agricultural

Research and other international organizations to support the discussion. The volume also spells out key policy lessons which can be useful for developing countries. It is hoped that researchers and students working in the area of research policy, research managers and policy makers in the developed and developing countries will find this volume useful.

Suresh Pal

ACRONYMS AND ABBREVIATIONS

AgGDP	Agricultural Gross Domestic Product
AICRPs	All Indian Coordinated Crop Improvement Projects
AMUL	Anand Milk Cooperative Union Ltd.
AP	Andhra Pradesh
APHIS	Animal, Plant and Health Inspection Service (US)
ASTI	Agricultural Science and Technology Indicators
ATIC	Agricultural Technology Information Centre
ATMA	Agricultural Technology Management Agency
B-C	Benefit-Cost (Ratio)
CGE	Computable General Equilibrium Model
CGIAR	Consultative Group for International Agricultural Research
CIMMYT	International Maize and Wheat Improvement Center
CSIR	Council of Scientific and Industrial Research
DAC&FW	Department of Agriculture, Cooperation and Farmers Welfare
DARE	Department of Agricultural Research and Education
DBT	Department of Biotechnology
DST	Department of Science and Technology
DUS	Distinctness, Uniformity and Stability
EPA	Environmental Protection Agency (US)
EPC	European Patent Convention
EV	Extant variety
FAO	Food and Agriculture Organization
FDA	Food and Drug Administration (US)
FTE	Full-time Equivalent
FV	Farmer Variety
GEAC	Genetic Engineering Approval Committee
GMOs	Genetically-Modified Organisms

GoI	Government of India
HYVs	High Yielding Varieties
ICAR	Indian Council of Agricultural Research
ICRISAT	International Crops Research Institute for the Semi-Arid Tropics
ICT	Information Communication Technology
IFFCO	Indian Farmers Fertilizers Cooperative
IGP	Indo-Gangetic Plains
IIRR	Indian Institute of Rice Research
IIWR	Indian Institute of Wheat & Barley Research
IPC	International Patent Classification
IPM	Integrated Pest Management
IPRs	Intellectual Property Rights
IRR	Internal Rate of Return
ISAAA	International Service for the Acquisition of Agri-biotech Applications
KRIBHCO	Krishak Bharati Cooperative
KVKs	Krishi Vigyan Kendras
LMOs	Living Modified Organisms
MANAGE	National Institute for Agricultural Extension Management
MoA	Ministry of Agriculture and Farmers Welfare
MP	Madhya Pradesh
MSGGA	Maharashtra State Grape Growers Association
NABARD	National Bank for Agriculture and Rural Development
NAIP	National Agricultural Innovation Project
NARS	National Agricultural Research System
NATP	National Agricultural Technology Project
NBA	National Biodiversity Authority
NBPGR	National Bureau of Plant Genetic Resources
NEPA	National Environmental Protection Act
NFSM	National Food Security Mission
NGOs	Non-Governmental Organizations
NITI Aayog	National Institution for Transforming India Aayog

NPV	Net Present Value
NSAI	National Seed Association of India
NSC	National Seeds Corporation
NSSO	National Sample Survey Office
NV	New Variety
OPVs	Open Pollinated Varieties
PCT	Patent Cooperation Treaty
PGR	Plant Genetic Resources
PPP	Purchasing Power Parity
PPPs	Public-Private Partnerships
PPV&FR	Protection of Plant Variety & Farmers' Rights
PVP	Plant Variety Protection
R&D	Research and Development
R&E	Research and Education
RCGM	Review Committee on Genetic Manipulation
RCT	Resource Conservation Technology
RKVY	Rashtriya Krishi Vikas Yojana
S&T	Science and Technology
SAARC	South Asian Association for Regional Cooperation
SAMETIs	State Agricultural Extension Management and Training Institutes
SAUs	State Agricultural Universities
SFCI	State Farm Corporation of India
SRR	Seed Replacement Rate
SSCs	State Seeds Corporations
T&V	Training and Visit
TDC	Tarai Development Corporation
TFP	Total Factor Productivity
TLS	Truthfully-Labelled Seed
TRIPS	Trade-Related Aspects of Intellectual Property Rights
TTCs	Trainers' Training Centres
UK	United Kingdom

UP	Uttar Pradesh
UPOV	International Union for the Protection of New Varieties of Plants
USA	United States of America
USAID	United States Agency for International Development
USDA	United States Department of Agriculture
WHO	World Health Organization
WIPO	World Intellectual Property Organization
WTO	World Trade Organization

Chapter 1

INTRODUCTION AND OVERVIEW

Suresh Pal

The application of organized research and development (R&D) in agriculture is now more than a century old in India. It began with the strengthening of agricultural departments in the Union and State Governments, and subsequently establishment of agricultural colleges in 1905 and of the Indian Council of Agricultural Research (ICAR) in 1929. Since then, agricultural research has evolved from a few isolated government organizations to serve imperial interests into a well-coordinated and responsive system under ICAR. This transition has been possible through a number of policy and institutional developments. Significant among these initiatives has been public funding for creation of scientific infrastructure and human resource development (Pal and Byerlee, 2006). The overriding objective of the policy of public investment was to achieve national food security through development of infrastructure for R&D, irrigation and input supply, and to put in place a supportive price policy. This strategy paid rich dividends in terms of ushering in the 'green' and subsequently 'rainbow' revolutions with impressive achievements in dairy, fisheries and oilseeds. Recent additions to these achievements can be seen in the spheres of poultry, cotton, maize, vegetables and fruits.

Since the unprecedented success of the green revolution, there have been significant advancements in science, its organization and management and transfer of technology to end users. The research system expanded considerably and extension system has undergone a continuous change. Advancements in molecular biology and information technology have taken shape and research on animals and horticultural crops has expanded. With these rapid developments, a system perspective on interdisciplinary and interinstitutional framework became the need of the day. The Indian agricultural R&D system responded to these developments, which has not been an easy task considering that there were hardly any developing countries whose experience could serve as an example. The conditions of developed countries, especially their agrarian structure and commercial orientation were in sharp contrast to the Indian agriculture, restricting the adaptation of their R&D strategy. This was particularly true for transfer of technology since majority of Indian farmers were small, resource poor and farming was subsistence in nature in most parts of the country. However, these experiences of expansion of Indian R&D system and organization of research and extension programs are still relevant for other developing countries.

The last two decades posed new challenges of management and regulation of R&D globally. A number of international agreements were put in force, which have significant implications for development and dissemination of agricultural technology. Important among these agreements are protection of intellectual property, conservation and sustainable use of biological diversity and regulation of transgenic products. These were new developments and a complete departure from the prevailing practices in the Indian system. An understanding of these new regulations and developing an appropriate strategy which could balance the interests of inventors and farmers in the national context was a challenging task. Therefore, it is worthwhile to study how the Indian agricultural R&D system has responded to these challenges and what lessons it holds for other developing countries. This volume deals with these issues.

EVOLUTION OF R&D POLICY

The fundamental principle of Indian agricultural R&D policy has been public funding and provision of R&D services for sustainable growth in productivity and self-reliance in food production. This policy continued during the country's transition to Independence and re-organization of the R&D system subsequently. Though real public funding for agricultural R&D has shown an upward trend since the early phase, the growth was especially high (more than six percent per annum) during the 1990s and 2000s. There has also been a marked shift in the funding pattern of the Union and State Governments. During 1960s and 1970s, with the establishment of the state agricultural universities (SAUs) there was a significant growth in the state funding. But since the early 1990s, the central funding has outpaced the state funding and a part of this was transferred to SAUs through sponsored programmes and development grants. On the other hand, agricultural extension was mainly funded by the State Governments, and the centre's support was available through development programs like *Rashtriya Krishi Vikas Yojana,* extension reforms, and technology missions. As a result, India is one of the few countries with sustained growth in funding for agricultural R&D (Beintema and Stads, 2010).

The second important element of agricultural R&D policy has been 'open access' to public research products for further use or commercialization. This policy in fact paved the way for public-private partnership, transfer of technology and diversification of input markets like seed. A deliberate attempt was also made to coordinate research being done under various organizations, largely under the coordinated programmes of ICAR with funds earmarked for this activity. International foundations like Rockefeller Foundation have played an important role in developing and institutionalizing these coordinated research programmes (Herdt, 2012). This policy of institutional linkage was also extended to private R&D organizations which were partners in the process of commercialization, up scaling and demonstration of technology.

With the growth of Indian R&D system, there was a realization of the fact that public funding need not be exclusive for public organizations and that private sector could be an important ally in addressing national R&D needs. In view of this, public funds were made available to private organizations either through sponsored research or competitive funding. Such programmes grew over time, both, under externally-funded projects of the World Bank as well as ICAR's Plan budget programmes. Nearly ten percent of ICAR budget is now spent on demonstration of new technology and skill development of farmers, in partnership with private and civil society organizations. Such initiatives have put India among the few countries having public-private partnership in R&D.

As the system expanded, research managers turned their attention to sharing information and resources among different disciplines, programmes and institutions, which was required to maintain productivity of the system. Concerns about relevance of research and linkages with the state line departments and stakeholders led to management innovations for better research planning, regulation of R&D and linkages with farmers and other end users. This was mainly due to two reasons. First, the Indian system had become one of the largest systems in the world necessitating innovations in management to better target research, improve its efficiency and foster partnerships. Important among these innovations have been adoption of eco-regional planning, objectivity and transparency in resource allocation and programme monitoring, and linking funding with performance through competitive funding. Performance assessment criteria both, for organizations and scientific personnel, have also been made more objective and transparent. The second important policy reform was related to regulation of biotechnology research and commercialization of transgenic products. The underlying principle was that risk assessment of the products must be scientifically sound and the products which are likely to generate high economic benefits should be commercialized. These tasks were performed by different agencies and now the government is considering unification of the regulatory system under one agency as well as incorporating social concerns in decision making.

As regards intellectual property rights, the country, in compliance with the international agreement, amended the patent act to allow product and process patents and also enacted the law for protection of plant varieties. This is a major departure from the past and now both public and private sectors are seeking protection of their intellectual property. But traditional methods like biological protection, excluding genetic use restriction technology which is banned in India, are still followed for plant varieties. Compliance to these legal protection mechanisms and requirements under the Biological Diversity Act (2002) will add to the transaction cost of access and commercialization of improved plant material. A final success of these mechanisms will depend upon their credibility and cost effectiveness (Koo *et al,* 2004 and Tripp *et al,* 2007). How far these regulations shall attract investment in agricultural R&D, diversify private research portfolio like shifting to breeding of open pollinated crops, and influence competition in input and technology markets will unfold in the years to come. However, there are instances of spillins of international technology in the area of plant genetic resources, machinery and agro-chemicals (Kandpal, 2014). This phenomenon can partly be attributed to expanding markets for these technologies due to commercialization of Indian agriculture.

ORGANIZATIONAL DEVELOPMENT

Sustained public funding has been instrumental in establishing research infrastructure in the public sector. The main organization comprises ICAR and a network of research institutions working under its administrative and funding control. There are more than one hundred research institutes under ICAR, which are mandated for strategic research of national importance. There are four institutes with the status of 'deemed to be university' which also impart post-graduate education in their respective fields. There is a central university funded by ICAR and two more are in pipeline for imparting undergraduate and post-graduate education. The deemed university model is considered to be rather successful in terms of quality education as they restrict themselves to post-graduate programmes and also because of the low student-faculty ratio. This fact may attract more institutions to join this group. Though the ICAR system is working well and has linkages with other national and international organizations, the 'national research centres' however have weakness in the form of less than critical minimum scientific manpower, which increases overhead costs and reduces their effectiveness. This needs immediate correction.

The second component of the public agricultural research is SAUs (63 in number in 2015) with funding from their respective state governments but administratively autonomous institutions. These SAUs mandated for agricultural education and state specific research have been working in partnership with ICAR institutes and get development and project grants from it. Lately however, in a bid to create a new university from the existing one, SAUs are getting fragmented leading to a shrinking faculty and loss of their multi-faculty character. This trend must be reversed and faculty strength of SAUs should be restored to the level of 1980s. Nevertheless, the ICAR-SAU model has been quite successful and adopted in many Asian and African countries. The main reasons for the success are a central agency of ICAR to guide and coordinate research and its funding and institutional linkages with other organizations.

The second strength lies in initiation of innovative programs and reforms by ICAR with funding support, ensuring greater compliance to these reforms. Other departments under the Union Government like Department of Biotechnology and Department of Science and Technology are now expanding their network on the pattern of ICAR. These Departments were largely supporting research through extramural funding; only the Council of Scientific and Industrial Research is organized into a research institute mode with greater autonomy to the centers.

The agricultural extension system has been evolving over time on three broad lines. The main extension system is with the state line departments, grappling to gain independent institutional identity. This began with a multipurpose development department which subsequently evolved into a specialized extension system, emphasizing direct contact with farmers under the 'Training and Visit System.' This model became rather ineffective with shrinking manpower and therefore shifted to the "Agricultural Technology Management Agency (ATMA)'—an agency represented by multiple stakeholders at the district level. ATMA has linkages with *Krishi Vigyan Kendras* (KVKs), SAUs etc. for technical backstopping and with the state line departments for technology transfer. The second component of the extension system is the institutions for capacity building of extension personnel both, at the centre and state levels. These institutions are expected to initiate and institutionalize extension reforms. Funding for these institutes is from their respective state governments. The third component of public extension is ICAR's network of *Krishi Vigyan Kendras* (KVKs) or farm science centres (642 in number in 2015) in all the districts to demonstrate new technology and impart training to farmers, rural women and youth relating to agriculture and allied activities. These KVKs have strong linkages with ICAR institutes and SAUs for technical support, thereby proving quite successful in demonstration and dissemination of new technology and associated inputs like planting material. In addition, ICAR-SAU system has its own activities of on-farm assessment and refinement of their technologies and dissemination of information through 'Agricultural Technology Information Centres.'

PRIVATE R&D

Private R&D both for profit and non-profit, has been active in agriculture since popularization of tractors, fertilizers and pesticides There were some isolated efforts by private sector to multiply and distribute seeds of high yielding varieties. The non-profit organizations are now mainly active in the area of natural resource management and promotion of location specific technology, notable examples being foundations for R&D, civil society organizations in technology transfer and farmers' organizations for commodity development. Private R&D for-profit, however, has increased over time with expanding markets for inputs and commercialization of Indian agriculture.

Availability of scientific manpower, infrastructure and access to public research products also paved the way for private investment in R&D. Most of the private investment is for in-house research of input companies and is concentrated in the area of plant breeding, pesticides, food processing, animal health and farm machinery (Pray and Nagarajan, 2012). These private R&D organizations can be broadly classified into multinational companies, mostly active in seeds, large national companies working in all fields of agricultural R&D, and small national companies working at the state or regional level. So far, input markets have been quite competitive but import of technology and enforcement of IPRs may result into dominance of some large companies , which in turn may influence prices of inputs, mainly seeds, plant protection chemicals and animal health products, based on proprietary R&D. Higher price may not be a problem for farmers provided they are compensated by economic gains in use of modern inputs. But disproportionate increase in prices owing to monopolization should invite interventions by the government, as in case of Bt cotton seed in Andhra Pradesh and by the Union Government recently.

EMERGING ISSUES

The Indian agricultural R&D system has so far responded well to the national challenges, but complexity of research and regulatory issues needs to be addressed now. There are multiple development challenges like efficient and inclusive growth, sustainability of natural resources, nutritive and quality products, environmental safety, etc., which are often cumulative and conflicting requiring more research resources and their targeting. The system now will require to regulate R&D in such a manner that it not only complies with international commitments and scientific principles but also seeks participation of stakeholders and incorporates social voice in decision making. These tasks will need more resources to put required mechanism in place and balance concerns of all the stakeholders. It may not be possible to achieve this goal within a short period of time but the system should learn from the national and international experiences and promote science for society. One major problem in this regard is that some of the regulatory mechanisms such as genetically-modified organisms (GMOs), will be outside the agricultural R&D system and there may not be adequate capacity to handle multiplicity of issues. This may require national efforts and capacity building within the government departments and fostering close interaction among them.

The international agricultural research system, mainly the Consultative Group for International Agricultural Research (CGIAR) has been a useful ally of the national system. However, it has undergone significant change, in terms of funding, organization and research thrusts. Most of the research is done under project funding while core funding has witnessed drastic reduction. There is also a greater emphasis on location specific, action research in a multidisciplinary mode (Pingali and Kelley, 2007). This is a welcome step to enhance the impact, but strategic research addressing long-term or emerging issues is getting less attention. This implies that technology spillovers and exchange of knowledge may be a concern if these are not given due priority. Also, responsibility of fostering linkages among NARSs rests with CGIAR and multilateral donors and these need up-scaling. The larger NARSs will have to shoulder increasing responsibility of providing leadership and facilitate technology spillins. Some technology in future will be routed through multinational companies as their participation in India and other developing countries is rising. Participation of private sector in the R&D for inputs, agro-processing, farm machinery, etc. is all set to increase and public system should initiate measures to foster partnership with private R&D. Most of these partnerships shall be facilitated by market transaction for commercialization or out scaling of technology and gradually research partnerships shall develop in the areas requiring substantial amount of efforts to address strategic technology needs. IPRs regime shall be an important instrument to facilitate research partnership which involves exchange of material, knowledge and technology.

Strengthening of SAUs shall be a major challenge, especially when ICAR has no or limited administrative control over them. There are concerns in terms of mobilizing operating funds, modernizing infrastructure, and most importantly maintaining critical minimum faculty strength in various disciplines. ICAR can provide necessary support in terms of seed fund and leadership, but efforts made by SAUs in mobilizing support of state governments will go a long way in their revival and bring them back on board as they employ two-thirds of the scientific manpower. This shall help restore research-education linkages and promote integration of knowledge and technology at regional level and facilitate their flow to farmers.

Research-extension linkages and revival of public extension shall continue to be a major challenge for improving overall effectiveness of agricultural R&D system. Lack of funds, manpower and skills are major weaknesses of the public extension system (World Bank, 2012). Development of ATMA has given an institutional identity to extension which has promoted decentralized extension in a bottom-up manner. But it needs to nurture linkages with other development departments and KVKs. Also, KVKs should play a larger role in skill development, participatory technology demonstration to address the location specific constraints and dissemination of information to farmers. Private input companies are also undertaking promotion of their products, viz. inputs embedded with improved technology, but they lack larger social objective to promote 'the best product.' Farmers' organizations and large farmers growing horticultural crops and livestock may pay for extension and thus may attract private investment. But for small and marginal farmers, public extension can play a supportive role and therefore there is a need to enhance its role. Public extension system may however outsource some of the activities to private sector but only when there are adequate public funds and an effective mechanism to monitor performance of private extension (Anderson and Feder, 2004). Thus, a pluralistic system of farm extension and advisory services should evolve in the years to come. The concept of agricultural innovation system is also gaining currency, which recognizes the role of various sources of knowledge creators, including traditional knowledge, interactions among the actors for sharing of knowledge and promoting innovations in use of this knowledge to address production constraints and harness growth opportunities in agriculture (World Bank, 2012). In this context, the extension system should play a larger role in developing linkages with various stakeholders and help farmers gain access to markets and farm services and acquire necessary technical and organizational skills. The necessary condition for this is to create an enabling environment for interactions and knowledge sharing among multiple-stakeholders and to create capacity to innovate products, processes and institutions to respond to market opportunities and enhance economic efficiency. Development of these conditions will again require substantial public investment, especially for human resource development at all levels, including farmers and strengthening responsive rural institutions like farmers organizations, ATMA, KVKs, etc.

PLAN OF THE BOOK

The main purpose of this book is to provide an in depth discussion on agricultural R&D policy in India and to spell out issues likely to unfold in future. The issues covered are related to investments, organizational developments, regulations of R&D and technology flow, including biotechnology, and research impacts. Chapters 2 and 3 provide trends in public investment in agricultural research and extension, their allocation across regions and commodity groups, and organizational issues. Public R&D investmtents in India are compared with the international trends and institutional developments to improve their effectiveness. This is followed by funding and management reforms to improve the organizational efficiency in chapter 4. Competitive funding, eco-regional planning and monitoring mechanisms are presented along with their effectiveness in the Indian system.

Indian agricultural R&D system is a pioneer among developing countries in enacting and implementing legislations to strengthen IPRs. Among legal mechanisms, plant variety protection and patents have significant implications for Indian agriculture, especially research on crops and animals. Implementation of these mechanisms, response of stakeholders, and early impacts are discussed in chapters 5 and 6. In addition, there are issues related to bio-safety assessment in commercialization of transgenic products. These involve both, scientific assessment of the products as well as socio-economic considerations like size and distribution of benefits, consumer acceptance, cost-effectiveness of the process etc. Socio-economic considerations in the biosafety policy and commercialization of transgenic products are discussed in chapter 7. Finally, the last chapter (8) summarizes the evidence on impact of agricultural research in India. It also includes, as a case study, an assessment of economic returns to recent technological interventions in the rice-wheat system in India, to illustrate that payoffs from agricultural R&D are still high.

REFERENCES

Anderson, J.R. and G. Feder (2004), Agricultural Extension: Good Intentions and Hard Realities, *The World Bank Research Observer* 19(1):41–60.

Beintema, N. and G. J. Stads (2010), Public agricultural R&D investment and capacities in developing countries: recent evidence for 2000 and beyond. Washington, DC: IFPRI.

Herdt, R.W. (2012), People, institutions and technology: role of foundations in international agricultural R&D: 1960-2010, *Food Policy* 37(2): 179-190.

Kandpal, A. (2014), Patenting activity in India: implications for agriculture. MSc thesis submitted to PG School, IARI, New Delhi.

Koo, B, C. Nottenburg and P.G. Pardey (2004), Plants and intellectual property: an international perspective, *Science* 306: 1295-1297.

Pal, Suresh and Derek Byerlee (2006), The funding and organization of agricultural research in India: Evolution and emerging policy issues. In P.G. Pardey, J.M. Alston and R.R. Piggott (eds), *Agricultural R&D Policy in the Developing World*. Washington, DC: The John Hopkins University Press and IFPRI.

Pingali, P. and T. Kelley (2007), The role of international agricultural research in contributing to global food security and poverty alleviation: the case of the CGIAR. In: Evenson, R, Pingali, P. (Eds.), *Handbook of Agricultural Economics*, vol. 3. Elsevier, New York, pp. 2382–2418.

Pray, C. and L. Nagarajan (2012), Innovation and research by private agribusiness in India. Discussion Paper 1181, IFPRI: Washington, DC.

Tripp, R, N. Louwaars and D. Eaton (2007), Plant variety protection in developing countries- a report from the field, *Food Policy* 32(3): 354-371.

World Bank (2012), *Agricultural innovation systems: an investment source book*, Washington, DC.

Chapter 2

THE FUNDING, INSTITUTIONAL DEVELOPMENT AND POLICY PERSPECTIVE OF AGRICULTURAL RESEARCH IN INDIA

Suresh Pal

INTRODUCTION

Agricultural growth is still a prerequisite for sustainable economic growth and poverty reduction for the economies in transition. Agriculture not only ensures food security and thereby keeps food inflation under control but it also provides livelihood to millions of rural poor. Therefore, the governments have been making substantial investments to enhance the productive capacity of agriculture by creating necessary infrastructure. Development of irrigation, research and development (R&D) and rural infrastructure have attracted most of these investments. These efforts have been supplemented with policy reforms to strengthen farm support services, distribution of quality inputs and development of product markets. India, like other economies in transition, has a renewed priority for higher public investment in agriculture, promoting sustainable use of land, water and energy, and undertaking policy and institutional reforms to improve access of farmers to institutional credit and markets (GoI, 2012). In particular, higher public investment in agriculture for irrigation, R&D and rural infrastructure is emphasized at all levels of the government. Recently, incentives for business investment in agricultural R&D were also enhanced by extending intellectual property rights in the field of agricultural science. How far have these reforms been successful in strengthening the national R&D capacity? This chapter examines the evolution of agricultural research policy and adequacy of public investment in this context. In particular, trends in public investment in agricultural research and its allocations, as well as institutional reforms are discussed at length. The chapter also lists important lessons for strengthening agricultural R&D in other developing countries.

ORGANIZATIONAL DEVELOPMENTS

Agricultural research and education in India had their origin in the establishment of agriculture departments in the Union Government during the pre-Independence era and have grown together since then. An organized attempt for agricultural research and education was made with the establishment of five agricultural colleges in 1905. At the early stage of development, focus was on training of manpower and research for commercial crops like oilseeds and cotton , which gradually expanded to cover more crops. These efforts culminated with the establishment of an apex organization, viz. the Indian Council of Agricultural Research (ICAR) in 1929 under the Union Ministry of Agriculture. ICAR was further reorganized by bringing more institutions under its fold in 1973. With the creation of the Department of Agricultural Research and Education, ICAR was better linked with the Government and it evolved as an apex organization to plan, coordinate and undertake agricultural research and education in the country. The State Agricultural Universities (SAUs) with the mandate for education, research and extension have been working in the various states since 1960 and eventually developed closer working linkages with ICAR. The public system comprising research institutes under ICAR and SAUs laid the foundation for a well-coordinated research and education system for agriculture in the country.

Another major development in ICAR-SAU system has been a manifold expansion of ICAR with the establishment of more institutions, mostly commodity and resource centric institutes for basic and strategic research. The number of SAUs has also increased over time. In 2015, the public system comprised of 100 ICAR institutes and 63 SAUs. ICAR institutes can be broadly grouped into five categories. At the top, there are four deemed universities, with a few more under consideration, for basic and strategic research and post-graduation in crops, dairy, veterinary and fisheries. At the next level there are 62 institutes, mostly organized for commodity research with the national mandate. There are six bureau for conservation of genetic (plant, animal, fish, microbes, and insects) and other natural resources like land. Then there are 14 national research centres for commodity or resource research which work in a multi-disciplinary "mission mode" approach. Lastly, there are 14 project directorates to manage the coordinated research projects and undertake necessary backstopping research. Centres of these coordinated projects are also housed in SAUs. ICAR institutes are managed by eight Subject Matter Divisions of ICAR.

As regards SAUs, these were multi-faculty and multi-campus universities initially, but currently small universities are being established which have specialized faculty like animal sciences, horticulture etc. ; most of the states have several SAUs. The programs of ICAR institutes and SAUs are linked through the coordinated research projects of ICAR, and externally-funded projects of donors like the World Bank. At the policy level, eight regional committees represented by ICAR, SAUs, state governments and other development agencies are mandated to oversee regional research, education and development activities for agriculture in the region.

There is increasing participation of private sector in the development, commercialization and provision of technology embedded inputs. This trend is likely to increase in future and as witnessed in the developed countries, near market research for commercial inputs may shift to private R&D (Alston *et al*, 1999). Recognizing the importance of this positive development, the public system is establishing linkages with private (for-profit) and civil society organizations involved in R&D. These linkages are mostly for commercialization of public technology by business sector. A few collaborative programs between public and private sectors were undertaken under the sponsored funding of the World Bank. Joint programs between public organizations, research foundations and civil society organizations are expanding in the area of sustainable development and demonstration of technology, which is a welcome development.

Another notable development in the ICAR-SAU system has been the strengthening of decentralized research and technology transfer capacity. Beginning 1980s, a network of regional centres was established in all the states under the administrative control of SAUs to cater to adaptive research and thereby accelerate transfer of technology to the farmers. The regional capacity was also strengthened with creation of farm science centres or *Krishi Vigyan Kendras* for assessment, demonstration and transfer of new technology to farmers, and development of skills of the farmers, women and rural youth. These farm centres, 642 in number in 2015, were mainly funded by ICAR and a few of them were managed by civil society organizations. These centres, spread across the country, form a network of frontline extension. This system also provides technical backstopping to the main extension system of the states which is responsible for large scale transfer of technology and implementation of agricultural development programs. KVKs also produce planting material of new varieties for direct sale to farmers. The main extension system is funded and administered by the respective state governments (for details, see chapter 3).

The Indian model has been adopted by a number of Asian and African countries with variations in terms of functional autonomy granted by the respective governments. The model is successful in the sense that it has independent institutions for agricultural research and education, which are easy to manage and whose progress is easy to track. Other Indian R&D Departments like the Department of Biotechnology (DBT) and the Department of Science and Technology (DST), are primarily responsible for promoting science in their respective fields, through sponsored programs. But these Departments are now shifting focus to the establishment of institutions under their administrative control. The Council of Scientific and Industrial Research (CSIR) has also been organized on the pattern of ICAR. Thus, basic and strategic research which is primarily a responsibility of the government can be better conducted through public funded and managed institutions. However, there must be adequate linkages among them and related organizations for greater synergies through sharing of knowledge and resources. These linkages between ICAR, DST, DBT and CSIR and other scientific organizations are largely need-based and fostered through externally-funded projects, or special programs of the government. Part of the core funding of these organizations is also earmarked for extra-mural funding for collaborative programs of national importance. Some examples of important contributions of these collaborative efforts are: capacity for biotechnology research, weather forecasting, application of space research in agriculture and climate change.

TRENDS IN THE PUBLIC INVESTMENT

India followed a policy of committed public resources for agricultural development, including that for development and dissemination of farm technologies till Independence Food shortages for several decades after Independence further mobilized support for greater public investment in agricultural R&D. This fact is evident from the trends in the national funding for agricultural research and education (Fig. 1 and Appendix I). Initially, growth in the national public funding in real terms was comparatively slow but it accelerated later, during 1960s when the SAUs were being established. After a moderate growth in 1970s, the national funding grew more than six per cent per annum during 1980s, a trend which continued during the 1990s and thereafter. Thus, the growth which was nearly six per cent since 1980s almost doubled the real investment in each decade. The annual real funding for research and education at 2011 prices during the triennium ending (TE) 2014 was Rs. 86.68 billion and nearly half of this funding was from the states. If we take research funding net of education, the national funding was Rs. 53.38 billion. A great deal of the growth in funding took place since the late 1990s, mainly because of increased funding from the central government.

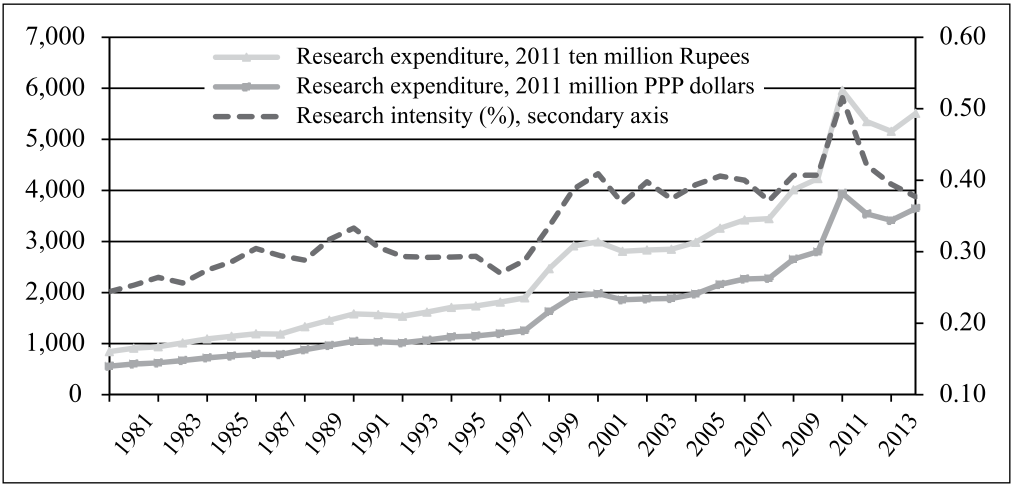

Fig. 1 : Trends in public funding for agricultural research in India

Table 1 : Level and intensity of agricultural research funding in India, triennium averages

	1981-83	1991-93	2001-03	2012-14
Research and education funding, 2011 million Rs.	14,003	24,697	44,669	86,682
Share (%) of the states in research and education funding	55.01	55.55	49.76	56.47
Research funding, 2011 million Rs.	8,974	15,624	28,778	53,379
Research funding, 2011 million PPP dollars	594	1,034	1,905	3,533
Research intensity (funding as percentage of AgGDP)	0.25	0.31	0.39	0.40
Annual growth rate (%) of total funding	6.07	5.94	6.70	
Annual growth rate (%) of Centre's funding	4.84	7.57	6.44	
Annual growth rate (%) of state's funding	7.09	4.39	6.84	

Note: Annual compound growth rates are for 1980s, 1990s and 2000s, respectively.

For international comparison, funding or expenditure is expressed in purchasing power parity (PPP) or international dollar rather than in US dollar (or any reference currency) using the nominal exchange rate. PPP conversion rate takes into consideration prices of a bundle of goods and services in both the countries, India and US in this case, with 2011 as a reference year. In 2011 PPP dollars, research funding stands at 3,533 million during 2011-14, as against 1,905 million during 2001-03 and 1,034 million in 1991-93 (Table 1). The highest investment was about 4,000 PPP dollars in 2011 (Fig. 1), indicating a near doubling of public funding in real terms in each decade. This trend however could not be sustained during the last few years.

There has been concurrent growth in funding, both from the Union and State (provincial) governments. In 2014, total public funding for agricultural research and education stood at Rs. 108.5 billion (or approx. 1,800 million US dollars) at current prices. Of this, the Union Government contributed 43.5 per cent through regular grants to ICAR and the rest 56.5 per cent was contributed by the State Governments for SAUs. A part of ICAR funds (37 percent) are used for supporting various activities like frontline extension, development of education and coordinated research projects in SAUs. In addition, there are research projects in SAUs which are sponsored under the funding from the World Bank and other donors. Thus, a considerable part of the expenditure incurred by SAUs is funded by ICAR and other sources. The funding of ICAR to SAUs has grown over time, providing an opportunity for better coordination among research, education and extension activities of ICAR institutes and SAUs. This leadership role of ICAR provided a unique advantage for planning and implementation of nationally important research programs in a 'mission mode' approach in partnership with SAUs. This resulted in a fast flow of technology to farmers making the Indian system one of the most productive systems in the world, with an estimated median rate of return of 58.9 per cent (Pal and Byerlee, 2006).

It would be useful to analyze the place of agricultural research in Indian science and technology (S&T) system. Although agricultural research began quite early in India, it did not get as high a priority in terms of allocation of public funds as the other fields of science. Since the Union Government is the major funding source for all scientific organizations in the country, its funding pattern reflects the position of various S&T organizations. In 2011, atomic and industrial research accounted for about one-fifth each of the total S&T budget while space research accounted for 17 percent. Other scientific organizations for basic sciences and biotechnology together spent 22 per cent of the resources. The share of ICAR was 20 per cent of the national S&T expenditure, which is rather low, given the high priority for food and security provided for rural livelihoods. Here it may be noted that there is no funding for general S&T from the State Governments, but SAUs and some research stations in the state of West Bengal which are also involved in research are funded by the State Governments. Even if we make adjustment for the state funding to SAUs, which is much smaller than the grant to general universities which also conduct basic research, agricultural research still remains underfunded.

In terms of research intensity, when we look at funding or expenditure as percentage of AgGDP, India spent only 0.40 per cent of AgGDP on research during 2012-14 and it has been at this level since 2001, except in 2011 when it reached 0.52 per cent because of higher plan allocations of the Union Government. The research intensity was 1.8 per cent in Brazil, 0.5 per cent in China and 3.01 per cent in the high income or developed countries (Alston *et al*, 1999; Beintema *et al*, 2012, Table 4). This gap in the expenditure intensity in India and other countries of comparable size was much higher during the 1980s and early 1990s, which narrowed down subsequently due to higher funding after the mid-1990s (Fig.1). The present trend is likely to continue as the government intends to reach the research intensity of one per cent of AgGDP, which shall bring India closer to the funding level of China and Latin America. This, coupled with well qualified scientific manpower should help strengthen India's position as a major provider of agricultural R&D services globally.

RESEARCH CAPACITY: SCIENTIFIC MANPOWER

Another important indicator of research capacity is scientific manpower employed in an organization. The minimum eligibility for assistant professorial position in ICAR and

SAUs is a master's degree, but a doctoral degree is preferred for career advancement. In 2011, 4,619 scientists of assistant professor or higher level were employed in ICAR, against the sanctioned strength of 6,429. Since they spend most of their time on research, except those working in four deemed universities, ICAR employed 4,084 full-time equivalent (FTE) scientists. SAUs employed more number of scientists but they spend nearly half of their time in teaching and therefore the number of FTE researchers was 6,158. The number of scientists has remained quite stable in ICAR institutes on account of periodic recruitments, but the number has reduced significantly in SAUs. The total number of faculty employed in SAUs has reduced from 17,678 in 1992 (Rao and Muralidhar, 1994) to 13,633 in 2001 (Jha and Kumar, 2006) which moderately increased to 14,701 in 2009 (IARI-ASTI survey) due to establishment of new SAUs. Thus, there is absolute decline in the scientific manpower since 1990s. The number of scientists per SAU now stands at 267, as against 426 in 2001, indicating a drastic reduction in research capacity over time, which is a most worrisome trend. The problem could be attributed to both, lack of funding and state recruitment policy, which is sometimes accorded low priority due to austerity measures adopted by the state governments. There are few SAUs which have retained a critical mass of scientific manpower owing to a low rate of attrition. The only positive development has been an increase in the number of scientists working on farm science centres due to higher budget allocation by ICAR to create new centres (642 in 2015). However, the staff spend it's entire time for extension and farmer capacity building activities and therefore are not counted as FTE scientists in our analysis. Thus, there is reduction in research capacity in SAUs, which needs immediate attention. This may require decentralization of the recruitment rules down to the university level and channeling direct funding to SAUs under a separate budget line. Ageing of scientists in SAUs is another major concern, and although there is no reliable estimate, it is often stated that average age of the faculty is rising and there may be a large vacuum after retirement of senior faculty within next few years.

REGIONAL AND COMMODITY PRIORITIES

A large number of commodities are grown in India under diverse agro-climatic conditions. With the changing times, their research priorities are addressed by making adjustments in resource allocation. Since food security has been a national priority, initially more resources were allocated for research to the high potential irrigated region in the north-west plains together with a concentration of extension efforts in these regions. The strategy paid dividends in term of making the country self-sufficient in food grain production. Such efforts were gradually expanded to dry land and other rain fed regions which occupy more than 60 per cent of India's agricultural lands. The same pattern is visible in the allocation of ICAR funds for creation of new research institutions over time.

However, there is a large variation in the funds allocated to SAUs. In 2014, dryland states accounted for 43.6 per cent of the total resources allocated by all the states, against 16.5 per cent by the irrigated states. The wet rain fed states of eastern India contributed 20.3 per cent; while the hilly and arid states contributed 7.7 per cent and 11.9 per cent to the total state funds (Fig. 2). These allocations are broadly congruent with their importance in terms of area or production, except for the northern irrigated states which now received comparatively less resources. The dryland states spent comparatively more resources, which is justified on the grounds of their production diversity, vulnerability of natural resources to various forms of degradation, and need for raising incomes in these states for equity concerns. But an analysis of the expenditure intensity at a disaggregate level indicates some degree of underinvestment by the state governments in a few states. As seen from Table 2, in the eastern region, both irrigated (Uttar Pradesh) and wet rain fed (Orissa, and West Bengal) have very low expenditure intensity. Among the dryland states, MP and Rajasthan have an intensity of 0.11 percent. These are the states which have low productivity and high incidence of poverty. Thus, there is a need for enhancing public investment through SAUs in these underinvested states. The states of Bihar and Assam have shown significant increase in the funding and in 2014 the intensity was 0.58 and 0.73 percent, respectively. AP, Chhattisgarh and Uttarakhand are the other states which need to increase the funding. ICAR is, however, strengthening its research facilities in the regions where the state capacity is weak. For example, strengthening of research complexes and establishment of new deemed universities in Assam and Jharkhand and creation of new institutions in Jharkhand and Chhattisgarh will add to research capacity. Although these institutes will have national agenda, but greater regional orientation and partnership with SAUs will contribute to the regional capacity.

