

ICAR - Industry Meet
**AGRICULTURAL
TRANSFORMATION
THROUGH
PUBLIC-PRIVATE
PARTNERSHIP**
AN INTERFACE



**INDIAN COUNCIL OF AGRICULTURAL RESEARCH
NEW DELHI**

ICAR-Industry Meet
Agricultural Transformation
through Public-Private
Partnership: An Interface

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Foreword

Indian agriculture is faced with several challenges, as also uncommon opportunities. The challenges in terms of climate change and land degradation and increasing global trade restrictions are also providing opportunities to redefine the ways we have to deal with the production and post-harvest processes. These include immense possibilities of applying tools of biotechnology and ICT in our endeavours and complimenting strengths in different areas for achieving higher efficiencies. A new paradigm that has emerged in the recent years to address the problems and the potentials in a holistic manner is the 'Public-Private Partnership'.

The Public-Private Partnerships are viewed as the governance strategy to minimize transaction costs and co-ordinating and enforcing relations between partners engaged in production of goods and services. They enable an optimal policy approach to promote social and economic development, bringing together efficiency, flexibility and competence of the private sector with the accountability, long-term perspective and social interest of the public sector. Both the partners have mutual gains from such arrangements. Private benefits from the R&D are usually company gains that stem from cost reduction and improved quality and increased quantity of sales' products. They also relate to strategic goals such as market penetration, improved competitiveness, exploration of new markets or market power. Public benefits include a wide array of positive social, environmental and economic effects influencing livelihoods of ultimate beneficiaries. These could be consumers as also others involved in production, processing and marketing.

In the context of Indian agriculture, we have had fruitful interactions between the public-funded institutions and private sector in several areas such as seed production, farm implements and machinery, disease diagnostics and vaccines, value-addition and post-harvest processing in cereals, pulses, oilseeds, fruits and vegetables, milk, meat and fish, product testing and evaluation. While the public-funded organizations have significant research results and the ability to absorb uncertainties of pay-offs, the private sector seems to have an edge in factoring clients into design of technologies and diffusion processes.

The Indian Council of Agricultural Research deals with a number of disciplines and commodities in Crops, Horticulture, Animals, Fisheries, Engineering and Resource management through a network of 48 Institutes, five Bureaux, 11 Project Directorates, 32 National Research Centres and 91 All-India Co-ordinated Research Projects. Further, the Central Agricultural University and 40 State Agricultural Universities are the constituents of the National Agricultural Research System. The process of public-private

partnership is increasing in the recent past; with several mechanisms placed in the Indian Council of Agricultural Research such as Consultancy and contract services, Commercialization of products and processes and so on. A major step in this direction has been the recently formalized comprehensive guidelines for 'Intellectual Property Management and Commercialization of Technologies', enabling stronger partnerships.

The ICAR has convened this Interface Meet during 19-20 January 2006 to discuss key challenges in the Indian agriculture that need to be addressed together to analyse sectoral expectations and identify areas that can be complemented, including validation and testing of products and processes, addressing global markets, commercialization of technologies and capacity-building. I am grateful to the speakers from both private and public sectors in the different areas of agriculture, who have contributed to the Meet as well as to the present publication. I am sure this would mark a milestone in furthering the cause of Indian Agriculture through the Public-Private Partnerships.



(MANGALA RAI)

Preface

In recognition of the increasing importance of the role and potentials of the Public-Private Partnerships in achieving higher productivity and efficiency in different facets of Indian Agriculture, the Indian Council of Agricultural Research organized the first ICAR-Industry Meet: Agricultural Transformation through Public-Private Partnership at New Delhi during 19-20 January 2006. The first Interface of its kind was designed to address potentials in different areas and to bring out strengths of the partnerships, and also learn from the previous experiences.

Varied aspects such as Seeds and horticultural planting materials, Agricultural biotechnology, Biofertilizers, Agriculturally important microorganisms, Animal vaccines, Poultry, Dairy, Fisheries, Textiles, Food processing, Farm implements and machinery, Post-harvest processing, Financing and Capacity-building were covered by distinguished speakers from both private and public sectors.

There were detailed discussions on these partnerships that are playing greater roles in On-farm testing of new technologies, Seed quality improvement, One window for commercialization of technologies, Soil-testing laboratories, Value-chain in different aspects, Water weedicides, Smaller machinery and appropriate technologies, Custom-hiring, Mobile feed dryers, Use of fertilizers and micronutrients, Extension systems and Mobility of researchers between public and private sectors, etc. The Meet also brought out action points for carrying the process forward, with the existing mechanisms in some cases, and with the new ones to be put in place in others, emphasizing objectivity and flexibility in building these partnerships.

The present publication is an outcome of the Interface, indicating various dimensions of the partnerships, as also immense possibilities in the areas. We are grateful to Dr Mangala Rai, Secretary, DARE, and Director-General, ICAR, for giving us the opportunity for organizing the Meet and also for editing this volume. We would like to thank the speakers for their presentations, and the participants for making the event a unique one. We hope that this publication would not only be a document of the Interface, but would lead to further actions for 'Partnerships for greater Prosperity in Agriculture' and a 'Win-Win' situation for all partners.

S. Ayyappan
Pitam Chandra
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Partnership for Prosperity

B.R. Barwale

All partnership efforts for agricultural transformation should ultimately lead to economic prosperity of the farmer. This means higher productivity of the crops with newer technologies, be it superior hybrids; exploiting phenomenon of hybrid vigour or transgenic crops, where an economic trait is incorporated from an unrelated species. Innovation is one thing and reaching of the technology to the farmer is another. Both are very important. All along in the seed industry concerns have been on Food Security and Nutrition Security for the nation. To achieve these goals, partnerships at various levels with different objectives have to be developed amongst various stakeholders, which shall bring prosperity to the nation through the prosperity of the main stakeholder, the farmer.

For the success of the partnership with Public Institutions and Private Organizations, identifying the strengths of the partner and the areas of complementarities are very important.

HYBRID RICE

In 1986, we were far behind in the hybrid rice development, but there was no doubt that Hybrid Rice was the need of the hour for our country, as it would have brought about an additional tonne of grains per hectare; as rice has a share of over 40% in our food output. The efforts initiated by the ICAR were praiseworthy. However, MAHYCO Research Foundation (MRF), now Barwale Foundation (a non-profit organization), wanted to play a catalytic role. A proposal was given to the ICAR to consider a contribution of one crore of rupees each year for three years for deploying money for hybrid rice development work in the country. No conditions were put, and ICAR was at liberty to use it. No expiry date was set; funds would not lapse by March end as was with funds from other agencies.

The bottom line was the acceptance and spread of hybrid rice cultivation by farmers. The collaboration was implemented by two committees.

- Steering Committee, where the Director-General, ICAR, chaired and representative Directors from MRF were involved with other members.

- The Technical Committee comprising representatives of all participant Universities, coordinated by Director, Directorate of Rice Research, Hyderabad. MRF was also well represented.

A brief report was prepared at the end of three years, and the impacts of the Foundation's contribution on the project were summarized thus by the Directorate of Rice Research.

Impact of the ICAR/MRF Project

Impact of the activities undertaken in the ICAR/MRF project in addressing the critical lacunae/gaps and on expeditious development and use of Hybrid Rice Technology in India had been significant. The project was specifically effective in the following aspects.

- Enhanced mobility through provisions of "Tata Sumo" vehicles to all the centres, enabling them to conduct compact block frontline demonstrations of the released hybrids effectively and efficiently.
- Major thrust given for purification of parental lines resulted in adequate availability of pure seeds of all parental lines of released and pre-released hybrids.
- Provision of critical and much needed field facilities, though minor, such as pollination chambers, net houses, pump sets, power tillers etc. were helpful in efficient implementation of the project activities.
- An innovative breeding approach, such as development of diverse gene pools for extracting maintainers and restorers, initiated and implemented under this project, payed rich dividends in terms of availability of genetically diverse parental lines for developing new hybrids.
- Another significant achievement of this project was development of diversified CMS lines with sterility inducing cytoplasm other than the most widely used "WA" system.
- Hybrids with tolerance to salinity were developed, which could be deployed effectively in the problem soils to enhance production and productivity.
- Several useful publications were brought out in local languages on hybrid rice cultivation and seed production. These were immensely useful in transfer of technology activities.
- Establishment of hybrid rice information network helped in faster and efficient communication among scientists and network centres.
- Awards for scientists were instituted to recognize the work on different aspects on hybrid rice.
- A greenhouse, as per the guidelines of DBT for transgenic work, was also provided at the DRR.

This unique and innovative partnership between a private research foundation (MRF) and a public sector research giant (ICAR) has set an example for others to emulate.

The present Director-General, ICAR, recognized that this was the first research contract with the ICAR by a Private NGO. And he mentioned that more private organizations are in the pipeline, particularly after the recent reforms in the ICAR policy to encourage such partnerships (G.O.I.1995, 1997).