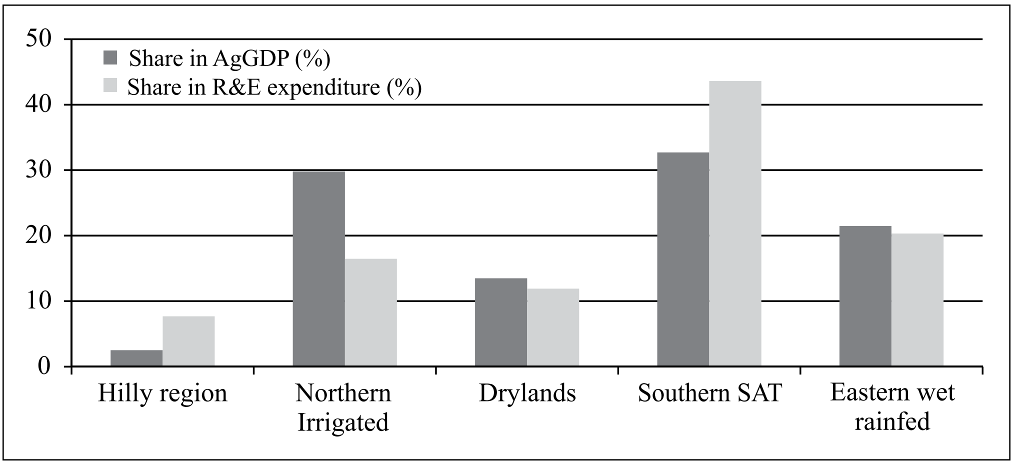

Fig. 2 : Allocation (%) of state funds to different production environments, 2014

Table 2 : Intensity of research and education funding by the states

	State	Share in state funding, 2014 (%)	Funding intensity, 2014 (%)	Funding intensity, 1999 (%)
1.	Andhra Pradesh	9.6	0.29	0.28
2.	Assam	3.26	0.58	0.33
3.	Bihar	9.21	0.73	0.28
4.	Chhattisgarh	1.45	0.27	-
5.	Gujarat	9.46	0.55	0.41
6.	Haryana	4.45	0.36	0.44
7.	Himachal Pradesh	2.52	1.28	1.52
8.	Jammu & Kashmir	2.75	0.88	-
9.	Jharkhand	1.51	0.35	-
10.	Karnataka	9.00	0.60	0.28
11.	Kerala	5.90	0.73	0.41
12.	Madhya Pradesh	2.37	0.11	0.14
13.	Maharashtra	10.83	0.48	0.43
14.	Orissa	1.72	0.23	0.21
15.	Punjab	6.94	0.50	0.30
16.	Rajasthan	2.45	0.11	0.18
17.	Tamil Nadu	8.27	0.55	0.59
18.	Uttar Pradesh	2.70	0.07	0.16
19.	Uttarakhand	2.42	0.18	-
20.	West Bengal	2.19	0.09	0.17
21.	All states	100	0.35	0.24

Note: Ratio of funding for research and education by state to state domestic product from agriculture.

Targeting of commodity research is another important dimension examined in the context of national research priorities. These priorities, compiled through a survey of agricultural research organizations (IARI-ASTI survey for 2009), were assessed by number of FTE scientists working for various commodities). Crop research continues to dominate the research portfolio in both ICAR and SAUs, accounting for 50 per cent of FTE researchers in the country, which is justified in view of the national food security objective and contribution of crops to agricultural income. Among other important commodity groups, 14 per cent of the scientists worked for livestock, 8 per cent for natural resource management and 6 per cent for fisheries. However, the research portfolio was more diversified in ICAR, with more resources spent on livestock, natural resources and fisheries research. SAUs continue to focus largely on crop research (71 per cent of FTEs). The dominance of crop research was much higher (84 percent) in SAUs in 2001 (Jha and Kumar, 2006), which has reduced moderately due to increase in number of animal science and horticulture universities during the last decade or so.

Although most of the research on crop improvement (breeding, pest management, etc) and resource management (conservation agriculture, nutrient management, micro-irrigation system, farm mechanization, etc) targets enhancement of crop productivity, their orientation towards farming system perspective needs system-wide emphasis. This is more relevant for SAUs where organization structure for crop, livestock and horticulture may grow in isolation and there could be limited interaction or exchange of material. Similarly, there are disciplines such as socio-economics, statistics and management which cut across sectors, commodity and resources. ICAR spent comparatively more resources on these research areas. Notwithstanding these gaps in inter-disciplinary, commodity and system-oriented research, the system is responsive to the changing research needs and more scientists are now working to address the issues of sustainable use of resources and agricultural diversification.

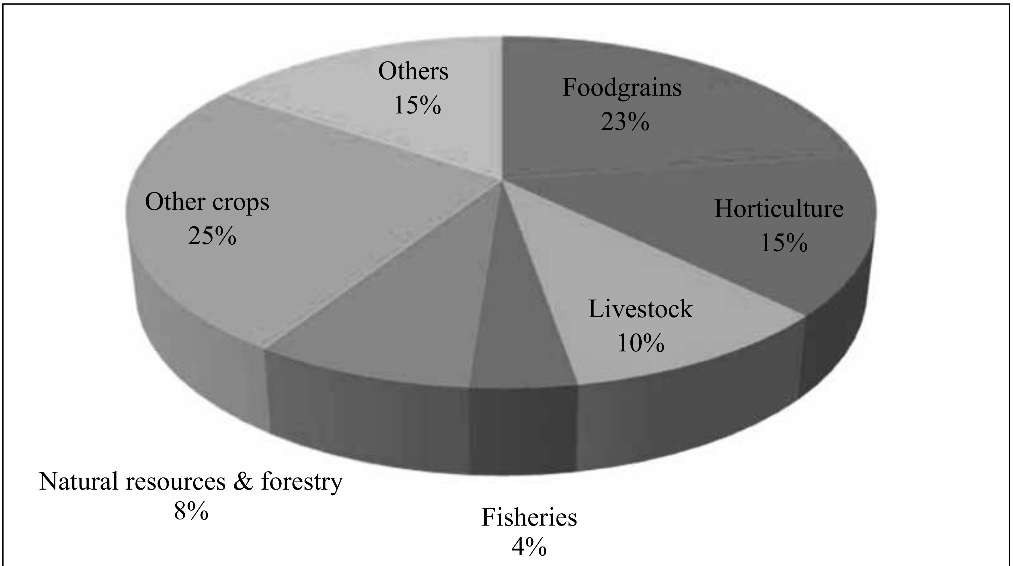

Fig. 3 : Commodity focus of research (FTE scientist shares, %)

DONOR FUNDING

International donors have significant presence in terms of funding and capacity building for agricultural research and education in India. In the beginning, USAID was a significant funder of agricultural research, particularly for establishment of SAUs since 1960s and the grant was in terms of both, financial assistance and training scientific manpower (Alex, 1997). The Rockefeller Foundation was instrumental in initiating the All India Coordinated Research Project for maize in 1957, and this model was replicated for other crops. During this time, CGIAR was under expansion and it provided considerable support in terms of human resource development through collaborative programs. Beginning 1980s, the World Bank became a major sponsor of agricultural research in India. It started with the National Agricultural Research Project in two phases during 1978 to 1996, which was followed by another major project the National Agricultural Technology Project with a funding of US$ 196.8 million during 1998-2005. This project focused on institutional developments like research-extension linkages, besides supporting research programs. The most recent project was the National Agricultural Innovation Project with a grant of US$ 200 million during 2006-14 (Table 3). This project focused on research partnerships and institutional innovations. Marginal production environment and gender empowerment were other aspects of research supported under this project. In addition, research and its linkage with extension and state line departments were also supported under agricultural projects funded by the World Bank for different states. For example, agricultural competitive project in Rajasthan implemented since 2012 has research and extension component to the extent of 45% of the total project grant. Although funding of the World Bank was

Table 3 : Trends in international lending for agricultural research and education in India

(in million US dollars)

Period	USAID	World Bank	Total
1963-1965	3.24	-	3.24
1966-1977	2.84	-	2.84
1978-1986	4.94	27.00	31.94
1986-1996	4.12	72.10	76.22
1995-2001	-	59.50	59.50
1998-2005	-	196.80	196.80
2006-2014	-	200.00	200.00

Source: Based on data in Alex (1997) and World Bank.

a small proportion of the core national funding for agricultural research, the former supported innovative ideas like management reforms, competitive funding, public-private partnership, commercialization of technology etc. Some of these aspects were up scaled under the government funding to ICAR-SAU system. It is likely that donor funding may slow down in the years to come and in fact, CGIAR has already shifted its priority to the African region. Therefore, the system has to allocate higher core grants to sustain institutional linkages and international activities, and given the magnitude of resources and commitment of ICAR to international programs, mobilizing resources should not pose a problem.

INTERNATIONAL FUNDING SCENARIO

India is one of the few developing countries which have witnessed sustained growth in the funding for agricultural research and all signs indicate that this trend will continue in future also. The question now arises as to how the trends in funding in India compare with other countries. China is another country which has shown significant growth in the funding during the last two decades or so. As seen from Table 4, China now spends nearly 9,366 million 2011 PPP dollars on agricultural research and the intensity of funding has reached 0.62 per cent of AgGDP. China also employs around 43 thousand FTE scientists, as against 10,242 FTE scientists in India. Here it may be noted that most of the scientists in India have a doctorate, whereas a large proportion of scientists in China have a bachelors or masters degree. In fact, Indian NARS is the largest in the world if number of scientists with masters or higher degree is considered. Therefore, except in terms of training of manpower, China spent more resources than India. Brazil is another country which spent comparatively less resources (2,704 PPP dollars), but expenditure as proportion of AgGDP was almost four-times of that in India. The same holds true for South Africa. The number of FTE scientists in these two countries is much below than that in India. India however is much ahead of other Asian countries in terms of size of its expenditure on agricultural research.

The expenditure by developed countries like US, Japan, Europe and Australia is much above that made by India or other developing countries. In 2008, public funding in all the developing countries was nearly half of the total funding and research intensity ratio was 0.54 per cent of their AgGDP. On the other hand, developed countries together had a research intensity ratio of 3.07 percent, which is almost six times. Here it may be noted that private research investment for agriculture in developed countries is also quite high. Another noticeable trend of public funding for agricultural research in developed countries and in India is its stability. Donor funding in small developing countries, particularly in Africa and other south Asian countries, makes overall funding more volatile, which is not desirable for sustaining of research capacity (Beintema *et al,* 2012 and Pardey *et al,* 2006). Therefore, developing countries should allocate more resources to catch up with developments in agricultural science in the developed countries. India has a target of one per cent of AgGDP, which can be achieved soon if the present growth trend in the funding is sustained.

Table 4 : International comparison of agricultural research funding, 2011-12

	Country	Number of scientists, Full-time equivalent	Funding in million 2011 PPP dollars	Research intensity (%)
1.	Brazil	5,869.4	2,704.0	1.8
2.	Bangladesh	2,121.0	250.6	0.4
3.	China	43,000.0	9,366	0.6
4.	Malaysia	1,609.4	592.3	1.0
5.	Pakistan	3,678.3	333.0	0.2
6.	Sri Lanka	618.8	61.8	0.3
7.	South Africa	746.3	294.5	2.0
8.	India	10,242.0	3,533	0.4

Source: Based on ASTI database (www.asti.cgiar.org) and our own data for India; India funding data are for 2014 and FTE scientists data for 2009; data for China are for 2013.

RESEARCH POLICY PERSPECTIVE

As discussed above, the main premise of agricultural research policy in India has been public funding and provision of R&D services for sustaining agricultural growth and reducing rural poverty. This basic principle was sustained during various development phases of the NARS, albeit with operational pragmatism to exploit the advancements in science and technology. The first major initiative was coordination of research in different organizations under coordinated projects and substantial resources were earmarked by ICAR for this purpose. The investment paid dividends in terms of avoiding duplication of research and sharing resources like breeding material and their testing. Another important development was the use of funding mechanism to promote excellence and relevance by upscaling of competitive funding under the core and external funding. The basic objective was to link funding with new research areas and promote improved planning and evaluation mechanisms, especially under the externally-funded projects. This shift proved to be beneficial and helped in bringing various research organizations, even those outside the NARS, closer to the priority research themes. On similar lines, partnership with civil society organizations for demonstration of new technologies and skill development of farmers through the agricultural science centres was found to be encouraging, and substantial resources were allocated for this activity. These centres were also helpful in fostering linkages with the state line departments for capacity building, thereby strengthening the public extension system. Following the success of partnerships under these programs and World Bank projects, ICAR is contemplating higher allocation of resources for research consortia involving various scientific and development organizations in XII Plan period (2012-17). These consortia will address strategic research issues. With the establishment of NITI Aayog, there could be some changes in the planning and funding process at the national or system level, but basic research thrusts and research planning at the institute level is likely to be sustained. The process is likely to focus on perspective planning, its linkages with research programs and their effective monitoring, which shall help in better allocation of resources and tracking progress of different schemes.

Attracting Private Funding

The government is conscious about the enormity of R&D challenges, and therefore has been making efforts to attract private funding for agricultural R&D. This is being done through several ways. First, there is tax incentive for investment in R&D and duty-free import of the lab equipment. The economy-wide reforms of 1991 which allowed foreign equity in firms benefitted agricultural research also. Many transnational companies began their operations in India and also established R&D facilities. Most of them entered through the takeover route and which led to consolidation and improvement of the existing R&D infrastructure, though the creation of new facilities was rather limited.

The second important initiative to attract private investment was the adoption of the policy of open access to public research material like improved varieties and planting material, which attracted private activities in commercialization of these technologies. Some of these firms eventually started their R&D activities in order to create a niche in the market. Most of these private activities were in the areas of seed and plating material, animal health, and plant protection. It is estimated that these companies spent 251 million US dollars in 2009, and 35 per cent of which was only in seed and biotechnology and another one third for pesticides and farm machinery (Pray and Nagarajan, 2012). The estimate based on information compiled from the reports of agribusiness companies gives an annual turnover of these companies to the order of 11,757 million US dollar in 2011 of which they spent nearly 2.5 per cent on R&D. Thus, contribution of private sector to the national agricultural expenditure was nearly 290 million US dollar, which is 13.8 per cent of the total spending..

These initial efforts laid the foundation of private R&D in India and most of the funding was for in-house research. This momentum gathered steam with the advancement of molecular biology and micro-plant propagation methods. Molecular breeding, genomics, transgenic research and tissue culture attracted considerable private investment for in-house R&D. Private investment in these areas is considered to be at par with that in traditional plant breeding research in the private sector. Private R&D in animal health, poultry and fisheries is also substantial and rising, but no reliable estimates are available for this. Although there is no empirical evidence to assess relative contribution of various factors to the growth of private sector, knowledgeable sources in the industry acknowledge that though fiscal and licensing policy is important to start R&D, it is availability of scientific manpower, access to public material and market opportunities which eventually fuel growth of the private R&D (Pray 2002; Pal and Byerlee, 2006).

How far has private R&D contributed to the national objectives? Obviously, there is increase in research intensity but it largely confined to seed, chemicals and now, farm machinery. The success of hybrids and Bt cotton has contributed to this trend. There are also examples of technology spillins which have largely accrued through private R&D. Notable among these are Bt gene, single cross maize hybrids, floriculture and agro-chemicals. At the same time, there are changes in market structure of inputs, which may be dominated by few companies and technology (see chapter 5). But a more substantive issue is related with the capacity and priority of private R&D to generate public good in partnership with public organizations (Das Gupta and Ferroni, 2012). There is no example to prove this. The ability of private sector to refine and commercialize technology developed by public R&D and create competition among private companies can perhaps generate larger benefits for farmers.

Management of Intellectual Property

India enacted the Patent Act in 1950 which was replaced by the Patent Act of 1970. The Act provided the process patent and excluded methods of agriculture and living organisms and part thereof from patent protection. The patent protection, with application in agriculture was for design of machinery, and pesticides, which had negligible protection activity. The Amendment of the Patent Act (1970) in 2005 provides protection to the process and product inventions in all fields of science. Methods of agriculture are still excluded from patenting, but living forms like microorganisms can be patented if substantial human intervention was involved. This definition is also interpreted as, new genes after human interventions can be protected,; and in fact, gene patents have now been granted in India. The protection having direct application in agriculture is for plant varieties which can be protected under the Protection of Plant Varieties and Farmers' Rights Act (2001) for 15 years subject to fulfillment of the conditions of novelty, distinctness, uniformity and stability. The Act also protects farmers' rights as breeder and user (of seed) to reuse and exchange farm saved seed. Thus, IPRs regime for agriculture has been strengthened significantly and necessary institutional mechanisms like the Protection of Plant Variety & Farmers' Rights (PPV&FR) Authority have been put in place to administer the law.

The immediate application of the strengthened IPRs regime will be in the Indian seed industry. Although the period with the new IPRs regime is very short to gather conclusive evidence of its impact, but the early experience is not very encouraging in terms of attracting new private investment or change in research priorities of the private sector in the area like plant breeding. Diversification of the seed industry with participation of private sector was already in process since 1980s because of biological protection provided by hybrid technology and open access to public material (Pal *et al,* 2007). However, there is demand for protection of new varieties both, from the public and private sectors. During 2007-2012, 4211 applications for protection of varieties were received, and of these 1123 were of new varieties and the rest were for extant or farmers varieties. Institutional breakup of the applications indicates that 1791 varieties were from the private sector and 1080 from the public sector (for details, see chapter 5). Thus these early trends show that there is demand for protection of material both from public and private sectors, which is likely to be higher for new varieties in future.

There could be two possible reasons for seeking protection for plant varieties. First, there are some valuable materials like single cross hybrids which can easily be exploited by the competitors and therefore seed companies would like to protect these hybrids and their parental lines. Some of these hybrids could be directly introduced by the transnational companies. Second, seed companies are establishing protection so that these varieties can be licensed to some other companies for commercialization, or the material exported for commercialization abroad. Whatever way the scenario unfolds in future it is clear that the industry considers the PVP mechanism credible and sees value in the mechanism for exchange, licensing and commercialization of plant varieties.

The recently announced IPRs policy (DIPP, 2016) underlines increasing awareness, generating intellectual property, institutional capacity for effective enforcement of the rights, and commercialization of intellectual property in the larger public interest. The public research institutions like ICAR have also developed IPR guidelines which underline the use of IPRs for fostering partnership with private sector for commercialization of technology. The benefits arising from commercialization of technology or any other product are also shared with the innovator scientists (ICAR, 2006). Although there is an increasing trend of commercialization of technology like varieties and animal vaccines, success stories are rather limited, primarily because the public institutions are adapting to the new system and exclusive licensing is avoided to realize larger impact in public interest. Private sector is also adjusting to the reality that they have to pay for the product and services which were freely available so far. Nonetheless, both the sectors see merit in the mechanism to access the research products and their commercialization.

Biotechnology Regulations

Research, evaluation and commercialization of genetically-modified organisms and cells are governed by the Environment Protection Act (1986), which laid the rules for manufacturing, use, import, export and storage of hazardous micro-organism, genetically-modified organisms and cells. The regulation entails the assessment of "harm to human beings, other living creatures, plant, micro-organism, property, or the environment." For this, there are two stage regulations. First, there is the Review Committee on Genetic Manipulation under the Department of Biotechnology in the Ministry of Science and Technology to monitor biosafety issues of GM research programs in the country which has issued guidelines for the lab and field experiments (contained and open). There is also a provision of Institutional Biosafety Committee to monitor biosafety issues at the institute level. The decision of large scale field trails and commercialization of genetically modified products rests with the Genetic Engineering Approval Committee (GEAC), a multi-stakeholder body under the Ministry of Environment and Forest, to recommend or otherwise, use of a genetically-modified organism (GMO). The Ministry of Health is responsible for post-release monitoring of GMO-based food products. The Ministry of Agriculture and Farmers Welfare is represented in various decision making bodies, but is not directly engaged with the decision making, except that it participates in agronomic performance evaluation of new GM varieties/products and is represented by ICAR in GEAC. The State Biotechnology Coordination Committee is constituted in all the states to oversee violations of the rules and take appropriate action. The mechanism at different levels is working well, except that often suggestions are made for greater coordination among different agencies. In this context, a national biotechnology regulatory authority is proposed for consent of the Indian Parliament. The proposed authority will bring all the three regulatory functions under one agency so that a uniform and consistent approach is followed for biosafety assessment of biotech products. Efforts are also made to harmonize the other regulations like provisions in the Biological Diversity Act (2002) to import or export genetic material, the Seed Act (1966) for use of GM seed, and PPV&FR Act (2001) for protection of GM plant varieties.

One of the important criteria for release of GMOs for commercial use is their market acceptability, which is rather difficult to assess ex-ante and therefore it is a matter of discussion. For this, evaluation studies are conducted to assess economic, social and environmental impacts. The information is quite useful in decision making, especially when product market development is low. Such analysis is often optimistic as constraints to technology spread and consumer acceptance is rather difficult to predict. Therefore, it would be desirable if such an analysis is done by a professional group, preferably outside the decision making body. Timely flow of information on the assessment of expected risks and potential benefits, institutions to commercialize the product, and distribution of benefits among various sections of producers and consumers are more useful. Also, information on likely unintended impacts on non-target groups is useful for decision making. The importance of such additional information like assessment of risk to biodiversity and its implications for local communities is also emphasized in the Cartagena Protocol on Biosafety (Article 26), which deals with safe transfer, handling and use of living modified organisms (LMOs). The Indian system is using information on socio-economic impacts whenever necessary, along with scientific evidence on the bio-safety assessment to arrive at a decision to commercialize a GMO or otherwise.

Governance and Management

Present focus of the government is to evolve agricultural innovation system with multiple sources of knowledge and technology and greater interaction among the institutions for sharing of knowledge and its commercialization. The role of public institutions like ICAR is central for development of the innovation system and facilitation of the flow of knowledge. In particular, emphasis on strengthening the institutions for knowledge integration and transfer to farmers must continue. Efforts to foster linkages with other scientific organizations within the country and enhancing the role of stakeholders, especially farmers and private sector, in the management of public institutions and network programs will enhance relevance and effectiveness of agricultural research. However, bringing all these institutions together will largely depend upon availability of research funding for such activities, which is currently made available in externally-funded projects. Efforts being made by ICAR to strengthen research under the coordinated projects and sponsoring research platforms involving multiple institutions in the national priority areas will go a long way in fostering partnership for research and technology development. These platforms even involve scientific organizations outside the NARS, including international agricultural research centres.

Commercialization of technology and resource generation is encouraged but there is limited success in terms of resource mobilization, primarily through sale of planting material, products and some cases of licensing of intellectual property. The main reason for this is that since most of the farmers are small, mobilizing substantial resources by sale of products directly or through companies may be limited. Secondly, most of these commercialization activities are through private input companies, which may like to increase their market share by selling their own products even based on public IP and therefore benefits accruing to the public institutions remain low. Public institutions are learning in the process and it is quite likely that resource generation may increase in future but its share in the total budget is likely to remain low.

While the system is grappling with new research regulatory mechanism and technology transfer activities, a significant proportion of the resources, both manpower and financial, will be used for compliance of the new research regulations. For example, in plant breeding, earlier only multi-location testing was done, but now DUS testing and evaluation of GM varieties are also added, and a great deal of this responsibility will be on plant breeders and other scientists in the NARS. This will reduce the manpower available for research, which is a major concern in SAUs who are already witnessing decline in scientific manpower. This must be restored by providing additional resources to SAUs for technology evaluation and transfer to farmers. In other words, research-teaching-extension linkages, which are the main strengths of SAUs, should be strengthened, which will be possible only through political commitment at the state level for sustained funding and decentralized recruitment to maintain the cadre strength.

Finally, there are some institutions, outside the NARS, for research on forestry and plantation crops like rubber, silk, tea, coffee, spices, etc., which are funded by their respective commodity boards under the Ministry of Commerce and Industry. By bringing these organizations closer to ICAR-SAU system, these institutions can also benefit from plant research being done in the main system. This can be done by establishing an institutional mechanism for joint programs at the national level, or by bringing them under ICAR.

CONCLUSION

Some important lessons can be learnt from agricultural research policy in India. The first and foremost lesson is that committed government support is a must for building a responsive research system. Public research system should take up a leadership role together with discharging the responsibility of strategic research and manpower training. The leadership role of public research can be sustained with the capacity for institutional learning and adaptation of funding and management reforms to ensure proactive participation of all the actors, including private and voluntary R&D organizations. This may even need allocation of a significant proportion of resources to sustain the reform process and promote partnerships. These reforms can be best institutionalized when these are linked with the funding.

Sustainability of public funding is important for capacity building, but this must be supported by measures to enhance innovativeness and productivity of research. Allocation of resources to national priority research programs and building a team of qualified scientists around these programs are important for improving research performance. Improved management tools to plan and monitor research progress, environment to share knowledge and resources, and mechanisms to protect intellectual property are useful in improving research efficiency and reaching to new partners, particularly private sector. The role of private sector will grow with the commercialization of agriculture, but its pace will be faster if there are facilitating regulations, trained manpower and a transparent mechanism for sharing of resources and benefits. There could be some issues related to cost-effectiveness of research regulations, like those for biotechnology, but there is no immediate solution for them. The best way is to learn during the implementation process and make necessary adjustments to improve effectiveness and credibility of these regulations. This shall build confidence of stakeholders in the regulatory process, help diversify R&D system, and foster research partnerships. The donors should bring international experience on such matters and help accelerate the diversification process and facilitate institutional reforms wherever necessary. Lastly, the research system should work with technology transfer system and government departments for capacity building of extension personnel and farmers and thereby sustain flow of technology to farmers.

REFERENCES

Alex, G. 1997. USAID and Agricultural Research: Review of USAID Support for Agricultural Research: 1952-1996. Agricultural Research and Extension Unit, the World Bank, Washington, D.C.

Alston, J M, PG Pardey and VH Smith (1999), *Paying for Agricultural Productivity*, John Hopkins University Press, Baltimore.

Beintema, N; G Stads, F Fuglie and P Heisey (2012), ASTI Global Assessment of Agricultural R&D Spending. IFPRI, Washington, D.C.

Das Gupta, P and M Ferroni (2012), Agricultural research for sustainability productivity growth in India, in M Ferroni (ed), *Transforming Indian Agriculture- India 2040: Productivity, Markets and Institutions*, Sage Publications, New Delhi.

DIPP (2016), National intellectual property rights policy, Ministry of Commerce and Industry, New Delhi.

ICAR (2006), Guidelines for intellectual property management and transfer of technology. ICAR, New Delhi.

Jha, D and S Kumar (2006), Research resource allocation in Indian agriculture, Policy Paper 23, National Centre for Agricultural Economics and Policy Research, New Delhi.

Pal, Suresh and Derek Byerlee (2006), The funding and organization of agricultural research in India: Evolution and emerging policy issues. In PG Pardey, JM

Alston and RR Piggott (eds), *Agricultural R&D Policy in the Developing World*. Washington, DC: The John Hopkins University Press and IFPRI.

Pal, Suresh, R Tripp and NP Louwaars (2007), Intellectual property rights in plant breeding and biotechnology: assessing impact on the Indian seed industry. *Economic and Political Weekly,* XLII (3): 231-240.

Pardey PG, JM Alston and RR Piggott (eds), (2012), *Agricultural R&D Policy in the Developing World*. Washington, DC: The John Hopkins University Press and IFPRI.

Pray, C (2002), Growing role of the private sector in agricultural research, in D Byerlee and R G Echeverria (eds), *Agricultural Research Policy in an era of Privatization*. New York: CABI Publishing.

Pray, C and L Nagarajan (2012), Innovation and research by private agribusiness in India, EPTD Discussion Paper 1181, IFPRI, Washington, DC.

Rao, DR and U Muralidhar (1994), Agricultural Universities Information System in India. NAARM, Hyderabad.

Appendix I : Trends in public funding for agricultural research and education in India

(Rs, million)

Year	Centre	States	Total
1981	730	893	1,624
1982	873	1,003	1,876
1983	1,019	1,056	2,075
1984	1,175	1,257	2,433
1985	1,319	1,512	2,831
1986	1,425	1,772	3,197
1987	1,622	2,024	3,646
1988	1,719	2,226	3,945
1989	2,046	2,779	4,826
1990	2,513	3,313	5,826
1991	3,172	3,965	7,137
1992	3,429	4,289	7,718
1993	3,644	4,685	8,329
1994	4,270	5,329	9,600
1995	4,956	6,107	11,063
1996	5,349	6,801	12,150
1997	5,651	8,012	13,663
1998	6,846	8,311	15,157
1999	9,820	10,105	19,925
2000	13,029	10,792	23,821
2001	12,989	12,865	25,854
2002	12,743	12,462	25,204
2003	12,990	13,810	26,800
2004	14,356	13,906	28,262
2005	15,883	14,992	30,875
2006	18,751	17,172	35,923
2007	20,658	19,514	40,172
2008	21,806	23,009	44,815
2009	28,227	26,431	54,658
2010	32,073	31,363	63,436
2011	53,831	36,720	90,551
2012	47,293	43,803	91,096
2013	45,097	50,901	95,998
2014	47,263	61,314	1,08,576

Source: Compiled by the author from various sources.

Chapter 3

STRENGTHENING DELIVERY OF AGRICULTURAL EXTENSION SERVICES IN INDIA: EXPERIENCES AND CONTEMPORARY ISSUES

Suresh Pal

INTRODUCTION

Sustainable agricultural and rural development has been the overriding objective of India's development policy. In order to attain this objective, public investment in agricultural infrastructure like irrigation, rural roads and markets, as well as agricultural research and extension was accorded high priority. Institutional arrangements were also strengthened to enhance supply of inputs and credit to farmers and to provide price incentives. The strategy has paid rich dividends in terms of rapid increase in crop yields. The total factor productivity grew by 1.5 to 2 per cent annually since the green revolution period, and non-price factors like land reform, irrigation, infrastructure and technical change were the main sources of growth (Fan et al., 1999). Of late, these growth trends have been echoed in livestock and horticultural sectors which now account for more than half of the agricultural gross domestic product (AgGDP). Agricultural growth accelerated during the second half of the last decade, after a moderate growth since the mid-1990s. The immediate concerns are how to sustain the agricultural growth, alleviate household food and nutritional insecurity and rural poverty, and enhance competitiveness of agriculture in the world market without compromising sustainability of natural resources and environmental security (Planning Commission, 2011). These developmental challenges have to be addressed in an era of economic and fiscal reforms when public funding will not be as liberal as it used to be in the past. Therefore, targeting and efficiency of public investments and interventions, especially in agricultural infrastructure, have become of paramount importance.

Strengthening research and extension (R&E) has been a key element of agricultural development strategy in India. An increasing amount of funds were allocated by the central and state governments to build the R&E infrastructure and enhance the flow of technology to farmers. Consequently, R&E were the major sources of agricultural growth in the country (Evenson *et al,* 1999; Fan *et al,* 1999). However, it is felt that a quantum jump in the productivity comparable to the green revolution era has become a rare phenomenon, with a few exceptions like cotton and maize, and to achieve it, there is a need for harnessing the potential of available knowledge and technology. These issues have been examined in the context of agricultural research system (see Jha and Kumar, 2006; Pal and Byerlee, 2006; Pal *et al,* 2012), but the extension system is rather less studied (Babu *et al,* 2013; World Bank, 2012). In particular, there is a dearth of information on extension capacity and recent innovations to accelerate the flow of technology. This chapter fills this information gap. Specifically, it addresses the question whether the level of public investment and institutional reforms initiated so far are adequate to equip the extension system to meet the emerging challenges. The chapter is organized as follows. After a brief discussion on current institutional structure of the extension system and contemporary developments, trend in the government funding and its allocation across various production environments are presented. The next section evaluates the recent institutional reforms in the public and private sectors. The chapter concludes with a discussion on the emerging policy issues for revitalizing the Indian extension system.

PUBLIC EXTENSION SYSTEM

Historically, agricultural extension in India has been in the public domain. It has been funded and delivered by agricultural line departments of the state governments. It originated with the Community Development Programme in 1952 on pilot basis, which was later replicated country-wide as the National Extension Service Programme in 1953. These programmes aimed at overall rural development, including agriculture, with a focus on extension services. With the advent of the green revolution, extension activities were intensified through agricultural development programmes like ‘grow more food’ campaign and the Intensive Agricultural Area/District Programme. However, professional extension service was organized under the Training and Visit (T&V) system in 1974/75 with funding from the World Bank. The extension approach followed was the dissemination of technologies through direct contact of extension specialists with the farmers on a regular basis. The front-line or first-line extension programme of research institutes of the Indian Council of Agricultural Research (ICAR) and State Agricultural Universities (SAUs) also grew with their expansion. The main objective of this programme was to test and demonstrate new technology on farmers’ fields, get first hand information on research needs, provide training support to state line department, and study and promote innovative extension methodologies (Prasad, 1989). This was based on a number of extension programmes like the National Demonstration Programme (1965), Operation Research Programme (1972), Lab-to-Land Programme (1979), and Institute Village Linkage Programme in the late 1990s. Since 1974 *Krishi Vigyan Kendras* (KVKs) or agricultural science centres have been established at district level to impart training to farmers on the principle of 'learning by doing.'

Current structure of the Indian agricultural extension system broadly comprises of three components. Directorate of Extension in the Ministry of Agriculture and Farmers Welfare at the Centre, is responsible for planning and coordination of central extension schemes and development of some extension material. The Ministry has also established the National Institute for Agricultural Extension Management (MANAGE) to develop and promote extension innovations and train senior extension functionaries. In addition, there are five Extension Education Institutes for training of staff of various departments in different states. On similar line, states have the State Agricultural Extension Management and Training Institutes (SAMETIs) to train middle and grass-root level extension workers. The Centre also sponsors other schemes like Watershed Development (of Ministry of Rural Development), Special Area (tribal and hill) Development Programmes, Technology Mission for Crops (e.g., maize, oilseeds, pulses) and National Food Security Mission (NFSM) under the Ministry of Agriculture and Farmers Welfare, which have transfer of technology components. The most recent programme in this category is the *Rashtriya Krishi Vikas Yojana* (RKVY) to strengthen decentralized planning and mobilize state resources. These schemes are implemented by the state line departments with funding from the central government. In addition, there are other public agencies like commodity boards, seeds corporations, National Dairy Development Board, public input industries etc. which directly or indirectly support or undertake transfer of technology activities in their respective areas.

The main component of the extension system is the agricultural departments of the state governments. There are departments of agriculture, animal husbandry, horticulture, soil and water conservation, dairy development and fisheries in all the state governments to undertake extension activities. However, only agricultural department has a strong extension programme and specialized extension specialists at different levels (state, district, and block). There is limited information on the number of extension personnel. Macklin (1992) estimated that a force of 88,000 trained extension workers, comprising 4,700 subject matter specialists and 82,000 village extension workers were positioned in the field ; however it is most likely that this number has reduced significantly. The field staff is also required to attend to other activities like distribution of inputs and subsidies under different development programmes. The extension approach followed is dissemination of technical information to farmers through personal visits and field demonstration, while skill development is given a rather low priority, as this is done by KVKs. In the recent past, as seen subsequently, efforts were made to integrate activities of the line departments and promote demand-driven farmer participatory extension through creation of the Agricultural Technology Management Agency (ATMA) at the district level.

Front-line extension programmes of ICAR/SAU system form third component of the public extension system. The important activities of this component are assessment, refinement and demonstration of new technologies and training of farmers, rural youth and women. This is done by 642 KVKs and 8 Trainers' Training Centres (TTCs). The KVKs are at the district level and disseminate technology, develop skill of farmers and make available planting material of new crop varieties, fruits etc, while TTCs are for specialized training like that for dryland agriculture, horticulture, dairy, etc. These centres have a staff of 8-12 professionals from major disciplines of agriculture. In addition, there is a directorate of extension in the SAUs and special programmes for on-farm assessment and transfer of new technologies with the help of multi-disciplinary team of scientists. For example, programme for distribution of seeds of promising varieties in mini kits, Institute Village Linkage Programme for technology assessment and refinement, outreach programmes like field days, farmer fairs, etc. are designed to provide first hand technology-related information to farmers, extension workers and other clients. In addition, researchers participate in extension activities of the state line departments and the private sector as and when required. The system is working well and as seen subsequently, it has certain achievements to its credit.

PRIVATE SECTOR DEVELOPMENT

Although involvement of private sector in agricultural extension has been encouraged since Independence, it remained at the periphery. In recent years, there has been rapid increase in private extension activities because of rapid growth of private input industries, availability of public funds for private extension, increase in outreach activities of the research system, availability of trained manpower and commercialization of agriculture. The economy-wide reforms and liberalization of input sector have further fuelled the growth of private input companies and hence private extension, and all signs point to strengthening of this trend (Pal and Tripp, 2003, and Gisselquist et al., 2002). Of late, there is increase in extension activities by agro-processing industries. These industries often work in contract farming mode to ensure availability of quality raw material and provide planting material and associated technical advice to contract farmers. Some of the noted examples are potato, basmati rice, and vegetables. In private non-profit sector, there are a number of non-governmental organizations (NGOs) engaged in agricultural extension. Some of them seek public funding, e.g. ICAR funding for NGO-managed KVKs, while others run their own independent extension programmes. The latter often have more number of qualified staff and region- or country-wide presence. Most of these NGOs work closely with farmers and therefore have the capacity of mobilizing farmers. Most of them depend on ICAR/SAU system and public agencies for technology-related information and skill improvement of their staff.

The other development in private extension has been the participation of farmers' organizations and cooperatives. Some of these organizations work on the pattern of contract farming and provide technical advice to member growers, while others offer extension services to all farmers. These organizations are mostly for commercial or high value crops and have quite a high extension intensity—1000 farmers per technical person—which is comparable to the public extension system (Sulainman, 2003). Important examples of these types of organizations are: Anand Milk Cooperative Union Ltd (AMUL), Maharashtra State Grape Growers Association (MSGGA). MSGGA has R&D programmes which provide all types of technical information to the farmers, while AMUL has a network for providing animal health services free of cost to farmers and make available quality feed on payment basis. A number of milk cooperatives are working in different states on the pattern of AMUL.

CONTEMPORARY INSTITUTIONAL DEVELOPMENTS

Public Sector Reforms

Notwithstanding past achievements, the public extension suffered from a number of weaknesses like excessive focus on crops, lack of coordination between different state line departments for agriculture, 'top-down approach' of extension and limited farmers' participation. Depleting field staff and financial resources further compounded these problems and impaired the effectiveness of the system (ICAR, 1998, Macklin, 1992 and Anderson and Feder, 2004). All this, coupled with developments in information communication technology (ICT) necessitated reforms of public extension system and shift to a new extension approach. Institutional reforms were therefore initiated under the National Agricultural Technology Project (NATP), which was implemented on a pilot basis in 1998 in 28 districts of 7 states and subsequently covered all the districts. The reforms aimed to make the system demand-driven with participation of stakeholders, enhance financial sustainability and promote partnership with private sector. Specific steps taken in this direction were: coordination between different line departments, human resource development, formation of farmer groups, 'bottom up' development of extension plan, augmentation of operating expenses, and modernization of extension system (ICAR, 1998). The main institutional innovation was the establishment of the Agricultural Technology Management Agency (ATMA) at the district level as a registered society. ATMA discharges the responsibility of technology dissemination at district level and establishment of linkages with all the line departments, research institutions, NGOs and other agencies associated with agricultural development. The Agency can receive and spend project funds, enter into contracts and agreements and maintain revolving funds by collecting fees for services. The governing board overseas functioning of the agency and is represented by senior officers from agricultural department, financial and marketing institutions, and representatives of various producer groups, women and weaker section. The day-to-day management is looked after by a project director with support from the management committee, comprising representatives from various agricultural departments, KVK, research institutions, NGOs, etc. In addition, ATMA is required to establish a farmer advisory committee at block level and encourage farmer groups with the help from NGOs. It is also responsible for developing strategic research and extension plan for the district in consultation with farmers and other stakeholders. Based on this plan, research issues flow to the research system, while those related to extension are taken up for implementation. ATMA has now completed more than ten years and field experience reveals mixed performance of this model in terms of attaining its objectives (Babu *et al,* 2013).