HYBRID *TUR* (PIGEONPEA)

There was a partnership between Mahyco, the Seed Company, and the ICRISAT. MAHYCO pioneered collaborative efforts for developing a CMS

system in breeding a pigeonpea hybrid. The funding to the extent of approx. rupees 60 lakh was made by MAHYCO, and a concept of consortium of about half a dozen interested organizations was created. A small fee was levied to join the consortium. The net result of these partnerships efforts will be 50% increase in productivity, from the current level of 600-700 kg/ha. The demand for pigeonpea in India has always exceeded the production, and the deficit of half a million metric tonnes is met through imports from Myanmar and Southern and Eastern Africa. ICPH 8 was the first pigeonpea hybrid in the world, released for cultivation in India, with 25-30% yield advantage in farmers' fields. However, this technology could not become popular due to difficulties associated with genetic nature of male sterility which restricts large-scale seed production of female parent and hybrids. Hybrid seed production feasibility studies conducted during 2003-04 by Mahyco have showed that hybrid pigeonpea seed could be produced at a reasonable cost. The first commercial hybrid based on the CMS system will be launched shortly in all the three maturity groups of pigeonpea (short, medium and long duration).

Impact of hybrid technology for increasing production and productivity of pigeonpea: The performance of various hybrids under multilocation testing system showed significantly higher grain yield as compared to popular varieties. The heterosis over best varieties ranged to 50% in multilocation testing. Under such a scenario, pigeonpea would become a more remunerative profitable crop for the farmers. The productivity will increase to approximately 1 tonne per hectare by considering the average yield increase of 50% over existing varieties. As pigeonpea-crop becomes more profitable, area under this may go up as much as double. That would mean addition of 7.32 million tonnes production; four times that of the existing production. It is very important to see that these pigeonpea hybrids are rapidly commercialized to bring these benefits to Indian farmers.

Private partnership takes results to farmers expeditiously: One big advantage of Public-Private Partnership of the Technology is that achievement can be taken to the farmer very rapidly. In case of development of new seeds, the private partner can arrange seed production to reach the farmer, as he is very keen to earn profit on his investment. If it is basic research then the private firm can work with the results for application research.

Public-Private Partnership is the best utilization today of the large facilities created in the public-sector institutions.

PPP: Institutional and Industrial Views

R.D. Kapoor

A public-private partnership is a contractual agreement between a public agency (federal, state or local) and a private sector entity. Through this agreement, skills and assets of each sector (public and private) are shared in delivering a service or a facility for the use of the general public. In addition to the sharing of the resources, each party shares risks and rewards potential in the delivery of the service and/or the facility.

As a science-based activity, agricultural research is best performed by multidisciplinary and inter-institutional teams of scientists from both public and private sectors. Agricultural growth is a prerequisite for economic development, especially in the countries with agri-based economy. Even when all irrigation potential is developed, one half of the arable land of the country remains rain-dependent. Therefore, the high growth in agricultural sector would progressively depend more on the development of rainfed agriculture. Unless production in rainfed regions is increased, inequalities between irrigated and rainfed areas in the country will remain.

To accelerate pace of rainfed agriculture and to harness its potential benefits, there is a need to introduce appropriate technologies and create suitable institutions and infrastructure to promote a shift to high-value-added crops. There are emerging opportunities for traditional and high-value crops that offer potential to raise rural incomes. Such a shift will enable rainfed agriculture to increase production, augment farm-income, generate employment, alleviate poverty and conserve precious soil and water resources.

Indeed, the promotion of high-value commodities may act as the catalyst to bring a “second-generation” Green Revolution in rainfed areas.

CURRENT STATUS

Though interaction of private sector and public sector is not new, yet the level is very low. Certain areas of interactions at present are as follows. *Agriculture*: Field trials, Pesticide testing, Germplasm evaluation, Collaborative technology development – hybrid rice; and *Biotech*: Biosafety

studies, Germplasm/Agronomic evaluation, Animal feeding studies, Ecological studies.

In spite of being registered under the Companies Act, the multinational companies are not considered at a par with the Indian companies; resulting in dissatisfaction among the private sector. Absence of established laws blurs the timelines that further disturb research procedures. Presently mid-term data-sharing is also very difficult.

With partnership between public and private sectors, the strengths of both the sectors are leveraged. On the one hand, public sector has highly skilled and efficient manpower in agriculture and on the other hand, private has excellent managerial resources. Private extension would improve commercialization of technology and make it available at the global level. The decentralized decision-making in private sector helps in reducing time for commercialization. Proper budget management and global regulatory expertise are certain other benefits of the system. While availability of diverse germplasm of different crops and diverse breeding crops can be boasted by the public sector. Another added advantage of private sector is years of experience.

With the rapid developments in agricultural technologies and evolving national seed policies, investments in hybrid seed research and development are bound to increase. This increase would mean different areas where public participation would be needed; some of them are as follows. Plant ecology:Field trials, Molecular characterization, Protein expression, Product safety, Residue studies, Composition and Seed production.

The different policies that are evolving, and will continuously affect the agricultural partnership are as follows. New Seed Bill, 2004/Insecticide Act, 1968; Environment (Protection) Act, 1986; Protection of Plant Varieties and Farmers' Right Act, 2001; The Plant Quarantine Order, 2003; Prevention of Food Adulteration Bill, 2004; Food Safety and Standard Bill, 2005; Indian Patent Act, 2005; National Biotechnology Development Strategy; Biological Diversity Act, 2002.

The alliance would reduce timeline for commercialization, and certain requisitions for such an alliance would be as follows.

- The entire value-chain and not just specific bottlenecks have to be addressed
- Empowerment of Directorate of the institute: CSIR
- Clarity on Material Transfer Agreement (MTA)
- Set-up joint help-lines for new technologies for the benefits of farmers
- Level playing field for both the parties
- Support social programmes
- Joint IPR in case of bilateral projects

There is a need to introduce a course on agricultural regulations at graduation level so that student are familiarized with the complexities of managing agricultural business.

SUGGESTIONS FOR STRENGTHENING PARTNERSHIP

There is a need for transparency and trust for mid-term review and for bilateral agreement for developing new technologies. Clear laws for transfer of technology and sabbatical provisions for scientists to work with industry need to be established. The industry needs to be accredited for Master and PhD programmes.

To draw a conclusion from the above, it would be appropriate to say that any partnership requires patience and trust to succeed. We are looking at the long-term benefits and it is very necessary to iron all creases at the first step itself. Regular inputs from both the parties and meetings would be an effective way to check any issue that would emerge at any stage.

3

Technology Commercialization and Financing

N. Srinivasan

MACRO ECONOMIC SCENARIO

The economy of India is the fourth largest in the world as measured by the purchasing power parity (PP) with a GDP of US\$ 3.36 trillion. India was the second fastest growing major economy in the world, with a GDP growth rate of 8.1% at the end of the 1st quarter of 2005-06. For more than two decades since 1981, the GDP of India has grown at an average of 5.8% per annum as compared to 3.5% during the previous three decades. The volatility of GDP growth rate has come down significantly with the rapid and sustained progress in the industry and the service sectors. However, per capita income continues to be low at Rs 11,762; mainly due to the consistent growth in population and declining share of agriculture in the GDP.

The average population growth, which was 1.96% in 1961, was hovering around 2.2% during the next three decades, and then declined to 1.9% in 2001. As the result, the total population of the country more than doubled from 439 million in 1961 to 1,029 million in 2001. Consistent growth of population at 2% for more than four decades has placed enormous pressure on land, water, forests, etc. resulting in large-scale human induced environmental degradation. The poverty-induced migration of people from rural to urban areas has degraded quality of life; as development of civil infrastructure in urban areas has not kept pace with the population growth.

In India, the share of agriculture in total GDP has steadily declined over years. In 2004-05, it was a little about 40% while it contributed almost 40% a few decades back. The decline in the contribution of agriculture to overall economy is natural; consistent in the economic development process in most nations. And this per se may not have been a cause of concern, had a corresponding demographic shift taken place. In India, however, agriculture continues to be the largest employment provider; as 58% population is dependent on the agriculture for their livelihood.

The deceleration in agricultural growth in India is certainly a cause of serious concern as 4% growth rate in agriculture is considered essential to achieve the target of 8% growth rate for the economy; as a whole as per the X five year plan. The sluggishness in agriculture sector is often traced to lack of fresh technological breakthroughs like green revolution in late sixties and seventies, and declining trend in public capital formation in agriculture. It is now widely acknowledged that though green revolution helped to achieve food self-sufficiency and also spurred the growth in economy, it remained confined mainly to cereals, and only in certain parts of the country.

PRESENT STATUS OF AGRICULTURE AND ALLIED ACTIVITIES

Progress of agriculture has been impressive in production terms over years, and the country now ranks in top positions in production for most of the agricultural items in the world. The foodgrains production increased from 74.23 million tonnes in 1966-67 to 209.80 million tonnes in 1999-2000. The estimated figure was at 212.05 million tonnes for 2004-05.

Livestock sector accounted for 5.4% of the total GDP and 27.7% of the GDP of agriculture in 2001-02 (current prices). Similarly, fishery sector accounted for 1.1% of the total GDP and 5.4% of agriculture GDP.

Despite rapid strides, agriculture and allied sectors face numerous challenges such as declining profitability; decline in growth rate of foodgrains production and yields; wide disparity in productivity over regions and crops; mismatch between food crops and cash crops; lack of market access; low price realization at farmers' level, compared to costs; inefficiency in use of resources; degradation of natural resources; continuation of dependence on import of pulses and edible oils; lack of reforms; diversification, and stagnant capital formation with declining public investments in agriculture.

In the present scenario, the challenge for the country is to make agriculture and allied sectors more profitable, and to ensure that rural population has a larger income to share. The emphasis should be on productivity, quality, diversification, sustainability, promotion of innovations and exports. The role of technology in meeting challenge is critical. The following sections of the paper are an attempt to outline the need for new technologies with potential to provide holistic solutions, and the issues that relate to their dissemination and commercialization.