For capacity building, emphasis is on strengthening SAMETIs in the states. Use of participatory methods for farmers' need assessment, application of ICT, improvement of communication, training and group formation skills, conflict resolution etc. are given high priority in the training programmes. The extension system both, at district and block levels is strengthened by providing hardware like computer systems for communication, training and farm demonstration. The idea is that there should be a balance between dissemination of technical information through modern ICT methods and improvement of skills through organization of training programmes, with support from scientists. There is also focus on interaction between extension functionaries and farmers within and outside the state. These initiatives were further strengthened with the recently launched National Mission on Agricultural Extension and Technology under XII Plan by the Union Government. This Mission has been able to bring various agricultural schemes under a single umbrella; it further aims to promote the use of ICT in dissemination of information on agricultural technology, involve private agents like those trained for agri-clinics (private extension experts) and input dealers in extension, and bring convergence in extension activities through ATMA. The Mission also aims to place greater effort on seed and planting material, farm mechanization and plant protection (DAC, 2014).

A few institutional reforms were also introduced in the front-line extension system of ICAR and SAUs. Establishment of the agricultural technology information centre (ATIC) was initiated at 24 ICAR institutes and SUAs under NATP for creating a 'single window' system for delivery of information and technology products to farmers, and to get feedback from them on use of new technology. These Centres were later started in other institutes and SAUs. It is expected that ATICs will not only serve farmers in an efficient manner but would also help generate some resources for research institutions. In another institutional development, new KVKs were established and some zonal research stations of SAUs (where KVK does not exist) were required to take up additional functions of KVK. This model is expected to offer a new form of technology transfer with stronger research-extension linkages. Support is also being provided to strengthen directorate of extension in SAUs to enhance their capacity, reach and overall effectiveness. In view of rising expectations from frontline extension, mainly KVKs, ICAR has reviewed the functioning of these KVKs and suggested renewed efforts for on-farm technology assessment and demonstration and capacity building of farmers and extension workers. Increasing manpower and operational funds, developing agriculture plan for the district and its implementation in a cluster approach and program-based linkages with ATMA and other line departments for outscaling of technology are major recommendations for increasing the effectiveness of KVKs (ICAR, 2014).

Innovations in Private Extension

Private companies dealing with agricultural inputs and products are facing stiff competition in the present era of economic liberalization and privatization. In order to maintain the volume of business and profit margin, these companies are providing value added services to farmers, besides their usual business activities. Provision of agricultural information and advisory services is one such strategy increasingly adopted by these companies. A number of input companies have established farmer service centres, which in addition to marketing of inputs, also provide technical information to farmers. Some companies dealing with farm inputs and machinery have also tied up with financial institutions for provision of credit, besides selling their products, or providing machinery like tractors on custom hiring basis. The National Bank for Agriculture and Rural Development (NABARD) is providing 100 per cent refinance facility for such service centres. Another important innovation in this sector is diversification of activities to provide all important inputs (fertilizers, seeds, pesticides) to farmers. These companies also provide information and advice related to the use of inputs, as well as other farm practices.

On the production side, as noted above, some agro-processing and other companies are shifting towards contract farming, linking production with processing. These companies also have farm specialists who provide technical information to contract growers and impart skill by visiting farms at different stages of crop growth. These specialists are in touch with research institutions for information and planting material. There are no charges for providing technical advice or making farm visits, but inputs are supplied on no-profit, no-loss basis and a nominal fee is charged for providing farm equipment on custom hiring basis (see Joshi *et al,* 2007). There is also integration of credit along with supply of inputs and services now. In such cases, there is partnership between input company, financial institution (commercial bank) and agro-processing or export company. The input company manages contract farming, provides input and extension service, and undertakes processing of credit on behalf of financial institution. Generally there is no fee for extension services, but contact with farmers, reduction in transaction cost and increase in business volume are incentives for the company to remain in this business. Transaction cost for farmers is also reduced as they get all services at their door step, besides some price incentive—price offered for farm produce is marginally higher than its market price. Contract farming for wheat, potato and *basmati* rice are some examples of this institutional arrangement. Thus, provision of extension service and seed in some cases of large rice mills, on no-profit, no-loss basis help contribute to assured supply of quality produce to the company. Another type of innovation is the use of web-based expert system and other modes of ICT by some agro-companies to provide information on technology, weather and market prices to farmers. These examples indicate that there is increasing trend for private extension services, but the concept of direct recovery of cost is yet to commence in a sustainable manner. The only initiative taken by the government in 2002 was financing agriculture graduates for establishment of agro-clinics with subsidy from the government and financial assistance from NABARD. These agro-clinics will provide diagnostic services, consultancy and other services to farmers on payment basis. MANAGE is also providing training to input dealers who are emerging as an important source of information for farmers. The increasing commercialization of agriculture, scope for appropriability of benefits in provision of specialized information with property of 'toll good', and farmers' willingness to pay for quality extension service would encourage private for-profit extension services in the years to come (Dinar, 1996; and Umali-Deininger, 1997).

Public-Private Partnership

The concept of public and private goods is also applicable to extension service and therefore a number of institutional arrangements like public, private and public-private partnership can emerge for its funding and delivery. The scope for public-private partnership is further enhanced when we delink funding from delivery of extension services. For example, public funding and private delivery of services having 'public good' characteristics like information on weather, markets and measures to enhance sustainability of natural resources and environment protection could be an option. Specialized information like soil testing and pest management which has high degree of excludability at least in short run, can be provided by private agencies. Award of contracts on competitive basis not only increases cost-effectiveness of the services, but also allows for charge of fee-for- service. This concept is being followed in the Indian extension system for quite some time. The most notable example is ICAR funding for KVKs managed by NGOs. The model is working quite well and is able to deliver extension services in marginal areas where the public sector is not well represented. This model is being replicated in the main extension system of a few states where extension staff is depleting fast or staff turnover rate is high. In the case where the state government enters into a contract with private agencies (NGO or private for-profit) for delivery of extension services, the entire funding is from the state government. This arrangement is quite common in the northern region, primarily under externally-funded projects.

Public-private partnership is also being tried under the front-line extension programmes. For example, for promoting integrated pest management (IPM), there is partnership between research institutions, government department, NGOs and input suppliers. NGOs help mobilize farmers, while input suppliers provide critical inputs used in IPM; researchers provide technical input, conduct field demonstrations and farmers training programmes. In the case of zero-tillage, participation of drill manufactures in training programme and traveling seminar helped in addressing the problems in the use of drills. In order to replicate such success stories, programmes for up scaling and commercialization of technologies under public-private partnership are given priority in the competitive grants programme of externally-aided projects like NATP and NAIP. Another form of partnership in a few but effective cases is private delivery of technical information generated by public research programmes. The information is disseminated by private for-profit firm through mass media (print and electronic). The model is quite successful since print media (news paper and farm magazine) and television are important sources of information for farmers (NSSO, 2005). Quality and reliability of information, method of communication and popularity of mass media help determine the success of such models.

These are some of the examples of successful public-private partnership in extension in India. Replication and institutionalization of such partnership in the system require putting in place proper guidelines for contractual arrangements, benefit-sharing mechanism between research institutions and extension agency, and an enabling policy environment. The experiences of the states in contracting private extension services on a larger scale can provide useful insights to shape further reforms in this direction.

FUNDING OF AGRICULTURAL EXTENSION

Public funding of agricultural extension is a powerful instrument of extension policy in India. The central and state governments allocate public funds through block grants and competitive funding is rather lacking. Some funding for agricultural development projects, e.g. *Rashtriya Krishi Vikas Yojana*, is also earmarked for extension activities. Most of the central funds are used through central schemes which are designed in a 'top down' approach. Funding from the state governments forms the major chunk of the total funding for extension. During the triennium ending 2011, all the state governments together contributed 75 per cent to the total government funding and the remaining 25 per cent was contributed by the central government. The estimates of funding by business sector (both public and private) are just not available. It is believed that their contribution in the total funding is negligible. Therefore, in this paper we focus only on the trends in the government funding .

Government funding for extension during 1960s and 1970s has been quite erratic due to dependence of extension on agricultural development projects for funding and the changing priorities of the government. During the early 1970s, the government increased investment in agriculture to achieve food self-sufficiency, and as a result, extension funding in real terms (at 2011 prices) doubled during this period; but it registered a declining trend thereafter (Roy and Pal, 2003). After a marginal correction during the early 1980s, the real funding again started rising since the mid-1980s—a period of expansion of T&V system in the country. There was again a sharp uptrend in the real funding from the mid- 2000s (Fig. 1). As a result, the real expenditure in the triennium ending 2013 was more than double of that during 2001-03. This period coincided with system-wise institutionalization of the ATMA model. The real funding registered more than five-fold increase since the early 1980s and about eleven times increase since the early 1960s (Table 1). Thus, the trend in public expenditure on extension is consistent with that observed for the agricultural sector and major institutional changes made in the extension approach. However, there is some variation in the extension intensity (extension expenditure as percentage of AgGDP), which showed marginal increase during last few years after its stagnation during 1990s.

Intensity of the Funding

Another way to assess funding is to compute various intensity ratios such as expenditure as percentage of agricultural gross domestic product (AgGDP), expenditure per farm household and expenditure per hectare of agricultural land. As seen from Fig. 1, the increase in the expenditure intensity was sharp in the second half of 1980s, which was maintained during the 1990s. The ratio however again rose sharply in the second half of the last decade, reaching 0.18 per cent during the triennium ending 2013. This is less than half of the research intensity (0.40 per cent) in this period. Other ratios of extension intensity also echo the same trends. Except for a marginal correction during the early 1980s expenditure, per farm household and per hectare of agricultural land showed a rising trend in real terms. However, major increase in the ratios was seen during the 1980s and 2000s. In TE 2013, the country spent Rs. 166.29 per farm household and Rs. 162.53 per ha at 2011 prices.

This ratio of extension to research intensity is broadly consistent with the international funding pattern, but certainly the extension intensity is low in absolute terms, given the size of the country and diversity of production environments. Taking extension intensity as half of that of research intensity, a norm for the former should be 0.22 for developing countries and one per cent for developed countries—a level already achieved in other countries in the mid-1980s (Judd et al., 1986). Thus, extension intensity is much lower in India, which is not surprising as research intensity is also low in comparison to the international levels (Pal *et al,* 2012).

Table 1 : Intensity of government funding for agricultural extension in India, 1961–2001

Indicator	1961-63	1971-73	1981-83	1991-93	2001-03	2011-13
Total extension expenditure						
Constant local currency units (million 2011 rupees)	2,117	4,288	3,882	8,297	10,025	22,998
International dollars (2011 PPP, million)	140	284	257	549	664	1522
Annual growth in the real funding (%)	10.91	-0.06	9.08	4.67	9.23	
Expenditure per farm household						
Constant local currency units (2011 rupees)	43.20	60.39	43.42	77.80	83.61	166.29
Expenditure per hectare of net cropped area						
Constant local currency units (2011 rupees)	15.58	30.82	27.40	58.83	70.98	162.53
Extension expenditure as a percentage of AgGDP	0.08	0.13	0.10	0.15	0.14	0.18
Research expenditure as a percentage of AgGDP	0.11	0.22	0.25	0.31	0.39	0.40

Source: Developed by the author using data available in various government publications (for details, see Pal and Singh, 1997).

Note: Figures are three-year averages; 1961 refers to 1960/61 and so on. Growth rate in column 1961-63 is for to the decade of 1960s, in column 1971-73 for 1970s and so on.

PPP indicates purchasing power parity, an index used to reflect the purchasing power of currencies by comparing prices among a broader range of goods and services than conventional exchange rates.

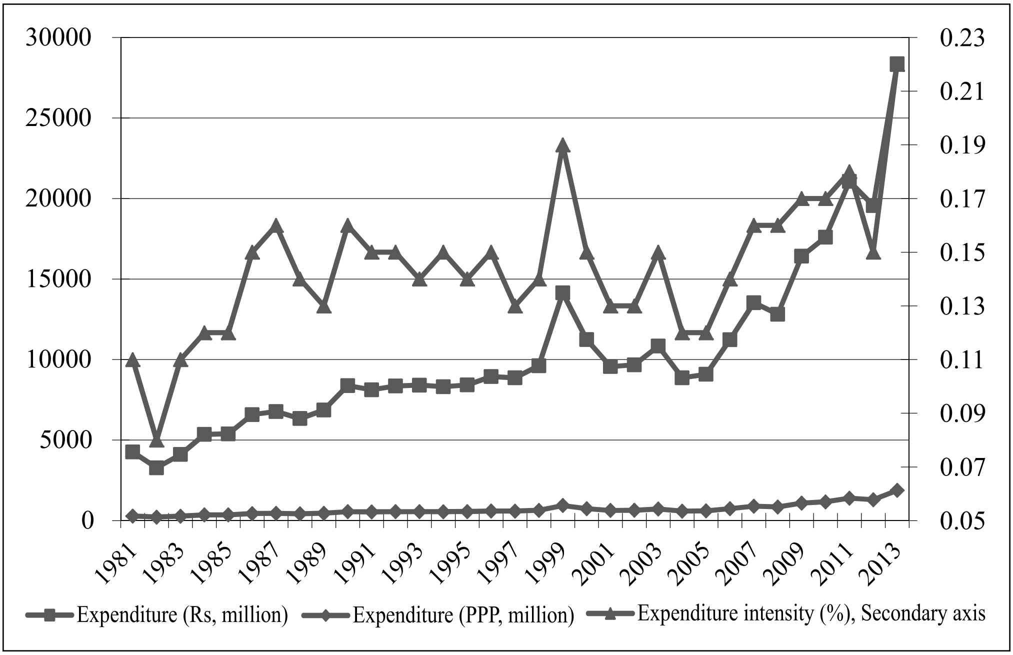

Fig. 1 : Trends in real public expenditure (2011 prices) on agricultural extension

Allocations by Regions

The funding was highly uneven among the states during the last two decades. The states of Tamil Nadu, Uttar Pradesh, Maharashtra, Assam, Bihar and Gujarat account for three-fourths of the national funding. Part of the difference in the funding could be attributed to donor funding received by some of the states. For example, the states of Assam, Andhra Pradesh, Maharashtra, Tamil Nadu and Uttar Pradesh received substantial funding from the World Bank, and therefore registered a higher growth in the real funding. A host of factors may explain variations in extension intensity across the states, the important determinants being, economies of scale and scope in extension, importance of agriculture, level of income, alternate sources of growth and political factors (Alston et al., 1998; Rose-Ackerman and Evenson, 1985, and Judd et al., 1986). Pal and Singh (1997) applied a political economy model to analyze impact of these factors on state funding to agricultural research and extension in India, using a cross-section and time-series data for the period 1982-1994. Although the results were mixed and unmeasured state-specific attributes were important, share of rural population and per capita government revenue had positive and significant impact on the per capita funding. Per capita AgGDP and irrigated area were negatively associated with the funding, which is rather surprising. The negative impact of irrigation could be because it competes for public funds as an alternate source of growth.

The large inter-state variations are reflected in regional allocations of the public funds. These disparities are more visible when extension expenditure is analyzed across different production environments. As seen from Table 2, dryland states covering 60 per cent of total agricultural land spent only 41 per cent of the expenditure in 1981-83. Their share further reduced to 35 per cent in 2001-03 and to 23.31 per cent in 2011-13, without any change in its share in the land area, which in fact increased marginally. On the other hand, the share of irrigated states increased from 24 per cent in 1981-83 to 33.8 per cent in 2001-03, which further rose to 34.8 per cent in 2011-13, whereas its share in the land area increased marginally from 23 to 24 percent. The share of resources allocated to wet rain fed areas however decreased from 28 per cent in 1981-83 to 17.2 per cent in 2001-03, but its share reached 33.7 per cent in 2011-13, which is more than twice its share in the national land area. Most of this increase in the share could be attributed to higher allocations by the states of Bihar, Assam and West Bengal. Thus, there is a disparity in allocation of extension resources across the states and it is widening over time, especially during the last decade. This has strong equity implications as land productivity is already low and incidence of poverty high in the rain fed regions. Hill regions also need more resources as these have smaller size of holding and production environment is vulnerable to various climatic risks. Studies have shown that further investment in these regions would generate higher economic and social benefits (Fan *et al*., 1999).

Table 2 : Allocation of public agricultural extension expenditure by production environments in India

Production environment	Percentage share in the total expenditure				Percentage share in total agricultural land			
	1981-83	1991-93	2001-03	2011-13	1981-83	1991-93	2001-03	2011-13
Dry rainfed areas	40.51	43.13	35.47	23.31	59.71	59.78	59.81	59.70
Wet rainfed areas	28.00	18.37	17.23	33.73	11.68	11.66	11.47	12.26
Irrigated areas	24.31	26.60	33.79	34.84	22.94	22.74	22.76	23.97
Hill and Mountain areas	7.18	11.90	13.51	8.12	5.67	5.82	5.96	4.06

Source: Based on data compiled from sources indicated for Tables 1.

EVALUATION OF EXTENSION SYSTEM

Returns to Investments

Like other developing countries, accountability and impact of public agricultural extension in India is often questioned despite the fact that extension system was a major partner in ushering the green revolution. This is primarily because of the fact that agricultural extension is funded and administered by government departments and public agencies having typical 'top down' bureaucratic functioning, weak commitment and inefficiencies (Purcell and Anderson, 1997). Many studies have examined the impact of agricultural extension in India and estimated internal rates of return to investments. Most of these studies have analyzed the returns to extension for individual crops or programmes, or for the sub-sector as a whole. These *ex post* impact studies have used both economic surplus model to estimate the benefits and econometric approach to decompose the growth in total factor productivity. The results are summarized in Table 3. There is considerable variation in the rate of return—it varies from 14 to 216 percent. The average rate of return was 75 percent, with a median value of 56 percent. These rates of return are comparable to those for agricultural research—average return of 72 per cent with a median value of 58 percent. This is in contrast to the international trend where the rates of return to extension investments are found to be lower than those for research (Alston *et al*., 2000).

Table 3 : Internal rates of return to investments in agricultural research and extension in India (per cent)

Measure	Agricultural extension			Agricultural research		
	Aggregate	Crop-specific	All	Aggregate	Crop-specific	All
Mean	55.8	118.3	74.6	75.4	69.9	71.8
Median	52.0	82.9	55.6	58.5	53.0	57.5
Minimum	14.0	56.2	14.0	46.0	6.0	6.0
Maximum	176.8	215.8	215.8	218.2	174.0	218.2
Number of studies	7	3	10	10	18	28

Source: Based on information in Alston *et al.,* 2000 and Evenson, Pray, and Rosegrant, 1999.
Note: Mode could not be calculated because no value is repeated in the observations.

These aggregate rates of return, though impressive, conceal a lot of inefficiencies of the extension system. Feder *et al.* (1987) analyzing the impact of T&V system in northwest India found that the system had no impact on rice productivity, but it resulted in at least 15 per cent rate of return in case of wheat. Nevertheless, there is a convincing case for enhancing public funding to agricultural extension. This is more so because of positive externalities of extension in the form of benefits to consumers, reduction in rural poverty and protection of environment. There are market failures and private investment in extension invariably is suboptimal. It would be desirable if additional public resources are allocated to low extension intensity states (e.g., dryland states). Also, efforts should be made to improve cost-effectiveness and efficiency of the system through institutional learning, modernization of the system and innovative extension methods.

Evaluation of Institutional Reforms

The role of agricultural extension should be seen in a broader perspective and it should include knowledge transfer from researchers to farmers, empowering and advising farmers in decision making, enabling farmers to clarify their goals and articulate their R&D needs, and stimulating desirable agricultural developments (van den Ban and Hawkins, 1996). Therefore, broad evaluation indicators like increase in productivity and rate of return are not adequate to evaluate performance of extension system. Even considering dissemination of knowledge to farmers (including technical, financial and marketing information and skill) and updating researchers about client needs as broad objectives of agricultural extension, there is a need for considering criteria beyond summary economic measures like rate of return. These criteria should include characteristics of extension system and information dissemination process. Feder *et al.* (2001) and Anderson and Feder (2004) have suggested that a number of characteristics affect performance of extension system. These characteristics are ability of extension system to address scale and complexity of agricultural systems, its interaction with knowledge system, accountability, political commitment and dependence on broader policy environment, encumbrance of duties of extension workers and fiscal sustainability. We assess performance of the extension system in relation to some of these characteristics.

Institutional reform at the state level in the form of establishment of ATMA at district level has initiated a number of processes which are expected to make a significant economic impact. First is the revival of state extension system by providing operating funds, which has not only increased outreach activities but also provided opportunities and resources to interact with other line departments, farmers and other stakeholders. ATMA now has resources and flexibility to identify and implement need-based extension programmes and ensure participation of all line departments, KVK and research institutions. Participation of farmers in the governing body, farmer advisory committee, commodity groups, etc has provided space to farmers and they are gradually learning to articulate their research, extension and developmental needs. Special attention is also paid to gender and other social issues. The immediate impact has been persistent demand for introduction and improvement of high value crops and need for support to improve access to agricultural markets. Scale and complexities of extension services are being addressed through formation of commodity groups, and there is an attempt to raise resources by charging token fee for training programmes. There is also an improved interaction with research system. The degree of success, however, varies across the districts; some have discernable presence, while others are just managing the assigned responsibility. Leadership and continuity of project staff have contributed to its success. Notwithstanding these achievements, there are some unfinished tasks and shortcomings. The project is yet to make full utilization of mass media to increase reach and realize cost-effectiveness. Also, ATMA continues to be a special centrally-sponsored programme; it is yet to be fully linked with the state department of agriculture and village-level *Panchayati Raj* Institutions. The renewed focus under the new Mission on Agricultural Extension can help address these limitations and make ATMA an agency for convergence of agricultural extension activities.

Sources of Information and Private Extension

Since innovations in private extension are demand and competition driven, they are expected to serve farmers efficiently and improve their economic conditions. Private input companies work through input dealers who have emerged as an important source of information for farmers. A recent NSSO survey indicates that, for the country as a whole, 13 per cent of farmers received technology-related information from input dealers—third important source of information after mass media (29 percent) and progressive farmers (17 percent). The percentage of farmers getting information from input dealers was as high as 36 per cent in West Bengal, 30 per cent in Andhra Pradesh and 24 per cent in Gujarat. Furthermore, the information received from them was considered to be as good as that received from public extension system, and most of the farmers followed the recommendation (NSSO, 2005). Since these dealers have a commercial interest, they may not pass on information to farmers about other useful products offered by their competitors. Also, farmers are not adequately informed about negative externalities, if any, in the use of the input sold by them, e.g., pesticides. This puts more pressure on public extension system to inform farmers about input markets and negative externalities. Contract farming, another model of private extension, has introduced a number of new varieties of vegetables suitable for processing, and productivity and income of participating farmers have increased significantly (Joshi *et al,* 2007). However, this practice is largely confined to developed regions like Punjab, for high value products, neglecting marginal rain fed areas. Within the developed region, the companies find it easy to work with large, resource endowed farmers, as it minimizes their transaction cost. Only in case of crops or commodities having less variation in product quality like milk and sugarcane, small producers have linkages with the industry. Thus, there is a large segment of farming community which is not served by private extension. There is a need to address this deficiency through suitable institutional and policy interventions. Public funding and private delivery of extension is another arrangement to address equity and cost-effectiveness issues in extension. But this requires a transparent system to award competitive funding to private agencies and an objective mechanism for their monitoring and evaluation, which are currently evolving in India.

CONCLUSION

Reshaping the Reforms

This paper has examined the trends in public funding, institutional reforms and performance of agriculture extension in India. The present extension system was mainly shaped during the T&V era and it has made significant contributions to agricultural development. The rate of return (median) to extension investments was 56 percent. Recent reforms of the public extension system and private sector developments have, no doubt, increased extension intensity and delivery of information to farmers, which in turn has contributed to higher productivity and income levels. Notwithstanding these achievements, there are some major challenges which require policy and institutional interventions. The first concern is regarding the level and sustainability of funding for extension. Extension intensity should at least be doubled through higher allocation of public funds. This is indispensable because 'public good' characteristics of extension services and spillover of benefits to non-users (e.g., consumers) in the form of lower prices and improvement in environmental services are significant. This is more so when the extension system is unlikely to generate substantial resources by charging fee for service in near future, owing to preponderance of smallholders. Most of the incremental public funds should be managed by the states and allocated to marginal dryland environments which are underinvested. Second important issue is to re-orient the extension system to current trends of diversification and commercialization of agriculture (Rivera and Alex, 2004). This implies greater participation of private sector and enhancing knowledge-intensity of agriculture. Since the nature and diversity of knowledge and information needs of farmers and rural innovators are changing rapidly, the scope of extension should expand beyond technology transfer and crop production and it should empower farmers, encourage rural innovations and facilitate development of value chains. Extension policy should also encourage multiplicity of extension service providers (public, private, NGOs, local communities, entrepreneurs, etc), and therefore, private sector should assume a much greater role. However, a large segment of farming community is not going to be served by private extension because of high transaction cost and lack of incentives for private extension to serve them. Therefore presence of a strong public extension system is a must. The public system can share the responsibility with the private sector by providing fiscal incentives like tax rebate or by contracting extension delivery to private agencies. The private agencies will find it attractive as it supports their main activity and marginal cost of serving more farmers is nominal. The public-private partnership is another viable option because of dependence of private extension agencies on public research system for acquiring new knowledge.

Third issue is of making the public extension system decentralized and demand-driven, which is essential to address location-specific extension needs, encourage farmers' participation and make the system accountable to farmers. The present reforms have addressed this concern to some extent. In order to sustain these efforts, development of capacity and skills of grass-root extension personnel is important. This will help in better assessment of extension needs, use modern communication methods like ICT, and improve the capacity of farmers to use new knowledge. Such capacity building efforts should be accompanied by stronger linkages of extension system with the knowledge or research system. This is important for access to new knowledge and technology and regular training of extension personnel both in technical aspects and extension methodology. ATMA and KVKs can play a major role in this task. In a way this will equip the extension system to adapt to changing circumstances and thereby improve the planning and decision making process in the system. Finally, monitoring and evaluation of extension schemes is rather weak because of excessive focus on central schemes. This must be corrected when public funds are likely to be used for private delivery of extension services. The state extension system should place more emphasis on efficient use of available funds, institutional learning and convergence of extension activities. These efforts will go a long way in improving effectiveness, efficiency and accountability of the extension system.

REFERENCES

Alston, J. M., P. G. Pardey, and J. Roseboom (1998), Financing agricultural research: international investment patterns and policy perspectives. *World Development* 26 (6): 1057–1071.

Alston, J. M., C. Chan-Kang, M. C. Marra, P. G. Pardey, and T. J. Wyatt (2000), A meta-analysis for rates of return to agricultural research: ex pede herculem. Washington, DC: International Food Policy Research Institute.

Anderson, J. R. and G. Feder (2004), Agricultural extension: good intentions and hard realities. *World Bank Research Observer* 19(1): 41-60.

Babu, Suresh, P.K. Joshi, C. J. Glendenning, K. Asenso-Okyere and R. Sulaiman (2013), The State of Agricultural Extension Reforms in India: Strategic Priorities and Policy Options, Agricultural Economics Research Review, 26(2): 159-172.

DAC (2014), Guidelines for the National Mission on Agricultural Extension and Technolohy, New Delhi (www.agricoop.nic.in).

Dinar, A. (1996), Extension commercialization: how much to charge for extension services? *American Journal of Agricultural Economics* 78(1): 1-12.

Evenson, R. E., C. Pray, and M. W. Rosegrant (1999), *Agricultural research and productivity growth in India.* Research Report 109. Washington, D.C.: International Food Policy Research Institute.

Fan, S., P. Hazell, and S. Thorat (1999), *Linkages between government spending, growth, and poverty in Rural India.* Research Report No. 110. Washington, D.C.: International Food Policy Research Institute.

Feder, G., L. J. Lau, and R. H. Slade (1987), Does agricultural extension pay: the training and visit system in northwest India. *American Journal of Agricultural Economics* 69(3): 677-86.

Feder, G., A. Willett and W. Zijp (2001), Agricultural extension: generic challenges and the ingredients for solutions", In S. Wolf and D. Zilberman (eds.), *Knowledge Generation and Technical Change: Institutional Innovation in Agriculture*, Kluwer, Boston, pp. 313-56.

Gisselquist, D., J. Nash and Carl Pray (2002), Deregulating the transfer of agricultural technology: lessons from Bangladesh, India, Turkey and Zimbabwe. *The World Bank Research Observer* 17(2): 237-265.

ICAR (Indian Council of Agricultural Research) (1998), National agricultural technology project: Main document. New Delhi.

ICAR (2014), Report of the High Power Committee on Management of KVKs, New Delhi.

Jha, D and S Kumar (2006), Research Resource Allocation in Indian Agriculture, Policy Paper 23, NCAP: New Delhi.

Joshi, PK, A Gulati and R Cummings Jr. (2007), *Agricultural Diversification and Smallholders in South Asia*, Academic Foundation, New Delhi-12.

Judd, M. A., K. A. Boyce, and R. E. Evenson (1986), Investing in agricultural supply: the determinants of agricultural research and extension investment. *Economic Development and Cultural Change* 35 (1): 77–113.

Macklin, M. (1992), *Agricultural extension in India.* Technical Paper 190. Washington, DC: World Bank.

NSSO (2005), Access to modern technology. 59^{th} Round January-Decemeber 2003, New Delhi: NSSO.

Pal, Suresh, and A. Singh (1997), *Agricultural research and extension in India: Institutional structure and investments.* Policy Paper 7. New Delhi: National Centre for Agricultural Economics and Policy Research.

Pal, Suresh and Derek Byerlee (2006), The funding and organization of agricultural research in India: Evolution and emerging policy issues. In PG Pardey, JM Alston and RR Piggott (eds), *Agricultural R&D Policy in the Developing World*. Washington, DC: The John Hopkins University Press and IFPRI**.**

Pal, Suresh, M Rahija and N Beintema (2012), India: recent developments in agricultural research, ASTI-ICAR Brief, IFPRI, Washington, DC.

Pal, Suresh and R Tripp (2003), India's seed industry reforms: prospects and issues. *Indian Journal of Agricultural Economics 57(3): 443-458.*

Planning Commission (2011), *Faster, Sustainable and More Inclusive Growth*: an approach to the XII Plan. New Delhi: Planning Commission.

Prasad, C. (1989), *Agricultural extension services.* In: 40 years of agricultural research and education in India. New Delhi: ICAR. P 234-267.

Purcell, D.L. and J. R. Anderson (1997), Agricultural extension and research: achievements and problems in national systems. World Bank Operations Evaluation Study, Washington, DC: World Bank.

Rivera, W. and G. Alex (2004), *Extension reform for rural development: national strategy and reform process* (volume 5). Agriculture and Rural Development Discussion Paper 12. Washington DC: World Bank.

Rose-Ackerman, S., and R. E. Evenson (1985), The political economy of agricultural research and extension: grants, votes and reapportionment. *American Journal of Agricultural Economics* 67: 1–14.

Roy, B. C. and S. Pal (2003), Investment, agricultural productivity and rural poverty in India: a state level analysis. *Indian Journal of Agricultural Economics* 57(4): 653-678.

Sulaiman, R. V. (2003), Restructuring agricultural extension in India. In Suresh Pal, Mruthyunjaya, PK Joshi and R Saxena (eds), *Institutional Change in Indian agriculture,* New Delhi: National Centre for Agricultural Economics and Policy Research.

Umali-Deininger, D. (1997), Public and private agricultural extension: partners or rivals? *The World Bank Research Observer* 12(2):203-224.

van den Ban, A.W. and H.S. Hawkins (1996), *Agricultural extension*. Blackwell, Oxford.

World Bank (2012), *Agricultural Innovations Systems – An Investment Source Book*, The World Bank, Washington, D.C.

Chapter 4

MANAGEMENT REFORMS TO ENHANCE THE EFFECTIVENESS OF AGRICULTURAL RESEARCH IN INDIA

Mruthyunjaya and Raka Saxena

INTRODUCTION

The Indian national agricultural research system (NARS) is one of the largest and institutionally most diversified systems in the world. The research and development (R&D) needs of different production environments which the system is catering to, are also complex and sometimes conflicting. Therefore, a great deal of professionalism is needed to manage the system and balance the research portfolio. For greater effectiveness of research, its management process should capture the changing scientific, production and economic environment in research planning and resource allocation process. Greater efforts will be required to analyze information on these changes and their implications for agriculture in general and research in particular. Also, the management process should link funding with the priority programmes and promote partnership among different research organizations and stakeholders to foster synergies. The informal process based on collective judgement was often found to be inadequate to capture these nuances and efforts were made by the international scientific community to design improved research management tools. These tools aim to bring more professionalism in research management process by bringing greater objectivity and transparency in the decision making. The experience of other countries has shown that systematic collection and use of information and creation of decision support system are necessary for institutionalization of these improved tools in the research system (Byerlee and Echeverria, 2002; Gijsbers *et al,* 2001 and World Bank, 2012). Some of these tools have been adopted in the Indian NARS under different externally-funded projects as part of the organizational and management reforms. This chapter presents important management reforms implemented in the system and key lessons learnt for the future. The chapter specifically discusses measures to improve research planning and monitoring, promote competitive funding and foster research partnership. The chapter also indicates further changes that are required in the management of public research organizations and in addressing the needs of smallholders. The key to success of these reforms lies in continued sensitization to prepare the stakeholders for reforms, reducing transaction costs in organization of various activities, fostering partnerships and decentralizing the management process.

ECOREGIONAL PLANNING

The first and foremost requirement of improving effectiveness of research and catering to the needs of different stakeholders is identification and prioritization of R&D needs. These needs are specific to a production system and, therefore, analysis of different production systems, which usually correspond to an ecosystem, is a must. An ecosystem is a homogenous region with respect to endowment of natural resources, agro-climatic factors and socio-economic conditions. Farmers in an ecosystem follow similar agricultural practices and face common production constraints and growth opportunities. Their research needs and response to new technology are also uniform. These characteristics help in better identification of research needs, targeting of research efforts and realizing larger impact of research outputs (Wood and Pardey, 1998). The merits of ecosystem-based research planning were recognized quite early in India, but efforts could not succeed because of some operational problems. Agro-climatic zones identified by the Planning Commission (1989) were very broad, mostly suitable for agricultural development planning, while the zones identified by the Indian Council of Agricultural Research (ICAR) for the National Agricultural Research Project (Ghosh, 1991) were small, covering a few districts, and therefore, were not suitable for research planning at the state or national level. Thus, wider acceptability of ecosystems would depend upon the criteria used for their delineation, clarity and stability of ecosystem boundaries and amenability to use them for research planning at all levels in the research system. Keeping this in view, ecoregional research planning was emphasised under the National Agricultural Technology Project of ICAR (1998-2005) with funding from the World Bank. The project envisaged major ecosystems in the country which were further divided into production systems. In a systematic exercise, six major ecosystems were identified in the first stage and these were then delineated into 15 production systems. The following procedure was used for the delineation using district-level data. First, arid, coastal and hill and mountain ecosystems were delineated based on topography, soil type and climate because these factors largely determine agricultural activities in these regions (Sehgal et al., 1992). Second, remaining districts were classified into two broad categories of irrigated and rain fed districts based on the extent of irrigated area. Districts having 40 per cent or more gross cropped area under irrigation (irrigation potential in India) were considered as irrigated and the remaining were rainfed. In order to further improve homogeneity, irrigated districts of semi-arid peninsular India and rainfed districts of humid eastern India were taken out as these form two separate production ecologies. The remaining districts formed two broad ecosystems, viz. irrigated system of the northern plains and rain fed semi-arid system of central and southern India. In the third step, these two broad ecosystems were further divided into their production systems using cluster analysis. District-wise crop area shares were used for cluster analysis because cropping pattern is a result of climatic, physical and socio-economic factors. A two-step procedure was followed. In the first step, hierarchal cluster technique was applied to know the approximate number of clusters. In the second step, several iterations of 'K' cluster method were done to arrive at stable clusters (for detailed methodology, see ICRISAT, 1999 and Saxena *et al,* 2000). To maintain contiguity, outlier districts were merged with their neighbouring production systems.[1]

The delineated production systems are shown in Fig. 1. There are wide variations among the ecosystems in terms of inputs use and productivity levels. The Irrigated and Coastal ecosystems follow high input and high productivity systems, while the Arid and Semi-Arid rain fed ecosystems practice low input and low productivity systems. Therefore, research strategy may differ for these two distinct production ecologies. Use of modern inputs and irrigation are very low in the Semi-Arid and Humid Rain fed systems, but these systems receive a good amount of rainfall (816-1500 mm). Therefore, management of rainwater can increase crop productivity and cropping intensity in these systems, covering nearly 60 per cent of the net sown area of the country. Coarse cereal and oilseed-based production systems of the Arid and Semi-Arid systems have low productivity with high risk owing to hostile production environment. These fragile systems may require more research efforts than those justified by pure economic consideration like their share in value of production.

The concept of ecoregional planning was used for assessment of research priorities and identification of research programs for funding. One of the major advantages of this concept was that it helped in systematic identification of research priorities and linking research with research needs of the production system. A by-product of this exercise was identification of extension activities to address the production constraints for which technological solutions were available. The second major advantage was that, for preparation of research programs to provide technological solutions to address a production constraint, expertise from different disciplines and organizations was needed and therefore, multi-disciplinary and multi-institutional projects were easy to formulate and implement. The efforts were successful, though these faced administrative problems in aligning research funding with the block grant system of the government.

[1] This work was done a part of the exercise to facilitate the research priority assessment under NATP.

Table 1. Important lessons from agricultural research management reforms in India

Reform area	Key objective	Lesson learnt
Research planning	Improving targeting and relevance of research	Ecoregional planning improves targeting but link this with fund allocations
		Information system, institutional mechanism and analytical capacity necessary for the success
		Objective criteria and combination of priority-setting methods useful for a large system
Research monitoring	Assess progress and learning for the future planning	Simple and verifiable monitoring indicators useful
		Monitoring mechanism should be cost-effective, decentralized and simple
Impact assessment	Justification for past investments and lessons for future	Analytical capacity and technology information system are necessary
		Better done in an impartial manner by outside agency, or group
		Focus on the institutional aspects of technology adoption process
Decentralization	Improve institutional efficiency and accountability	Decentralization of administrative and financial responsibility up to the project and scientist level
Competitive funding	Improving relevance and efficiency of research	Identify goals and priorities of the fund and a body to oversee its functioning
		Define acceptable modalities of the fund, including transparent criteria for project evaluation and monitoring
		Ensure competition for the funds through scoping activities
		Can also be used for technology transfer and dissemination of information
Research partnership	Resource sharing and synergies	Identification of research programs of mutual interest
		Sustained efforts for building of capacity, confidence and commitments
		Availability of public funds in the initial phase to institutionalize the process
		Institutional mechanism for sharing of research resources and benefits

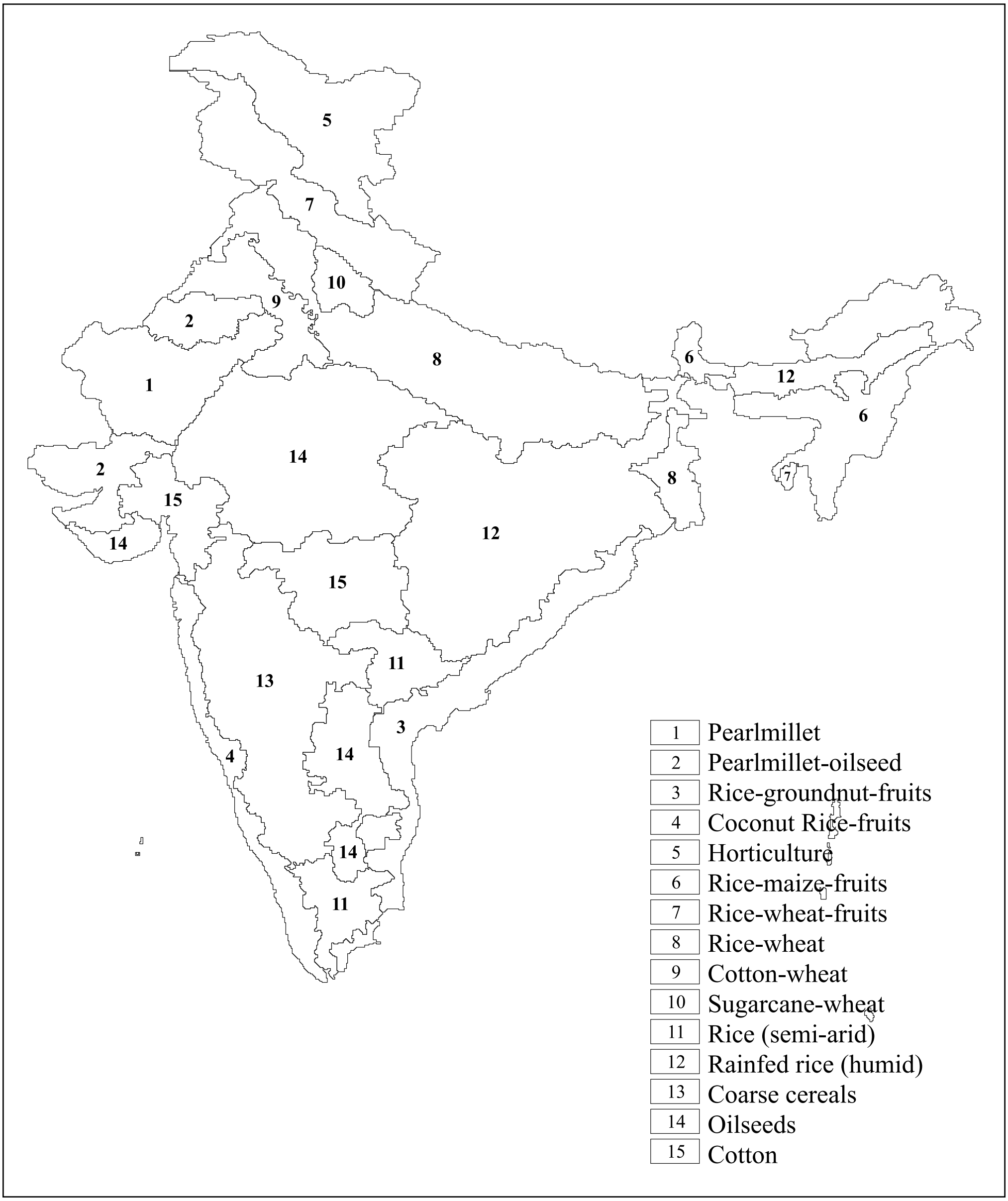

Fig. 1 : Major production systems of India

Assessment of Research Strategy and Priorities

Research strategy and priorities can be assessed at different levels. First are the macro considerations at the research system level, which shape research strategy to address the national development objectives. The strategy framework entails guiding long term investment decisions, institutional expansion and partnerships. These decisions are important for building research capacity to address the long-term issues. However, this was not done explicitly and was guided by collective wisdom of peers and senior managers. A systematic attempt began with the visioning exercise done in the system. This exercise enabled revisiting the mandate, addressing the weaknesses and identification of programs to realize mission and vision of different research organizations, including ICAR (ICAR, 2000). This exercise was revisited later, at different time intervals to revalidate the earlier initiatives and priorities.

The second important attempt in this direction was made for preparation of the National Agricultural Innovation Project (NAIP) funded by the World Bank. This exercise was done with the help of professional experts in strategic planning with participation of key stakeholders. This exercise used the scenario planning method for Indian agriculture. Four scenarios were attempted, based on the major driving forces and risk factors. The scenarios were arrived based on the uncertainties associated with acceptable degree of income inequality and the globalization process. These scenarios thus pertain to different levels of economic performance or growth, inequality and degree of economic reforms (for details see, Rajalahti *et al,* 2006). The main recommendation emerging from this exercise was that the role of the government shall change over time, ranging from direct interventions for capacity building to facilitating role, fostering partnership with private sector, and direct interventions to benefit disadvantageous regions and farmers to ensure inclusive growth. These elements were adopted in the planning of research programs for NAIP, especially developing research consortia for value chains and livelihood security. Such an exercise can be even more effective in planning for commodity research.

The next stage of research planning is assessment of research priorities and allocation of resources to address them. This is important for making the system demand-driven and improving the overall effectiveness. A weak research planning would lead to poor targeting, cost overruns and frequent delays. At the planning and initial stage of implementation, there is a scope for change, and any oversight identified at a later stage is difficult to rectify; it would simply require repetition of research cycle. Research planning involves two basic processes: (a) development of research programs in a bottom up participatory approach and using objective criteria and systematic analysis, and (b) allocation of resources based on prioritized research portfolio. The idea is that resources should be allocated based on economic and other significance of the programs and the programs must be of direct relevance to the clients. This significance is ascertained in terms of likely contributions to research objectives (economic and distributional gains, environment etc), and a number of analytical methods are available to assess this significance (see Norton and Davis, 1981; Alston et al., 1995; Gijsbers et al., 2001). The choice of method is determined by availability of data and computational skills, dimensions of priority assessment (ecosystem, commodity, research theme, etc.) considered in the analysis and degree of transparency of results required by research managers. Some international agricultural research centres (IARCs) with adequate analytical capacity have used sophisticated methods like economic surplus model (Davis *et al.*, 1987 and Kelley *et al.*, 1995). This model was also applied for some NARSs of developing countries with the help of international consultants, but it could not be sustained due to lack of in-house analytical capacity and inability of research mangers to understand and appreciate the results (Nagy and Quddus, 1998; Mutangadura and Norton, 1999 and Dar and Jaunillo, 2000). Part of the failure could also be attributed to the fact that economic models are sometimes rather inadequate to consider non-economic objectives in the analysis, like sustainability and equity considerations.

The choice of priority assessment model also confronts some additional problems for a large research system like the Indian system. Use of a sophisticated model in such cases could prove to be expensive, both, in terms of time and resources. Also, such models often require reliable data on scientific opportunities and other technology-related parameters which are difficult to obtain for a large number of commodities grown in diverse production environments. Under these circumstances, it is appropriate to undertake the priority assessment exercise in stages, using a combination of methods. At the national level, it is better to focus on demand-side considerations using a simple method like modified congruence analysis. This analysis suggests that research resources should be allocated in proportion to relative importance (economic or other parameter) of a commodity or an ecosystem. This approach, however, assumes that the cost and opportunities of generating new knowledge are equal across commodities, and value of new knowledge/technology is proportional to the value of production (Gryseels et al., 1992). Despite these restrictive assumptions, this model has a lot of conceptual appeal, as it is simple to apply even for a large number of commodities and regions/ecosystems. Also, as explained below, this model can easily incorporate multiple research objectives using an appropriate weighting scheme. Therefore the modified congruence model is commonly used for assessment of macro (regional and commodity) priorities. The model was also used for India and south Asia for assessment of commodity and eco-regional priorities using the criteria of efficiency, sustainability and equity which are derived from the national policy objectives (for details see, Mruthyunjaya *et al,* 2003).

Identification of research programs or projects is the third level of priority assessment, which is important for an organization or a funding agency to approve them for funding. This exercise is best done in a decentralized and participatory mode. The idea is to identify research priorities to address the mandate of an organization or goal of a research fund. Assessment of the priorities at this level requires an understanding of R&D imperatives to raise commodity yield, or efficiency of resource use and technology required to address binding constraints in a production system. The production constraints are usually identified involving development agencies, extension personnel, farmers and other stakeholders. This gives a list of researchable issues which can then be converted into research programs. This information, along with scientific opportunities and probability of research success can help arrive at the economic significance of the programs. One can calculate the expected benefits in a more systematic way by addressing different production constraints. These benefits are in proportion to value of the commodity adjusted with yield loss, area affected and frequency of occurrence of a constraint, e.g. insect, disease or drought. Alternately, one can apply economic surplus model to estimate research benefits and also use the concept of probability of research success in addressing the constraint (Alston *et al,* 1995). This method will require additional information on commodity market (production, prices and elasticities), expected technology adoption path and shift in supply curve of the commodity due to adoption of technology developed by the program. The expected economic benefits thus arrived can then be compared with the cost likely to be incurred to do the research. This ex-ante framework of economic impacts can provide various summary measures like benefit-cost (B-C) ratio, internal rate of return (IRR) and net present value (NPV) for different programs and prioritize them based on these impact measures.

Ideally, this decentralized priority assessment can provide input to macro priority assessment but such information flow is rather limited, and often national priorities are identified by the peer group with the information readily available. Nevertheless, micro-priorities can be used to draw implications for strategic research, i.e. what kind of strategic research should be done to support applied research programs developed in a bottom-up approach. All these programs should be linked through an appropriate institutional mechanism like coordination or monitoring task force.

Often an intermediate product of this exercise is the identification of extension programs to attend to those production constraints which can be addressed by dissemination of available knowledge or technology. This exercise was initiated under NATP in the form of formulation of strategic research and extension plan, which was also used by the Agricultural Technology Management Agency (ATMA) for development of extension activities.

Monitoring and Evaluation

Research monitoring or concurrent evaluation is an important process to ensure implementation of the prioritised programmes and evaluate the progress. This is possible through explicit identification of activity milestones and outputs along with a timeframe. These activities and outputs are then monitored using quantitative as well as qualitative indicators of inputs and outputs. It is important that these monitoring indicators are simple, objective and verifiable. Log frame, linking activities with program objectives and identification of verifiable indicators was widely used for monitoring of research programs. This is now replaced with the Result Framework where activities and their indicators for different outcomes (or results) are identified and monitored for their progress. Both these tools were used for program and project management under the externally funded projects of ICAR. However, within the Indian system, as part of governance reforms, Outcome Budget and Result Framework Document were developed and used by all the government departments, including Department of Agricultural Research and Education (DARE)/ICAR. These documents have identified the output and outcome indicators for various objectives, or mandate of all the research institutes; these indicators are then aggregated at the system level for periodic monitoring of the progress. Attempts were also made to use these indicators for evaluation of individual scientists.

Some factors are responsible for success of the monitoring mechanism. First, it is important how monitoring process is taken in the system. It is essential that monitoring should be viewed as a earning and not a 'controlling' process to help improve program implementation. This is possible when it is easy to institutionalize the process in the system at different levels (system, institute, program etc) and use it for improving the progress and future planning. The monitoring indicators must be simple, objective and verifiable. These indicators are often suggested by the researchers. Second consideration is the frequency of monitoring which should be need-based. Financial monitoring could be frequent (even quarterly), but technical monitoring should be less frequent, ideally annual but can be half yearly. ICAR institutes monitor their programs twice in a year internally and once in a year by an external scientific advisory committee. Third issue is of linking monitoring with funding and this is best done under the externally-funded programs. Only successful programs or activities should be allowed to continue and if needed, necessary adjustment in the activities and resources should be made. Efforts have also been made to develop a computer based information system for project monitoring, but timely updating of information is still a concern. The last factor which can restrict the success is complexity of the format and monitoring system; a cumbersome format needing a lot of information and high frequency of monitoring can prove to be expensive, both in terms of need of resources and scientists' time needed for monitoring. This is more so when the system is large and information is needed for various purposes. Therefore, monitoring process should be simple.

Impact assessment

Ex-post evaluation or impact assessment of research against well-defined criteria is an integral part of research evaluation process. Usually, impact assessment efforts in the NARS are scanty and confined to a few successful technologies at the initiative of economists. But with greater funding coming from international donors, there is increasing emphasis on assessment of their research programmes. Therefore, efforts were made in the Indian system since NATP to develop and institutionalize the capacity for impact assessment. *Ex-post* impact is usually carried out after completion of the programme when the technology has made some impact on farmers' fields. ICAR has a system of evaluation of its institute after every five years with a purposely constituted team of outside experts. This team also analyses research impact, besides financial, administrative and research aspects. Sometimes, agency like the Planning Commission also commissions external evaluation of performance of ICAR institutes as part of evaluation of government programs.

However, research impact can be carried out in a more systematic way at different levels, e.g. farmers' fields, commodity or sector level, regional level and national level. In all the exercises, primary information is collected from the farmers, but it is used in different ways, at different levels. For example, at farmer level, data on cost, yield, return, etc are used in a partial budgeting framework. This can also be extended to the regional level. But at the commodity level, farm level information is used to arrive at the shift in supply function in the economic surplus framework. This is the most commonly used method for impact assessment. For sector and national level exercise, which is usually done for larger impacts, methods like total factor productivity (TFP) measurement and computable general equilibrium (CGE) model are used. There are few examples of CGE being applied during the green revolution period, but TFP is quite frequently used for sectoral level analysis and this is regressed on R&D expenditure to assess the impacts (see Alston *et al,* 1995, Evenson *et al,* 1999, Chand *et al* 2011 and World Bank, 2014). Initially, economic impact (returns and poverty reduction) was analysed, but of late there has been interest in environmental, health and other social benefits like gender impact (Renkow and Byerlee, 2010).

Besides justification for past investments, *ex-post* impact assessment can also provide feedback to research planning by looking at the extent and causes of shortfalls and failures. Some useful lessons can be learnt from the adoption process. The analysis can provide insight into the factors which expedited or restricted the adoption. The experience of the national and the Consultative Group on International Agricultural Research (CGIAR) system has shown that research impact assessment helps understand institutional imperatives for dissemination of seed, resource and other information-based technology. The exercise also validates results of priority-setting exercise, improves technology design and accelerates rate of technology adoption. Lastly, in order to add credibility to the impact assessment work, it is important that the analysis is carried out in an impartial manner.

Information system

As discussed above, research monitoring and evaluation require lot of information on project activities, output, costs, technology adoption, etc. Timely availability of information improves quality of research planning, enables judicious use of resources, reduces duplication of research efforts, helps in quantification of impact and thereby contributes to cost-effectiveness of the research system. Compilation of such information requires considerable amount of resources. Therefore, there is a need for development of an information system. Besides computer and other support, an integrated system of information on research programs, scientific manpower, financial resources, research products including technologies, patent and publications, technology adoption and other value-added information should also be accorded high priority. Past efforts to develop such a system were frustrated because of inadequate infrastructure for the exchange and updating of information and lack of user-friendly information system. In order to revive the past efforts, development of research information system and network connectivity was given high priority since NATP period. But now, use of information communication technology (ICT) is quite common and reliable and therefore, information system for research projects, personnel, financial resources, etc is maintained at the institutes and ICAR headquarters, and it is increasingly used for decision making. However, this information system should be supplemented with data on research outputs, their dissemination, outcomes and impacts.

Decentralization

One of the most important tasks to address the ‘second generation’ problems of the NARS is to make public research system autonomous and decentralized. This point was also echoed by the review panel of ICAR (1988). When liberalization and deregulation are part of the economy-wide reforms, there is no reason why the public research organizations should not be made fully autonomous for improving their flexibility and efficiency. It is also important to recognize the fact that research is a highly specialized creative process with uncertain outcomes and it requires different working rules, incentive system and flexibility in management of resources. Thus, autonomy should ensure flexibility in the governance as well as management functions such as human resource development, finance, administrative procedures and international collaboration (Nickel 1997; and Byerlee and Alex 1998). Several models have been tried all over the globe; they vary from a completely autonomous system of the CGIAR Centres to the corporate model of *EMBRAPA* in Brazil. Within the country, there are examples of autonomy given to the Aeronautical Development Agency (ADA), which is supported by a professional body for technical matters, and enjoys functional flexibility. At the same time, the agency is accountable to the government. The NARS can incorporate some of these elements, while remaining accountable to the government, which shall continue to be a major source of finance in future also. ICAR's vision document, ICAR Vision 2020, also envisages for business-oriented rules and greater independence for the Governing Body. A similar change is required at the state level, especially in terms of recruitment and financial allocations. Here it is important to note that if the system has to deliver in an environment of competition, it must have the same flexibility as exists in those organizations with which it has to compete or collaborate.

Research management requires considerable amount of resources and time and therefore it should be rationalized through decentralization of responsibility. The decentralization of the system shall help in two ways. Firstly, it will encourage management reforms to reduce transaction cost and improve research efficiency. Secondly, scientists, research programmes and institutions can be made more accountable. ICAR has made considerable progress in terms of decentralization of responsibility at the project level, which also involves delegation of financial powers. But sometimes delegation of financial powers and compliance to the government financial rules set the limit for decentralization. This conflict should be resolved.

Competitive Funding

Government funding to the Indian NARS is mostly in the form of block grants under the successive Five Year Plans, which is further transferred to different institutes under the different expenditure heads (establishments, capital, contingency etc). There are also non-Plan funds to meet the establishment and other overhead costs. Part of the Plan funds is managed by ICAR through competitive grants where a large number of institutions and researchers compete for funds on the strength of their proposals. It is likely that this Plan and non-Plan funding may be done away with, under the new process of perspective planning by the *NITI Aayog*. But some proportion of core funding from the government can be allocated through a competitive mechanism. Competitive funding is a powerful mechanism to bring institutional reforms in the research system. These funds can improve relevance, cost effectiveness and accountability of research (Kampen, 1997). Institutions and scientists compete for funds to work on the identified priorities. Objectives, key concerns (like multidisciplinary and inter-institutional approach for equity-driven research) and modalities of the funds are well-defined and disseminated (Gill et al. 2000). Although some of the funds like Agricultural Produce Cess Fund of ICAR were established long ago, these were hardly used for bringing institutional reforms. This fund was mainly used for new research ideas which, if successful, can be up scaled and supported under Plan funds. It was only recently that competitive funding under NATP and NAIP was designed to strengthen public-private partnership in agricultural research. It is, therefore, important that an increasing proportion of research funds are used for competitive funding for specific objectives.

Objectives of the fund, operational procedures and research priorities should be determined well in advance for transparency and credibility in management of the fund. In the absence of these, it is likely that subjectivity and inconsistency will be involved in evaluation of research proposals. Peers' perceptions of priorities may vary, 'good science' may overshadow need-based research, and the competitors' credentials may dominate relevance of proposal in terms of clients' needs and objectives of the fund. Finally, in order to make these funds successful, there should be enough flexibility in financial and management operations— an essential requirement, often lacking. Here, it is important to note that the competitive funds finance the short-term projects, usually of 3-5 years duration, and therefore, timely availability of resources and flexibility in their use are essential for the successful and timely completion of projects.

Research Consortia and Partnerships

Consortium and networking approaches are powerful mechanisms to foster partnership among research organizations and individual scientists. Usually, the former is a formal arrangement between two or more research organizations to address a specific objective, while the latter establishes informal but effective links among scientists working on a common research theme. Both the approaches are gaining popularity in the research systems. For example, the Rice-Wheat Consortium had established joint research programs between CIMMYT, International Rice Research Institute and NARSs of South Asia for sustaining the productivity of the rice-wheat system in the Indo-Gangetic Plains. Similarly, there are a number of research networks both, at the international and national levels, which are operating at a comparatively smaller scale. Both the approaches are cost effective and can generate synergies, and therefore, should be encouraged. Electronic connectivity and flexibility in establishing linkages, including international linkages are essential for their promotion. On a larger scale, research consortium approach was followed under NAIP to promote innovations along the production to consumption system research. The consortia involved participation of national, both public and private, and international research organizations.

Another important aspect of research partnership which is currently gaining currency is involvement of private sector for synergy in development and commercialization of technology. This is because private sector is playing greater role in funding and conducting agricultural research globally. Its presence is particularly significant in the developed countries where it contributes about half of the total research efforts (Alston et al. 1999). The developing countries have started witnessing this institutional change (see chapter 2). Conceptually, the private sector is expected to build on basic research done in the public research organizations for its commercial application. The products of applied research have high appropriability—a necessary condition for private investment (Umali, 1992). Therefore, a closer link between the two sectors can substantially reduce R&D lag and improve efficiency of the research system. These links would also improve client orientation of research efforts, as the private sector works more closely with the clients. The available evidence indicates that in such linkages, the government-funded work preceded the industry-funded work and researchers in both the sectors were in constant touch—academic researchers identified problems in consultation with the researchers in industry, while the latter availed the consultancy services from the former. Further, the standard of faculty, scale of research and geographical proximity were found to be positively associated with the perceived contribution of academic researchers to industrial revolution (Mansfield, 1995). Such instances of public-private interface are few in the developing countries and India is no exception to this. The successful examples are plant breeding consortium of the International Crops Research Institute for Semi-Arid Tropics, hybrid rice program of ICAR and some programs under NAIP.

The need for public-private interface is likely to increase with further spurt in private research activities because of advancements in molecular biology and genetic engineering. The new trade regime is also expected to help globalization of biotech products, and therefore, developing countries are likely to witness exponential growth in private-sector research. A variety of actors, viz. national public research system, international public research system and national and international R&D companies may form new alliances and partnerships. Such partnerships should be based on comparative advantage and strengths of the partners. Public research organizations should learn to gain access to proprietary research material through joint ventures, secrecy agreements, licensing purchase and material transfer agreements. They should also learn to manage their intellectual property and exchange it for gaining access to proprietary technologies for larger public interest and social welfare (Byerlee and Fischer, 2000). The national research system should initiate a strategic response to development, management and transfer of technologies. The success on this front will largely be determined by transparency and effectiveness of the regulatory framework for protection and transfer of technologies and mechanism for sharing of research benefits.

A number of initiatives have been taken in India to foster public-private partnership in agricultural research. Broadly these partnerships can be classified into three categories. First and the most common partnership in India is private delivery of public products. Availability of information and transparent mechanism for access to the products of public research programs has facilitated this kind of partnership. Examples of this kind are found in the Indian seed industry (Pal *et al,* 2000) and frontline extension of ICAR where public funds are made available to private non-profit organizations for KVK. The second kind of partnership has been driven by the transaction cost of contractual relations in agricultural research (Williamson, 2000). There is an increasing realization among the private companies that market dominance is possible only when they have superior product to offer to farmers. This can be realized with adequate R&D support. In case the R&D support is provided by the public sector, there should be explicit mechanism for joint venture and trust between the partners; mechanism for benefit sharing and secrecy of the contract are important for success of such partnerships. These conditions are, however, easily met in the private-private partnership, and therefore, new partnerships between the national and trans-national companies are emerging in India. The most frequently cited examples are in the seed sector— joint ventures of Monsanto and Mahyco for commercialization of Bt cotton.

Third type of public-private partnership was encouraged in the consortium mode with public funding. Notable examples are the rice-wheat consortium and research consortium under NAIP. Capacity building and strengthening partnerships were the major elements in all the components of the NAIP. Here partnerships refer to collaborations among public sector institutions, farmers' organizations, self-help groups, non-governmental organization (NGOs) and the private sector. Partnership is promoted using a consortium concept. A consortium facilitates flow of knowledge, collaborations, experimentation and implementation as well as articulating demands for knowledge and technology. It also helps in pooling of competencies and resources and increasing synergies among participating institutions. In all, 206 consortia leaders and 653 consortia partners participated in the project, adding up the number of participating institutions to 856, which covered public research institutions, Farmers' Organizations, NGOs and private sector. For example, a total of 51 consortia were supported to develop market oriented agricultural value chains. They covered 28 ICAR institutions, 22 state agricultural universities (SAUs), 38 private industries and 29 NGOs. It is reported that nearly 50 per cent of the partners in these value chain projects were from outside ICAR/SAU system, mostly from the private sector. In case of sustainable rural livelihood security component of NAIP, nearly 50 per cent of the partners were reputed NGOs having long experience of working with farmers in rural settings.

It took considerable time in the beginning to bring in like-minded partners from diverse backgrounds having skills, expertise, resources and interest to bridge missing links/gaps in knowledge. There were concerns about government funding to non-public entities, management of IPRs, sharing of capital expenditure, recovery of fixed assets after the project, etc. Systematic campaigning about the project, organization of several sensitization workshops, creation of a help desk to support project preparation, clear cut intellectual property rights (IPRs) policy by ICAR, agreement on sharing of capital expenditure on the basis of research content in the projects, etc. have helped to improve participation rate, build confidence and trust among the partners and share knowledge about the rules of the game. Though there were reports of stress points among partners during implementation of some of the sub-projects, but the partnership continued in almost all the sub-projects as per the plan till the completion of the project. As a result, under NAIP, there was development of 130 production and 142 processing technologies, piloting of 62 rural industries, commercialization of 80 technologies/ products, filing of 149 patents or intellectual property applications, publication of nearly 635 research papers in high impact international journals, establishment of about 165 public-private partnerships, 22 business planning and development units and 5 producer companies (for details see, ICAR, 2014 and Mruthyunjaya, 2014). This shows that substantial investment and capacity building efforts are required to initiate and sustain the partnership, which subsequently lead to significant research outcomes.

CONCLUSIONS

There are some important lessons which can be learnt from the institutional reforms in agricultural R&D in India. The first and foremost is an enabling environment which promotes participation of multiple actors and stakeholders in provision of R&D services. Part of this is derived from the macro policy environment, but leadership role of the public sector, namely ICAR, is extremely important. This is because the public system has to provide leadership, resources and confidence among the partners to initiate the process of change to serve the farming community effectively. This is particularly true when participation of private sector is rising rapidly and the public sector is required to guide its development. A greater understanding of functional realities of both the sectors, procedures for material, resource and benefit sharing can help both the sectors to come together and address the R&D challenges more effectively.

The second important lesson is that, with the rising complexities of R&D challenges and size of NARS, management and decision making process should be made more informed and professional. This task requires considerable investment in development of research information system and institutionalization of management tools. In particular, the tools for research planning and monitoring, accountability and impacts are found to be very useful. The process, like decentralization of decision making with accountability helps reduce transaction cost and improve institutional efficiency. These changes will also require considerable efforts to sensitize people and develop the capacity for change. Institutionalization of such efforts can be comparatively easy if these are linked with funding, and competitive funding is such a mechanism.

Finally, institutional change is a continuous process and its success lies with the capacity for institutional learning within the system. The leadership can play an important role in building and nurturing the learning process at all levels, viz. the system, organization, program etc., and use this in strategic decision making. This aspect of institutional capacity will be critical when next level of issues in research management like partnerships, management of intellectual property and commercialization of technology assume greater significance.

REFERENCES

Alston, J.M; G.W. Norton and P.G. Pardey (1995), *Science Under Scarcity: Principles and Practice for Agricultural Research Evaluation and Priority Setting,* Ithaca: Cornell University Press.

Alston, JM, C Chan-Kang, C Marra, PG Pardey and TJ Wyatt (2000), A meta analysis of rates of return to agricultural R&D: *Expede herculern*. Research Report 113, Washington, DC: IFPRI.

Alston, Julian M., Philip G. Pardey and Vincent H. Smith (1999), *Paying for agricultural productivity*. London and Baltimore: The Johns Hopking University Press.

Byerlee D and RG Echeverria (2002), *Agricultural research policy in an era of privatization*, Wallingford (UK): CABI Publishing.

Byerlee, Derek and Gary E. Alex (1998), *Strengthening national agricultural research systems: policy issues and good practice*. Washington, DC: The World Bank.

Byerlee, Derek and Ken Fischer (2000), Accessing modern science: institutional and policy options for biotechnology in developing countries. Paper presented at the 4th International conference on the Economics of agricultural biotechnology. Ravello, Italy, 24-28th August 2000.

Chand, R, P Kumar and S Kumar (2011), Total factor productivity and contribution of research to agricultural growth in India, Policy Paper 25, New Delhi: NCAP.

Dar, W D and R M Jaunillo (2000), Institutionalization of priority setting, monitoring and evaluation: the PCARRD experience. In *Priority Setting, Monitoring and Evaluation in Agricultural Research: Selected Readings*, Suresh Pal and P K Joshi (eds). New Delhi: National Centre for Agricultural Economics and Policy Research.

Davis, J S, P Oram and J G Ryan (1987), *Assessment of agricultural research priorities: an international perspective*. Monograph No. 4. Canberra: Australian Centre for International Agricultural Research.

Evenson, R E, C E Pray and M W Rosegrant (1999), *Agricultural research and productivity growth in India*. Research Report No. 109. Washington, DC: International Food Policy Research Institute.

Ghosh, S P (1991), Agro-climatic zone specific research: Indian perspective under NARP. New Delhi: Indian Council of Agricultural Research.

Gijsbers, G, W Janssen, HH Odame and G Meijerink (2001), *Planning agricultural research: a sourcebook*, Wallingford (UK): CABI Publishing.

Gill, G J and D Carney (2000), *Competitive agricultural technology funds in developing countries*, London: Overseas Development Institute.

Gryseels, G, C T de Wit, A McCalla, J Monyo, A Kassam, E Craswell and M Collinson (1992), Setting agricultural research priorities for the CGIAR. *Agricultural Systems,* 40: 59-103.

ICAR (2000), *Vision 2020: ICAR Perspective Plan*, New Delhi.

ICAR (2014) NAIP Monitoring and evaluation report, New Delhi : ICAR.

ICRISAT (1999), *Typology construction and economic policy analysis for sustainable rainfed agriculture.* Patancheru: International Crops Research Institute for the Semi-Arid Tropics and Indian Council of Agricultural Research.

ICAR (1988), Report on the ICAR Review Committee, New Delhi: ICAR.

Kampen, J (1997), Financing agricultural research: lessons learned with agricultural research funds, Washington, DC: World Bank (Mimeo).

Kelley, T G, J G Ryan and B K Patel (1995), Applied participatory priority setting in international agricultural research: making trade-offs transparent and explicit. *Agricultural Systems,* 49: 177-216.

Mansfield, Edwin (1995), Academic research underlying industrial innovations: sources, characteristics, and financing. *Review of Economics and Statistics,* 77: 55-65.

Mruthyunjaya (2014), NAIP: pushing the frontiers of transformation, *Indian Farming,* 64(2): 8-12.

Mruthyunjaya, Suresh Pal and R Saxena (2003), Agricultural research priorities for south Asia, Policy Paper 20, New Delhi: NCAP.

Mutangadura, G and G W Norton (1999), Agricultural research priority setting under multiple objectives: an example from Zimbabwe. *Agricultural Economics,* 20: 277-286.

Nagy, J G and M A Quddus (1998), National agricultural commodity research priorities for Pakistan. *Agricultural Economics*, 19: 327-340.

Nickel, J. (1997), Institutional aspects related to agricultural research in Pakistan. Washington DC: World Bank, South Asia Regional Office.

Norton, G W and J S Davis (1981), Evaluating returns to agricultural research: a review. *American Journal of Agricultural Economics,* 63(4): 685-699.

Pal, Suresh, Robert Tripp and A. Janaiah (2000), Public-private interface and information flow in the rice seed system of Andhra Pradesh (India). Policy Paper 12. New Delhi: National Centre for Agricultural Economics and Policy Research.

Planning Commission (1989), *Agro-climatic regional planning: an overview*. New Delhi: Planning Commission.

Rajalahti, R, W Janssen, K Heijden and E Pehu (2006), *Scenario planning to guide long-term investments in agricultural science and technology: theory and practice from a case study on India*: Washington, DC: World Bank.

Renkow, M and D Byerlee (2010), The impacts of CGIAR research: a review of recent evidence, *Food Policy*, 35: 391-402.

Saxena, R, S Pal and PK Joshi (2000), Delineation and Characterization of Agro-ecoregions, PME Note 6, New Delhi: NCAP.

Sehgal, J L, D K Mandal, C Mandal and V Vadivelu (1992), *Agro-ecological regions of India*. Nagpur: National Bureau of Soil Survey and Land Use Planning.

Umali, D.L. (1992), Public and private sector roles in agricultural research: theory and experience. Washington, DC: World Bank, Discussion paper 176.

Williamson, O.E. (2000), *The economic institutions of capitalism-firms, markets, relational contracting*. New York: The Free Press.

Wood, S and P G Pardey (1998), Agro-ecological aspects of evaluating agricultural R&D. *Agricultural Systems,* 57(1): 13-41.

World Bank (2012), *Agricultural innovation systems: an investment source book*, Washington, DC: World Bank.

World Bank (2014), *Accelerating agricultural Productivity in India,* Washington, DC: World Bank

Chapter 5

INDIAN SEED INDUSTRY IN THE ERA OF INTELLECTUAL PROPERTY RIGHTS

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INTRODUCTION

The Indian seed industry has undergone rapid transformation from a public seed system to a diversified industry involving a number of public, private and other small local seed agencies. The process began with the introduction of high yielding varieties (HYVs) during the green revolution period. Dissemination of these HYVs required concerted efforts for seed production and distribution. For this purpose, a number of public seed corporations were established by the Union and State Governments. These institutions grew over a period of time and worked closely with the public research institutions for source seed and technical expertise on the one hand, and with farmers for seed multiplication, on the other. The model worked very well and helped in spreading HYVs rapidly, especially in the irrigated regions.

Indian agriculture witnessed considerable changes in rainfed areas as well, which increased the demand for quality seed. This paved the way for entry of other players in the industry. Most of these players had some experience in seed production which made the transition rather easy. The diversification process got further impetus with the introduction of hybrids in crops like maize, sorghum, pearl millet and cotton. At this stage, organized private seed companies commenced their operations and their presence grew over time (Morris *et al,* 1998). The government regulations mostly focused on varietal testing, seed production and quality control. The system worked well and enhanced seed replacement rate for most of the crops, especially those sown with hybrids. Of course, necessary policy reforms like access to foreign material, open access to public material and entry of private firms were introduced time to time which also facilitated the transition process (Pray *et al,* 2001).

There were further developments relating to entry of multinational firms, particularly during the period of economic reforms, and import of planting material. More recently, there have been new regulations relating to intellectual property rights in the field of plant breeding, commercialization of transgenic seeds and increasing presence of multinational companies in the field of seed and biotechnology research. However, the implications of these regulatory reforms on the Indian seed industry are not well understood, giving rise to questions related to the changing roles of public and private sectors, impact of proprietary material on seed prices and market structure and access of farmers to improved material. This chapter addresses some of these questions.

The chapter begins with the evolution of Indian seed industry, followed by trends in varietal development for major crops. Structure of seed markets and seed replacement rates for major crops are discussed subsequently. The chapter ends with a discussion on demand for plant variety protection and implications of other regulatory reforms for development of Indian seed industry.

EVOLUTION AND CONTEMPORARY STRUCTURE

Historical Evolution—Key Milestones

After Independence, major steps for development and dissemination of quality seeds were taken by the state line departments as part of agricultural development programs. However, one of the these important milestones in development of organized seed system has been the establishment of the National Seeds Corporation (NSC) in 1963. In order to further streamline the seed system and ensure quality of seed, especially of HYVs, the Government enacted the Seed Act in 1966 which was implemented in 1969. During the same period, the Tarai Development Corporation (TDC) was also established with funding support of the World Bank. The State Farm Corporation of India (SFCI) was established in 1969 which also had seed business as one of its activities. These institutions marked the beginning of organized seed production and distribution in the country.

Subsequently the need to increase capacity of seed production was felt by the Seed Review Team (1968) and since organized seed production was done through a seed chain involving breeder, foundation and certified seeds, it became necessary to strengthen the capacity for supply of these seeds. The National Seed Project (1975-85) with funding support from the World Bank addressed this need and a large number of State Seeds Corporations (SSCs) (now 19) were established in different states. At the same time, State Seed Certification Agencies, now 22 in number, and a network of State Seed Testing Laboratories were created to ensure quality of seed to farmers. The capacity for breeder seed production in the institutes of Indian Council of Agricultural Research (ICAR) and State Agricultural Universities (SAUs) was also expanded. All these institutions played a vital role in developing public seed system and popularizing the concept of certified seeds, adoption of seed standards and setting procedures for quality seed production in the country.

The public system has done well and many spillovers for seed production in private sector have started coming up. These were started by former employees in public research or seed production, or progressive farmers producing seed for public seed corporations. Also, the need for introducing foreign seed material in the country, particularly for horticultural crops, was being felt. Therefore, as a progressive step, the New Policy for Seed Development was initiated in 1988, which allowed imports of seed and planting material available anywhere in the world, subject to the availability of parental lines of these materials. Also, parental lines of public bred hybrids were made available to private companies, which accelerated the pace of development of private seed sector in the country. The National Seed Association estimate indicates total seed business of about 35 million quintals, worth US$ 30 billion, with nearly two-thirds of this business in private sector.

With the increasing participation of private sector, including multinational companies, the need for protection of proprietary material was catching up and therefore the Government enacted the Protection of Plant Varieties and Farmer' Rights Act in 2001. This was followed by enactment of the Biological Diversity Act (2002) and amendments in the Patent Act (1970) to allow product and process patents in all fields of science. The Indian intellectual property rights (IPRs) system balances the rights of researchers, rural community and farmers. It protects farmers' rights to save, use, exchange and sell farm-saved, unbranded seed. In particular, the rights of rural community and farmers on plant genetic resources and benefit sharing in their commercialization are recognized.

With these developments, the Indian seed sector has made impressive progress in terms of supply of quality seed, but it remained uneven across regions, crops, and also across different sections of farming community. To address these gaps and to meet the demand of diverse agro-climatic conditions, National Seed Policy came into existence in 2002 with major thrust on varietal development, enhancement of seed replacement rate, production of breeder seed and fiscal incentives to domestic seed industry. The country also witnessed the most dramatic change during this period, with introduction of Bt cotton which is now grown on 90 per cent of cotton area and has shown 39% increase in the productivity. In order to harmonize the provisions of the Seed Act with genetically-modified (GM) crops and PPV, the New Seed Bill was introduced in the Parliament in 2004, which is still under consideration. Another important development was signing of an agreement with the South Asian Association for Regional Cooperation (SAARC) in November 2011 for establishing the Regional Seed Bank to strengthen regional seed security and foster inter-country partnerships.

Contemporary Structure

The Indian seed industry primarily comprises of public and private seed companies which have grown over time. In the public system, there is NSC, with a national presence, for production and distribution of seed and it is involved in seed business of field and horticultural crops, which is mostly based on public bred varieties. At the state level, there are SSCs, mostly catering to the seed needs of respective states. However, in terms of size of the operation not all of them are doing equally well; some SSCs are small in business, mainly because of increase in private seed companies. In addition, there are some cooperatives and para-statal agencies involved in seed business which vary considerably in terms of size of their business. For examples, Indian Farmers Fertilizers Cooperative (IFFCO), Krishak Bharati Cooperative (KRIBHCO) and SFCI have a national presence, while others have operations in a state or few districts. All these cooperatives mostly deal with open pollinated varieties (OPVs) and do not have plant breeding program.