EMERGING PARADIGM OF TECHNOLOGY COMMERCIALIZATION

It would be appropriate to set bounds of the term '**technology**' for the purpose of this paper as the term has different connotations in different contexts. The word 'technology' has its origins in the Greek word *technologia*, (techno="craft"+logia="saying"). It is an encompassing term dealing with use and knowledge of humanity's tools and crafts. The following usages of the word may be considered.

Technology as tool: In its most common usage, technology is the tools and machines that help to solve problems. In this usage, technology is

a far-reaching term that can include both simple tools, such as a sickle or a plough, and complex tools such as seed-cum-ferti drill or harvester combine.

Technology as technique: In this usage, technology is the current state of our knowledge of how to combine resources to produce desired products, to solve a problem, to fulfill a need, or to satisfy a want. Technology in this sense includes technical methods, skills, processes, techniques, tools and raw materials (tissue culture, polyhouse, micro-irrigation method, cultural practices, etc).

The above usages of the word technology are focussed on what comprises technology; may be in the form of a concept, knowledge, an instrument, methods of using instruments and so on. These paradigms do not take into account side effects of the use of the technology on natural resources, environment and social aspects such as health, safety, sanitation, life-style, traditional rights of the people, ethics, values, community structures and governance systems. The long-term consequences of ignoring these concerns have been well recognized across the globe, and presently the focus is pegged on holistic technologies that not only deliver intended effects but also take care of the fallout. Thus a third paradigm of technology which can be termed as '**culture forming technology**' is gathering momentum. This seeks to ensure a broadened extension of appropriate technologies so that compatibility between technology, environment and society is ensured. Only such technologies would have the potency to address the issues of equity along with growth and productivity, which are relevant in the context of the developing nations.

The word **Commercialization** is obviously linked to commerce which means trading of goods, services, information and money between two or more parties. Commercialization therefore refers to the process of transforming a productive or value-adding activity into a commercial activity. In other words, when a productive activity is commercialized, the benefits thereof (the goods, services etc.) are produced by the firm/entrepreneur primarily for the purpose of exchanging with others for certain pecuniary consideration or services in return. Usually the success of commercialization depends on the demand for the product, the cost at which it is offered, the intrinsic benefits of the product and the associated services that provide convenience to customer in purchase, installation, usage, maintenance and disposal once the life of the product is over. Mass production, increasing factor efficiency, efficient distribution, product knowledge dissemination, reinforcement of consumer confidence, and efficient service constitute the strategic pillars of successful commercialization.

Combining working definitions of technology and commercialization, **Technology Commercialization** in the context of agriculture and rural development in India would encompass whole range of issues and activities, from stage of need identification, development of appropriate technology, demonstration, creating demand and rolling out package for wider adoption on commercial terms. The technologies may be either low cost or high cost, simple or complex, but they should be suitable for adoption on a wider scale.

*NEED AND CHARACTERISTICS OF NEW RURAL TECHNOLOGIES***Need**

Technology, infrastructure, markets and finance are four factors which play a decisive role in growth and sustainability of any production activity.

In case of foodgrains, technologies comprising high-yielding seeds, use of chemical inputs and irrigation have boosted production. Healthy plant material through modern nurseries and modern cultural practices have helped production in horticulture and plantation areas. In dairy sector, artificial insemination, nutrition, veterinary care and integration of milk producers with processing units in a cooperative mode have made remarkable impact in milk production, which has been termed as white revolution. Availability of credit from banking system has boosted adoption of new technologies by the small producers and also their commercialization.

These technological advances have focussed basically on two aspects — genetic improvement and high dose input regime—and have been instrumental in taking production as well as productivity of crops, livestock and fisheries to much higher levels. However, the present yields in our country for most crops are way below the world average level. As our population is likely to grow at a rate between 1.5 and 2.0%, increased food production can be achieved only through productivity improvement. Further, with removal of trade barriers for agricultural commodities and emerging regime of intellectual property rights, the competitive efficiency of Indian agriculture in the global scenario can be best addressed only through improvement in productivity, quality and value-addition. While we have the challenge of productivity improvement on one side, the impact of the presently commercialized technologies seems to be tapering off or even declining. This has given rise to the need for a fresh thinking on what kind of technologies are required for agriculture and rural sector, and how to commercialize them quickly.

Characteristics

The challenges of the time largely decide choice of technologies. In pre-green revolution period, the overriding challenge was food security of the nation and the choice was on technologies that held promise of generating greater outputs as quickly as possible. Now the challenge is one of conservation of natural resources, environmental protection, preservation of diversity alongside productivity improvement and value-addition. The present challenge is a more complex and comprehensive one as it has to address several variables simultaneously. Another dimension is that of the compressed time-frame for absorption and commercialization of new technologies. Earlier, a longer time-frame could be afforded to ensure wider dissemination of technology as the economy was relatively immune from external markets. With economic reforms and structural adjustment mechanisms firmly in place, a free market economy prevails now and the swiftness of the market forces is such that there is hardly any scope for

longer lags in technology induction and commercialization; as the production sectors have to quickly align themselves with the demands of the marketplace, lest their competitive advantage will be eroded. Higher lag means loss of opportunity to participate in the global trade process and harness the benefits of the same for the masses.

While productivity enhancement remains the core of even the future technologies, the following points also would require due consideration and weightage in the process of their development, dissemination and commercialization.

1. The technologies should be of end-to-end nature addressing the opportunities along the total value chain rather than isolated segments of it.
2. The choice of technology needs to be demand-driven and based on the felt needs of the local people, and preferably the local people should be involved in the process of technology development right from the idea formation stage.
3. The application aspects of the technology should be simple and user friendly, which minimizes gestation period.
4. Linkage with the industry is essential at all stages viz, concept development, research design, pilot testing, demonstration and commercial application to harmonize commercial considerations with social considerations.
5. The cost of technology should be affordable by small and marginal farmers, artisans, women and other weaker sections so that technology is scalable and results in more equitable percolation of benefits among the rural poor.
6. Post-harvest handling, preservation, processing, storage, transport, distribution and marketing are required in an energy-efficient and eco-friendly manner.
7. Conservation of natural resources is needed like soil, water, flora, fauna, and recycling of degradable and non-degradable agricultural wastes.

Having set broad boundaries for emerging technologies as mentioned above, this paper makes an attempt to examine some of the technologies having potential for commercialization with public-private partnership and involvement of financial linkages from banking sector.

SOME EXAMPLES OF 'CULTURE FORMING TECHNOLOGIES'

Conservation Agriculture

It is proposed as an alternative model for bringing improvement in stagnating agricultural scenario particularly in Green Revolution states (Punjab and Haryana). The concept involves minimum disturbance of soil and perfect land levelling to conserve both soil and water, besides saving labour and fuel. The package consists of levelling of land with high-tech

laser-based levelling machines, growing crops on raised-land beds interspersed with furrows to provide irrigation in root zone, dispensing with pre-sowing tillage and usage of zero-tillage planting equipment. The crop yields rise perceptibly due to enhanced input-use efficiency. These techniques are supported by crop-residue management and crop diversification to include leguminous crops in cropping system and only need-based application of chemical fertilizers. The reduced cost and higher output fetch higher returns to farmers. The crop yields have been reported higher by about 2.5 quintals a hectare. As per the estimates available already 2 million ha out 13.5 million ha under wheat-rice crop rotation came under conservation agriculture by 2004-05.

Watershed Development

Participatory Watershed Development Programme implemented by the NABARD under the Indo-German Watershed Development Programme since 1991-92 is an example of a cocktail of several appropriate soil, water management measures seamlessly integrated with social mobilization measures. The technology comprises water-and-soil conservation techniques like contour trenching, gully plugging, check dams, farm bunding, afforestation, etc., on ridge to valley principle with active involvement of local village communities. These measures are supplemented with training of farmers on agronomic practices, livestock rearing, and also non-farm activities. The women in the area are organized into self-help groups who are encouraged to participate in activities planned around community health, sanitation, adult education, besides their economic empowerment through savings and credit. The private participation is ensured by involving NGOs for carrying out project measures in partnership with the Village Watershed Committee comprising members of Gram Sabha. The stake of the villagers in the project is ensured through *shramdan* (voluntary contribution of labour) to sustain their interest. The technology has been found suitable for resource-poor rainfed areas with undulating topography, which experience water stress for considerable period every year resulting in poverty induced migration. These areas are traditional stranglehold of pulses, oilseeds, coarse cereals and millet which are grown by small and marginal farmers. The project has shown very impressive results in terms of crop diversification, fodder cultivation, rearing of dairy cattle etc. and higher incomes to villagers. The social impact is perceptible in decreasing drop-out rate in schools due to decline in the numbers of poverty induced migrant families. Dependence on government tankers for drinking water has almost come to a naught in completed watersheds. Though commercialization in terms of expansion of watershed treated area has taken place to a considerable extent (1.1 lakh ha), there exist gaps in water utilization patterns, productivity of crops and connectivity with markets, which are challenges yet to be tackled. While watershed development is carried out on a wide scale, there is a need to adopt participatory technology to ensure lasting benefits in watershed to the entire community.