There are few crops where formal seed agencies are rather limited. For example, in case of potato, seed production and distribution is done by horticulture department of the state governments. Only recently, some private companies have started seed production using tissue culture method. These companies produce mini-tubers with tissue culture and later multiply them on farmers' fields. Similarly, for groundnut in Andhra Pradesh, federation of oilseed growers is involved in seed business but seed chain is rather weak.

With the presence of private seed companies increasing over time, there is a high degree of diversity in terms of crops covered, size of seed business, and intensity of R&D efforts. These companies supply a significant proportion of seed and all signs indicate their growing presence. However, these companies are mostly confined to hybrid seed or crops like paddy which have a strong possibility of hybrid in future.

An important part of the Indian seed industry is quality assurance through seed certification. For this purpose, State Seed Certification Agencies were established in all the states. This is mostly done at the seed production and processing level. To complement this, there are seed testing labs to assess seed quality at the point-of- sale seed inspection. Seed certification may not support business of seed agencies but it assures that they have taken due care in seed production; some farmers prefer certified seed in case varietal selection is difficult in the market. Another important advantage is that certified seed finds place in certain government programs, thereby benefitting the seed agency.

All the public seed agencies and most of the private seed companies use public material for seed production. Therefore, these agencies depend upon public plant breeding programs for production of source or breeder seed. The Department of Agriculture, Cooperation and Farmers Welfare (DAC&FW) collects indents for breeder seed from different seed agencies which are allotted to breeding programs for production of breeder seed of their varieties. The breeder seed is supplied at a nominal cost for most of the varieties. But now, some public institutions are entering into agreement with seed agencies for licensing and charging royalty. The breeder seed is multiplied for foundation seed, which is used for production of certified or commercial seed. The seed multiplication is done by contract grower farmers who are paid higher than the grain prices. There are some regions for seed production in off-season, mostly in southern India, so that seed can be supplied immediately for the main season in other parts of the country.

Different kinds of contractual arrangements are emerging in seed production. Most of the companies directly work with contract farmers for seed multiplication. They work through organizers who have direct contact with farmers and are responsible for helping farm operations along with technical staff of the company. Some companies license their material to other seed companies for commercialization, while others have formed joint ventures with the national companies, e.g. Mahyco-Monsanto for Bt cotton seed.

Marketing of seed is done through private wholesale and retail agents. Seed companies have direct contact with retailers and seed is supplied in adequate quantity as assessed by the dealer. There are also arrangements for return of seed which is not sold. Most of the promotional activities like farm demonstrations and publicity material are done by the seed company. Some public seed agencies and cooperatives sell seed through sale counters on their premises.

Another important component of Indian seed industry is seed production by ICAR institutes, SAUs and Krishi Vigyan Kendras (KVKs). Although the quantity is a small proportion of the total commercial seed produced in the country, this system fills a critical gap in terms of dissemination of new varieties, making available source seed and providing feedback on varietal performance to plant breeding programs. This is supplemented with field demonstration of new varieties which is helpful in their popularization. The continuation of these critical activities in the era of commercialization and IPRs will be a challenge for the public system.

Typologies of Private Seed Companies

The presence of private seed companies has increased substantially during the last two decades and all signs point to the increasing dominance of private sector, including in plant breeding. It is estimated that private research and development (R&D) expenditure in India was 88.6 million 2005 US dollar in 2009, most of which grew during the last one decade, and now the private sector employed about 1500 scientific and technical personnel. The last decade also witnessed participation of multinational companies, both in plant breeding and biotechnology. The share of the firms with foreign ownership was 40 percent, mostly in hybrid and biotech seeds and share of proprietary hybrids in the total hybrid seed sale was three-fourths or more (Pray and Nagarajan, 2010). Multinational seed companies mostly use their breeding material, except in cotton where Bt gene was incorporated in the Indian material. It is likely that proprietary hybrids of the Indian companies are based on public material but private sector has successfully incorporated these lines into hybrids and distributed them to farmers. This is a significant contribution and successful example of public-private partnership in the Indian seed industry.

The Indian seed companies can be classified into three groups. The first group comprises of large seed companies usually dealing with plant breeding and seed production of multiple crops. These companies have national presence and mostly deal with hybrid seed. The second group of companies have a somewhat regional presence, comprising few states and deal with hybrid and OPV seeds of regionally important crops. Some of these companies have their own breeding programs but they also depend upon the public system for source seed. The third group of companies are small in size and large in number and cater to local seed needs. Most of them deal with OPV and hybrid seeds of public material and a few multiply seed of proprietary hybrids accessed through licensing. Rice is the only crop which has OPV seed produced by private companies, including the multinationals.

Unlike many other countries, Indian companies could compete with the multinational companies and therefore access of farmers to quality seed increased at a reasonable price. This is primarily because Indian material is still popular in field crops and the national companies can multiply and distribute seed of this material. It is only in temperate vegetable crops that a significant proportion of foreign material is being used. It is difficult to estimate the market share of different groups of companies because of lack of data and changing status of the companies. But it can be said that multinational and large Indian companies have dominated the seed market. Also, there has been some consolidation of the Indian companies and a few have been brought under single management, but they continue to maintain different brand names. In spite of acquisitions and mergers, top four firms have cornered 36 per cent of total seed sale. One needs to watch whether this concentration will increase in future when IPRs are effectively enforced by the owners

VARIETAL DEVELOPMENT AND SEED MARKET

Priorities and Trend in Variety Development

As discussed above, plant breeding began with the establishment of agricultural research organizations and has traditionally been in the public domain.. The breeding programs were further strengthened with the establishment of All Indian Coordinated Crop Improvement Projects (AICRPs), beginning with maize in 1957 and later for all major crops. These AICRPs also paved the way for systematic evaluation and release of plant varieties. The main focus of breeding programs has been development of OPVs, but later efforts led to development of hybrids in crops like pearl millet, maize, sorghum, vegetables etc. Another notable aspect of plant breeding has been increase in emphasis for building tolerance to various abiotic and biotic stresses. Notable examples with large scale success in the adoption are, rust resistance in wheat, salinity tolerance in rice, wheat and mustard, submergence tolerance in rice, and bacterial leaf blight tolerance in rice, to indicate a few. The share of varieties for marginal production environments has also increased over time (Pandey and Pal, 2007). Of late, focus has been on quality traits and significant success has been achieved in vegetables, rice and fruits. Incorporation of these multiple traits is being attempted with the advancement in molecular biology.

Entry of private sector in plant breeding has complemented the public efforts and there is wider use of public material for breeding purposes in all crops, notable examples being maize, cotton, sorghum and vegetables. However, development of hybrids has been the main priority of private plant breeding for obvious reasons—increased seed sales and use of biological protection for proprietary hybrids and parental lines. Rice and wheat are two new crops where efforts to develop hybrids have been intensified and some success has been achieved in rice, both in public and private sectors.

Increase in plant breeding intensity in public and private sectors is reflected in the number of varieties released over time. Here it may be important to mention that not all proprietary material gets through official variety release process and their seed is sold as truthfully-labelled seed (TLS). A perusal of Table 1 reveals a significant increase in release of varieties of major crops during the recent decade (2000-2010) as compared to the previous two decades (1980-2000). Major cereal crops (rice, wheat and maize) recorded a higher growth in variety development in the recent decade, whereas a sluggish growth was observed in pearl millet and a declining trend in sorghum. These two crops have received greater attention in private sector. The varietal growth in pulses was also higher during the recent decade as compared to the previous two decades, except for red gram and black gram. The number of varieties released for major pulse crops such as chickpea, green gram and red gram, slowed down during 1990s, which was however corrected in the last decade (2000s).

Table 1 : Crop-wise decadal growth in number of notified varieties (1980-2010)

Crops	1981-1990	1991-2000	2001-2010
Cereals			
Paddy	206	197	282
Wheat	75	68	103
Maize	46	61	111
Sorghum	61	50	46
Pearl millet	41	42	48
Pulses			
Chick pea	42	37	62
Green gram	37	32	44
Red gram	38	27	30
Black gram	18	27	26
Field pea	15	17	25
lentil	10	13	19
Oilseeds			
Ground nut	42	39	60
Mustard	9	6	53
Soybean	26	24	32
Sesame	24	15	26
Sunflower	10	20	28
Linseed	19	7	20
Castor	11	14	12
Vegetables			
Bhendi	6	7	13
Brinjal	20	25	22
Cauliflower	3	6	9
Onion	7	4	10
Potato	3	8	13
Tomato	15	13	28
Cotton	76	81	85

Source: Compiled by authors from www.seednet.gov.in.Seednet (2012).

The decadal growth of notified varieties in oilseed sector was higher in the last decade than the previous two decades. Mustard crop recorded an impressive growth, more than five-time increase in the number of releases in the recent decade as compared to the previous decades. This was mainly because of intensification of plant breeding efforts under the National Oilseed Mission since the 1980s. Almost all crops, except castor have registered a higher growth in the recent decade. A gradual and steady trend was also found in the case of vegetables, whereas the increase was moderate in case of cotton. Actual number of varieties in these crops could be much higher as several proprietary materials are not notified under the Seed Act.

Overall, a higher growth was recorded in the number of varieties released for majority of the crops, which could be attributed to strengthening of plant breeding capacity through coordinated research programmes of ICAR and improvement in breeding methodology. Undoubtedly, plant breeding in private sector has intensified overtime but this was more so for hybrids. However, it would be pre-mature to attribute this enhanced rate of varietal development to plant variety protection as some of the crops have not received private attention for plant breeding.

Source and Commercial Seed Production

Breeder seed is used as source seed for production of next stage foundation seed, which in turn, is used for production of commercial seed (certified or truthfully labelled seed) for farmers. Breeder seed is produced by different ICAR institutes and SAUs for their respective varieties. The official data showed that breeder seed production has consistently increased over the years for all crops, except cotton. In particular, there is impressive increase in breeder seed production of cereals and oilseeds after 2003 (Figure 1). Surprisingly, breeder seed production of cotton declined after 2003,

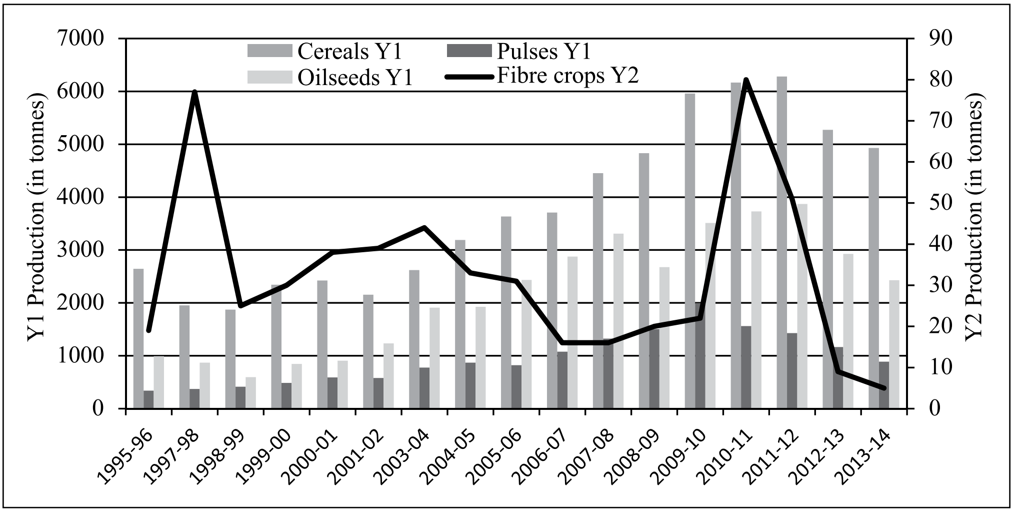

Fig. 1 : Trends in breeder seed production: All India (in tonnes)

primarily due to use of hybrids which were largely produced by private sector. This trend was further reinforced after the introduction of *Bt* cotton in the country.

The production of commercial seeds has also shown a sharp uptrend (Figure 2). The increase is nearly three-fold during 2002 to 2011-12 for all crops, except cotton, where commercial seed production has been even higher since the introduction of hybrids. However, the growth in seed production of pulses is rather weak as these crops have not received attention of private sector because of high volume and risk. One of the reasons for increase in seed production is the launch of ICAR seed project in 2005-06. The project had a financial outlay of Rs. 198.89 crores, covering 86 centres throughout the country, which increased the capacity for breeder and quality seed production in ICAR-SAU system (Prasad *et al.*, 2011).

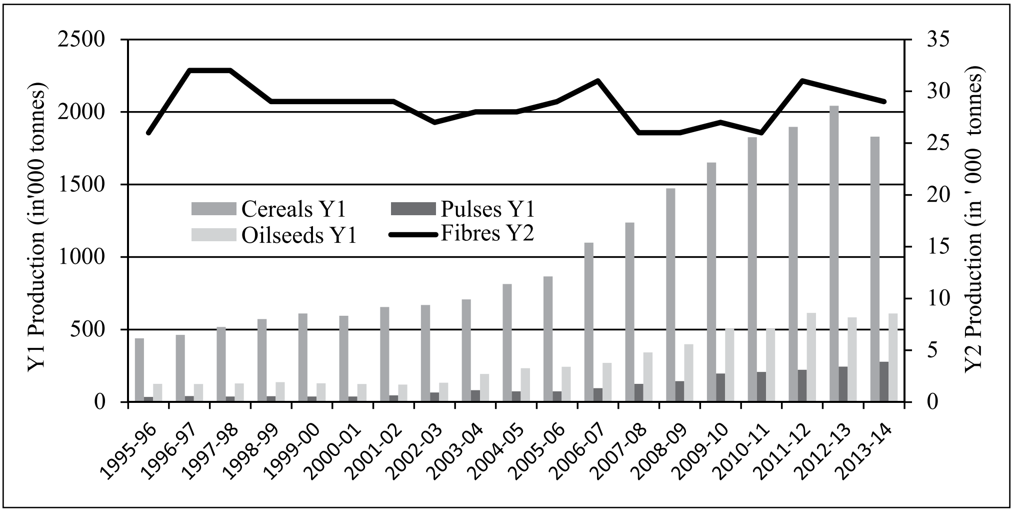

Fig. 2 : Trend in quality seed production: All India

A significant proportion of commercial seed production was done through public-private partnerships (PPPs). The data on PPPs related to commercialisation of new varieties or new seed technologies were compiled from the Association of Seed Agencies (NSAI, 2011). The evidence indicates that a noticeable change occurred after 2006, when the number of PPPs in a year increased to 30 in 2006 from merely five until 2005, and the highest (42) was in 2011. A total of 174 Memoranda of Agreements (MoAs) were signed between the public institutes and private seed companies during 2003-2011, which involved 75 private companies, 28 public institutes (ICAR and SAUs) and 4 centres of the Consultative Group on International Agricultural Research (CGIAR). The analysis of crop-wise PPPs concentration indicates that at the top of PPPs list were cereals (105), followed by vegetables (50), while pulses and oilseeds had a very small number of PPPs. Thus, partnerships were more common for crops having a large seed market, and this was more so for varieties with high market potential as in case of wheat where a single popular variety attracted a number of private seed companies.

Institutional and Variety Shares in Commercial Seed

The data on commercial seed sales clearly reveal that the Indian seed market is dominated by private seed companies. This is true for major crops, only exception being groundnut where the share of public sector is higher than the private sector (Table 2). The private sector's share in sale of hybrid seed was as high as 90 per cent for most of the states. Further, in cereals like paddy, wheat and sorghum, a large share of seed sales (more than 50 per cent) was with the private sector. On the other hand, the role of private sector was comparatively small in low-value and high-volume seed crops like groundnut and redgram. As private seed companies are not keen in seed business of these crops, public sector plays an important role. Another important feature of private sector participation in seed production is that it has a nation-wide presence, and states like Uttar Pradesh, Punjab and Rajasthan use large amount of privately produced seed. Most of private seed is produced in the southern states and supplied all over the country.

Table 2 : Share of the public and private sector in seed sales and variety concentration for major crops in India (2012-13)

States	Quality seeds (in'000 Qtls)	Public share (%)	Private share (%)	Share of top four varieties
Paddy				
Andhra Pradesh	1378.8	34.5	65.5	82.3
West Bengal	981.3	42.1	57.9	53.0
Uttar Pradesh	809.9	19.0	81.0	60.4
Tamil Nadu	620.6	26.3	73.7	62.1
Punjab	300.7	19.1	80.9	32.5
Haryana	45.6	32.9	67.1	57.2
Wheat				
Uttar Pradesh	4039.6	48.3	51.7	39.5
Haryana	1417.6	26.5	73.5	56.0
Punjab	1209.1	13.5	85.1	32.5
Rajasthan	990.0	54.7	45.3	63.4
Maize				
Karnataka	193.7	0.2	99.8	99.9
Andhra Pradesh	122.4	31.6	68.4	97.9

cont...

Table 2 contd...

Maharashtra	97.2	2.6	97.4	100.0
Rajasthan	87.9	50.9	49.1	48.4
Sorghum				
Maharashtra	101.8	32.0	68.0	90.3
Karnataka	40.7	33.5	66.5	96.4
Andhra Pradesh	22.4	9.7	90.3	92.1
Rajasthan	17.6	88.8	11.2	97.8
Red gram				
Maharashtra	44.1	47.9	52.1	92.4
Andhra Pradesh	34.7	57.0	43.0	97.5
Karnataka	27.2	37.2	62.8	73.5
Uttar Pradesh	16.7	28.1	71.9	100.0
Groundnut				
Andhra Pradesh	1301.3	58.5	41.5	98.9
Karnataka	237.3	72.2	27.8	97.0
Tamil Nadu	64.5	83.6	16.4	38.6
Rajasthan	35.7	8.3	91.7	41.3
Cotton				
Maharashtra	80.8	0.3	99.7	100.0
Punjab	15.3	1.3	98.7	98.4
Rajasthan	15.2	1.7	98.3	47.2
Karnataka	8.6	0.0	100.0	9.6
Tamil Nadu	5.5	12.8	87.2	60.5

Source: Compiled by authors from www.seednet.gov.in .Seednet (2012).

As regards variety concentration, i.e. share of top varieties in seed sales, there are similar trends, irrespective of nature of crop. The share of top four varieties is more than 90 per cent for maize, sorghum and cotton in most of the states. The same holds true for redgram and groundnut in some states. The concentration ratio ranges from 32 to 82 per cent for paddy and 40 to 63 per cent for wheat. This implies that there is some degree of varietal concentration in all crops whether there is participation of private sector or not. Another important implication of high variety concentration ratio is that few varieties dominate the seed market in spite of the fact that a number of varieties are released every year. This is partly because it takes time to popularize a new variety and partly due to the fact that not all varieties have acceptance of farmers. In fact, in harsh production environment, variety replacement rate is low, as indicated by dominance of an old variety of groundnut (TMV 2) in drought prone areas of Andhra Pradesh and Karnataka because of its better fodder and oilseed yield under drought conditions.

Seed-to-grain Price Ratio

One of the implications of dominance of of private sector and variety concentration is that it may lead to an increase in seed prices. It can be seen from Table 3 that seed-to-grain price ratio has increased from 2002-03 to 2012-13 for maize and cotton, whereas for paddy it has declined, for both hybrids and OPVs. It implies that over the period seed price has increased more than the grain price, particularly for the crops which are dominated by private sector. The high price ratios may be attributed partly to recovery of R&D cost by private sector, risk associated with highly unstable seed demand and the fact that not all seeds are sold every year. However , for crop like paddy, where mostly public varieties are in seed production, a marginal decline is seen in the price ratio over time because there is no R&D cost. Also, entry of more seed agencies has increased competition, thereby restricting seed prices. It is to be noted that the price ratio for hybrids is significantly higher (six times) than that for OPVs because of high seed production cost of hybrids. Byerlee *et al* (1994) found that during the emergence of seed industry, the price ratio was low, it increased slowly along with growth of the industry and settled within the range of 25 to 30 for an established seed industry. The price ratios are thus moderate in India, except for Bt cotton where a significant proportion of seed cost goes as fee and royalty of Bt technology.

Table 3 : Seed-to-grain price ratio for major crops

Crop	2002-03		2012-13	
	Hybrid	OPV	Hybrid	OPV
Paddy	22.6	3.0	18.5	2.9
Maize	9.0	3.1	16.3	5.9
Cotton	37.4	7.2	48.7	7.9

Notes: The values for 2002-03 have been taken from the Pal *et al.* (2007) study. For cotton, the ratio is computed using lint prices.

SEED REPLACEMENT RATE AND CROP PRODUCTIVITY GROWTH

Seed Replacement Rate

The Government of India while preparing the National Seed Plan has specified the desirable seed replacement rate (SRR) to achieve higher productivity of crops based on pollination type, viz. 25 per cent for self-pollinated crops, 35 per cent for OPVs of cross pollinated crops and 100 per cent for hybrids (GoI, 2005). The trend in SRR shows that during early 2000s, SRR was in the range of 10-20 per cent for majority of crops, except pearl millet and rapeseed and mustard, and it increased to 20-40 per cent in 2011-12 (Table 4). The increase in SRR was higher in the last five years (2006-12).

The SRR is 79 per cent for rapeseed and mustard, 60 per cent for pearl millet and 57 per cent for maize. It is much higher than the desirable rate in paddy (40 percent) and wheat (33 per cent), but is quite low for pulses and groundnut. The hybrid dominated crops like pearl millet, cotton and maize recorded higher SRR because hybrid seed is replaced every year. Therefore, in the states where hybrids are popular, SRR is much higher. Paddy, although a self-pollinated crop, has a high SRR because seed requirement for per unit area is less and cost of seed production is comparatively low. Therefore, there is not much expenditure on seed but use of fresh seed gives yield advantage to farmers. Therefore, one can say that diversification of the seed industry has increased the availability of quality seed to farmers. Of course, there have been concentrated efforts by the state line departments to promote new varieties of seed under various schemes like Rashtriya Krishi Vikas Yojana and National Food Security Mission.

Table 4 : Seed replacement rate for major crops in India

Crop	2001-02	2006-07	2011-12
Wheat	13	22	33
Paddy	19	22	40
Maize	21	44	57
Sorghum	18	19	24
Pear millet	46	55	60
Bengal gram	4	9	19
Red gram	9	12	22
Groundnut	5	10	23
Rapeseed and Mustard	38	61	79
Soybean	12	28	53
Cotton	21	20	33/100*

Note: *indicates SRR for hybrids.

Seed Use by Size of Holdings

The data on seed use by different size of holdings were collected from input survey published by the Ministry of Agriculture and Farmers Welfare (MoA, 2013). A perusal of Table 5 clearly indicates that there was a wide variation in the percentage of farmers using certified seeds across the states, 40 per cent in Madhya Pradesh to 93 per cent in Haryana, for all the size groups in 2011-12. More importantly, there was no variation in use of certified seed across the size of holdings, and proportion of small farmers using certified seed was also quite high. For example, more than 47 per cent of small and marginal farmers used certified seed in the states of Gujarat, Haryana and AP. This is because increased availability of quality seed and low seed cost in comparison yield benefits in the use of quality seed. These trends are likely to strengthen further in other states and crops where SRR is comparatively low.

Table 5 : Percentage share of households used certified seeds by land size, 2006-07

States / Land size	Marginal	Small	Semi-Medium	Medium	Large	All Groups
2006-07						
Gujarat	75.1	71.4	73.3	74.5	74.3	73.5
Haryana	74.5	85.4	87.7	88.8	85.2	81.0
Karnataka	55.8	65.1	66.8	66.5	66.9	61.0
Andhra Pradesh	35.3	39.8	43.1	47.4	47.6	37.7
Odisha	33.1	38.6	42.4	47.3	47.3	36.0
Madhya Pradesh	20.4	24.9	26.2	27.2	26.1	23.6
2011-12						
Gujarat	60.5	61.4	61.4	59.6	57.3	60.8
Haryana	89.0	94.3	96.9	97.1	97.1	92.6
Karnataka	39.6	53.2	57.0	61.9	62.7	47.8
Andhra Pradesh	47.7	54.6	57.9	59.9	57.9	50.7
Odisha	29.4	39.2	46.8	55.3	65.4	32.9
Madhya Pradesh	39.3	41.6	41.5	42.1	39.6	40.6

Source: Authors compilation from inputsurvey.dacnet.nic.in (MoA, 2013).

It is rather difficult to assess the impact of SRR on crop productivity as it is influenced by multiple factors. Nevertheless some broad relationship can be seen, with the crops and states witnessing high SRR and productivity growth. As seen from Table 6, there is impressive increase in the yields of cotton and maize—cotton yield has doubled during the last decade and a similar growth is witnessed for maize during the last two decades. The spread of hybrids in new areas of maize, Bt cotton and high seed replacement rate have contributed to this growth. Paddy and wheat are other important crops showing doubling of SRR during the last decade which translated into higher yield rates for these crops. The evidence also indicates that small farmers use commercial seed as well and realize a yield level which is comparable to or even higher than large farmers. Thus, Indian farmers do realize the importance of quality seed and are willing to pay a price for this. They are also gaining an understanding of seed market as they buy seed quite frequently and any attempt to charge a high price without adequate benefit could be counterproductive for the seed companies.

Table 6 : Area, production and yield of major crops in India

(Area in million hectare, production in million tonne, yield in kg/ha)

Year/crop	Rice			Wheat			Maize		
	Area	Production	Yield	Area	Production	Yield	Area	Production	Yield
1951-52	29.83	21.3	714	9.47	6.18	653	3.31	2.08	627
1961-62	34.69	35.66	1028	13.57	12.07	890	4.51	4.31	957
1971-72	37.76	43.07	1141	19.14	26.41	1380	5.67	5.1	900
1981-82	40.71	53.25	1308	22.14	37.45	1691	5.94	6.9	1162
1991-92	42.65	74.68	1751	23.26	55.69	2394	5.86	8.06	1376
2001-02	44.9	93.34	2079	26.34	72.77	2762	6.58	13.16	2000
2011-12	43.94	104.32	2372	29.9	93.9	3140	8.71	21.57	2476
2012-13	42.75	105.24	2462	30.00	93.51	3117	8.67	22.26	2566
2013-14	43.95	106.54	2424	31.19	95.91	3075	9.43	24.35	2583
	Red gram			Bengal gram			Food grains		
1951-52	2.45	1.83	748	6.83	3.39	496	96.96	51.99	536
1961-62	2.45	1.37	559	9.57	5.79	605	117.23	82.71	706
1971-72	2.35	1.68	718	7.91	5.08	642	122.62	105.17	858
1981-82	3	2.24	745	7.87	4.64	590	129.14	133.3	1032
1991-92	3.63	2.13	588	5.58	4.12	739	121.87	168.38	1382
2001-02	3.33	2.26	679	6.42	5.47	853	122.78	212.85	1734
2011-12	4.04	2.65	656	8.32	7.58	912	125.03	257.44	2059
2012-13	3.89	3.02	776	8.52	8.83	1036	120.78	257.13	2129
2013-14	3.88	3.29	849	10.22	9.88	967	126.04	264.77	2101
	Groundnut			Rapeseed & Mustard			Cotton		
1961-62	6.89	4.99	725	3.17	1.35	425	7.98	4.85	103
1971-72	7.51	6.18	823	3.61	1.43	396	7.8	6.95	151
1981-82	7.43	7.22	972	4.4	2.38	541	8.06	7.88	166
1991-92	8.67	7.09	818	6.55	5.87	895	7.66	9.71	216
2001-02	6.24	7.03	1127	5.07	5.08	1002	9.13	9.99	186
2011-12	5.31	6.93	1305	5.92	6.78	1145	12.18	35.2	491
2012-13	4.72	4.70	995	6.36	8.03	1262	11.98	34.22	486
2013-14	5.53	9.67	1750	6.70	7.96	1188	11.69	36.59	532

Source: Agricultural Statistics at a Glance, Directorate of Economics and Statistics, MoA, GoI (2012).

SEED REGULATORY REFORMS

Access to Genetic Material

India followed the policy of open access to public material and plant genetic resources, and the procedures were laid out for accessing the material, especially by foreign research institutions and individuals. Plant genetic resources (PGR) were routed through the National Bureau of Plant Genetic Resources (NBPGR), an ICAR institution responsible for conservation and exchange of PGR. The policy worked well in terms of strengthening crop improvement and varietal development programs. There was a productive partnership between the national system and CGIAR for plant breeding resulting in development of improved varieties of maize, wheat, rice, pearl millet, sorghum, pulses, groundnut etc.

The situation changed drastically with the passage of the Biological Diversity Act (2002), granting sovereign rights to the nation over its genetic resources. Foreign nationals or organizations now need prior approval of the National Biodiversity Authority to access the Indian material. The same holds true for private companies accessing the Indian material. There is also a provision of prior approval for seeking protection of intellectual property based on the Indian material or associated knowledge. In case of commercialization of the product derived from Indian material or associated knowledge, the Act has the provision of equitable sharing of benefits, and share of the benefits is decided by the National Biodiversity Authority (NBA). The system is in place and a number of cases have been decided for benefit sharing, with part of the benefits transferred to local community wherever they were associated.

NBPGR is still the nodal agency for exchange of PGR. The trends are, however, not very encouraging. The official statistics indicate uneven trends in the exchange of PGR, with an overall declining trend. This is in spite of the fact that India is a signatory to the International Treaty on Plant Genetic Resources, which facilitates exchange of PGR and entails a provision of benefit sharing from commercialization of PGRs. This implies that there is slow down of material exchange even among public plant breeding programs. Private sector however is introducing new material in India and also exporting to other countries after mandatory approval of NBA.

Varietal Evaluation and Release Procedures

Public plant breeding programs have a well-established system of variety evaluation, identification and notification. This system is jointly managed by ICAR and DAC&FW under the Ministry of Agriculture and Farmers Welfare. In the first stage, breeding materials are evaluated by concerned plant breeders for superiority of yield and other economic traits. The material for respective crop, thus identified, is submitted to the

All India Coordinated Crop Improvement Project for evaluation on selected locations, in different zones identified for the crop. These trials are called Initial Yield Evaluation Trials. Entries qualifying for yield, disease and quality are recommended for large scale testing under the Advanced Varietal Trials for economic and agronomic evaluation, usually done for two years. The results of these trials are evaluated by the Varietal Identification Committee of ICAR and the material found superior over the check, i.e. present popular variety, is recommended for release and notification. The areas for cultivation are also recommended, and the variety doing well in a state is recommended by the state seed sub-committee for cultivation in that state. The varieties found suitable for more than one state are released by the Central Sub-committee on Crop Standards, Notification and Release of Varieties Central Variety Release Committee constituted by the Central Seed Committee established under the Seed Act. The varieties are later notified by DAC&FW. The Sub-Committee has representation from ICAR institutes, SAUs, seed agencies, government and farmers. The varieties thus released are taken up for breeder seed production.

There is a provision of quality seed in the Indian Seed Act (1966). A significant proportion of commercial seed by the private sector is supplied as TLS seed which is not certified. This seed includes those varieties as well which are not released under the Seed Act Also, private seed companies were allowed to sell seed of foreign varieties after testing because official release of a variety was not mandatory under the Seed Act. But now the registration of new varieties has been made mandatory in the New Seed Bill under consideration of the Parliament.

Seed Quality Assurance

Statutory provisions were made in the Seed Act for seed quality assurance since there were not many seed agencies when the Act was passed. The standards for seed quality were established and specified in the Act. The assurance of these standards is made through seed certification by an independent agency, the State Seed Certification Agency. The agency is responsible for verification of the standards during production, processing and packaging of seed. Seed germination and grow-out tests are conducted to ensure germination, vigour and genetic purity of seed. There is a mandatory requirement of seed labelling indicating variety, germination percentage, inert material, etc. The seed producer has to issue a white tag indicating conformity to these standards. The seed meeting the prescribed standards are issued the certification tag (blue color tag) by the Certification Agency which is attached to all seed bags. The TLS seed contains only white tag issued by its producer.

There is also a provision of testing of seed quality at the point-of-sale under the Seed Act. The seed inspectors are authorized to draw seed samples from retail shops and send them for testing in the labs established for this purpose. The test should ensure that the seed qualify all the standards (germination, health, vigour etc) spelled out in the Act; the seed lot not meeting these standards is prohibited for sale and suitable action can be initiated against the seed producer. However, evidence indicates that instances of sub-standard seed are very few (Pal *et al,* 2007). There have been some incidence of poor germination which is more due to agronomic reasons and less because of poor seed quality.

Some seed companies see limited role of 'third party' certification as it sometimes delays seed supply due to time taken in the grow-out test. Moreover it does not reduce the liability of the company in case of sub-standard seed. As a result, most of the companies sell TLS seed. There are also voices for making seed certification voluntary and allowing private agencies to certify seed. The New Seed Bill has provisions for self certification and accreditation of private seed certification agencies. In addition, there is another aspect of seed quality assurance which is less exploited in developing countries. The seed companies have a strong interest to ensure seed quality and protect their brand image and therefore certification requirement can be relaxed. Similarly, association of seed companies can also monitor seed industry and any unscrupulous seed company can be identified and legal proceedings can be initiated against it. As the seed industry matures, these provisions for seed quality shall become more effective. This, coupled with legal provision of protecting farmer users through consumer forums can go a long way in ensuring quality of commercial seed. The consumer forums however need to be made more proactive in rural areas to address farmers' grievances.

Regulation and Commercialization of GMOs

The regulations for development of transgenic seed, its evaluation and commercialization began with transgenic cotton and guidelines were developed during 1990s. As discussed in chapter 2, these regulations are governed under the Environmental Protection Act (1986). The responsibility of monitoring transgenic research is with the Department of Biotechnology (DBT) under the Ministry of Science and Technology. DBT has constituted the Review Committee on Genetic Manipulation (RCGM) to supervise the research and development of recombinant DNA products or transgenics. This committee, with representation from various scientific organizations, authorises R&D and overseas confined field trials of research organizations. The Institute Biosafety Committee is responsible for close monitoring of research at respective institutes involving low risk and for verifying the information sent to RCGM.

The trials are conducted for economic benefits against potential risk to human and animal health, and environmental safety. Considering the level of risk, three types of trials are conducted for transgenic products. First is the contained trials done under glass or green house conditions, restricting contamination or crossing to other plants. The high risk green house trials and confined field trials are conducted on experimental farms with the approval of RCGM. These trials are required to maintain prescribed isolation to restrict out-crossing and contamination.

The open field trials are authorized by the RCGM and the Genetic Engineering Approval Committee (GEAC) under the Ministry of Environment and Forest. GEAC has representation from scientific organizations, government departments, civil society organizations etc. The open field trials are required to maintain isolation and test the material for economic superiority. The promising material is recommended for commercialization or environmental release of recombinant DNA products. The socio-economic considerations entails explicit deliberation of potential economic benefits, their distribution among different sections of producers and consumers and impact on non-adopters (for details, see chapter 7). GEAC also authorises large scale imports of GM material for agriculture and industrial use. There is a proposal to establish the Biotechnology Regulatory Authority for better governance and coordination and a bill to this effect is under consideration of the Parliament.

IPRs AND SEED INDUSTRY

Management of IPRs was not important in the Indian seed industry so long as plant varieties and methods of agriculture were not eligible for protection. Private seed companies mostly used biological protection of parental lines provided by hybrid technology. This mechanism is still being used by the companies because of its effectiveness. In addition, the Protection of Plant Varieties and Farmers' Rights Act (2001) provides protection of new and 'extant' plant varieties, including farmers' varieties. There is also a provision of benefit sharing in case protected material is used. Farmers' rights to save, use and exchange seed are protected, along with their right of benefit sharing as saviour of genetic resources. The Protection of Plant Varieties and Farmers' Rights (PPV&FR) Authority is responsible for administration of this Act. As seen subsequently, there is considerable demand both, from the public and private sectors for protection of plant varieties. The public institutions (ICAR and SAUs) have issued guidelines for protection of plant varieties and sharing the benefits with breeders in case of commercialization. Another significant development is amendment of the Patent Act (last in 2005) to allow product and process patents in all fields of science and biotechnology, especially gene and microorganism with human interventions, which is of particular importance to seed industry. This is effective from 2005 and exclusive rights have been granted to Bt gene used for cotton. This gene was earlier protected by the owner through licensing to different seed companies against upfront payment and royalty on seed sale, but now legal protection is available. Apart from Bt cotton, PVP is the most common IPRs with implications for seed industry. This section examines the progress in PVP so far in India.

Trend in PVP Applications

The PPV&FR Authority started functioning in 2006 and initially invited applications for only 12 species of major food crops under the Act. Gradually, it expanded its coverage to other crops and now (2011) a total of 54 species are covered which include cereals (8), pulses (7), oil seeds (11) vegetables (7), spices (5), fibre crops (6), flower crops (6), medicinal plants (4) and other crops (3). The Authority started receiving the applications from 2007 and a total of 8,465 applications were received till 2014 (Table 7); of these, the highest number of applications were filed for extant variety (EV) category followed by farmer variety (FV), and new variety (NV). The number of new varieties nearly doubled from 153 in 2008 to 339 in 2014. There was substantial increase in farmers' varieties from 127 in 2009 to 1962 in 2014.

Table 7 : Trend in PVP applications and titles issued under PPV&FR Act in India

Year	Applications filed by all sectors					Titles issued
	EV	NV	FV	EDV	Total	
2007	355	75	2	0	432	0
2008	389	153	5	0	547	0
2009	385	176	127	0	688	168
2010	96	440	4	1	541	60
2011	257	164	939	1	1361	106
2012	260	137	302	0	699	212
2013	255	350	1001	71	1677	304
2014	197	339	1962	22	2520	833
Total	2194	1834	4342	95	8465	1683
(%)	25.9	21.7	51.3	1.1	100	

Note: EV=extant variety; NV=new variety; FV =Farmers variety; variety includes hybrid also.

Institution and Crop Focus of PVP Applications

The composition of the applications filed by different institutions shows that about 32 per cent of the applications (8465) were filed by private sector and most of these were in the NV category (Table 8). Concentration of the applications for proprietary material was the highest in cotton, followed by vegetables. This implies that applications were more for those crops which have commercial interests like cotton, and the applications of EVs are perhaps with the intention of benefit sharing in case these varieties are used for breeding of proprietary materials. In case of FVs, almost all the applications were filed for cereal crops, particularly rice, and very few applications were for pulses and oilseeds. Interestingly, four applications had been filed under the NV category by the farmers. Overall, private sector accounts for 32 per cent of the total applications, while the public sector owns 16 per cent of the applications and the rest were submitted by farmers.

Table 8 : Share of public and private sector in the total PVP applications during 2007-14

Titles issued	Private sector	Farmer	Public sector	Total
Cereals	845	3638	681	5164
Pulses	32	267	222	521
Oilseeds	151	131	148	430
Vegetables	707	132	89	928
Fibres	973	17	141	1131
Others	9	193	89	291
Total	2717	4378	1370	8465
(%)	32.1	51.7	16.2	100.0

Most of the applications (80 per cent) filed by the public sector were for EVs, mainly for cereals and pulses, and only 11 per cent were for fibre crops. On the contrary, the private sector has a diversified portfolio with more applications for the varieties of fibres, cereals and vegetables. The applications for pulses and oilseeds were rather less. This implies that the private sector focused on all the crops with commercial seed market and paid comparatively less attention to the crops where public R&D is high and mostly OPVs are used by farmers. Similar findings were reported by Hu et al. (2006) for China and Srinivasan (2003) for the UPOV-member countries.

Cost of PVP in Major Countries

The cost for establishing PVP varies across crops and average cost for field crops was worked out for a comparative analysis of important countries. Table 9 shows that cost structure of PVP is not uniform across the countries. Application and variety examination fees were charged in all five selected countries. Certificate fee is charged by USA, Canada and Australia, whereas distinctiveness, uniformity and stability (DUS) testing fee was charged by India and China. The cost of protection was the highest in USA ($5,150), which is nearly six times higher than that in India ($846). Tripp et al. (2007) quoted that there are no easy answers for establishing appropriate fees. The high fees can recover the cost (as intended in developed countries) but it can also discourage applications, especially from public institutes and small firms. In the developing countries, low fees may be justified in early stages of seed market development, but such subsidies can place a burden on the state resources. Although Indian PVP fee structure was the lowest among the countries considered here, there was a mixed reply by different seed companies during the field survey. The fee was considered high by small seed companies (less than Rs. 1000 million annual turnover) and only a few of their best performing varieties were applied for protection. On the other hand, large companies (more than Rs. 5000 million annual turnover) opined that fee was nominal (Venkatesh and Pal, 2013). This is more so when protected varieties realize 11-16 per cent premium on seed prices over the unprotected crops (Table 10), which should be more than enough to recover the cost of protection and earn some profit. The benefits could be much higher for the varieties having large adoption. Thus, economics also favours PVP, but private seed companies would like to see expansion of the infrastructure of the Authority for timely testing of varieties and enforcement of the Act in case there are disputes.

Table 9 : Comparison of cost of PVP in major countries in 2012-13
(Value in US$)

Country	Application	Examination	Certificate issue	Others	Total	Annual fee
USA	518	3864	768	-	5150	-
China	220	810[a]	-	-	1030	182
Canada	250	750	500	1355	2855	300
Australia	300	1400	300	-	2000	300
EU	1125	2300	-	300	3725	375
India	146	700[b]	-	-	846	40[c]

Notes: a includes 250 DUS test fee; b includes 700 DUS test fee: c in addition 0.2 per cent of the sales value of the seeds of the registered variety during the previous year plus 1 per cent of royalty, if any, received during the previous year from the sale proceed of seeds of a registered variety.

Table 10 : Valuation of premium price for protected varieties through hedonic pricing model

Variable	Rice (N=60)		Maize (N=60)		Cotton (N=60)		Pooled (N=180)	
	Coeff.	SE	Coeff.	SE	Coeff.	SE	Coeff.	SE
Response variable: ln price of varieties								
Intercept	2.75	0.06	3.11	0.12	5.64	0.09	3.19***	0.16
X_1 (Yield)	0.002***	0.00	0.002***	0.00	0.001***	0.00	0.001***	0.00
D_1 (Protected variety)	0.11**	0.02	0.16*	0.07	0.13*	0.05	0.39***	0.07
D_2 (Origin)	-0.11*	0.06	-0.12**	0.06	-0.09**	0.05	-0.08	0.07
D_3 (Resistant variety)	0.09	0.01	0.11**	0.06	0.10**	0.04	0.21***	0.07
D_4 (Maize variety)	-	-	-	-	-	-	0.56***	0.12
D_5 (Cotton variety)	-	-	-	-	-	-	3.25***	0.16
D_6 (Long-staple cotton variety)	-	-	-	-	0.09*	0.05	-	0.09
R^2	0.81		0.73		0.87		0.94	

Note: ***, ** and * are significance level at 1%, 5% and 10% respectively.
Source: Adopted from Venkatesh and Pal (2013).

One can therefore conclude from these results that there is demand for PVP from all the sectors and the cost of establishing PVP is not that high. At the same time, private seed companies are using biological and legal protection for their material. The use of protected gene has certainly increased seed prices of cotton; but this has not affected its accessibility to large number of farmers as more and more companies are selling seed containing the gene. As of now, there appears to be no concentration of the protected gene based seeds but one can't rule out the possibility of their dominance in future. Another major concern is access of small seed companies to protected genes which may be beyond their means, and therefore these companies are left with no other option but to look towards public agencies for access to novel genes, or work in consortium mode to survive in the market. Notwithstanding these implications, it is expected that multinational companies shall introduce more transgenic products in India and immediate candidates will be Bt gene in crops like maize and brinjal, and herbicide tolerant maize and soybean. The regulatory process should encourage scientific evaluation of these products and their need-based commercialization.

There may not be other significant impacts of IPRs on the Indian seed industry like diversification of private plant breeding into varietal development and raising the private investment substantially. But it is expected that it shall provide a mechanism for flow of material among private seed companies. Some of private seed companies have already started licensing of their second line varieties (not so close to better performing varieties, or varieties with limited demand) to small companies for commercialization. Similarly, it should help foster partnership between public and private sectors and thereby accelerate flow of material to farmers.

CONCLUSIONS

This chapter has examined recent developments in Indian seed industry in the context of IPRs. The results indicate that there is increase in the rate of variety development and production of commercial seed for most of the crops. The industry has become more diversified and private sector supplies significant proportion of commercial seed. As expected, the share of seed produced by private sector is high for hybrids of cotton, maize, sorghum and pearl millet; paddy is the only crop with OPVs which has attracted larger private sector participation. The last decade has witnessed nearly doubling of seed replacement rate in most of the crops. This success was achieved by keeping the seed prices low, indicating that Indian seed industry has been more diversified and competitive.

There is demand for PVP for most of the crops from both public and private plant breeding programs. The private sector now accounts for 32 per cent of the applications, mainly for cereals, vegetables and fibres, where hybrids are popular. The cost of establishing and maintaining PVP is rather low in India, in comparison to other countries. There is use of protected gene (Bt) in cotton but evidence of concentration in the industry is rather limited because of use of Indian material. The seed-grain price ratio is normal, with few exceptions, like cotton seed, and farmers use commercial seed. However, there is no sign of change in breeding priorities of private sector and it is likely that it will continue to work with hybrids and use a mix of biological and legal measures for protection of proprietary material. There is a need to monitor the industry for concentration and price rise, and any tendency for monopoly should be dealt with appropriate measures by the government.

REFERENCES

Arora, A and S Bansal (2012), Price Control on Bt Cotton Seeds in India: Impact on Seed Providers, Discussion Papers in Economics, Centre for International Trade and Development, School of International Studies, Jawaharlal Nehru University, New Delhi, India.

Byerlee, D and M A Lopez-Pereira (1994), Technical Change in Maize Production: A Global Perspective. CIMMYT Economics Working Paper 94-02. Mexico, D.F.: International Maize and Wheat Improvement Center (CIMMYT).

GoI (Government of India) (2005), National Seed Plan http://seednet.gov.in/Material/National%20Seed%20Plan.pdf.

GoI (Government of India) (2012), Agriculture at a Glance, Directorate of Economics and Statistics, Department of Agriculture and Cooperation, Ministry of Agriculture, Government of India, New Delhi. (Available at http://agricoop.nic.in/agristatistics.htm).

Hu, R., J Huang, C Pray and J Huang (2006), The Determinants of Plant Variety Protection Applications in China. *Journal of Intellectual Property Rights*, **11:** 260-268.

MoA (Ministry of Agriculture) (2013), Input Survey data base. Available at: http://inputsurvey.dacnet.nic.in/ nationaltables.aspx.

Morris, ML, RP Singh and Suresh Pal (1998), India's maize seed industry in transition: changing roles for the public and private sectors, *Food Policy*, 23(1): 55-71.

NSAI (National Seed Association of India) (2011), NSAI Magazine (April-June). New Delhi.

Pal, Suresh, R Tripp and NP Louwaars (2007), Intellectual property rights in plant breeding and biotechnology: assessing impact on the Indian seed industry. *Economic and Political Weekly* XLII 42(3): 231-240.

Pandey, S and Suresh Pal (2007), Are less-favored environments over invested? The case of rice research in India. *Food Policy* 32 (5-6): 606-623.

PPVFRA (Protection of Plant Varieties and Farmers' Rights Authority) (2012), Available at http://www.plantauthority.gov.in/pdf/FAQ_New.pdf.

Prasad S.R., G Somasundaram, HP Vijayakumar and S Natarajan (2011), Seed production in agricultural crops. In: Proceedings of Sixth Annual Review Meeting of ICAR Seed Project, held at IARI, New Delhi.

Pray, C E, B Ramaswami and T Kelley (2001), The Impact of economic reforms on R&D by the Indian seed industry, *Food Policy* 26(6): 587-98.

Pray, C.E., and L Nagarajan (2010), Price controls and biotechnology innovation: Are state government policies reducing research and innovation by the ag biotech industry in India? *AgBioForum*, 13(4), 297-307.

Seednet (2012), *Seed Variety Management System* (Available at http://seedvariety.dacnet.nic.in/).

Srinivasan, C S (2003), Concentration in ownership of plant variety rights: some implications for developing countries, *Food Policy*, 28 519–546.

Tripp, R., N Louwaars and D Eaton (2007), Plant variety protection in developing countries: A report from the field. *Food Policy*, 32: 354–37.

Venkatesh, P and Suresh Pal (2013), Determinants and valuation of plant variety protection in India, *Journal of Intellectual Property Rights* 18:448-456.

Chapter 6

PATENT REFORMS AND TECHNOLOGY SPILLOVERS: IMPLICATIONS FOR INDIAN AGRICULTURE

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INTRODUCTION

Agricultural research and development (R&D) scenario has undergone significant change in developing countries. There has been diversification of institutions and funding and now technology are transferred through commercialization for appropriation of benefits. Although R&D continues to be dominated by public research institutions, they are placing increasing emphasis on commercialization of their technology and resource generation. This is because most of the inputs are now being supplied by private sector due to commercialization of agriculture and the demand for modern inputs is rising. Some of the leading private input companies are also investing in R&D to increase their market share. Evidence indicates that private R&D is expanding rapidly, especially in areas like biotechnology, hybrid seed, plant protection chemicals, farm machinery and animal health (Pal *et al,* 2012, and Pray and Nagarajan, 2011). Besides, private sector is an important ally in commercialization of public sector technology. In order to intensify these trends and provide incentive to innovators, intellectual property rights (IPRs) are being made stronger in developing countries and amendments being made in national legislations to comply with the agreement under the World Trade Organization (WTO).

IPRs provide exclusive rights to the inventor to appropriate research benefits for a certain period, which is a strong incentive for investment and innovation. IPRs mechanism also facilitates in a transparent manner generation, sharing and commercialization of knowledge and technology originating from the inventions. These factors are especially important for private sector to recover the money invested in R&D and thereby increase investment intensity of R&D. The IPRs regime also helps public R&D organizations to build partnership with private sector for research and technology transfer and share benefits thereof (Naseem *et al,* 2010 and CIPR, 2002). Therefore, demand for a stronger IPRs regime was felt in developing countries with increasing privatization of input and R&D systems. Among various mechanisms for protection of intellectual property, patent is the strongest legal mechanism. In the context of developing countries, patent protection has important implications for chemical, biological and mechanical inventions, but limited application for plants primarily due to the reason that a weaker form of protection is agreed for them, e.g. *sui generis* system for plant variety protection, under WTO. This has widened the geographical basis of protection of plant varieties but most of the protection activity has been confined to the commercial crops (Koo *et al,* 2004). However, inventions protected through patents in other fields of science also have considerable implications for agriculture. This is particularly true for chemicals and biotechnology, which have wider applications in agriculture even in developing countries. How are these changes going to impact agriculture in India, which has strengthened the patent regime recently and also seen significant developments in private R&D With this background, this chapter analyses the trends in patent grants in India vis-à-vis other countries, especially after patent reforms. It also examines their implications in terms of access to technology and expected impact on Indian agriculture.

PATENT REFORMS

Evolution and International Scenario

The origin of the patent system can be traced back to various developments in Europe, particularly in Italy and England. Later, the practice of patenting was extended to America, which adopted the Patent Act of 1790. This Act has gone through several amendments, eventually culminating into the Patent Act of 1952. Meanwhile, the British Patent regime was also shaping up and the new patent system was introduced through the enactment of 1852 Act, which was designed for development of the industry. These legislations were further improved by incorporating the criteria of novelty, pre-grant opposition, and introduction of compulsory licensing. The European Patent Convention (EPC) was established in 1973 to create a centralized European patent system. Other important international developments were establishment of the World Intellectual Property Organization (WIPO) in 1967 for the purpose of providing services, information and policy guidelines for intellectual property and the Patent Cooperation Treaty (PCT) signed in 1970 to evolve an international system for processing of patent applications. The agreement on trade-related aspects of intellectual property rights (TRIPS) under WTO harmonizes the IP protection system globally with effect from 2005.

Further developments in IP policy at international level have brought considerable harmony in the criteria (e.g. novelty, inventiveness, application etc) and the period of protection. These developments also addressed the concerns of discrimination against any field of science or country of residence of inventor. Inventions in all fields of science can now be patented and foreign inventor is also eligible for the same right or treatment as given to the national of the country in granting the right. However, there is considerable variation in the patent laws across the countries. The US Patent Act is considered to be stronger as it allows patents for inventions in all fields of science, including plant patents. Under the US plant patent, "whoever invents or discovers and asexually reproduces any distinct and new variety of plant, including cultivated spores, mutants, hybrids and newly found seedlings, other than a tuber propagated plant or a plant found in an uncultivated state, may obtain a patent" (www.uspto.gov). Sexually reproduced varieties of plant are protected under the US Plant Variety Protection Act (1970). The European Patent Law does not allow protection of plant varieties by patent, which is protected by plant breeder's rights under the International Union for the Protection of New Varieties of Plants (UPOV). Some variant of the European law is adopted by the developing countries, keeping in view their requirements and national interests. For example, the Andean countries having common intellectual property (IP) regime prohibit patents on plant, animal and essentially biological processes. Other notable features of the patent laws are exclusion of those inventions from patentability which are against public order, methods (not products) for treatment of human and animals, and essential biological processes of reproduction. The use of patented invention for nonprofit (like academic) purpose and compulsory licensing in public interest are important provisions in the law.

The cost of establishing and maintaining a patent also varies among the countries. As expected, the cost is very high in Europe and US, nearly seven and four times, respectively, of that in India. Further the cost of maintenance of a patent is higher after tenth year. The low cost in the developing countries is expected because of presence of small firms and low paying capacity of ultimate users of the product. In addition, there is a fee for international filing of a patent. The application fee is US$ 1,471 up to 30 pages and additional fee of US$ 17 per page for the subsequent pages. The search fee for an international application is US$ 2,080 in USA and US$ 2,545 in Europe, against US$ 1,212 in Korea (Table 1). The search fee varies for the regular (institutional) and small innovators, the former being twice that for the latter in case of US patent search.

Table 1 : Application and search fee for the PCT international patent filing, 2017

International fee (in US dollar)	Regular entity
International filing fee (for first 30 pages of the international application)	1367
International filing fee (first 30 pages - filed in paper with PCT-EASY file on diskette, CD-R or DVD-R or filed electronically without PCT-EASY zip file)	1264
International filing fee (first 30 pages - filed electronically with PCT-EASY zip file)	1161
Supplemental fee for each additional page over 30 pages	15
Fee for requesting restoration of the right of priority	1700
Search fee (in US dollar)	
United States Patent and Trademark Office (USPTO) as International Searching Authority (ISA)	2080
Supplemental search fee, per additional invention (payable only upon invitation)	2080
European Patent Office (EPO) as the ISA	1992
Korean Intellectual Property Office (KIPO) as ISA	1114
IP Australia (IPAU) as ISA	1688
Russian Federal Service for IntellectualProperty (Rospatent) as ISA	449
Israel Patent Office (ILPO) as ISA	911
Japan P.O. as ISA	1372

Note: The fee for restoration of the right of priority is US$850 for small and micro-entities, and the search fee is US$ 1040 for small entity and US$ 520 for micro-entity.

Source: www.uspto.gov

Institutional Mechanism

The patent right is granted through national legislation and so far there is no provision of international patent. Each country has an institutional mechanism (patent office) to process, grant and consider further matters related to patents. However, a single window application procedure is established under PCT for the member countries. This is convenient to the applicant and the cost of protection is also less. Another significant advantage is that an extended protection period is realized by filing an application (provisional or complete) first in the member country and then filing an international application within twelve months, thereby buying a bit lengthy protection for the invention. Eventually, all the PCT applications have to go through the national phase for examination and grant of the patent right in the country where the patent is sought.

In India, all the four regional offices of the Controller General of Patents, Design and Trademark are receiving offices of the international applications. The international application must contain necessary details like description, claim(s), drawings etc, and language of the publication may be Chinese, English, French, German, Japanese, Spanish or Russian. A PCT application from India has to be either in English or in Hindi. However, as Hindi is still not recognized in WIPO, the preferred language should be English or else, a translated copy of the original application verified by a translator should be submitted. Three basic fees have to be deposited with the receiving office while submitting a PCT application; these fees are transmittal fee, international filing fee and search fee (Table 1).

Patent Reforms in India

Among the developing countries, India has a fairly long history of patents and the Patent Act (1970) allowed process patents in the country. This Act was amended to comply with WTO agreement, allowing process and product patents for 20 years in all fields of science. The patent grant is subject to researchers rights, i.e. use of a patented process or product for research purpose is not considered infringement of patent, and there is a provision of compulsory licensing of a patent in public interest. Also, methods of agriculture, plant and animal or part thereof, and methods of treatment of human and animal are excluded from patenting. Therefore, it is considered that patent reforms may not have significant impact on Indian agriculture, and protection of plant varieties, which are protected under the Protection of Plant Varieties and Farmers Rights Act (2001) is of greater significance. However, with unfolding of patent scenario in the country, it is seen that some patents in the field of chemicals, biotechnology, and animal health have significant implications for agriculture.

The office of the Controller General of Patents, Designs and Trademarks under the Union Ministry of Commerce and Industry is responsible for administration of the Patent Act. This office has branches in Delhi, Chennai, Kolkata and Mumbai. Since India is a member of PCT, an international application can be filed under PCT after prior approval of the competent authority. Approval can be sought to apply abroad under rule 71(1) of Section 39 of the Act after not less than six weeks of application filed in India for the same invention.

A major difference between Indian patent regime and that of the developed world and even many members of the developing world, lies in accepting what is termed as the ‘Utility Model’. Utility patents are ‘Petty Patents’ valid for generally 6-10 years, granted after checking the novelty and applicability without much emphasis on the ‘obviousness’ which is essential for 20-year valid patents. With rapid development there is more interest in filing these kinds of patents as 20 years down the line inventions generally become obsolete. Many countries have already adopted the utility model under different names, such as in Australia, it is termed as ‘Innovation Patent’ with validity of 8 years.

Another major difference is found between the patentable articles. As in USA, it is popularly said, “anything under the sun that is made by man is patentable”. The provisions in the US Patent Act are illustrative in nature and define what is patentable in US, whereas the Indian Patents Act also lists subject matter which is not patentable. Unlike USA, where patents are granted for ‘Designs’ under ‘Design Patent’, India has created separate Act, The Designs Act, 2000, especially meant for the industrial designs. Also, there is no provision of plant patents in India and protection of new plant varieties is done under the ‘The Protection of Plant Variety and Farmers’ Right Act (2001), which to some extent follows UPOV 1991. The National Biodiversity Authority administers the Biological Diversity Act (2002) to protect the natural indigenous species and to regulate access to the national biological resources. Thus, there is considerable variation in the patent regime in India and the developed countries. This is done essentially to meet the national requirement. The Indian IP regime provides adequate incentive to the inventor, while safeguarding interest of the users by granting them access to a protected technology.

TRENDS IN THE WORLD PATENTS

The World Intellectual Property Organization (WIPO) maintains a database on patent grants and their details in different countries. This database was searched for patent grants in different countries in various fields of science since 1980. As seen from Figure 1, there is an upward trend in total patent grants in the world. The trend is really sharp after the mid-1990s when the negotiations were in advanced stage and after 2005 when the agreements were implemented globally. The average annual patent grants in the world during the period 1980-1994 were 401,372 patents, which increased to 729,360 in the post-TRIPS period, i.e. 1995 to 2014. However, patents were mostly registered in the high income developed countries, mainly USA, European Union and Japan. The upper middle income countries witnessed increase in patents only after 2005, and the trend remained almost the same for the lower middle and low income countries. During the year 2014, average annual patent grants in case of the high income countries were 878,300 patents, which is 3.2 times higher than that of the upper middle income nations (273,900 patents) and 52 times higher than the low-middle and low income nations (16,900 patents). Among the high income countries, USA and Japan rose in the world patents scenario becoming the highest patent holders during the period 2004-2014. Among the developing countries, China has improved its position. Earlier Chinese science was not comparable with the developed nations, but after 1991, Chinese patenting activity grew rapidly; average annual number of patents increased from 27,425 during 2000-04 to 136,637 during 2005-14. In the case of India, patenting activity was not much during 1980-1995, as the average annual patent grants were 1,650 only. As a result of patent reforms, number of patents increased from 1,501 in 1980 to 6,153 in 2014 which was much below that in China (233,288).

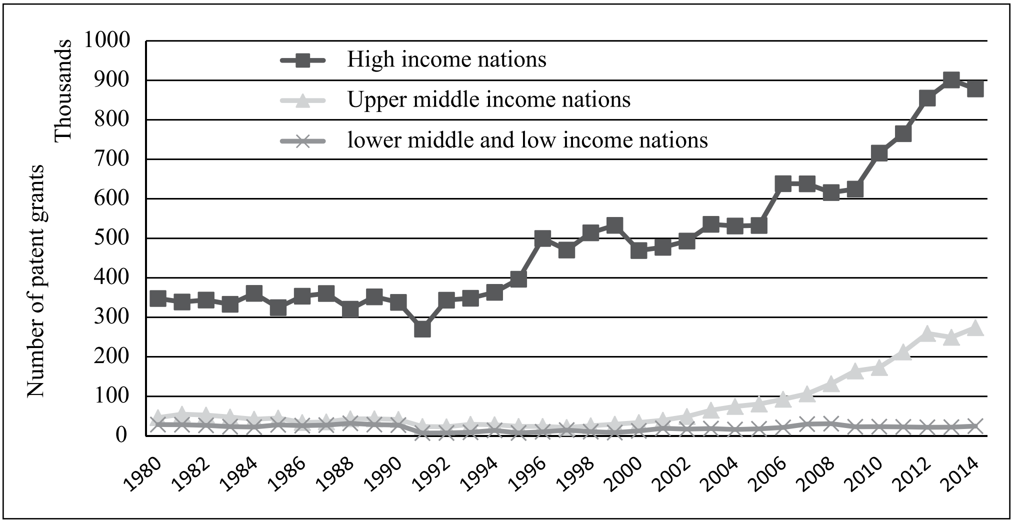

Fig. 1 : Trends in patent grants in different income group countries

As regards the number of patents in different fields of science in the world, telecommunications, computer technology and organic fine chemistry dominated the scenario in all the countries. This was followed by pharmaceuticals and biotechnology. This trend holds true for the upper middle and lower income countries (Table 2). All the fields of science received greater patenting activity during the last decades, especially after 2005, but this was more so for computer technology which witnessed phenomenal increase in number of patents during 2005-14. In the high income nations, resident patent owners accounted for a larger share in the total patent grants in telecommunication and computer technology, while non-residents have equal or higher share in the total patents in other fields of science. The non-residents also have higher share in the middle and lower income countries, the difference being sharp in the lower middle and low income countries.

Table 2: Patent grants in different income nations in major sectors

High income nations	Sectors	R/NR*	1981-90	1991-2000	2001-14	2005-14
	Telecommunications	R	17,753	58,587	208,668	166,625
		NR	23,981	47,548	128,572	102,410
	Computer technology	R	16,127	88,300	414,063	345,216
		NR	24,902	66,033	240,049	203,968
	Organic fine chemistry	R	39,722	52,987	106,928	81,818
		NR	101,860	82,401	125,623	94,432
	Biotechnology	R	8,154	30,432	77,668	59,143
		NR	19,213	34,998	74,767	58,142
	Pharmaceuticals	R	12,847	34,075	95,677	73,487
		NR	51,008	64,135	139,977	109,523
Upper middle income nations	Telecommunications	R	547	422	23,417	22,299
		NR	1,128	1,554	28,561	23,278
	Computer technology	R	650	495	41,144	39,154
		NR	902	1,292	47,579	43,090
	Organic fine chemistry	R	2,865	2,137	29,202	27,180
		NR	16,064	15,080	36,346	28,200
	Biotechnology	R	487	554	25,784	24,659
		NR	2,802	4,064	12,985	10,809
	Pharmaceuticals	R	1,378	2,370	57,017	51,961
		NR	9,554	11,570	33,981	27,081
Lower middle and low income nations	Telecommunications	R	5	21	238	190
		NR	140	136	437	338
	Computer technology	R	7	9	296	238
		NR	83	66	284	209
	Organic fine chemistry	R	8	18	451	396
		NR	4,600	2,305	5,225	3,735
	Biotechnology	R	7	8	327	279
		NR	559	481	1,299	1,032
	Pharmaceuticals	R	18	58	1,255	992
		NR	2,994	2,207	7,052	5,298

*R: resident, NR: non-resident; Source; Based on data compiled from WIPO database.

PATENT GRANTS IN INDIA

To get an overview of the patent grants in India, data on number of patent grants in different fields of science have been compiled from WIPO database, and the data on the patents in agricultural science were taken from the Indian Patent Statistics maintained by the Indian Patent Office. As seen from Figure 2, there was limited patenting activity in India during the 1980s and 1990s. It picked up after implementation of the patent reforms in 2005. The number of patents granted in India was 1,501 in 1980 which increased marginally to 1,526 in 2004. However, after third amendment in the Patent Act, the number of patent grants in India increased tremendously from 2,317 in 2005 to 16,061 in 2008, i.e. an increase of 593 % due to provision of product as well as process patent. But the patent grants followed a declining trend during the recent period of 2008-2014, indicating that applications filed in the mail box system were closed or granted immediately after 2005, and there were fewer new applications for consideration after 2008.

Patents in Various Fields

An analysis of patenting activity in different fields of science in India reveals that it was rather low in all the fields in 1980s but picked up in 1990s. In the field of pharmaceuticals, the number of patents increased from 26 in 1980s to 103 in 1990s (4 times), which further rose rapidly to 3,420 patents (132 times) during the period 2000-2014. An increase in the grants during the last decade was seen mainly in computer

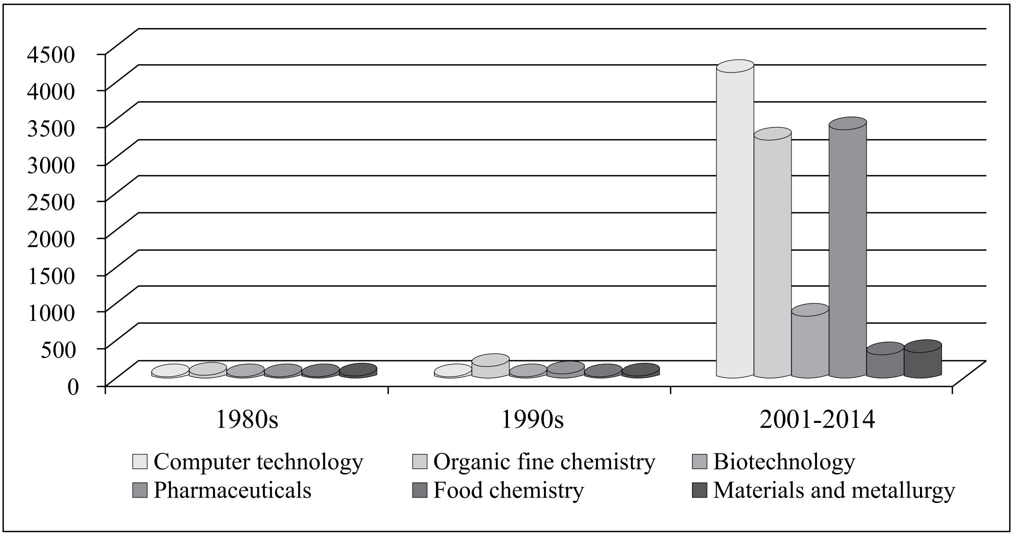

Fig. 2 : Patents granted in different fields of science in India

Source: Based on data from WIPO, IP statistics.

technology, organic chemistry, pharmaceuticals, metallurgy and biotechnology. The highest growth during 2000s was seen in computer technology with 500 times increase over that in 1990s. The second major field was organic fine chemistry, having the highest patents among all the fields during 1980s and 1990s with 51 and 201 patents respectively, which increased to 3,290 patents in 2000-2014. Biotechnology has seen two-times jump in number of patents from 1980s to 1990s but patent grants were only 905 during 2000-2014, which is 25 times of that during 1990s. Food chemistry and material and metallurgy are other two fields where substantial growth in the patent grants was seen (Fig. 2).

Patents in Agricultural Science

To view the patents granted in different fields of agricultural science in India during 2007-15, data have been taken from the IPO database. The search was done in accordance with s the International Patent Classification (IPC) and patents which fall in IPC code "A01" were taken into consideration. In agricultural science, 1201 patents were granted during 2007-15. Most of the patents (80 percent) during 2007-15 were granted to private companies, 90 per cent of which were non-resident or foreign companies. The public sector, mostly the national system, accounted for 12 per cent of the total patents and the rest 8 per cent were owned by individuals. The resident owners accounted for 21 per cent of the total patent grants (Table 3). Thus, most of the increase in patenting activity was due to the patents filed by foreign innovators for commercialization of their IPs in India.

Table 3: Institutional ownership of patent grants in agricultural sciences in India, 2007-15

Sector	Residential	Non-Residential	Total
Public	105	41	(12.2%) 146
Companies	94	868	(80.0%) 962
Individuals	58	35	(7.8%) 93
Total	(21.4%) 257	(78.6%) 944	(100) 1201

Note: Figures in parentheses are parcentage of the total patents.
Source: Based on data compiled from IP statistics.

As regards the patents in different areas of agricultural science, as seen from Table 4, maximum patents (822) have been granted in biocides and pesticides group (A01N) which accounts for 68 per cent of the total granted patents in agricultural sciences in India. This is followed by 74 patents granted in plant or new process for obtaining them like plant tissue culture, 65 in animal husbandry and 59 in horticulture and forestry. There were few (19) patents in the area of post-harvest and storage technology and 66 patents for machinery or products related to planting, fertilizer and soil management. The minimum number of patents has been granted in manufacturing of dairy products with 9 patents and shoeing of animals with 7 patents. Thus, chemical technology has led the patenting activity in India and most of these patents were owned by the non-resident private companies.

Table 4 : Institutional ownership of patent grants in different areas of agricultural sciences in India, 2007-15

Assignee	Private	Public institutions	Residential			Non-residential			Total
			Total	Private	Public	Total	Private	Public	
Soil, machinery (A01B)	18	3	8	6	2	13	12	1	21
Planting, sowing, fertilizing (A01C)	36	9	13	7	6	32	30	2	45
Harvesting, mowing (A01D)	19	6	10	4	6	15	15	-	25
Threshing, storing (A01F)	15	4	8	4	4	11	11	-	19
Horticulture, forestry (A01G)	51	8	24	18	6	35	33	2	59
Tissue culture technique (A01H)	49	25	22	10	12	52	39	13	74
Manufacture of dairy products (A01J)	8	1	5	4	1	6	6	-	9
Animal husbandry (A01K)	53	12	22	14	8	43	39	4	65
Shoeing of animals (A01L)	7	-	2	2	-	5	5	-	7
Catching, trapping of animals (A01M)	45	10	26	17	9	29	28	1	55
Biocides, pesticides, herbicides, pest repellants, pest attractants, PGRs (A01N)	753	69	120	69	51	702	684	18	822
Total	1054	147	260	155	105	943	902	41	1201

Source: Based on data compiled from IP statistics.

As regards country-wise patent grants, USA ranks first in the number of patents granted with 302 patents (25.1 percent) out of a total of 1201 patents granted in agricultural sciences in India during the period 2007-2015. India holds the second position with 257 patents (21.4 percent) followed by Germany 240 patents (20 percent). UK, Japan, European Union and Australia together have 242 patent grants in India. It is important to note that most of the patents granted to foreign nationals or agencies were in the field of chemistry (biocides, pesticides, etc), but the patents granted to the Indians were comparatively diverse, and less than 50 per cent were in the field of chemistry. Some patents in the field of tissue culture (19) and animal husbandry (15) were owned by the residents of US (Kandpal, 2014). Thus, most of the patents were in the field of chemical technology and these were owned by the companies registered in the developed countries, indicating spillover of chemical technology to India.

IMPLICATIONS FOR INDIAN AGRICULTURE

The available evidence is inconclusive in terms of the impact of patents or other IPRs on the development of R&D capacity. In general there will be an outflow of resources from developing countries to access technology invented in developed countries. The developing countries should therefore evolve a system to build their capacity to invent and access a protected technology. It is also seen that the impact is less in countries with limited R&D capacity. Weak IPRs has however benefitted the East Asian countries as it encouraged local capacity to innovate and imitate (CIPR, 2002).

Another major reason for inconclusiveness of the impact is that it is difficult to separate the influence of IPRs from other policy changes on developments in R&D capacity. This was particularly true in the case of plant variety protection in developing countries where seed industry was witnessing significant changes and biological methods proved equally important in protection of genetic material (Tripp *et al,* 2007). Once there is a reasonably good R&D capacity, a country can benefit from IPRs mechanism to access technology and promote competition among the inventors. The cross country evidence also indicate that legal IPRs along with biological protection do help bridge the yield gap among the countries (Spielman and Ma, 2014). Another important advantage is that IPRs facilitates interaction among inventors and the information on patent serves as an important tool for future technology forecasting and policy formation. Therefore, patent can be instrumental in accelerating economic progress through technological innovations.

Since India has a strong R&D base, stronger IPRs regime is expected to strengthen the innovation capacity, which is judged by the amount of additional resources the country is able to attract in R&D and commercialization of intellectual property. Realization of such an impact shall take some time and will be influenced by the cost-effectiveness of IPRs mechanism also. This is essentially derived from the enforcement mechanism of IPRs regime and entails going beyond IPRs regime to the legal system to deter any potential infringements. Therefore, additional investment in R&D attributable to the patent reforms may be difficult to foresee in near future, and at best it can sustain the present trend of R&D investment in private sector due to expanding market opportunities and economy-wide reforms.

However, a major impact can be seen in terms of access to foreign technologies being protected and commercialized in India. This access would have been either delayed, or it would have been possible to commercialize the technology by other methods like contractual arrangement or trade secret. With the availability of these technologies now, there are instances of commercialization of technology by the firms owning them, or establishing partnership or joint venture for commercialization of technology, e.g. Mahyco-Monsanto for Bt gene. There are umpteen examples of licensing-in the protected technology, especially in pesticides and animal vaccines. All these developments have reduced the imports of technology-based products.

The second major impact is likely to be seen in the cost of agricultural inputs and their market structure. With the increasing presence of private sector the supply of inputs and services is slated to increase with a likely increase in their prices. Already this is being witnessed in seed sector where price of hybrid seed (e.g. Bt cotton) supplied by private sector has risen significantly (see chapter 5). Besides brand reputation and services of a company, economic potential of the technology shall determine the size of the market which will be dominated by a few technology-based products with distinct advantage.. This implies that there could be a possibility of concentration in input market which will be dominated by a few firms and technology. This phenomenon has been observed globally and it is estimated that the firm concentration ratio (market share) has increased over time. The four-firm concentration ratio for crop protection chemicals was 53 per cent and the eight-firm concentration ratio was 74.8 per cent in 2009; the former became double and the latter increased by 50 per cent within last 15 years. An increase of similar magnitude in the concentration ratio was noticed for crop seed and traits (Fuglie *et al,* 2011). Here it may be important to mention that seed prices in India are under check, to some extent, due to use of domestic plant material by private seed companies but this may not be applicable to agro-chemicals which are mostly based on new molecules invented by transnational companies. Therefore, likelihood of technology based dominance of input markets is high for agro-chemicals. Thus, the tendency of private companies to appropriate research benefits and their concentration in input markets may push the input prices considerably, especially for agro-chemicals. For instance, higher price for new patented drugs is a serious issue in Indian pharmaceutical industry. In agriculture, however, it may be little premature to witness such a trend, but there is a need to monitor the markets for this tendency and address it through appropriate interventions under the trade or the patent law. The guiding principle is that the owners of IP should be compensated for their efforts and small farmers should have access to technology. Another effective way to address the monopolistic tendency of input markets is effective competition and partnership which is offered by public R&D system, a major source of technology in India. This is particularly true for seed industry where public system plays an important role and thereby makes the seed market competitive with prices within the reach of Indian farmers.

Major impact of greater access to foreign technology would be realized through higher farm yields. Since most of the patents owned by foreign companies are for plant chemicals and animal health products, their wide scale adoption will help reduce yield losses and thereby lead to realization of higher yields by farmers. This has been clearly established by Bt cotton. There are other applications of Bt gene in brinjal, maize, etc which are awaiting approval for their commercialization. Similar impacts can also be visualized for pesticides and herbicides which result in considerable yield gains in all major crops. In addition, there are patents for plant growth regulators which can also help realize yield potential in fruits and vegetables. Information available does not permit calculation of potential benefits, but a moderate reduction in yield losses for major crops can translate into substantial economic benefits. Since chemical and biological technology is neutral to scale, these benefits shall also accrue to small farmers and consumers.

The other areas which are likely to witness technology access are farm mechanization and plant propagation. Quality planting material for fruit crops and farm mechanization are going to have major impact on crop productivity and efficiency of farm operations, respectively. Animal health is an area which needs immediate attention. A number of animal health products available on-shelf in developed countries shall be available to livestock sector, beginning with commercial dairy and poultry. Thus, there are going to be immense benefits from technology spillins and Indian commercial sector has the capability to commercialize them by licensing the technology or forming a partnership. This, coupled with developments in the Indian R&D sector shall lead to greater technology flow to farmers.

CONCLUSION

The foregoing discussion clearly indicates that after the patent reforms there is considerable increase in patenting activity in developing countries, including India.. However, these countries still lag behind in terms of ownership of patents because of their R&D capacity and lack of focus on patenting of innovations. Most of the patents in India after the patent reforms were owned by the foreign companies and their number increased after the patent reforms of 2005. In the context of agriculture, there are a considerable number of patents in India in the area of plant chemicals, animal husbandry and biotechnology, indicating spillins of technology in these areas. Therefore, significant impact could be realized through reduction in yield losses in crops and animals. Since India has a strong R&D base, there shall be increase in the number of inventions and their protection in the country. It is also likely that multinational companies shall establish their R&D facilities in the country. This should promote competition in the industry on the one hand, and on the other, it should lead to higher exports of technology-based products from the country. At the same time, one cannot rule out dominance of private companies in agro-chemicals markets and its impact on prices. Therefore, policy of the government should be to use IPRs mechanism to promote competition, share protected IPs for their commercialization and build partnership among R&D organizations.

REFERENCES

Commission on Intellectual Property Rights (2002), *Integrating Intellectual Property Rights and Development Policy*, London, DFID.

Indian Patent Office, The Patents (Amendments) Act 1970, http://www.ipindia.nic.in

Fuglie, KO, PW Heisey, JL King, CE Pray, K Day-Rubenstein, D Schimmelpfennig, SL Wang and R Karmakar-Deshmukh (2011), Research investment and market structure in the food processing, agricultural input and biofuel industries worldwide, ERR-130, USDA, Economic Research Service, Washington, D.C.

Kandpal, A (2014), Patenting activity in India: implications for Indian agriculture, MSc thesis submitted to PG School, IARI, New Delhi.

Koo, B, C Nottenburg and PG Pardey (2004), Plants and intellectual property: an international appraisal, *Science* 306 (5700): 1295-1297.

Naseem A, DJ Spielman and SW Omamo (2010), Private-sector investment in R&D: a review of policy options to promote its growth in developing-country agriculture, *Agribusiness*, 26 (1): 143–173.

Pal, Suresh, M Rahija and N Beintema (2012), India: recent developments in agricultural research, ASTI-ICAR Brief, IFPRI, Washington, DC.