Clean Milk Production

Production of milk in the country for a long time has been focussed on high solids percentage as the price of the milk is decided based on the proportion of fats and other solids in the liquid milk. Now having achieved number one position in milk production, India has potential to tap external milk markets. The major constraint however is the quality and high bacterial content in our milk and milk products. In most cases hand milking and storing milk in open containers at room temperature for a long time before it is actually procured by the cooperative society or the private agency is the cause of the contamination and deterioration in quality. This can be reduced to minimum by using milking machines and direct collection of milk into cans, avoiding human contact. This technology is simple, scalable and can be easily commercialized with reasonable investments. However to provide inbuilt incentive to the milk producer and for motivating to use milking machines, the price premium needs to be pegged to quality parameters in the milk.

Village Knowledge Centres/ Internet Kiosks

The villagers unlike urban populations are often not able to access technologies, markets and governance services due to lack of adequate knowledge about facilities, prices and conditionalities to be complied with. The Government extension system, which traditionally delivers new technologies to rural people, has serious capacity limitations on physical outreach and is plagued with systemic inefficiencies. The urban-rural divide has widened further due to digital revolution that is sweeping across our towns and cities.

This gap has given rise to a new opportunity; i.e. IT-driven information and service providing centres that have come to be known in generic terms as village knowledge centres or rural information kiosks. These have been established mostly through public-private partnerships. Some of the examples are: *e-choupals* of ITC, rural information kiosks of n-Louge (Tamil Nadu), Tata Kisan Kendras of Tata Chemicals, Drishtee in Madhya Pradesh, *e-seva kendras* in Andhra Pradesh, which have illustrated the potential for knowledge empowerment of rural communities and rendered them certain services on a commercial basis. Villagers have recognized the economic benefits that can be derived from information, communication and technology (ICT) based facilities in terms of savings on travelling expenditure for small things, accessing medical facilities, government services, and transaction costs involved in buying inputs and selling produce. As the result they are willing to pay a part of their cost savings to kiosk operators, who are entrepreneurs themselves from local area. The government had embarked upon a plan of establishing village knowledge centres in 100,000 villages by the end of the Xth plan; as these kiosks are relatively low-cost enterprises; providing equal access to all and employment opportunities to rural-youth. The scope for flow of credit support for establishing kiosks is reflected in partnerships entered by large

banks like the ICICI and SBI in some areas, who ultimately are eyeing delivery of full range of financial services through such kiosks in long-run.

CREDIT ENABLED INITIATIVES FOR TECHNOLOGY COMMERCIALIZATION

The catalytic role of credit in providing necessary private capital for adoption of any technology needs no elaboration particularly when most of our farmers are resource-poor.

Irrigation and Micro-irrigation (MI)

So far, only 68% of the county's irrigation potential has been harnessed, out of the ultimate irrigation potential assessed at 139.9 million ha. Credit support for minor irrigation activities, tube wells, dug wells, pump sets, micro-irrigation etc. has been one of the major areas of finance. Cumulatively credit extended was Rs 10,716 crore for MI during 1999-2000 to 2003-04. This has resulted in more area under assured irrigation, leading to multiple cropping. MI has been the environmental friendly technology. Assistance under RIDF to state governments over the years has resulted in additional irrigation potential of 92.47 lakh ha. Micro-irrigation (sprinkler and drip) has helped conserving water and increasing area under fruits, vegetables, floriculture etc. Maharashtra with nearly 60% area of the country under drip is a fine example in this regard.

Centrally Sponsored Schemes

Finances are given under various centrally sponsored subsidy schemes—for Cold storages and onion godowns; Rural godowns; Rainwater harvesting scheme for SC/ST farmers; Development/strengthening of agricultural marketing infrastructure, grading and standardization; Commercial production units of organic inputs, and Central plan schemes—Dairy/Poultry Venture Capital Fund that facilitated in capital formation under agriculture, providing increased credit avenues to banks, strengthening forward and backward linkages and also commercialization of activities.

A capacity of 39.77 lakh MT of cold storages (807 cold storages schemes have been sanctioned involving bank loan of Rs 498.89 lakh and subsidy of Rs 207.13 lakh), 0.31 lakh MT onion storage, and 98.74 lakh MT Rural godown capacity (4,440 rural godowns in 19 states) have been created, which would help prevent post-harvest losses and distress sale by farmers.

Agro Export Zones

Sixty AEZs in the country envisage integration of activities of all agencies with an end-to-end approach. AEZs envisage increasing export of identified commodities with economics of scale and providing remunerative returns to farming community in a sustained manner through convergence of interventions of various agencies. Creation of AEZs has facilitated in the exposure of new technologies to farmers and their adoption by them. And also creation of infrastructure (Pack houses, Grading units, Cold storages, etc.) and commercialization of crop cultivation in identified agroclimatic

zones. A separate scale of finance for export purpose for grapes has helped in quality production to meet export norms.

Agriclinics and Agribusiness Centres (ACABC)

The ACABC scheme for agri-graduates has resulted in setting-up of nearly 782 units. The scheme has facilitated in extension support through agri-graduates on commercial basis and helped farmers in getting services and technology transfer, besides employment generation for graduates.

Contract Farming

Commercialization by integration of all activities involved in production, processing and marketing of agricultural commodities has been made possible with the advent of contract farming. Traditionally contract farming was confined to production of sugarcane, tea, coffee, cotton, milk, etc. Contract farming has been gaining ground as a solution for assured supplies of uniform quality for processors and traders. Corporatization of contract farming has potential to boost farm incomes and to increase global trade of Indian agri-produce. The farmers especially small farmers also benefit in the process from diversification, technological upgradation and assured market. The pace of contract farming is on the rise after the amendment to APMC Act by the state governments.

Contract farming corporates in our country include: Himalaya Health Care, Mysore SNC Oil Company, Sami Labs, Ion Exchange (Enviro Farms), United Breweries, Satnam Overseas (Basamati rice), Amrta Feeds, PepsiCo, Punjab Agro Foods, Apache Cotton Company, Mahindra and Mahindra, Cadbury, Godrej, ACE Agrotech, L&T, Hafed, BEC Co, Reliance Group, JK Paper, Shakti Sugar, Fritto Lay India, etc. An area of about 2.7 lakh ha is under contract farming in the production of basamati rice, maize, cotton, medicinal plants, gherkins, vegetables and flowers, cocoa, oil-palm, aloe vera, sugar, eucalyptus, exotic vegetables, chips-quality potatoes, soybean, sugarcane, orange, caprica chilli, pulses and spices, tomato, guar-gum, barley, turmeric, sunflower, safed musli, ragi seeds, etc.

Contract broiler sector is now spreading at a rapid pace. Nearly 35–40 % of broilers turn over (47 million per month) is now under contract farming. Tamil Nadu, Andhra Pradesh, Karnataka and Maharashtra are the major states. The contract farming in broilers is facilitating in integration and insulating farmers from wide price fluctuations. The contract is also helping in encouraging scientific farming and value-addition through processing.

Contract farming has the potential for dissemination of new technologies over a wide area, with benefits for producers, processors, marketers and technology providers. The future of a market-led agriculture seems closely aligned to orderly development of contract-farming arrangements.

ISSUES IN TECHNOLOGY COMMERCIALIZATION AND FINANCING

1. Prevalence of informal credit, accounting for more than 35% of

population being covered by informal finance, limits financing of emerging technologies, especially those which are investment-intensive.

2. Continuing reluctance of finance to lead technology – The lack of familiarity and heightened risk perception about new technologies hinder adequate credit flows.
3. Failure of high-profile ventures that failed to honour commitments to procure from farmers; market failure of new crops and new technologies (safed musali, vanilla, BT cotton in some areas).
4. Adverse fall out of some technologies on environment and ecology.
5. Threat perceptions arising from GMOs entering food-chain.

Suggestions

Technology

1. Productivity and income generation should be hand-in-hand. The technology which gives higher surplus at the level of farmer/producer needs propagation. There has been undue emphasis on production and productivity rather on profitability and increased incomes at farm level. Technology should pave way for increased returns at the level of producers.
2. Use of IT and Internet Kiosks for all services at the door-step of farmers for facile access to information.
3. The processing units should be facilitated in obtaining HACCP certification and other quality standards.
4. Promoting more certification agencies for organic farming, exporting of fruits etc.
5. The ICAR and Agricultural universities to join hand with corporate sector for taking up need-based R& D to facilitate transfer of technology to field.
6. Development of drylands and rainfed farming regions needs top priority. Suitable selection of crops, use of satellite-based forecasting system, and sustainable approach, insurance coverage need focussed attention. Implementation of watershed projects is the ideal sustainable option.

Commercialization

- Involvement of grower organizations for various commodities like Grape/ Pomegranate/Mango, etc. for identifying commercial activities that can be replicated.
- Contract farming can be one of the approaches for commercialization to facilitate adoption of modern technology/ improved package of practices for improving productivity at optimal cost of production so that farmer/producer and processor/exporter/ consumer are benefited.

- The productivity variations are wide in the country from region to region and even within agroclimatic region. A pilot project can be encouraged for replicating technology adopted by progressive farmers, who could achieve best productivity in a region among other farmers within the agroclimate.

Finance

1. Use of existing non-formal agencies for credit delivery is an option to be explored by banks to widen outreach with cost efficiencies. The greater local knowledge and low overhead costs make SHGs, joint liability groups, arathiyas, village mahajan, input suppliers, wholesale procurers and the like very suitable franchisees of bank credit. The direct selling agent concept used in urban areas can be implemented with suitable changes in rural areas through these non-formal agencies.
2. The insurance mechanisms need to be strengthened to facilitate claim settlement at individual farm levels so that risk management becomes meaningful. Technology risks should also be covered effectively.
3. The contract-farming arrangements that help in recovery of bank loans through buyers of produce have been welcomed by banks. These arrangements on account of assured market and hassle-free recovery of bank loans have gained support at all quarters. Further the contract-farming mechanism would require a different credit product that needs to be administered and serviced differently. The tripartite agreements need a stringent enforcement mechanism; for which suitable legislation may be necessary.
4. The cost of credit has to be kept at realistically low levels so that farming operations become profitable. This would be possible only if transactions and risk costs are kept at the minimum by banks.
5. The changing nature of credit demand has to be fully understood by banks to design appropriate customer-friendly products. Enterprise farming requires larger loans, more as working capital than as crop production loans. Marketing loans are likely to be demanded more on account of higher marketable surpluses and more efficient transport arrangements.
6. Processing and packaging units are increasingly being set-up and hence term loan requirements are on the rise. Understanding the nature of agro-processing is a critical requirement for banks wanting to enter this sector.
7. The shifts in demand pattern in agricultural credit offer opportunities to banks for customizing products for large players, and standardizing credit facilities to reduce cost in case of small loans.

8. Banks to build capacity of their rural development officers for exploring credit to new areas like AEZs, ACABC, Organic farming, micro-irrigation, protected cultivation of flowers in poly-houses, financing in completed RIDF projects, etc.
9. Banks need to play a proactive role in the preparation of credit plans involving NGOs and financing for identified activities in completed watersheds for sustainable development.
10. Banks need to take advantages of centrally sponsored schemes, schemes under NHB, NHM, and can identify new borrowers through various Grower Associations (Grape, pomegranate, mango, orange), Cooperative Milk unions, private dairy units, FFDA etc. for expanding credit base.

The short-term and long-term impacts of technology need to be analysed before commercialization. The tradeoffs between alternatives also need to be studied and decisions taken in the interest of greatest good of the largest number.

Often rural people find that their skill sets have become obsolete with the advent of new technology and that their livelihoods are threatened. In such cases the economic costs of impoverishment are very high. Commercialization of such technologies should necessarily be carried out with great caution.

Health risks arising from transgenic plant varieties and other GMOs are real. The widespread incidence of mad-cow disease and bird flu are warning bells. Technology should not end-up making enemies of humanity stronger. Commercialization would market produces that are profitable. Finance should take a long-term view and support those ventures that are sustainable and viable over a long-term.

Let us use technology to make our livelihoods and habitats better, not only for us, but for the future too.

4

Private-Public Partnership: Problems and Potentials

Mruthyunjaya

Public-private sector partnership (PPP) is a new institutional innovation to bring in synergy, mobilize resources, generate, validate and transfer technologies. Signs of progress in forging alliances among partners are seen in the last few years in some pockets, but such examples making system-wide impact are not many. The success stories have raised expectations, but a high-level policy statement unequivocally promoting PPP is still wanting. Further, there are still misperceptions between public and private sectors with regard to intentions, goals and credibility of achievements. And another problem is lack of accurate mapping of proprietary assets and responsibilities between these sectors for effective functioning. There should be appreciation and follow-up of best practices followed by public and private sectors with regard to business approach and skills; decision-making and operational procedures; connectivity with largest constituency – farmers, traders and consumers; technology generation, validation and delivery; interface with civil society organizations; efficiency promoting work-culture; response style and time and incentive. All these, if mutually imbibed and internalized, will add to run-away success of PPP.

Potentials: One of the great potentials of PPP lies in human resource development and training. Under HRD / training, success has been achieved through PPP in seed technology, DNA fingerprinting, quarantine / plant protection, artificial insemination, feed compounding and supplementation, eco-friendly technology for hatchery management, polyculture technology for carps, etc. More and more areas of mutual interest are to be identified and pursued. Another areas of great potential include apex trial of varieties, testing of equipment etc. Such activities will build in much needed confidence, credibility and may lead to business promotion of both partners.

In view of the changing market context, specialized research in agreed areas particularly covering entire value-chain, sustainable rural livelihood options etc. will be immensely helpful. Similarly, development of new

molecules of chemicals, improvement of quality of produce like carpet-wool, reduction of aflatoxin in groundnut, etc., setting-up pilot plants for processing of produce, establishment of technology incubation centres, identification/establishment of referral laboratories and certification facilities should receive attention. The other potential areas of PPP include organizing periodic open field days and interactive meets, joint project proposal preparation for funding from different donors, providing easy access to facilities in public and private sector institutions, and sponsoring joint studies on adoption and impact of technologies.

ACCELERATED PROGRESS UNDER PPP: SOME SUGGESTIONS

PPP is a reality and a compulsion. Achieving fast progress is dependent on certain requirements. They include, a high-level national policy statement that unequivocally promotes PPP in agricultural research, developing national policy and guidelines for PPP, devolution of powers, freedom, flexibility with accountability in public sector institutions, more studies and analyses of problems, prospects, mechanisms etc. of PPP within the NARS and other science organizations, sponsoring fellowships to PG students of public research institutions by private sectors, need-based mobility of staff between public and private sectors, creation of apex technology transfer and commercialization unit at the ICAR for guidance, policy-analysis, regulation and policy communication, following principles of PPP, namely, identifying partner, understanding partner, identifying priorities, understanding common goal and ensuring communication among partners, bringing in organization and management reforms including organizing extensive trainings to contribute to build-up of positive mindset, efficient work-culture, response style and time and incentives and meet every year regularly to take stock and outline steps for moving forward.

PPP is going to stay with us. But certain problems relating to trust, credibility, work-culture, clear-cut business rules and legal framework, are to be immediately addressed if fast progress is to be achieved. Strong realization on both the sides to come together and work together will help in overcoming these problems. Regular meetings and clear communication between them will hasten the pace of progress under the PPP.

Crop Varieties and Planting Materials

G. Kalloo

Seed is the basic input for higher productivity. About 8,000 tonnes of breeder seeds for different crops, including 2,500 tonnes for potato itself, are produced annually. National Agricultural Research System has so far released more than 3,300 improved varieties of food crops, pulses, oilseeds, horticultural crops and commercial crops for commercial cultivation. Integrity of seed multiplication chain is a crucial requirement for successful agricultural production activity. We have a well-knit seed multiplication and distribution system in the country with a network of 19 seed certification agencies and nearly 100 notified seed-testing laboratories. The country has varied agroclimates and a fast developing private seed sector, presenting both challenges and opportunities.

There are about 150 research and development units in the country with a significant capacity in the private sector for development of improved seed material including hybrids. In addition to the National Seed Corporation and State Farm Corporation of India, there are 13 State Seed Corporations and several para-state bodies to multiply seed.

The vegetable seed requirement for India has been estimated about 35,000 tonnes annually. In this connection, the ICAR has initiated 20 revolving fund schemes at 16 institutions with an initial cost of Rs 167.62 lakh. Several certification standards for disease-free, tissue-cultured planting materials have also been developed.

Plant Varieties and Farmers' Rights Act: This act provides protection for newly developed varieties including extant and farmers' varieties. To provide protection to these varieties, there should be significant distinctiveness, novelty, uniformity and stability. Both public and private sectors should be partners in this effort. So far, 35 crops have been brought under DUS testing. Strategic public-private partnership is necessary for promotion of extant varieties. With the help the plant varieties and farmer's rights act, 2001, extant varieties can be effectively marketed abroad by public-private consortia, and this requires, among other things, clear guidelines for benefit-sharing among partners.

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SEED QUALITY AND HEALTH

The seed quality has to be ensured including that of genetically modified crops. Hybrid varieties provide 15-30% yield advantage. Techniques for economic hybrid seed production are required to be developed, and hybrid seed production needs to be promoted on a large scale to meet country's requirement. This is possible through an effective cooperation between public and private sectors in seed technology such as production, testing, training and awareness generation. Use of indigenous genes, constructs and promoters is essential for long-term sustainability. Both cooperative and corporate approaches have been found effective for varieties popularization.

In addition to improving availability of quality seed, quality-planting material for different crops also needs to be made available. Wherever possible, we should develop and adopt modern techniques such as shoot-tip graft, softwood graft, budding, micro-tubers and synthetic seeds to produce sufficient quantities of planting materials. There has been a considerable progress in the development and use of micropropagation techniques for potato, banana, spices and flowers with appropriate certification standards. True potato seed (TPS) production is an alternate low-cost technology for producing healthy planting material for potato. In fact, a combination of *in-vitro* multiplication and sensitive virus-detection techniques have resulted into threefold improvement in potato seed health. Several other fast and accurate protocols and kits for disease diagnostics have been developed. Seed health is influenced by insects and pathogens. Seed health can however be detected and monitored through such non-destructive techniques as X-ray radiography and NMR imagine. Methods are available for ensuring genetic purity of varieties and parental lines.

ORGANIC CROP PRODUCTION

A new dimension for seed industry has been added for organic production of crops. While there is a need for breeding suitable cultivars and planting materials for organic farming, there is also a need for suitable package of practices for seed and planting material production. Considerable value-addition to varieties of seeds is possible through maintenance breeding, seed priming, seed invigoration, seed coating and seed pelleting.

The whole range of production and availability of quality seed and planting material require a vibrant public-private partnership, nurtured and supported through suitable agreements, contracts and sharing of resources. Such alliances should come into existence in the very near future. The seed production and availability of different crops must be governed through appropriate quality standards and certification practices so that stakeholders along the value-chain are benefited.