Pray, C and L Nagarajan (2012), Innovation and research by private agribusiness in India, EPTD Discussion Paper 1181, IFPRI, Washington, DC.

Spielman, DJ and X Ma (2014), Intellectual property rights, technology diffusion and agricultural development, Discussion Paper 01345, Washington, DC: IFPRI.

Tripp, R, N Louwaars and D Eaton (2007), Plant variety protection in developing countries: a report from the fields, *Food Policy*, 32:354-371.

USPTO, Consolidated Patent Laws, United States Code Title 35 – Patents, http://www.uspto.gov assessed on 20/10/14

Chapter 7

SOCIO-ECONOMIC ASSESSMENT IN BIOSAFETY DECISION-MAKING IN DEVELOPING COUNTRIES

Guillaume Gruere[1] and Suresh Pal

INTRODUCTION

These past few years, socio-economic considerations associated with the use of genetically modified (GM) crops have been increasingly present in decision making world-wide. In India and other countries, many civil society groups have opposed the use of GM crops, including the widely popular Bt cotton, primarily on non-safety related claims (e.g., Herring, 2009). Scientists, politicians, journalists and others have expressed their concerns on the use of GM crop technology on many accounts, but while the safety aspect remained in the background, the more consistent and vocal messages relate to the other aspects of the use of GM crops, such as the use of proprietary technology, the control of seeds, the effects on small farmers, organic products, consumer choice, or even their potential links to farmer suicides in the case of India (Gruere and Sengupta, 2011).

These issues are not new in the global debate over the use of biotech crops, but their explicit inclusion in political decisions around the use of GM crops is a relatively recent and seemingly growing phenomenon (Falck-Zepeda 2009; Ludlow, Smyth and Falck-Zepeda, 2014). Several recent decisions in developing countries confirm this view. In the fall of 2009, the biosafety authority in the Republic of South Africa rejected the commercialization of a Bt potato mainly for socio-economic reasons, including the potential loss of markets feared by the potato industry, and the fact that it was perceived as a relatively low-benefit technology. There were no safety concerns. Yet, farmers would not have adopted it if they had not seen any benefit, and buyers would not have bought it if they did not want to, so the decision appears to be redundant. Several other decisions in South Africa also seem to show the increased influence

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of assumed market risks in biosafety decision making (Gruere and Sengupta, 2010). The same year, France set up a new GMO authority with a panel on socio-economic considerations that includes experts and non-experts from the civil society to give recommendations on discrete biosafety decisions. Many other countries have included socio-economic considerations in their biosafety frameworks (Falck-Zepeda, Ludlow and Smyth 2014). In India also, lack of enough evidence on socio-economic impact was felt these last few years, particularly in the run up towards the decision to reject Bt brinjal.

These discussions may have been at least partially initiated by the increased debates on socio-economic considerations at the Cartagena Protocol on Biosafety, an international agreement regulating the transboundary movements of GM organisms under the UN Convention on Biodiversity, to which India is a member. Under Article 26 of the Protocol, socio-economic considerations, and more specifically the effects of introducing a GM organism to indigenous communities and biodiversity, should be taken into account in the decision to import new GM material for planting. The Protocol members are also encouraged to share information about the socio-economic impacts of living, modified organisms (Secretariat of the Convention on Biodiversity, 2010). While the Protocol only prescribes the inclusion of these issues in decision to import GM seeds for very specific cases restricted to biodiversity and indigenous populations, a growing number of parties have been pushing for a wider interpretation of the rule to include all types of considerations in all biosafety related decision making (Falck-Zepeda, 2009).

At a time when India is reforming its biosafety regulatory system, considering the potential role of socio-economic considerations in or outside of the decision making process, an analytical framework is needed to help avoid last minute consultation based on limited or no evidence. There exist reports on general principles around socio-economic assessment (e.g., Fransen *et al.* 2005), but more discussion is needed in the design of appropriate policies especially in the case of countries like India with multiple stakeholders and growing research and development efforts. In particular, there is no clear definition of what constitutes a valid socio-economic assessment, when it makes sense to apply it or what its advantages and drawbacks may be.

The objective of this chapter is to inform future debates on the use of socio-economic considerations in the new biosafety framework in India and potentially other developing countries. More specifically, the paper aims to address three questions. First, under what condition socio-economic assessment is useful and what principles should govern its use? Second, what type of analysis is required under such an assessment? And third, what consequences socio-economic assessment would have on commercialization and application of future GM crops? While socio-economic considerations can be interpreted in many ways, our discussion of the methodology for assessment will focus primarily on applied economic analysis, which has a significant role to play. This is a caveat, but the general principles we discuss are applicable to the possible inclusion of other social science disciplines.

The analysis is based on a review of the literature and an extensive consultation, with national and international economic and regulatory experts in Washington DC and New Delhi in the Fall of 2009.[2] While the United States has a distinct regulatory structure, it has more experience than any other country in the approval and use of GM crops and its regulatory framework does include socio-economic considerations. As a complement to our consultation with U.S and international experts, a seminar was conducted with Indian economic and regulatory experts, on biosafety, in New Delhi. Overall, seventeen meetings were organized with three types of stakeholders: economists working in biotech regulatory agencies, researchers in national and international organizations, and other biotech stakeholders with experience in biosafety regulations. Each of these meetings discussed the above-listed questions, but they also served three distinct purposes. Meetings with regulators aimed at discussing the use of cost-benefit analyses in regulatory decision making in the United States. Discussions with researchers intended to provide guidance on methodologies for socio-economic assessments and their practical use in the context of biosafety regulations. Lastly, conversations with other biotech stakeholders served the purpose of discussing the role and implication of including socio-economic assessment in biosafety regulatory frameworks.

The following section introduces the general principles and modalities around the use of socio-economic assessment, analyzing examples from multiple countries. The third section focuses specifically on methodological options for rigorous ex-ante economic analysis to support decision making and the fourth section discusses the benefits and costs of conducting socio-economic assessments. We conclude the paper with some conclusions and policy suggestions.

SOCIO-ECONOMIC ASSESSMENTS AND BIOSAFETY SYSTEMS

General Principles

Biosafety regulations serve the purpose of managing risks arising from the use of modern biotechnology, but there are wide differences in regulatory approaches across countries. Furthermore, these regulations have significantly evolved during the last two decades and continue to evolve in most countries. Still, in the case of new GM technologies, these regulatory frameworks tend to include key milestones

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[2] The list of institution consulted is available in the appendix.

for applicants. Any new GM crop goes through at least three layers of efficacy and biosafety testing: trials in the lab or greenhouse, confined field trials and large-scale field experiments. Food safety requirements can be met in parallel with these tests and are the only ones needed for imports of commercial products (not for planting) containing GM ingredients in countries with import authorization processes.

The main differences across countries relate to the specific data requirements at each step of the process, the type and number of agencies requesting information, the time of response, additional requirements and appeal, and who takes the final decision. Developed countries with a long experience in GM crops or products like Canada, the United States, or Japan have established biosafety systems with well-defined rules and requirements, but their rules are still being revisited from time to time, and may be subject to revisions in the near future. Other countries are changing their system almost every year, like those in the European Union. A third group of countries that includes India and South Africa, are reforming the rules and regulations that they originally adopted, to improve the system and comply with their international obligations. Lastly, many developing countries are still at the early stage of development of their regulatory frameworks, often at the stage of parliamentary discussions around the adoption of a biosafety act.

Biosafety risk assessments are conducted based on scientific knowledge and practices, but the stringency of the requested tests and their acceptance differ according to the regulations. A number of countries do follow the same general principles, especially in the case of food and feed safety. In fact, the European Food Safety Agency and their North American counterparts do share the same guiding principles in their assessment stages. The basic principles are outlined in a UN WHO/FAO Codex Alimentarius standard based on a widely respected international consensus. With respect to environmental safety, while the same potential risks are being studied, there are larger differences and no international standard. The Cartagena Protocol on Biosafety, which governs the environmental risks associated with transboundary movements of GM organisms, includes over 150 member countries, but not some of the largest GM crop producers, such as Argentina, Australia, Canada or the United States. This means that its guiding principles would not apply to a very large share of existing and future GM crops, and therefore remain mostly of relevance for countries that have not adopted any GM crop.

Following the trials and risk assessment stages, an opinion or approval is given to a political body to decide on a potential commercialization. This decision making stage is critical, and this is where other factors can be accounted for. Most often a decision is based on the opinion or approval, but does not necessarily follow its specific recommendations. Socio-economic considerations can be part of the discussions and play a role in allowing or most often rejecting an application. In parallel, the decision making agency or an attached government body may require specific management practices post-release, to ensure that the technology is properly used and follows certain standards.

When considering the potential role of socio-economic assessment and more specifically, market related considerations, like farmers income or consumers benefits, the first major principle to understand is that the market is the ultimate test. Before a company invests in a new technology, it assesses the likely profitability of its future product-- non-appealing products being rejected and avoided. Export risks are also increasingly taken into consideration. If the product is commercially released, it is then open for sale to farmers, but farmers will not adopt the seeds if it does not provide any visible benefit to them. Farmers may try a new seed technology for a cropping season, but will discontinue its use if it does not provide benefit. Lastly, buyers and consumers will also buy products based on their preferences; food companies will purchase based on their choices and consumers will choose based on their information set. While the level of information does matter in these choices, companies that want to sell a product unwanted by consumers take a significant risk and will ultimately have to pay for their choices. Similarly, seed companies selling a non-profitable seed will lose their market rapidly.

Naturally economic and market related issues are not the only ones that matter, but international experience shows that they occupy a significant share of existing practices. A technology with credible and visible benefits to adopting farmers and consumers will face less risk of being rejected by policy makers. As noted above, several technologies were rejected largely because of real or perceived market risks (Gruere and Sengupta, 2009). Other technologies were shelved post approval, like GM wheat or GM potato in North America, because of the potential loss of buyers. If not all fears are credible, several incidents (Starlink, LL 601 rice) have demonstrated that trade disruption can occur at a significant scale if a new GM product has not passed importers' approval.

Significant International Differences

At the international level, Falck-Zepeda (2009), reports that several countries have already included socio-economic considerations in their legal text. Argentina has required a market impact assessment to avoid export losses with new GM products. Brazil's regulatory body can require a socio-analysis as part of commercialization decisions. Indonesia's regulations include considerations for socio-economic issues, including cultural, ethical and religious aspects. The Philippines regulatory body is supposed to account for various socio-economic aspects, including the impact on small farmers, indigenous people, women and small enterprises. As noted above, South

Africa's regulatory arm is allowed to account for socio-economic considerations. The European Union does request a report every three years on the socio-economic impact of GM crops, and certain members like France have included social and economic aspects in their assessment panels.

Economic assessments are included in the United States' regulatory framework, but most are done at the rule making level rather than the decision making level. Figure 1 shows the insertion of economic analysis in the three bodies in charge of regulating the approval of new GM crops. The Environmental Protection Agency (EPA), which is in charge of regulating pesticide products (like Bt crops), but not herbicide tolerant products, does include a risk-benefit analysis for each new product and/or each new renewed registration (Berwald, Matten and Widawski, 2006). The analysis is done with data gathered by consultants on the farm level effects of different technologies and information on the exposure and hazards. The US Department of Agriculture Animal Plant Health Inspection Service is in charge of deregulating new GM crops based on their performance. In certain cases, it is required to conduct an environmental impact assessment for GM crops under the National Environmental

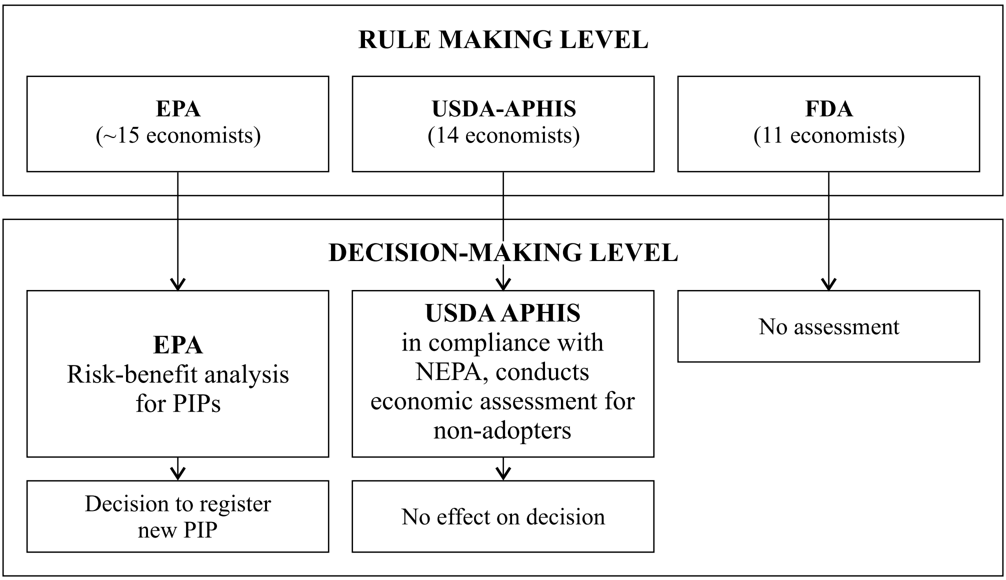

Fig. 1 : Economic analysis in the biosafety regulatory framework of the United States

Note: EPA: Environmental Protection Agency, FDA: Food and Drug Administration, USDA-APHIS: United States Department of Agriculture Animal, Plant and Health Inspection Service, PIPs: plant insect protected, NEPA: National Environmental Protection Act.

Source: authors, based on consultations.

Protection Act, which includes an assessment of their effects on new crops.[3] The Food and Drug Administration, in charge of food safety related issues, does not have any specific requirement for new GM products that are deemed substantial equivalent, and therefore "generally recognized as safe" (GRAS). In contrast with the decision making level, all three agencies include economic analysis to support any significant change in rules and regulations.

This emphasis on the rule making level does have the advantage of discussing potential socio-economic consideration for any application going through the regulatory process. At the same time, it does have the inconvenience of not discussing the potential benefits and risks of specific GM product. But this is where the EPA and USDA-APHIS have a role to play on specific technologies. On the one hand the system looks balanced and proportionate to concerns. On the other, it may not be as flexible as needed. Recent State and Supreme Court rulings tend to show that there should be more assessment on issues of coexistence before approval. Furthermore, recent introduction of unapproved GM crops that resulted in significant export losses (e.g., see Carter and Gruere, 2012) suggest a need to include market risk assessment and management in certain cases to avoid repeated crises in the future.

In contrast with the United States and other countries, India's 2002 regulations do not explicitly include socio-economic considerations. Applications for new GM product release have included information on economic performance of new GM crops, and there have been post commercialization report of the socio-economic effect of Bt cotton, but there was no formal channel to include these issues in the rule making or decision making levels. In 2009, as it was in the process of approving Bt brinjal, the Genetic Engineering Approval Committee (GEAC) did request an economic study of Bt brinjal. But the model the study offers was far from being perfect and subject to discussion.

Proposed Modalities

In this setting, it is still time to investigate how socio-economic assessment should be applied in a new biosafety regulatory system. Based on our review of the literature and meetings with various experts, there was strong support to include socio-economic assessment, aside of the risk assessment framework. Economic theory suggests that information should be provided when there is market failure; in this context, this could happen because of the presence of unaccounted externality such as the effect of a GM crop on non-adopters, and/or if there are imperfect markets with asymmetric information, such as if farmers, buyers or consumers do not know the effects of the

[3] In 2008-10, the USDA-APHIS was found to be at fault by not conducting these assessments in the case of GM alfalfa and GM sugarbeet (Carter and Gruere, 2012).

technology. If farmers in countries like the United States are sufficiently well educated and informed to make their own choices, not all small Indian farmers may be able to know whether the technology will benefit them. This means that a first check at the regulatory level could reject technologies that risk putting farmers at distress. In fact, representatives from the industry are not against the principle of adding information, their position was that information on economic effect could be useful as long as it was not detrimental to the overall process, and more specifically the cost, predictability and timeliness of a biosafety regulatory framework.

At the same time, results from our consultation suggest that 'a one size fits all' mandatory requirement would not work. Instead, the socio-economic assessments should be done on a case-by-case basis. More specifically, we suggest the use of a decision tree with selected criteria and accounting for existing studies. Why should it be selective? Not all applications need to have a full socio-economic analysis, just like for environmental and health risk, the requirements should be proportional to risks. For instance, a new variety of Bt cotton hybrid with the same gene as others should not trigger a specific additional assessment. The use of a GM plant for non-food purposes (like cotton), not subject to regulations worldwide, should not prompt an export risk analysis. The stacking of two approved traits, that have passed the socio-economic test, should not be required to face another one.

The specificity of the decision tree would have to be decided, but it could be set up as a set of dichotomous questions that could be answered directly by yes or no, leading to a particular opinion. For instance, Figure 2 presents a suggested way to assess potential

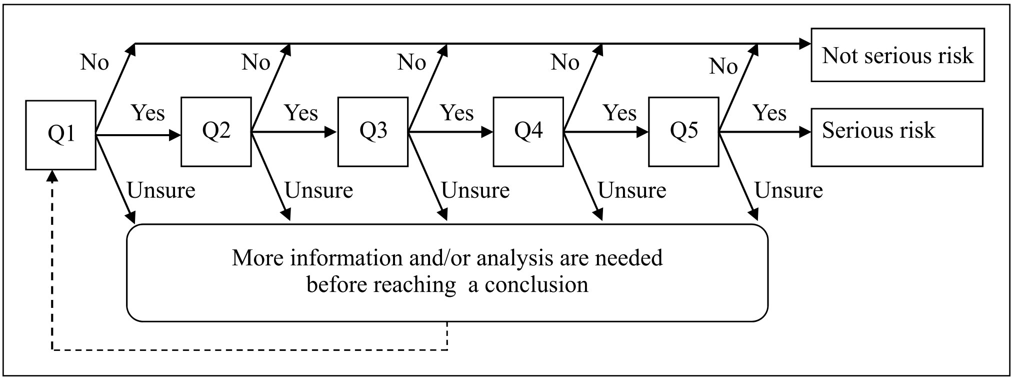

Fig- 2 : Example of decision tree in the case of a market risk assessment

Notes: Q1. Is the alleged risk substantiated? Q2. Are export losses likely with the decision? Q3. Are presumed export losses non-negligible for the country? Q4. Is the risk unavoidable? Q5. Is the risk greater than the benefits?

Source: Gruere and Sengupta (2009)

market risk. Five questions (Q1 to Q5) are suggested, all requesting a yes/no answer, or more information. A no answer to one question suffices to determine no risk. If more information was needed to respond to one of the questions, a rapid or more thorough economic assessment could be requested. This model would have to be adapted to other questions, but could help provide a relatively rapid determination of risk, with information requested only if necessary and not present in the general application.

As to the specific modalities, the assessors would preferably be researchers, either inside the new regulatory agency or outside (university or public research institute). In either case, a minimum expertise would be needed inside the agency to apply the decision tree. The specific content of the analysis would be determined by the assessors, within a well defined framework, with clear limitations: with a scope and assigned time limit. Depending on the crop or product, the assessment could be done at the pre-release stage when the crop is being field tested on a small scale, but it all depends on variability in the crop productivity effect- whereby small-scale trial data (as in the case of brinjal) could be sufficient.

At the same time, several participants in our meetings supported the idea of introducing official post-release socio-economic assessments at the national level. Currently, there is no post release requirement in India, and while there have been academic and official studies, a more systematic exercise would be useful and provide more robust results than small surveys. Furthermore, such assessments would also help increase confidence in the population. For instance, post release assessment of Bt cotton could help confirm that in Punjab, Bt cotton has resulted in an increase in the population of honeybees, which is a positive indirect impact/externality. Other indirect impacts could be measured, especially those related to production and consumption externalities.

As for the utility of the assessment, meeting participants noted that the findings would not necessarily be all taken into account but that it would support better decision making in the relevant cases. Regulatory assessors tend to only look at scenarios; decision making remains a political process – as noted by a participant: "*they may ignore the result of the assessment but its mere existence will influence the quality of decision*". Socioeconomic assessments made by independent bodies may or may not be used by the decision makers but at least the information would be available. In the case of India, the story of Bt cotton shows that in the absence of such assessment, farmers can make their own assessment and obtain the technology if they find it beneficial. Ultimately, the issues that are not assessed, like market externalities, (that were ignored in the past) "*will always come back to the table of decision makers*", so addressing them in an analytical framework before they occur is better than rapidly responding to an emergency.

DEFINING SOCIO-ECONOMIC ASSESSMENT

Ex-ante Economic Analysis

It is generally agreed that the primary objective of a socio-economic assessment should be to determine the expected magnitude and distribution of the benefits and potential costs associated with the commercialization or use of a new GM crop. The analysis also helps in understanding the potential technology diffusion pathways. The primary target of the analysis should be the producers and consumers and what they can expect from the technology. Specific non-economic effects and effects on non-users (externalities) could also be relevant to specific cases.

There are, however, many different methods available for assessing a new technology, which can also be applied to GM crop. Here we will focus on methodologies for ex-ante assessment of economic effects that will likely be the first type of studies used as part of a regulatory framework. Smale *et al.* (2009) conducted a comprehensive review of the applied economic literature on socio-economic assessment of transgenic crops in developing countries, and they identified three main methods for ex-ante evaluation: partial budgeting (farm level analysis), economic surplus analysis (sector level) and trade simulation (international sector or economy wide analysis). Each of these methods has specific advantages and drawbacks; here we briefly review their relevance in the context of supporting decision making process.

The partial budgeting method has the advantage of providing a simple but realistic evaluation of the expected effect of a technology at the farm level. It does require production survey data, which may be costly to collect at a larger scale, as well as assumed productivity effects with the new technology (which may be coming from trials). This approach is used by U.S. EPA in its risk-benefit evaluation. If carried out properly with a well-designed sample, it can provide some useful data on the distribution of expected benefits from adopting the technology. On the other hand, the analysis is not completely rigorous; it may suffer from various statistical biases, and does not provide an accurate measure of the net effect of the technology (Smale *et al.* 2009). Survey approaches, such as estimation of demand for the new technology can complement the partial budgeting analysis, as done by Krishna and Qaim (2008) in the case of Bt eggplant.

The economic surplus analysis goes one step further by simulating the effects of the new technology on the sector, using farm survey data for calibration and assumptions on the productivity shock, the cost of technology, the adoption pattern, and demand. Several examples can be found in Ramasamy *et al.* (2007) in the case of new GM technologies in India. The approach uses an equilibrium displacement model, as fully explained in Alston *et al.* (1995). It provides a valid representation of a supply shift with some flexibility and can capture the effects of commercialization for producers, consumers and innovators. Some assumptions, particularly the productivity shock, price of the new seeds and the supply elasticity assumption are critical to the results and largely determine the scope of the total benefits (usually taken around 1). One way to cope with uncertainties around these parameters is to use stochastic parameters, where specified probability distribution of each key parameter is entered in the model. This more robust approach provides a distribution of potential gains or losses for each of the actors concerned. Different scenarios can also be used to model adoption, potential foreign competition, imperfect competition in the seed sector, or the effect of biosafety and marketing regulations. Of the three approaches, this may be the most flexible and provide informative results for policy makers on the scale and distribution of benefits as well as the probability of net losses.

Trade analysis can also be done in complement, on a case-by-case basis (e.g. following the decision tree in Figure 1) if there are potential export risks (Gruere, 2014). Three different approaches can be used; a descriptive assessment of export risks, trade simulations in a partial equilibrium framework and multi-country, multi-sector computable general equilibrium analysis (Smale *et al.* 2009). The first approach is the fastest and simplest; it requires collecting and sorting export data by destination countries and provides a share of export volume or value potentially facing regulatory challenges if a GM crop is commercialized. Paarlberg (2006) uses this simplified approach to show that selected Sub-Saharan African countries do not face much risk of losing exports to Europe.[4] Of course, evaluating trade risk based on past data may provide a misleading assessment of what would happen if a GM crop is produced. Simulation models (in the sector and economy-wide) can go one step further by including other countries as destinations, competitors and additional regulatory complexities to model the price and welfare effects of adopting a GM crop under various scenarios. The opportunity cost of non-adoption can be evaluated and the maximum price of segregation can also be assessed. But these models do require sophisticated modelling tools and some relatively strong assumptions on the market and the technology.

Additional features can be added to the assessment. First, the distributional effects in terms of equity can be added in complement to a survey based study. A market chain analysis is sometimes necessary as a complement to the trade and market component

[4] Gruere and Sengupta (2010) use a more comprehensive sorting to determine the share of South Africa's past GM product imports and exports, using GM adoption and regulations to sort out volumes by product and year.

to identify any potential issue for market actors and intermediaries and assess whether there will be any consumer effects (e.g., see Figure 3). An institutional analysis can help identify key actors and institutions, their roles, constraints and opportunities (e.g., Horna *et al* 2009). And last but not the least, an analysis of non-market effects, such as the environmental and health effects can also be entered into account, based on collected and secondary data. This last type of economic analysis, however, may be more challenging and still require some methodological refinements. However, some information based on farm survey on reduction in practices and inputs which are detrimental to environment and human health could be useful in providing these impacts.

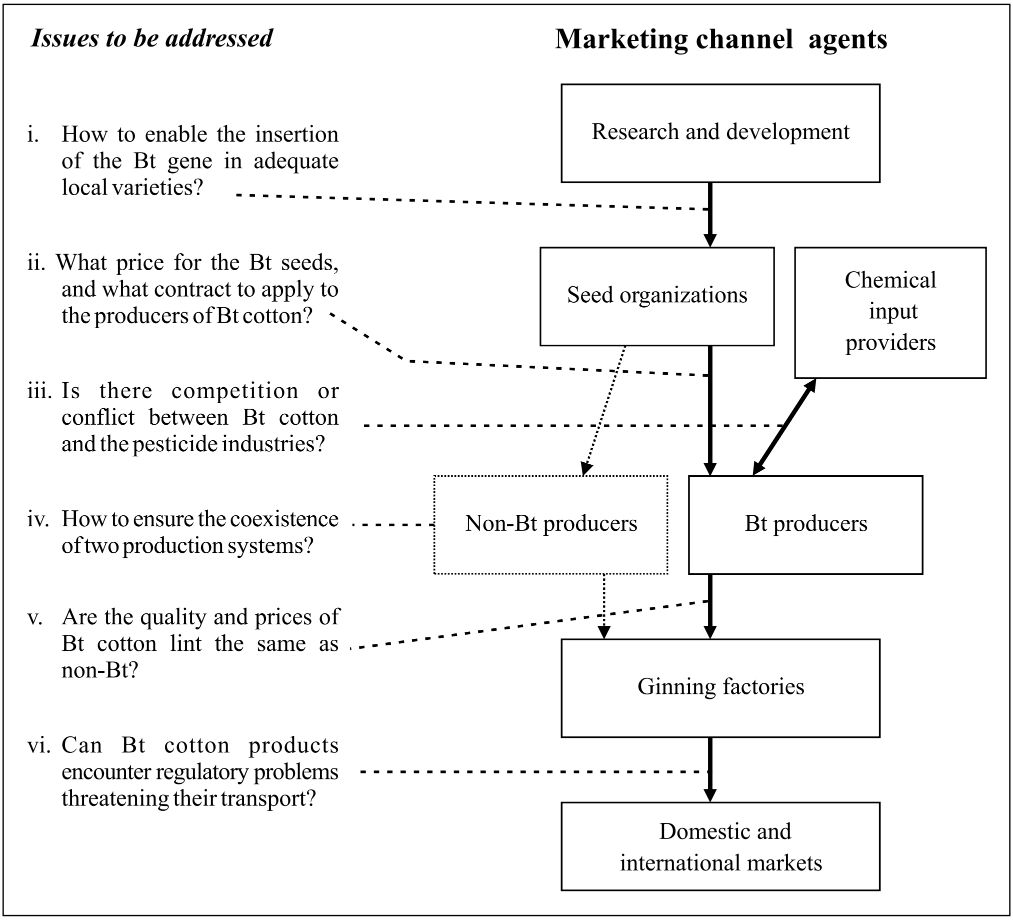

Fig. 3 : Example of market chain analysis: key issues with the introduction of Bt cotton in West Africa

Source: Gruere and Cartel (2006)

Discussion

In the choice of approaches, three key constraints should be accounted for. First, the total time and staffing required for analysis, as socio-economic assessment should not delay a decision unnecessarily nor be too costly. Second, the data requirements do differ, and while survey based data may be needed for analysis, the collection may not have to cover all states or agricultural zones- choosing the right target will be necessary to cope with budgetary and time constraints. More generally, information requirements highly depend on the crop. For certain crops, like cotton, wheat, rice, a lot of information is available; for others, like brinjal, there is a need to collect basic data. Third, the analytical and modelling capacity of the assessors differs across approaches. A full scale computable general equilibrium would require specific skills and modelling tools that may not be available when needed.

Lessons can be drawn on the value of different approaches based on past ex-ante studies. Smale *et al.* (2009) have argued that in some cases, ex-post benefits were found to be lower than ex-ante estimate based on field trials, because field trials do not represent real situation. At the same time, in the case of Bt cotton in India, some of the meeting participants argued that the first published ex-ante studies underestimates the real economic effects observed after commercialization, notably because of factors that were not accounted for (such as the rapid adoption of hybrids in parallel to Bt cotton commercialization).

Several important economic aspects have been neglected in the past studies. Institutional factors influencing the spread of technology and economic benefits have often been less studied despite their importance in the ultimate success of GM technologies. For instance, Tripp (2009) provides a comprehensive review of key institutional issues that largely determine the success or failure of GM cotton in developing countries. There is also an imbalanced focus between aggregate benefits and micro-farm realities-- the use of surplus approach does not provide a complete assessment of the constraints at the farm level. Furthermore, sometimes non-market benefits are more important than measurable productivity gains, e.g. ease of weed management in herbicide tolerant GM crops. A participant noted that evaluating farmer benefits is a straight-forward exercise, the contentious and more challenging issues relate to externalities that increasingly matter. For instance issues related to biodiversity, while debated in the case of Bt brinjal have not been analyzed properly.

Meeting participants noted the importance of following a holistic approach when assessing a new GM crop and the challenges associated with it. Companies do have sufficient information to conduct their own assessments. Regulators need to define what should be included in socio-economic assessment; it would be good if such assessments included dataset requirements integrating every aspect of the relevant issues.

ECONOMIC IMPLICATIONS OF SOCIO-ECONOMIC ASSESSMENTS

As noted in the introduction, well designed socio-economic assessments can be beneficial and support better informed biosafety decisions. They can objectively provide benefit and cost assessments, and let policy makers weigh these factors in their decisions to approve, release or reject a specific GM application. They can provide useful lessons that may help avoid future problems and suggest management practices to reduce any potential problems. They will support economically beneficial technologies and can also pave the way for other potentially useful technologies.

On the other hand, they can also add to the total cost of biosafety regulation for any new technology. Several studies have shown that biosafety regulations have a significant cost (e.g., see Pray *et al.* (2006) for China and India). If socio-economic assessments were to be added, they could add more cost for applicants, thereby creating another hurdle that would be most detrimental for small companies or public research institutions willing to submit an application.[5] If these assessments were funded by public agencies, it would also bear a cost for tax payers. But perhaps more importantly, adding socio-economic assessment would result in the possible increase in delay for approval, with large opportunity costs for farmers. For example, Bayer *et al.* (2010) showed that a one year delayed approval for four GM technologies in the Philippines would reduce the net present of benefits more than multiplying the cost of applications by five. Any delay of a useful technology will result in irreversible foregone benefits for farmers potential consumers and the environment.[6] Naturally, this presumes that technology would be successful and there is no uncertainty associated with adoption or acceptance of technology.

In this context, the following three recommendations would help increase the benefit-cost ratio of socio-economic assessment, assuming it is requested for at least certain types of GM technology.

- First, as noted above, the regulations should set clear limits to the scope and time of the study (including possible refinements).
- Second, the assessment should be conducted at an advanced stage of field trials rather than at the end of risk assessment to avoid any delay.
- Third, the assessment should not just provide quantitative economic estimates but rather include key constructive recommendations for sustainable use of the technology.

[5] For a discussion on industry consolidation and regulations, see Heisey and Schimmelpfennig (2006).

[6] For instance, based on the results of Krishna and Qaim (2008), the delay in approval of Bt brinjal in India will cost approximately $108 million per year, with an additional $3-4 million of foregone health benefits for the farmers and much more if one included consumers and the environment (less pesticides).

CONCLUSIONS

In this chapter, we discussed the need for and the modalities and consequences of including formal socio-economic assessment as part of biosafety regulatory systems, with relevance to developing countries like India for possible adaptation in its upcoming new regulatory framework. Our rapid review of the major principles governing biosafety regulations underlined the importance of scientific assessment as a basis for any analytical argument. Thus, socio-economic assessment, if included in decision making, would have to follow rigorous scientific practices.

Our analysis of existing regulations, with support from the literature and expert solicitation, help us identify a few key features of socio-economic assessment. First, such assessment can take place at the rule making level and/or decision making stage, and it appears that a mix of the two may be the most useful for effective regulations. Second, at the decision making level, socio-economic assessment can be beneficial but is not always necessary. We found a consensus of meeting participants around the need to have a focused and well designed socio-economic assessment with well communicated results that include issues related to externalities, on a case-by-case basis. There is a need to set up criteria (decision tree) for the regulatory agency to determine when an analysis is needed and when it is not, accounting for existing information. At the same time, if undefined or too broad, an assessment can become significantly costly; the priority then should be to focus on addressing key questions within a well defined timeline. Third, including socio-economic assessment requires capacity and expertise; and a minimum knowledge within the regulatory agency to apply the decision tree criteria, with more advanced analysis outsourced to research institutes, if needed.

The specific modalities of the assessment still need to be refined; our consultation and literature review only provide a few suggestions for when, where and how it could take place. While the study could be made outside of the regulatory body, it would serve as additional information to the decision makers. To ensure a timely delivery and no delay in the approval process, the assessment may be better placed in parallel with the risk assessment. Our brief review of applied economic methods to assess a new GM crop application before its release (provided it is needed) suggests that the most flexible approach seems to be a survey based economic surplus model, with stochastic parameters, distributional effects and potential additional features as needed (trade and market analysis, estimate of positive and negative externality).

Lastly, an independent, government led monitoring of GM crops in the field (post release) would be very useful, as it could provide an independent reporting of what effects these crops have in the fields. This would complement academic studies, ideally with a larger dataset, and would help in providing some objectivity to the debate around

GM crops that tends to be polarized and often does not reflect what effects these crops actually have.

REFERENCES

Alston, Julian M. George W. Norton, and Philip G. Pardey (1995): *Science under Scarcity: Principles and Practice for Agricultural Research Evaluation and Priority Setting*, Ithaca, New York: Cornell University Press.

Bayer, J.C., G.W. Norton, J. Falck-Zepeda (2010): Cost of compliance with biotechnology regulation in the Philippines: Implications for developing countries. *AgBioForum*, *13*(1): 53-62.

Berwald, D., S. Matten, and D. Widawski. (2006) “Economic analysis and regulating pesticide biotechnology at the U.S. Environmental Protection Agency” in Just, R.E., Alston, J.M, and D. Zilberman (eds), *Regulating Agricultural Biotechnology: Economics and Policy*, New York, NY: Springer.

Carter, C.A. and G. Gruere (2012), New and Existing GM Crops: In Search of Effective Stewardship and Coexistence. *Northeastern University Law Journal*, 4(1):169-207.

Falck-Zepeda, J.B. (2009), Socio-economic considerations, Article 26.1 of the Cartagena Protocol on Biosafety: What are the issues and what is at stake? *AgBioForum*, *12*(1): 90-107.

Falck-Zepeda, J.B., Ludlow, K., and S.J. Smyth. (2014), International context of socioeconomic considerations and the regulation of genetically modified organisms. In Ludlow, K., Smyth, S. and J. Falck-Zepeda (eds), *Socio-Economic Considerations in Biotechnology Regulations*. New York: Springer.

Fransen, L., A. La Vina, F. Dayrit, L. Gatlabayan, D.A. Santosa, S. Adiwibowo (2005), Integrating socio-economic considerations into biosafety decisions: The role of public participation. WRI White Paper. Washington, DC: World Resources Institute (WRI).

Gruere, G.P. (2014), National Trade Interests. In Ludlow, K., Smyth, S. and J. Falck-Zepeda (eds), *Socio-Economic Considerations in Biotechnology Regulations*. New York: Springer.

Gruere, G.P., and M. Cartel (2006), Trading hot potato from farm to port: the case of Bt cotton in West Africa. Selected paper presented at the 2006 Winter meeting of the International Agricultural Trade Research Consortium.

Gruere, G.P. and D. Sengupta (2009), Biosafety and perceived commercial risks: The role of GM free private standards. IFPRI Discussion Paper 00847. Washington, DC: International Food Policy Research Institute.

Gruere, G.P., and D. Sengupta. (2010), Reviewing South Africa's marketing and trade related policies for genetically modified products. *Development Southern Africa,* 27(3):333-352.

Gruere, G.P. and D. Sengupta. (2011), Bt cotton and farmer suicides in India: an evidence-based assessment. *Journal of Development Studies,* 47(2):316-337.

Heisey, P., and D. Schimmelpfennig (2006), "Regulation and the structure of biotechnology industries" in Just, R.E., J.M. Alston, and D. Zilberman (eds), *Regulating Agricultural Biotechnology: Economics and Policy*. New York, NY: Springer.

Herring, R (2009), Persistent narratives: Why is the "failure of Bt cotton in India" story still with us?. *AgBioForum*, *12*(1): 14-22.

Horna, D., P. Zambrano, J. Falck-Zepeda, T. Sengooba, G. Gruère, M. Kyotalimye, E. Schiffer (2009), *Assessing the Potential Economic Impact of Genetically Modified Cotton in Uganda*. Program for Biosafety Systems report, April 2009. Washington, DC: IFPRI.

Krishna, V.V. and M. Qaim (2008), Potential impacts of Bt eggplant on economic surplus and farmers' health in India. *Agricultural Economics*, 38(2) :167 -180.

Ludlow, K., Smyth, S. and J. Falck-Zepeda (eds). (2014), *Socio-Economic Considerations in Biotechnology Regulations*. New York: Springer.

Paarlberg, R.L (2006), Are genetically modified (GM) crops a commercial risk for Africa? *International Journal of Technology and Globalisation,* 2 (1): 81-92.

Pray, C.E., J. Huang, R. Hu, and Q. Wang (2006), "Benefits and costs of biosafety regulation in India and China" in Just, R.E., J.M Alston, and D. Zilberman (eds), *Regulating Agricultural Biotechnology: Economics and Policy*. New York, NY: Springer.

Ramasamy, G., K.N. Selvaraj, G.W. Norton, and K. Vijayaraghavan (2007), *Economic and Environmental Benefits and Costs of Transgenic Crops: Ex-ante Assessment*. Coimbatore, India: Tamil Nadu Agricultural University.

Ramesh, J. (2010), Decision on commercialization of Bt brinjal. Ministry of Environment and Forests. February 9th 2010.

Secretariat of the Convention on Biodiversity (2010), Socio-economic considerations. Factsheet for the Protocol on Biosafety. https://www.cbd.int/doc/publications/cpb/sec.pdf

Smale, M., G.P. Gruere, J. Falck-Zepeda, A. Bouet, D. Horna, M. Cartel, and P. Zambrano (2006), *Assessing the Potential Economic Impact of Bt Cotton in West Africa: Preliminary Finding and Elements of a Proposed Methodology.* Final report to the World Bank. 160p.

Smale, M., P. Zambrano, , G.Gruere, J. Falck-Zepeda, I. Matuschke, D. Horna, L. Nagarajan, I. Yerramareddy, and H. Jones (2009): *Impacts of Transgenic Crops in Developing Countries during the First Decade: Approaches, Findings, and Future Directions*. IFPRI Food Policy Review 10. Washington DC: International Food Policy Research Institute.

Tripp, R. (2009), *Biotechnology and Agricultural Development: Transgenic cotton, rural institutions and resource-poor farmers.* Oxon, UK: Routledge.

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APPENDIX

List of institutions, whose members participated to our consultations (in alphabetical order): Biotech Consortium India Limited, Biotech Industry Organization, Cornell University, Center for Maize and Wheat Improvement (CIMMYT) India, Food and Drug Administration, Oxfam America, Indian Agricultural Research Institute, Indian Statistical Institute, International Life Science Institute, International Food Policy Research Institute, International Service for the Acquisition of Agri-biotech Applications (ISAAA) South Asia Office, Jawaharlal University, Rutgers University, United States Agency for International Development (USAID Washington and New Delhi), United States Department of Agriculture (USDA) -Animal and Plant Health Inspection Service, USDA -Economic Research Service, USDA- Foreign Agricultural Service (Washington and New Delhi), United States Environmental Protection Agency, Virginia Tech University, The World Bank.

Chapter 8

RECENT PRODUCTIVITY TRENDS AND IMPACT OF TECHNOLOGY IN THE RICE-WHEAT SYSTEM OF THE INDO-GANGETIC PLAINS

Shaloo Punia, P Anbukkani and Suresh Pal

INTRODUCTION

Evolution of the rice-wheat cropping system (RWS) in the Indo-Gangetic Plains represents, in a way, the path of agricultural development in South Asia. Although this system has been practiced since the 16^{th} century, it spread widely with the expansion of canal and tube well irrigation during the 1960s and 1970s (Woodhead *et al.,* 1994). Availability of high-yielding varieties (HYVs) of rice and wheat has further expanded the area under RWS, ushering the Green Revolution. Eventually, the system emerged as one of the most widespread, intensively cultivated and extremely important for food security and agricultural prosperity of the region. It is estimated that RWS is followed on more than 14 million hectares of agricultural lands and nearly two-thirds of the existing cereal supplies of the region comes from this system.

Recent literature indicates that RWS in the Indo-Gangetic Plains is now facing a number of stresses. The growth in crop yields in the north-western plains of India (Punjab, Haryana and western Uttar Pradesh) is decelerating, and the system intensification is putting pressure on land, water resources and environment. Micro-level parameters like properties and fertility of soil, pest infestations, nutrient balance, etc. indicate a deteriorating trend (Timsinha and Connor, 2001; Chauhan *et al,* 2012), while trends in the macro indicators like groundwater exploitation and total factor productivity are also a cause of worry. A similar tendency is appearing in other parts as well. The immediate consequence of these changes is reported to be a threat to long-term sustainability of the system (Paroda *et al.,* 1993; Byerlee 1992; Fujisaka *et al* 1994; Hobbs, 2007). These undesirable trends are further compounded with the challenges of climate change, which may reduce the agricultural gross domestic product by 4-5 per cent and crop yield to the extent of 30 per cent (World Bank, 2010). There is apprehension that food security of the region may be under pressure if these undesirable trends are not corrected in time through suitable technological and policy interventions.

The national and international research organizations and donors have made concerted efforts to improve productivity and environmental sustainability of RWS. Integration of research efforts of the CGIAR Centres and the national agricultural research systems in the region, and mobilization of additional resources from international donors have been attempted through several programs and research consortia. In terms of research focus, major thrust areas pursued were development of high yielding and stress tolerant varieties of rice and wheat, tillage and crop residue management, weed control, reclamation of salt-affected lands and water and nutrient management. Small-scale mechanization, system diversification, analysis of socio-economic issues and on-farm experimentations and field demonstrations also received considerable attention (Hobbs *et al.,* 2000, RWC 2004). These programmes resulted in several important outcomes. In particular, resource conservation technologies (RCT) like zero and reduced tillage made significant impact (Vijaylaxmi *et al,* 2007, and Erenstein *et al,* 2008). Considerable work is in progress on water-saving methods of rice cultivation but these are yet to make some impact on farmers' fields. There has been significant progress in terms of development and spread of rice and wheat varieties, especially superfine rice. This study analyses adoption and impacts of these plant varieties and resource management practices. The chapter specifically deals with recent trends in RWS, and adoption and economic impacts of new varieties and RCTs. Empirical evidences are however confined to the Indian region of IGP.

AGRICULTURAL DEVELOPMENT

The RWS in India is largely practiced in the states of Uttar Pradesh (UP), Punjab, Haryana, Bihar, and some parts of Madhya Pradesh (MP) and West Bengal. However, much of the RWS area is concentrated in the states of UP, Punjab, Haryana and Bihar. Stability of the area under RWS or even expansion, wherever possible, indicates that rice and wheat crops still enjoy superiority over other crops, both in terms of economic returns and their stability. Infrastructure, market and price policy also favor rice and wheat crops, resulting in widespread cultivation of the system and expansion of market operations of the governments (Chand and Pal, 2003).

The states practicing RWS are primarily agrarian states. The share of agriculture in the state gross domestic product is higher than the national average of 14 per cent in 2013. In Punjab, agriculture's share is as high as 20 per cent and it is 20 per cent in UP. In terms of area, these four states contribute nearly 30 million hectare to the total land area of 140 million hectare. The RWS area in India is about 10 million hectare and nearly half of this is in Uttar Pradesh. Adding Bihar, these two states occupy nearly 70 per cent of the total RWS area in the country.

However, crop productivity is low and combined yield of rice and wheat is about 5 tonnes/ha in these states in 2013. This is against 8 tonnes/ha in Haryana and 9 tonne/ha in Punjab (Table 1). Thus, RWS in India can easily be characterized into the high productivity region of Punjab and Haryana and the low productivity region of UP (eastern part), Bihar and other eastern region. The eastern region, with high rainfall, is primarily rice growing region and the yield is now picking up. Another significant characteristic of agriculture in the low productivity region is that it is primarily smallholder agriculture. The current official statistics indicate that average size of holding is less than one hectare in UP and Bihar, whereas it is 2.2 ha in Haryana and 3.8 ha in Punjab, because of outmigration of population and changes in agrarian structure through consolidation of holdings and reverse tenancy. Infrastructure development like irrigation and input use also echo these two diverse development trends.

Table 1 : Agricultural development indicators in the major states

Particulars	Punjab		Haryana		UP		Bihar		All India	
	2001	2013	2001	2013	2001	2013	2001	2013	2001	2013
Share of Ag GDP in GSDP (%)	39.8	19.67	26.40	14.12	33.20	20.18	35.10	16.54	20.00	13.68
Annual growth (%) of Ag GDP (2006-12)	1.77		4.26		2.94		5.33		3.54	
Net sown area (M. ha)	4.30	4.10	3.52	3.50	17.62	16.50	5.66	5.40	141	140
Gross cropped area (M. ha)	8	7.8	6	6.4	25	25.8	8	7.7	187	194
Share (%) of small farmers (< 2 ha) in cropped area	30	34	65	68	91	92	93	97	82	85
Ave. size of holding (ha)	3.95	3.77	2.32	2.25	0.84	0.76	0.56	0.39	1.33	1.17
NPK use (Kg/ha)	163	249	151	208	110	180	99	199	91	130
Share of tube wells in irrigated area (%)	74	73	50	58	72	72	62	69	41	46
RiceYield (t/ha)	3.50	4.00	2.55	3.27	1.97	2.46	1.48	2.28	1.9	2.4
Wheat Yield (t/ha)	4.56	4.72	4.10	4.45	2.72	3.11	2.14	2.43	2.7	3.1

The sources of growth in output also show a distinct pattern. The growth in the total factor productivity (TFP) contributed about one-third to output growth in the Trans-Gangetic Plains of Punjab and Haryana, and the rest was contributed by the growth in inputs and area since 1980s. This trend was observed a bit later, in the 1990s, in UP and Bihar. The decomposition of growth in TFP showed that investment in agricultural R&D was the major source of growth in TFP (Kumar, 2004). This implies that, when the hope of output growth in future is pinned on the productivity growth, agricultural R&D should aim to provide technological solutions for binding production constraints of the system. Important among these are depleting ground water, increasing cost of cultivation, weed infestation and deteriorating soil health.

CROP PRODUCTIVITY TRENDS

Trends in the yields of rice and wheat in the region since 1980s are shown in Table 2. This table clearly shows that there has been a slowdown in the yields growth for both the crops in Haryana and Punjab. The yield growth was even negative for rice in Haryana during 1990s mainly because of expansion of area under basmati rice. Rice yield however accelerated moderately in both the states in 2000s due to spread of high yielding superfine varieties. Both Punjab and Haryana also showed high rates of growth in rice area during 1980s and 1990s, which continued in Haryana even in 2000s. In 1990s, the yield growth was comparatively better in UP and Bihar, even comparable to that in 1980s, except rice in UP, mainly due to spread of the green revolution technologies during this period in these states. Wheat yield grew one to one-and-a-half per cent in all the states in 2000s. The slowdown of rice yield was more pronounced during 2000s, except in Bihar where it grew at 2.5 per cent per annum. This stagnation or slowdown of crop yield is a cause of concern. There are factors responsible for this, but low input use due to inadequate infrastructure, non-dependable source of irrigation and low seed replacement rate have largely constrained the crop yields (Roy and Datta, 2000). This is well reflected in the yield gap (Table 3). Except Punjab and Haryana, where yield gap is almost non-existent, rice yield can be increased by one-third of the current yield levels in the eastern part of IGP. The same holds true for wheat yield. UP and Bihar, covering most of the IGP area have the high yield gap, and therefore efforts for large scale transfer of technology, along with assured input supply, will result in substantial yield gains. The Government has a major thrust for bringing green revolution in the eastern region. The program entails dissemination of new technology, increasing input supply and strengthening R&D capacity. These efforts should be backed by development of market infrastructure, rural electrification and development of tube well irrigation and farm mechanization in the region.

Table 2 : Trends in the growth (%) of area and yield of rice and wheat in the major states

	Punjab	Haryana	UP	Bihar	All India
Rice area growth					
1980-1990	5.39	2.40	0.03	0.25	0.41
1990-2000	2.48	6.12	0.81	0.14	0.68
2000-2014	1.01	3.52	0.15	-1.03	-0.02
Rice yield growth					
1980-1990	1.28	-0.15	5.65	3.87	3.19
1990-2000	0.02	-1.64	2.21	4.76	1.34
2000-2014	0.29	0.84	1.67	2.50	1.96
Wheat area growth					
1980-1990	1.26	1.94	0.86	2.32	0.46
1990-2000	0.27	2.24	0.91	0.95	1.72
2000-2014	0.29	0.96	0.62	0.18	1.43
Wheat yield growth					
1980-1990	3.00	4.06	2.87	2.50	3.10
1990-2000	1.98	1.51	2.24	2.56	1.83
2000-2014	0.97	1.47	1.44	1.55	1.35

Table 3 : Potential for increase in yields of rice and wheat with improved practices, 2010-11

State	Rice yield (q/ha)		Increase in yield (%)	Wheat yield (q/ha)		Increase in yield (%)
	Demon-stration	Local check		Demon-stration	Local check	
Bihar	39.35	29.68	32.58	36.07	26.96	33.79
Haryana	40.15	37.40	7.35	48.44	45.69	6.02
Punjab	57.95	56.55	2.48	47.50	43.55	9.07
UP	44.60	36.24	23.07	42.37	35.05	20.88
Average yield (India)	45.18	36.64	23.32	38.06	30.03	22.66

Source: Division of Agricultural Extension, ICAR.

A complete picture of trends in inputs and crop yields is best given by total factor productivity (TFP), which is often used, along with other indicators, to assess sustainability of a production system. The study of the growth in input and output indices and TFP in the Indo-Gangetic Plains since 1981 reveals that the growth has slowed down during the 1990s as compared to that in the 1980s. Overall, the growth rate of TFP during 1981-96 has been around one per cent in the plains of Punjab, Haryana and south Bihar, and it is slightly lower than one per cent in other parts of Bihar. It is a matter of concern that TFP growth is either negative or stagnant on about 35 per cent of the entire RWS area, and on another 12 per cent of the area, TFP growth is less than one per cent (Kumar, 2002). These trends are quite alarming, and efforts are being made to provide technological solutions to increase input use efficiency, reduce cost of cultivation and enhance sustainability of land and water resources. RCTs conservation technologies like zero-tillage have shown considerable success in this regard and some others like aerobic or dry seeded rice and laser land levelling are in the stage of on-farm experimentation and initial adoption. The experience of zero-tillage can be used to target these technologies and accelerate their adoption. These efforts have paid dividends in terms of growth in total factor productivity. Although no recent estimates are available for various crops, the sector analysis indicates significant improvement in TFP growth during post-2003 period and a large part of this growth was attributed to livestock and horticulture. For the rice-wheat states, TFP growth for major crops during post-2003 has been much higher than that estimated during 1980s and 1990s. The TFP growth was 3-5 per cent in Bihar, Haryana and Punjab and 1.1 per cent in UP during 2003-2008. Part of this growth could be attributed to maize in Bihar and cotton in Haryana and Punjab, but rice and wheat have also witnessed TFP growth. The major sources of this TFP growth were public investment, governance and institutions, diversification and most important, technological change (World Bank, 2014 and Fuglie, 2012). Thus, the rice-wheat system has been experiencing some technological changes which, along with irrigation expansion and other infrastructure development, have contributed to TFP growth. Investment in these sources of growth must be sustained.

VARIETY DEVELOPMENT

The research institutions of the Indian Council of Agricultural Research (ICAR) and the State Agricultural Universities (SAUs) have plant breeding programs for all the crops; but these started quite early for wheat and rice and they have close collaboration with CIMMYT and IRRI, respectively. The breeding efforts are coordinated by the All India Coordinated Crop Improvement Program for respective crops. Crop varieties developed under these programs are evaluated and those found superior to the existing varieties are released and notified by the government for seed multiplication and distribution. The trends in the number of varieties developed and notified for rice and wheat in the country are given in Table 4. As evident from this table, there is an increasing trend in the number of varieties developed over time, with the number of rice and wheat varieties developed during the last decade being much higher. During 2001-14, 114 varieties of wheat and 338 varieties of rice were developed and notified, which are much higher than those developed during 1990s or 1980s. For rice, there are other notable developments in breeding, like development of hybrids and doubling of yield of basmati rice. Also, a higher proportion of the varieties developed during the later period have better grain quality and tolerance to biotic and abiotic stresses. In particular, there is increase in the number of superfine rice varieties during the last two decades or so. The share of varieties tolerance to biotic stress and shorter in-crop duration have also increased significantly. The varieties developed for irrigated conditions can be grown in RWS; their share in the total varieties developed during the last decade is 29.5 per cent for rice and 40 per cent for wheat.

Table 4 : Trends in varietal development of rice and wheat

	1981-1990	1991-2000	2001-2014
Wheat			
Number of varieties developed	65	67	114
Varieties for North-East Plains (%)	24.61	29.85	21.05
Varieties for North-West Plains (%)	49.23	31.34	39.47
Varieties for Northern Hills (%)	7.69	17.91	15.78
Varieties for Central Plains (%)	18.46	20.89	23.68
Varieties tolerant to diseases/pests (%)	66.66	85.71	93.33
Short to medium duration varieties (%)	73.68	82.85	94.33
Rice			
Number of varieties developed	171	212	338
Varieties with fine grain (%)	33.10	36.60	45.12
Varieties tolerant to diseases (%)	62.32	69.26	73.45
Varieties tolerance to insect pests (%)	45.67	58.18	69.64
Varieties for marginal areas (%)	38.25	21.20	14.36
Varieties of short to medium duration (%)	64.43	68.14	80.15

Source: compiled from various sources, IIWR (Karnal), IIRR (Hyderabad).

The State Seeds Corporations, public seed agencies and private seed companies sell seed of rice and wheat in the region. However, the presence of private sector in rice seed is stronger and its share in total seed supply varied from 48 per cent in UP to 81 per cent in Punjab. In the case of wheat, private sector's share is comparatively low and it varies from 25 per cent in Bihar to 59 per cent in Haryana (Table 5). It is interesting to note that most of the farmers use quality seed while the share of farm-saved seed was moderate, ranging from 15 to 27 percent. Most of the farmers buy seed from private dealers, who also sell seed produced by public agencies. The proportion of farmers buying seed from the public agencies is comparatively higher in Punjab and Haryana (Table 6). Thus, private dealers could play an important role in popularization of improved varieties and increasing farmers' access to quality seed.

Table 5 : Variety concentration and share of new varieties in commercial seed sale of rice and wheat, 2010

Particulars	Punjab	Haryana	UP	Bihar
Rice				
Total seed sale ('000 q)	226	166	35	232
Share of private seed (%)	81	67	48	58
Share (%) of new varieties released after 2000	70	45	46	40
Share of top one variety (%)	21	14	20	36
Share of top two varieties (%)	38	26	40	45
Share of top three varieties (%)	53	36	56	53
Wheat				
Total seed sale ('000 q)	1259	1157	1031	672
Share of private seed (%)	48	59	52	25
Share (%) of new varieties released after 2000	35	63	41	27
Share of top one variety (%)	59	32	34	47
Share of top two varieties (%)	77	60	66	63
Share of top three varieties (%)	83	76	87	76

Source: Based on seed sale data compiled from respective state governments.

Table 6 : Sources of seed purchased by farmers, 2011-12

State	Crop	Sources of seed (%)			Farm saved
		Private	Public agencies	Others	
UP	Rice	56	20	7	17
	Wheat	65	12	4	19
Punjab	Rice	54	23	5	18
	Wheat	40	28	5	27
Haryana	Rice	45	30	10	15
	Wheat	51	26	7	16

Source: based on farm survey.

Table 5 also shows some degree of variety concentration in seed sale and the concentration is much stronger in wheat. The share of top one variety is 32-59 per cent in wheat, which further rises to more than two-thirds if the share of top two varieties is taken. The share of top three wheat varieties was as high 76 per cent in Haryana and Bihar, 83 per cent in Punjab and 87 per cent in UP. The share of top three varieties of rice varied from 36 per cent in Haryana to 56 per cent in UP. In case of rice, the share of top one variety was much smaller (14 - 36 percent) as compared to wheat. The share of top three varieties was also comparatively low, ranging from 36 per cent in Haryana and 56 per cent in UP. The high varietal diversity in rice is expected because of varietal choice available to farmers, especially for grain quality, and wide variation in the production environment, particularly in UP and Bihar.

Another notable trend in the varietal concentration is that the share of new varieties, released after 2000 is rather low for both rice and wheat. This is more so for the states of UP and Bihar where production environment is less favourable because of erratic weather and low irrigation intensity. This is in spite of the fact that number of varieties released after 2000 for the irrigated conditions is quite high (nearly 75 percent). Therefore, it would be worthwhile to revisit the variety evaluation criteria and release only those varieties having significant superiority in all agronomic and economic parameters. This will also reduce the chances of rejection of a variety by farmers because of significant yield loss due to its susceptibility to disease. Also, there is a need to strengthen the breeding programs located in the eastern IGP which have low variety development rates. Most of the popular varieties, particularly of wheat, were bred by the programs located in the north-west IGP and this trend has been witnessed since the early days of wheat breeding (Jain and Byerlee, 1999).

Recent Technological Interventions

As indicated above, applied research efforts in the past mainly concentrated on development of improved crop varieties and resource conservation technology. The successful interventions include improved varieties of rice and wheat and zero or reduced tillage in wheat. For rice, there is large scale adoption of improved basmati varieties along with other fine grain varieties, and for wheat, there is replacement of old varieties with the new ones which are resistant to rust and tolerant to terminal heat conditions. The yield potential on research stations is also higher by about one tonne (Fig. 1). After taking into consideration the yield gap, rice varieties have an yield advantage up to one tonne per hectare but wheat varieties have a moderate yield advantage, about half a tonne per hectare. The varieties which were released after or picked adoption in 2000 were taken for impact assessment. Another important technological intervention in IGP is the introduction of zero-tillage for wheat, which occupied substantial area. The main advantage of this technology is cost reduction due to no or reduced tillage and saving of irrigation water in wheat. Incorporation of paddy stubbles also enriches soil, resulting in moderate yield gains in some locations. The spread of these technologies is quite significant in terms of area coverage. However, most of the adoption area is limited to Punjab, Haryana and west UP. The efforts are in progress to demonstrate and encourage adoption of these technologies in the eastern IGP also.

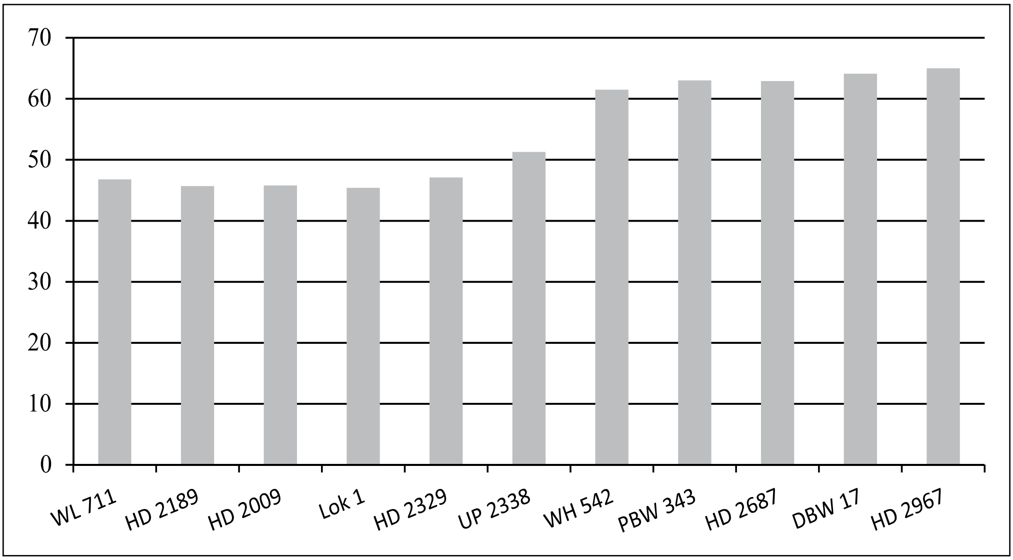

Fig. 1 : Yield potential (quintal/ha) of popular wheat varieties in India

Technology adoption

Dissemination of improved varieties has been quite smooth as there are number of seed agencies for multiplication and distribution of seed of paddy and wheat. Recently, some exporters and rice millers have also shown interest in promotion of basmati rice varieties because of their commercial significance. Therefore, spread of basmati varieties is much faster and these are now grown on larger area. The adoption of zero-tillage was rather slow initially and it took few years to spread the technology on a wide scale. There are important lessons from the adoption of zero-tillage in the Indian IGP. *First,* small refinement of technology, like modification of tine and furrow opener blade of ZT drill, could lead to its large-scale adoption. *Second,* active participation of the manufacturers has improved availability of ZT drill, thus facilitating the adoption process. Training and encouragement provided to the drill manufactures by the government and research organizations encouraged their participation. This means that input suppliers, whether in public or private sector, should be seen as partners in technology dissemination process—an aspect which was not given due attention until now. *Lastly*, persistence of efforts to disseminate a resource conservation technology and its modification to suit local conditions can even dispel myth and help farmers embrace modern agricultural technologies and practices. Of late, a large number of farmers shifted from zero tillage to reduced tillage with rotavator.

Level of technology adoption is an important parameter for assessing economic benefits and therefore due care must be exercised in estimation of this parameter. The task is even more challenging when farmers have limited information about the technology, i.e. name of the varieties grown. The information on adoption was estimated in two stages. First, secondary information on sale of commercial seed of paddy and wheat was obtained from the state government departments. After adjustment of farmer-to-farmer spread of seed, these data give variety shares in crop acreage. These data were adjusted with information on the spread of varieties obtained through farm survey in Punjab, Haryana and UP. The sample comprises 96 farmers each from two districts of Punjab (Ludhiana and Amritsar) and Haryana (Karnal and Kaithal), and 152 farmers from UP (Bulandshahar, Mirzapur and Chandauli). The farmers were selected randomly, after stratification into different sizes of holdings. Profile of the sample farmers is given in Table 7 and reference year of the survey is 2012-13. The survey for zero tillage was conducted in 2010 in Haryana for 70 farmers from five villages, where the adoption was widespread. Performance of major varieties based on the survey is given in Table 8.

Table 7 : Socio- economic characteristics of sample farmers

Particulars	UP	Punjab	Haryana
Education (% of farmers)			
Illiterate	12	7	10
Primary	7	14	17
Secondary	50	47	58
Higher secondary and above	31	32	14
Average age of farmer (years)	49	52	46
Percentage of farmers owning tubewells			
Electric	25	81	75
Diesel	70	10	20
Both	5	9	5
Farmer owning tractor (%)	49	90	65
Average size of holding (ha)	4.56	6.43	4.74
Rice-wheat area (%)	69.3	77.2	73.2

Table 8 : Performance of major varieties of rice and wheat on farmers' fields, 2011-12

State	Variety	NPK (Kg/ha)	Number of irrigation	Yield (q/ha)	Share in crop area (%)
Rice					
Eastern UP	'Old'	144	9	43	45.77
Western UP	'New' basmati	136	11	34	54.17
	'Old'	120	10	44	36.26
Punjab	'New'	246	10	56	54.52
	'New' basmati	185	9	42	28.78
Haryana	'New' basmati	142	11	40	65.58
	'New' basmati	140	10	34	23.53
Wheat					
Eastern UP	'Old'	135	3	36	26.00
	'Old'	155	2	39	22.02
Western UP	'New'	140	5	42	34.58
	'New'	150	4	38	15.72
	'New'	165	5	46	15.14

Cont...

Table 8 contd...

Punjab	'New'	225	3	45	18.00
	'New'	230	4	46	14.87
	'New'	215	4	48	11.61
Haryana	'New'	214	3	42	27.02
	'New'	210	3	47	23.46
	'New'	177	4	43	14.18

Note: 'New' variety is defined as a variety having initial adoption around 2000 or later, and 'old' variety was on farmers fields before 2000.

Source: Based on farm survey.

After estimating the present adoption level, it was necessary to compute the future adoption path, which also requires an assessment of ceiling level of adoption. Basmati rice varieties and zero-tillage have nearly reached the maximum adoption level which was used for computing the adoption path. Information for wheat varieties was rather difficult and the maximum adoption was assessed based on the area covered by the varieties which are likely to be replaced by the new varieties.

ASSESSING THE ECONOMIC IMPACT

Economic surplus method is commonly used to estimate economic benefits of commodity research. The technologies considered here are perfect examples of commodity-specific research and therefore this method was applied for rice and wheat. The estimation of increase in economic surplus due to technology adoption, needs data on market parameters (demand, supply, production, prices etc), reduction in per unit cost of production and adoption level. These data are presented in Table 9. Following (Alston *et al,* 1995), change in economic surplus is computed as:

$$\Delta CS = PQ\,Z\,(1+.5\,Z\eta)$$

$$\Delta PS = PQ\,(K\text{-}Z)\,(1+.5\,Z\eta)$$

$$\Delta TS = \Delta CS + \Delta PS = PQ\,K\,(1+.5\,Z\eta)$$

where $Z = K\ \varepsilon\ /\ (\varepsilon + \eta)$; K is vertical shift in supply function as proportion of initial price;

η is elasticity of demand (absolute); and ε is elasticity of supply.

Table 9 : Parameters for estimation of economic benefits and the rate of returns

	Parameter	Zero-tillage	Wheat variety	Basmati rice variety	Common rice variety
1.	Yield or cost advantage (%)	6	11.7	25	18.8
2.	Ceiling level of adoption (%)	25	61	60	29
3.	Price (Rs/tonne, 2014)	14,000	14,000	27,718	13,100
4.	Production (million tonnes)	29.8	64.8	7.79	35.46
5.	Research cost (million Rs, 1999)	2741			
6.	R&D lag (years)	10			
7.	Net present value (Rs billion)	190.79			
8.	IRR (%)	38.80 per cent			

The estimate of downward vertical shift in the supply function is calculated as proportionate change in the per unit cost of production. This change in the cost is realized due to cost savings in zero-tillage in wheat and reduction in yield losses due to various stresses for wheat and rice (common) varieties. In case of basmati rice variety, per unit cost of production decreased because of higher yield of new varieties (Pusa 1121, CSR 30, Pusa 1509) over the traditional basmati, or improved basmati bred earlier, like Pusa Basmati 1. The demand elasticities of rice and wheat were taken from Kumar *et al* (2011). Economic surplus with closed economy was applied for wheat variety and zero-tillage, while the open economy model was used for basmati rice as nearly half of total basmati rice production in India is exported.

These economic benefits can be compared against the research cost, which is arrived based on research expenditure incurred by the states of Punjab, Haryana, Bihar and UP. These aggregate research expenditures were adjusted by the shares spent on crop research (excluding livestock and horticulture research), assuming that SAUs in RWS system spend nearly half of the crop research expenditure, or 35 per cent of the total research expenditure on these crops. In addition, there are some ICAR institutes working the region and considering their budget, 15 per cent of ICAR expenditure was also taken as research cost (for details and source of data, see Pal *et al,* 2012). The expenditure on extension was taken as 42 per cent of the research expenditure in

RWS states, which is the ratio of extension to research expenditure (Singh and Kumar, 2011). Thus, there may be slight over estimation of the research and extension cost but this can be justified as all crop and resource management research target crop productivity of these two important crops in the region. In addition, there are some research cost incurred by CG Centres, especially for development of rice and wheat varieties and on-field research for zero tillage, but this was not considered due to non-availability of data. Thus, the estimated benefits are returns to the research investment made by India.

Table 9 presents economic benefits of the selected technologies. The aggregate gross economic benefits from all the technologies were compared with the research cost for computation of the net benefits. As seen from this table, all these technological interventions are likely to generate economic benefits (net present value) of Rs. 190.8 billion over 20 years at 2014 prices. More than three-fourths of the aggregate benefits were generated by wheat and common rice varieties due to their larger adoption, and most of the aggregate benefits are likely to be shared by the consumers. The estimated internal rate of return is 38.80 per cent and the ratio of net benefits to the cost is 17.31. In addition, there are environmental benefits of saving of fuel and low carbon emission in zero-tillage, incorporation of plant residue in reduced tillage and water saving in zero-tillage and shorter duration of basmati rice varieties.

These estimates of economic benefits are slightly lower than the median rate of return (IRR 53%) reported for India in the past for the green revolution technologies (Alston *et al,* 2000), but quite comparable to the rate of returns (IRR about 40 percent) from technological interventions under the National Agricultural Innovation Project (NAIP, 2014). Our estimates are comparable to those obtained for CGIAR research; estimated B-C ratio for system-wide research was 4.76 for the period 1960-2001, which improved to 17.26 when the benefits were extrapolated through 2011. The estimated internal rate of return was 34 percent. Most of these benefits were generated by rice and wheat varietal improvement programs and biological control of cassava mealybug (Raitzer and Kelley, 2008). Of late, there has been greater focus on natural resource management and policy research in CGIAR and the benefits generated are quite impressive, but crop improvement programs still continue to dominate the research impacts (Table 10). Another noteworthy aspect of these studies is that most of the impacts were realized through widespread adoption of technology in Asia, particularly in India and China (for details, see Evenson and Gollin, 2003; Pal, 2011 and Renkow and Byerlee, 2010). Thus, the Indian system has been successful in generation, adaptation and application of technology and realizing impacts on farmer fields.

Table 10 : Summary of important crop research impact assessment studies for CGIAR

Study	Technology	Region	Study period	Type of analysis	Benefits
Lantican, Dubin and Morris (2005)	Wheat breeding research	Global	1988-2002	Value of additional wheat production	• Annual benefits US$ 2-6.1 billion (2002 dollars) • Benefits attributable to CIMMYT US$ 0.5-1.5 billion annually with a B-C ratio of 50 (most conservative estimate)
Hossain, Gollin, Cabanilla, Cabrera, Johnson, Khush and McLaren (2003)	Rice breeding research	Asia and Latin America	1965-1999	Net yield gains based on field-level data	• Yield gain of 0.94 t/ha (or US$ 150/ha) with annual gains of US$ 10.8 billion in South Asia and Southeast Asia • Annual benefits US$ 500 million for Latin America • Significant increase in rice yield per day and tolerance to biotic stress
Zeddies, Schaab, Neuenschwander and Herren (2001)	Biological control of cassava mealybug	Africa	1974-2013	Value of crop loss reduction, or saving of alternative crop i.e. maize	• Cassava loss reduction of US$ 26/ha with a total yearly gain of US$ 235 million (1994); B-C ratio of 199 • B-C ratio 170 with an yearly saving of US$ 200 million (1994) worth of maize • Benefits are much higher if the losses are
Morris, Mekuria and Gerpacio (2003)	Maize breeding research	Global	Late 1990s	Value of additional production	• Annual gains due to germplasm improvement US$ 668 million to 2.0 billion • Annual benefits due to CIMMYT germplasm in the range of US$ 557 to 770 million

Cont...

Table 10 contd...

Aw-Hassan and Shideed (2003)	Barley germplasm improvement	Global	1980-2000	Economic surplus	• Annual gross research benefits US$ 92 million in 1997 • IRR 32%
Johnson, Pachico and Wortmann (2003)	Beans germplasm improvement	Africa and Latin America	1980s-1998	Value of additional production	• Annual value of increased production US$ 177 million in Latin America and US$ 26 million in Africa due to CIAT research • IRR in the range of 18-33%

Source: Pal (2011).

CONCLUSIONS

This chapter has examined the productivity trends, technological interventions and their impacts in RWS in the Indian IGP. The results confirm the trend of slowing down of productivity growth of rice and wheat in IGP, except for rice in Punjab and Haryana where the growth has accelerated due to significant increase in the productivity of superfine rice. The rate of varietal development and notification has increased for both the crops and newer varieties have better tolerance to yield reducers. But there is varietal concentration, particularly in wheat where top three varieties contributed more than three-fourths of total seed sales. Private sector supply an increasing proportion of quality seed and the share of farm-saved seed is reduced to less than one-fifth. The zero tillage in wheat and crop variety improvements are major technological interventions in the system, which have generated the returns to the order of Rs. 190.80 billion since 2000. The estimated IRR is 38.8 per cent and the ratio of net benefits to the cost is 17.31, which are slightly lower than the rates reported in the past. Nevertheless these returns are quite high to justify higher allocation of public funds to agricultural research.

REFERENCES

Alston, J.M; G.W. Norton and P.G. Pardey (1995), *Science Under Scarcity: Principles and Practice for Agricultural Research Evaluation and Priority Setting,* Cornell University Press, Ithaca.

Alston, J.M., C. Chan-Kang, C. Marra, P.G. Pardey and T.J. Wyatt (2000), A meta analysis of rates of return to agricultural R&D: *Expede herculern*. Research Report 113, IFPRI, Washington, DC.

Byerlee, D. (1992), Technical change, productivity and sustainability in irrigated systems of south Asia: emerging issues in the post green revolution era. Journal of International Development 4: 477-496.

Chand, R. and Suresh Pal (2003), Policy and technological options to address India's food surpluses. *Current Science*, February 2003.

Chauhan, B.S., G. Mahajan, V. Sardana, J. Timsina and M.L. Jat (2012), Productivity and sustainability of the rice-wheat cropping system in the Indo-Gangetic Plains: problems, opportunities and strategies, *Advances in Agronomy*, 117: 315-369.

Evenson, R.E. and D. Gollin (Eds.) (2003), *Crop Variety Improvement and Its Effects on Productivity*. CABI Publishing, Wallingford, UK.

Erenstein, O, U. Farooq, R.K. Malik and M. Sharif (2008), On-farm impacts of zero-tillage wheat in south Asia's rice-wheat systems, Field Crops Research 105: 240-252.

Fuglie, K.O. (2012), Productivity growth in the global agricultural economy and the role of technology capital, In *Productivity Growth in Agriculture: An International Perspective,* edited by K.O. Fuglie, S.L. Wang, and V.E. Ball. Wallingford, UK: CAB International.

Fujisaka, J. S., L. Harrington and P. Hobbs (1994), Rice-wheat in south Asia: systems and long-term priorities established through diagnostic research. *Agricultural Systems* 46: 169-187.

Gupta, R.K. and A. Seth (2007), A review of resource conservation technologies for sustainable management of the rice-wheat system cropping systems of the Indo-Gangetic Plains, *Crop Protection*, 26: 436-447.

Hobbs, P.R. (2007), Conservation agriculture: what is it and why is it important for future sustainable food production, *Journal of Agricultural Science* 145: 127-137.

Kumar, P, A. Kumar, Shinoj P. and S.S. Raju (2011), Estimation of demand elasticity for food commodities in India, *Agricultural Economics Research Review* 24(1): 1-14.

Jain, K.B.L., and D. Byerlee (1999), Investment efficiency at the national level: Wheat improvement research in India. In M.K. Maredia and D. Byerlee (eds), *The Global Wheat Improvement System: Prospects for Enhancing Efficiency in the Presence of Spillovers*. Research Report No 5, CIMMYT, Mexico.

Kumar, P. (2002), Economic analysis of total factor productivity of crop sector in the Indo-Gangetic Plains of India by district and region. Research Report 2002(2), Division of Agricultural Economics, Indian Agricultural Research Institute, New Delhi.

NAIP (2014), Monitoring and evaluation report, ICAR, New Delhi.

Pal, Suresh (2011), Impacts of CGIAR crop improvement and natural resource management research, *Agricultural Economics Research Review*, 24(2): 185-200.

Pal, Suresh, M Rahija and N Beintema (2012), India: Recent developments in agricultural R&D. ASTI-IFPRI, Washington, DC.

Paroda, R.S., T. Woodhead and R.B. Singh (1993), *Sustainability of Rice-Wheat Production Systems in Asia,* Ropa Publication 1994-11, Oxford & IBH Publishing Co., New Delhi.

Pingali, P. L. (ed.) (1998), Sustaining Rice-wheat Production System: Socio-economic and Policy Issues, Rice-Wheat Consortium Paper Series 5, Rice-Wheat Consortium for the Indo-Gangetic Plains.

Raitzer, D.A. and T.G. Kelley (2008), Beneût-cost meta-analysis of investment in the international agricultural research centers of the CGIAR. *Agricultural Systems,* 96(1–3), 108–123.

Renkow, M and D Byerlee (2010), The impacts of CGIAR research: a review of recent evidence, *Food Policy*, 35: 391-402.

Roy, B.C. and K. K. Datta (2000), Rice-wheat system in Haryana: Prioritizing production constraints and implication for future research. *Indian Journal of Agricultural Economics,* 55(4): 671-682.

RWC (2004), The rice-wheat consortium: an institutional innovation in international agricultural research, CIMMYT, New Delhi.

Singh A and S Kumar (2011), Trends in the public and private investment in agricultural R&D, in Suresh Pal (ed), Agriculture for Inclusive Growth, IARI, New Delhi, 194-203.

Timsina, J. and D.J. Connor (2001), Productivity and management of rice-wheat cropping systems: issues and challenges, Field crop Research 69: 93-132.

Vijaylaxmi, O. Erenstein and R.K. Gupta.(2007), Impact of zero tillage in India's rice-wheat systems. Mexico: CIMMYT.

Woodhead, T., R. Huke, E. Huke and L. Balababa (1994), Rice-Wheat Atlas of India, IRRI, CIMMYT, ICAR.

World Bank (2010), Development and Climate Change, World Development Report 2010, Washington, D.C.

World Bank (2014), Accelerating Agricultural Productivity in India, World Bank, Washington, D.C.

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