Capabilities in Agricultural Biotechnology

N. K. Singh

FOODGRAINS PRODUCTION *VIS-À-VIS* POPULATION GROWTH TRENDS IN INDIA

India has made remarkable progress by quadrupling its foodgrains production during the five decades of post-independence period, which made the country self-sufficient to feed its burgeoning population that tripled in the same period (Fig. 1). It used to suffer from repeated famines during the colonial period and the early part of the post-independence era, but overcame its food supply problems by concerted efforts of public policy makers, project implementing government agencies, agricultural scientists, and overall by the tenacity and wisdom of the Indian farmers in adopting new technologies. The transformation in foodgrains production scenario received much impetus during much celebrated “green revolution” in late sixties and seventies. A look at the food production statistics clearly shows that a steady increase in food production trend has been maintained beyond the years. However, there were dips in food production growth curve that were closely associated with the years of drought, and there is a worrying hint of flattening of graph during the last 3-4 years. Although much less celebrated, similar gains in production have been achieved in fruits, vegetables, milk and poultry production in India. Unfortunately, the production of grain-legumes including pulses which are the main source of food proteins has remained stagnated over the years, leading to reduced per caput availability, forcing heavy imports.

The gain in production was achieved and sustained largely by the efforts of the public sector, public sector undertakings and the National Agricultural Research System (NARS) that includes state agricultural universities (SAUs) and the institutions under the Indian Council of Agricultural Research (ICAR). The main components of our green revolution were: (i) Continuous development of high-yielding fertilizer-responsive semi-dwarf varieties of wheat and rice; (ii) Quality seeds supplied by the national and state seed corporations; (iii) Improved crop management practices including (a) assured irrigation water, fertilizers and

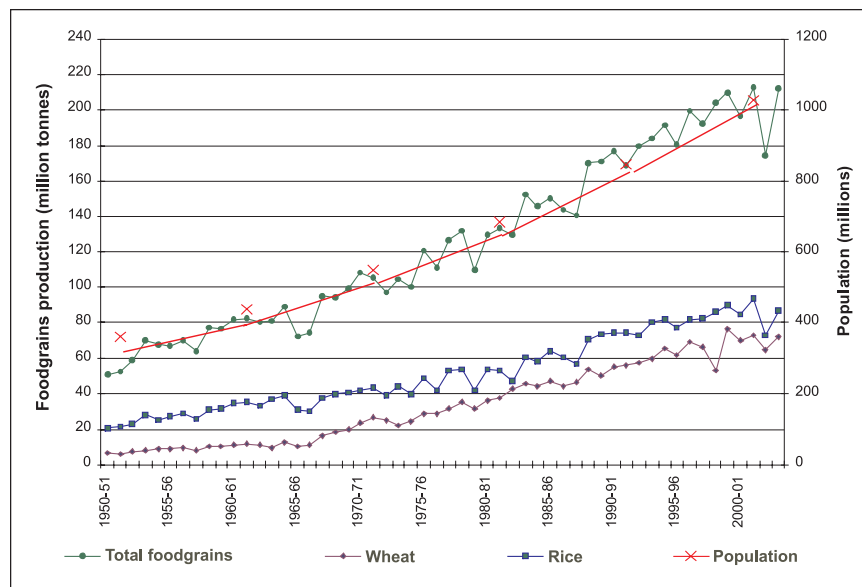


Fig. 1 Foodgrains production increased sufficiently to feed India's burgeoning population during the post independence five decades

pesticides, (b) use of farm machinery and implements, (c) availability of rural credit on easy terms through co-operatives and rural banks, and (d) imparting of know-how of the production technology to the farmers through frontline demonstrations; (iv) Procurement price support system and actual procurement of the produce by the government agencies. The role of the private sector during this period had been minimal except for the production and supply of pesticides and farm machineries. However in changed economic scenario, the role of private sector is increasing as there are now growing business opportunities in seed sector, contract farming and food processing and marketing.

COMPLEMENTARITIES IN STRENGTHS OF PUBLIC AND PRIVATE SECTORS

There are certain key features of public and private sectors that determine the extent of their likely involvement in any endeavour. The private sector is profit oriented, which is crucial for its survival, and a part of their earning is paid to the government in the form of taxes. The public sector on the other hand has social responsibilities and must invest in all kinds of infrastructure to support overall development for the benefit of all the citizens to ensure peace and prosperity of the society in a holistic sense. Many of the public sector activities may not be profitable in short-term, but are essential for long-term stability of the country. The private sector is known to have better marketing skills, efficient product delivery system, quality service providing capability, and better up-scaling technologies. The public sector has extensive infrastructure, institutions of higher learning that can generate knowledge

through basic research, and it has a vast pool of both teachers and trained human resource. Also, the public sector has the capacity of solving those problems that do not have immediate rewards in the form of monetary profits. In changed economic scenario, complementarities of the public and private sectors must come together for a better future of the Indian agriculture. With proper regulatory mechanisms in place, the private sector will play increasingly significant role in enhancing the security of the nation. There is a paradigm shift in the role of public and private sectors in the agriculture as we are moving from a largely agrarian society towards an industrially developed nation.

Status of the Public-Private Partnership in Agriculture

The public-private partnership is quite common in medicine. There are several joint university-industry research projects, multi-party and multi-sectoral research consortia, local development programmes between small businesses and government, or large-scale global partnership programmes in medicine, e.g. international health sector hosts more than 100 public-private partnerships addressing 40 distinct diseases and conditions. Here incentive clearly lies in prospect of marketing and licensing rights for medicinal products by the associated private sector in the international market. There are valid reasons for low willingness and ability to enter into public-private partnerships in agriculture. The agricultural sector is challenged by fundamentally different ground realities. Quite often partners do not adequately account for and minimize direct and hidden costs of a collaborative research investment, as they are hindered by persistent negative perceptions of each other. Furthermore, there is a lack of creative organizational mechanism to reduce inter-sectoral competition for key assets and resources.

Even though demography of Indian population is different where about 70% of its people is involved in farming activities; it is a fast developing country, where demography is now changing rapidly towards more urbanization. There is a shift in the share of public and private sectors expenditure in agriculture as the nation moves from agrarian societies to urban societies. According to a UN survey conducted in 1995, there was a sharp difference in the proportion of public and private sector investments in agricultural research in developing and industrialized countries in 1993. While public sectors in both developing and industrialized countries had spent almost similar amount on agricultural research i.e. US\$11,469 million and US\$10,215 million, the share of the private sector expenditure in developing and industrialized countries was drastically different, i.e. US\$672 million and US\$10,829 million, respectively. Thus, only 5.5% of the total expenditure on agricultural research in the developing countries was coming from private sector, whereas the proportion was 55% in the industrialized countries.

There may be several reasons for this but one obvious factor is the high investment risk and lack of assured returns in agricultural sector of a developing country like India, where farm-holdings are very small and most farms are not running efficiently due to lack of basic inputs and managerial

skills. With the growing prosperity in India, the private sector is discovering niches where it can make sufficient profits, which will be the main incentive for its involvement in the agricultural sector. There are now many examples of public-private partnerships in agricultural research and development. For example, in Southeast Asia, Zeneca has provided genetic material to several national agricultural research systems to develop delayed-ripening traits in papaya, but has licensed the technology for local, non-export use only through material transfer agreements. In Kenya, KARI received training and technology from Monsanto to develop virus-resistant sweet-potato for use only in the region through a licensing agreement on technology donations. Proprietary technologies can be bought by the public sector for use in the developing countries, e.g. a consortium of public-sector institutes in Asia led by the International Rice Research Institute (IRRI) has purchased the rights to a *Bt* gene owned by Planttech, a Japanese company.

Public Sector Capabilities in Agricultural Biotechnology

It is clear that conventional methods of crop improvement have now exhausted their potential, and have become inefficient at least in major crops. The future transformation in the agricultural production in India requires infusion of new technologies, e.g. Biotechnology, just as the adoption of semi-dwarf varieties in the sixties and seventies played a crucial role in ushering in a new era of recombination breeding in cereal crops, that has sustained growth in crop productivity till now, but is now showing signs of technology fatigue. Due to unique strengths and weaknesses of the public and private sectors and a favourable intellectual property regime, it is feasible to harness synergy of public and private sectors by complementing strengths of each other through their partnerships.

Institutional Infrastructure

India has created a large number of public-sector institutions for agricultural research and development. These include 97 directly under the control of the Indian Council of Agricultural Research (ICAR), 38 State Agricultural Universities (SAUs), 5 deemed universities, 1 Central Agricultural University and Agricultural colleges/institutes under the traditional central universities like Banaras Hindu University, together comprising public sector National Agricultural Research System (NARS) (Table 1). It is this NARS that has sustained gains of so called green revolution by active research and development, human resource development and agricultural extension activities over the last five decades. Some of the NARS institutions are of international repute and have contributed in major national and international scientific endeavours; others are location-specific and commodity-specific to cater for multifarious needs and aspirations of diverse climates and agro-ecological zones. There is no other country in the world that can match the diversity of Indian agriculture. The traditional farmers, the tribals and the modern agricultural

research scientists have collected and developed immense wealth of germplasm, which is a gold mine for gene discovery and allele mining in post-genomic era. The ICAR has very wisely established 4 national bureaux for collection, maintenance, evaluation and utilization of animal, plant, fish and microbial germplasm resources of the nation; considering alarming rate by which species are becoming extinct with rapid industrialization and urbanization.

Table 1. Institutional infrastructure in the Indian National Agricultural Research System

Sl No.	Institution	Number
1	ICAR institutes	
	Central Research Institutes	47
	National Bureaux	5
	Project Directorates	12
	National Research Centres	33
2	State Agricultural Universities	38
3	Deemed Universities	5
4	Central Agricultural University	1
5	Central Universities with Agriculture Faculty	1
6	Biotechnology Parks (established and proposed)	17

Administrative Infrastructure

India has been one of the few countries in the world and perhaps the first developing country to develop elaborate bio-safety guidelines to conduct molecular biology and biotechnology research and development activities. The setting-up of a separate Department of Biotechnology (DBT), under the Ministry of Science and Technology, as early as in 1986 gave a new impetus to the development of the field of modern biology and biotechnology in India. In nearly two decades of its existence, the department has promoted and accelerated pace of development of biotechnology in the country. Through several R&D projects, demonstrations and creation of infrastructural facilities, a clear visible impact of this field has been seen. The DBT has made significant achievements in growth and application of biotechnology in the broad areas of agriculture, health-care, animal sciences, environment and industry. Of particular relevance is the putting in place of detailed guidelines for food and environmental safety guidelines for the genetically modified organisms. The three tier system set-up for regulating recombinant DNA research, controlled trials and finally the environmental release of transgenic organisms includes Institutional Bio-safety Committee (IBSC), Review Committee on Genetic Manipulations (RCGM) and Genetic Engineering Approval Committee (GEAC). It is this system that supervised the release of India's first genetically engineered crop, i.e. Bt-cotton, a product developed by the private sector. Several genetically engineered products are in pipeline going through the mandatory regulatory testing mechanism.

Similarly, India has also developed an intellectual property rights

regime that balances its obligations under the WTO, and at the same time safeguards the interests of its farmers and the public sector research and development system by enacting a Plant Variety Protection and Farmers' Right (PVPFR) act, and amending Indian Patent act to allow for product patenting as required under the WTO. These administrative and policy changes should encourage public-private partnerships in the agriculture sector also. The government nodal agencies are mostly from the Ministry of Science and Technology, the Ministry of Environment and Fisheries and the Ministry of Agriculture and Cooperation.

Trained Human Resource

India has one of the largest pool of trained human resource engaged in agriculture. The ICAR alone has about 30,000 personnel, 7,000 of which are active research scientists in all branches of agriculture. In addition, the SAUs have about 26,000 scientists/professors teaching and involved in research and extension activities in agriculture. There are more than 130 traditional state and central universities; many of which have agricultural faculties and research workers in excess of thousand. The selected laboratories of the Council of Scientific and Industrial Research (CSIR) are actively engaged in the development of Biotech products, particularly in the area of food, fermentation and medicinal plants. The Defence Research and Development Organization (DRDO) has separate group of Defence Agricultural Research Laboratories (DARLs), which employ a pool of highly trained scientific personnel. The research activities and inventions of scientists working in the public-sector institutions could derive more values through upscaling and marketing skills of private commercial set-up through public-private partnerships.

The Indian public-sector institutions produce more than 3,000 highly trained M.Sc. Biotechnology professionals and similar number of PhDs per year, a large fraction of which seek and find highly paid jobs in industrially developed countries of Europe and North America. Although, many of these postgraduates are now getting placement in private-sector industries, their training could be modulated depending upon the industry needs with effective public-private cooperation.

Major Achievements of Public Sector in Agricultural Biotechnology

Two decades of concerted efforts in public research and development in identified areas of modern biology and agricultural biotechnology have given rich dividends. The proven technologies at the laboratory level have been scaled up and demonstrated in fields, particularly in micropropagation of planting materials, biofertilizers and biocontrol agents. Patenting of innovations, technology transfer to industries and close interaction with them have given a new direction to biotechnology research in medicine and diagnostics. Initiatives have been taken to promote transgenic research in plants with emphasis on insect-pest and virus resistances, nutritional quality enhancement, silk-worm genome analysis, plant genome research,

development, validation and commercialization of diagnostic kits and vaccines for communicable diseases, food biotechnology, biodiversity conservation and bio-prospecting, setting-up of micropropagation parks and biotechnology based development for socially disadvantaged groups, rural areas and women in different states. Some noteworthy examples of public-sector achievements in agriculture biotechnology are as follows.

- Decoding of rice genome chromosome 11 (Nature, 11 August 2005).
- DNA fingerprinting of rice, wheat, mustard, sugarcane, brinjal, citrus, grapes, *ber*, jute etc.
- Map based cloning of rice blast resistance gene *Pik^h*.
- Mapping of genes and quality trait loci (QTLs) for yield, quality, drought and salt tolerance and insect resistance traits in rice and downy mildew in maize.
- Marker-assisted breeding in rice (bacterial leaf blight) and wheat (rust resistance) and maize (quality protein), for which lines are under advance field trials.
- A large number of genes and promoters have been cloned for transgenic development
- Transgenic rice, brinjal, tomato and mustard with genes for insect resistance, virus resistance and drought tolerance are under limited field trials.

Research programmes initiated : The ICAR and the DBT have started a number of multi-institutional network projects for gene discovery, transgenic development and marker-assisted breeding in crop-plants. These include: DBT network project on Rice Functional Genomics; DBT network project on Tomato Genomics; ICAR network project on Functional Genomics and Transgenics in Crops; ICAR network project on Molecular Breeding in Crops; ICAR network project on Gene Pyramiding in Crops; ICAR network project on Biosystematics of Insects; ICAR National Seeds Project

In addition, project proposals are under consideration for Microbial Genomics and Pigeonpea Genomics initiative.

Future Prospects and Modes of Public-Private Partnership

With the opening up of Indian economy during the last decade, the role of private sector has increased in many areas, which used to be predominantly public-sector activities. In agriculture, the private sector has found business opportunities in seed sector and allied biofertilizer, biocontrol and micropropagation industries in addition to chemical pesticides and farm machineries that they have already been engaged. Based

on the experience of the public-private partnership in the developed countries there are many successful models on which public-private partnership can be developed for the benefit of the society at large. These include: (i) Joint R&D projects from conception to commercialization (with joint IPR); (ii) Licensing of the public research output to private sector for commercialization (iii) Private sector sponsored chairs and fellowships in public institutions; (iv) Public sector infrastructure for testing of private- sector products for agronomic performance and bio-safety; (v) Academia-industry interface by regular dialog is a must, and establishment of biotechnology parks for technology incubation before commercialization is highly desirable to promote such partnership.

India's Herbal Heritage

Satyabrata Maiti¹ and K. A. Geetha²

India has a rich heritage and a long history of using medicinal and aromatic plants in improving quality of life. And our country is also fortunate, perhaps, to have the richest reservoirs of traditional herbal medicinal plants and prescriptions. The Indian system of medicines comprising Ayurveda, Siddha and Unani have their long roots in our society. Ayurveda is about 5,000 years old, and predominantly uses medicinal plants for its preparations and formulations. Modern pharmacopoeia has also enlisted about 25% of drugs derived from plants. A vast majority of modern drugs although are synthetic analogues but are built on prototype compounds isolated from plants. The present era is witnessing a fascinating rejuvenation in traditional system of medicine.

India's plant biodiversity is one of the richest in the world. It homes about 43,000 of plant species on the earth; many of which have not been fully explored and cultivated. Western Ghat and Himalayas are the most tempting locations for those in bio-industries, causing a serious danger to the plant wealth due to its over-exploitation, causing serious depletion. About 7,500 plant species, out of 43,000 that are said to exist in the country, are recorded in various folklore medicines. About 1,700 species are referred in the Ayurvedic texts.

From time immemorial, India has long heritage of use of herbal products not only for medicine but also for cosmetics, health hygiene, toiletries, fragrance and food supplements. The global herbal industry is projected to be worth US\$ 200 billion in 2008 and US\$ 5 trillion in 2050 (Source: The World Bank Report, 2000). Functional foods are becoming very important in international markets. These foods are used for correction and maintenance of gut health, heart health, bone health and immune function. A large number of tropical plants high in antioxidants, proteins and immunomodulator contents are good candidates for functional food to capture burgeoning market. Present market is about US\$ 2.0 billion in Europe and about US\$ 5.0 billion in US. At present, herbal cosmetic is a new emerging field, known as cosmeceuticals (functional make-up); parallel

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to trend of functional food. Cosmeceuticals are cosmetics and pharmaceuticals hybrids designed to promote skin health and beauty. Some of the moisturizers, for example, are designed for transdermal system of nutrients delivery to body. Indicating prospect of the field, L'Oreal has entered into a joint venture with renowned food manufacturing company Nestle to develop cosmeceuticals. Present market of cosmeceuticals is US\$5.0 billion in Europe and US\$ 2.5 billion in US. Products of *Aloe vera* are now widely used in cosmetics. Similarly identifying traditional skin-care and beauty products may offer good scope for future business.

India's share in the growing world herbal market is negligible mainly because of the inadequate investment in research in this sector and lack of validation of our old heritage knowledge in the light of the modern science that is acceptable to westerners. However, the potential of India is immense, if orchestrated efforts are put forth with a clear vision to capture a lion-share of the world herbal trade in the next 10 years. We need to give a special emphasis on natural products derived from herbs, spices, and aromatic and medicinal plants from rich biodiversity of our tropical rain-forests of western Ghat and temperate forests of Himalayas.

STATUS OF TRADE IN MEDICINAL PLANTS

Out of 8,000 plant species recorded in medicinal use in India, more than 1,000 are estimated to be in commercial trade as plant raw drugs. Inventory of such species, prepared by FRLHT, based on extensive surveys of plant raw drug markets across the country and responses obtained from a few sampled ISM industries, enlist about 880 botanical species. Out of top 100 traded medicinal plants of India, only 5 of these species are obtained entirely from cultivation, *Aloe barbadensis*, *Cassia angustifolia*, *Lawsonia inermis*, *Plantago ovata* and *Trachyspermum ammi*. The remaining 95 species occur in cultivated as well as wild state (41 species) or only in wild state (54 species). There is a need to develop appropriate strategies for cultivation of the remaining species.

CHALLENGES BEFORE THE INDUSTRIES

- Our export is stagnating around Rs 500 crore during the last several years. In spite of our immense potential, the export is not going up. This is because of our export is mainly of crude drugs. Until we increase our share in finished products, our share in export earnings will remain stagnating. At present, we export about 27% finished product, 20% extracts and 53% crude drugs.
- Supply of quality products free from pesticide residues and heavy metals and microbial contamination is a real challenge for India, since international market is quality conscious.

WEAKNESSES OF THE MP SECTOR

There are weaknesses of the sector which need immediate attention.

- Poor database (do not match with production, utilization and supply)
- Lack of well-defined quality standards of raw drugs and ISM products
- Lack of knowledge on quality aspects of variability available in nature
- Inadvertent use of wrong plant species
- Marketing inefficient; informal; secretive and opportunistic
- Lack of desire to collaborate and co-operate among stakeholders

ROLE OF THE ICAR IN PROMOTION OF MP

The Indian Council of Agricultural Research had established a National Research Centre for Medicinal and Aromatic Plants (NRCMAP) on 24 November 1992 at Boriavi in Anand district of Gujarat to work exclusively on medicinal and aromatic plants.

The ICAR is also operating an All-India Coordinated Research Project on medicinal and aromatic plants since 1971 which has been renamed as All-India Networking Research Project on Medicinal and Aromatic Plants (AINPMAP) in the 10th five year plan. There are ten centres of this in SAUs distributed in different climates

ICAR's Strength

- We have diverse climates for growing large number of medicinal plants and rich biodiversity from our tropical rain forests of Western Ghat and temperate forests of Himalayas.
- We have created All-India Networking Research Project centres located in almost all conditions.
- NRCMAP offers a platform for genotype × environment interaction studies which are important for quality assurance of MP.
- NRCMAP gives a forum for germplasm assembly within the country.

Research Mandates

- Develop good agricultural practices (GAP) for important medicinal plants through basic, strategic and applied researches.
- Germplasm enhancement of various medicinal and aromatic plants.
- Co-ordinate research under the All-India Networking Research Project on Medicinal and Aromatic Plants
- Act as the National Repository for genetic resources of some important medicinal and aromatic plants
- Act as an Information Data Bank on medicinal and aromatic plants.
- Transfer of technologies developed by the NRC to farmers through cooperation with the developmental agencies

*NRC Research Thrusts**CROP IMPROVEMENT*

- Introduction, collection and enhancement of germplasm
- Breeding for high yield
- Breeding for quality
- Breeding for disease-pests resistance

CROP PRODUCTION

- Development of good agricultural practices
- Water, nutrient integrated pest management
- Developing yield forecasting models

CROP PROTECTION

- Development of IPM technology
- Disease and pest forecasting

QUALITY ASSESSMENT

- Development of new and fast techniques for quality assessment
- Monitoring quality of raw materials
- Fixing standards for raw materials

POST-HARVEST MANAGEMENT

- Development of efficient drying system
- Development of storage technology for reducing post-harvest losses
- Monitoring of aflatoxin contamination

BIOTECHNOLOGY

- Genetic fingerprinting
- Micropropagation

Transformation in Floriculture through Public-Private Partnership

Vishnu Swaroop

Flowers and gardens have been associated with Indian culture from pre-historic and Vedic times. Aesthetic, social and economic aspects of flowers, directly influencing mankind and environment, have received due attention only in recent years. Ornamental plants have an important role in environmental planning of urban and rural areas for abatement of pollution, social and rural forestry, wasteland development, afforestation and landscaping of outdoor and indoor spaces.

Flower-crops provide higher income from comparatively smaller areas with high profitability as compared to other crops. However, advanced floriculture technology is capital-intensive in view of the high cost of greenhouses, net houses, equipment, machinery, chemicals, storage, packaging and other infrastructural facilities. Floriculture generates gainful employment for youth in suburban and rural areas. It is no longer considered to have an aesthetic value alone, as it has proven to be useful in export trade, and India must strive forward to explore fully potential of labour-cost advantage, manpower and favourable climate.

Today floriculture has blossomed into a profitable agri-business in India, both for domestic and export markets. The floriculture industry comprises following.

- The florist trades of
 - Traditional fresh flowers, either as loose/stalkless flowers or with small stems, like rose, jasmine, marigold, aster, chrysanthemum, tuberose, crossandra, barleria, lotus etc.
 - Contemporary cut-flowers with long stems and cut foliage such as roses, lilies, chrysanthemum, dahlia, gerbera, gladiolus, carnation, orchids, anthuriums and a few others.
 - Dried flowers and foliage that are naturally dehydrated or desiccated.
 - Value-added products, like bouquets, floral baskets, flower arrangements, garlands, floral ornaments, pot-pourri etc.

- Plant nursery for propagation and supply of live ornamental plants including those multiplied by tissue culture.
- Supply of seedlings and rooted cuttings of bedding plants.
- Production and sale of seeds, bulbs, tubers, corms and other propagating materials.
- Flower perfume trade of essential oil, attar, concrete etc. mainly rose, jasmine, lavender, tuberose and geranium, required for cosmetic, food, beverage, incense and flavour industries and also natural floral colouring pigments for food industry.
- Plant rental services of indoor plants for commercial complexes, offices and business centres, etc.
- Landscaping of outdoor spaces including parks, gardens, avenues and indoor landscaping in homes, offices and shops

FLORICULTURE TRADE IN INDIA

Flowers and ornamental plants are grown for domestic and export markets. The rise in growth of floriculture recently in domestic market is primarily due to three major factors — changes in social values of people and transformation in life-style, increase in income-levels, particularly disposable income and changes in urban-rural population mix with increasing population in cities. Besides, the expansion of tourism and hotel industry has also contributed to change in social value. Traditional flowers are grown on 80,000 hectares with an annual production of about 3.5 lakh tonnes loose/stalkless flowers and 600 million cut-flowers for domestic market. The total value of domestic flower trade is about Rs 250 crore annually.

There are about 1,000 horticultural nurseries in different parts of the country; most of which deal with fruit-plants and also ornamental plants (trees, shrubs, climbers etc.) , indoor plants, flower-seeds and bulbs, tubers and corms. A few tissue-culture units established in Karnataka, Maharashtra, Gujarat, West Bengal, Kerala, Sikkim, Andhra Pradesh and Tamil Nadu produce tissue-cultured plants for distribution to large growers and also for export.

Flower seeds are produced on about 1,500-2,000 acres per year mainly in Karnataka, Maharashtra, Andhra Pradesh, Punjab and Haryana; most of which are exported. About 40-50% of total flower seed production area is in Punjab from where about Rs 6-7 crore worth of seeds are exported annually.

Export Trade

The floriculture export trade had started in 1991-92 with the establishment of the export-oriented cut-flower units under greenhouse at Bangalore, Pune, Hyderabad and a few other places after the thrust on the export of floriculture products and liberalization of import and export policies by the Government of India. The infrastructures of greenhouses, machinery, planting material as well as the production technology for roses

were introduced here mainly from the Netherlands and Israel. Presently about 210 hectares are under cut-flower production, mostly roses in greenhouses. The total export of cut-flowers, dried flowers and dried plants, live plants and foliage, bulbs increased to Rs 249.5 crore in 2003-04 from Rs 18.80 crore in 1993-94. Cut-flowers export contributed 18% while 71% was from dried flowers and dried plants. Among cut-flowers, the export of roses was about 95%. However, India's share is only 0.18% in the world floriculture trade of US\$ 9.4 billion, which is likely to grow to US\$ 16 billion by 2010.

Public and Private Partnership

Role of public sector: The public and private partnership based on the symbiotic relationship with mutual confidence and trust is vital in the national development of floriculture in the country. Both public institutions and private companies are important stakeholders in the development and rapid advancement of floriculture in the country. The private sector will always look for backward linkage with public institutions in respect to scientific and technological innovative and updated knowledge enhancement and enrichment and human resource development of highly qualified and skilled scientists and technicians required in agri-business.

Research and extension: The research in public institutions and agricultural/horticultural universities should be oriented towards floriculture- industry need-based projects in important growing areas of specific flower crops for both domestic and export markets. In this context, a few important aspects requiring research priority are mentioned as follows.

- To develop efficient, eco-friendly and cost-effective production system for cut-flowers under greenhouses or protected environment under the Indian tropical climate in the export zone areas for export. The beginning of floriculture export of cut-flowers, particularly of cut-roses coincided with economic reforms introduced in the country in 1991. Several export-oriented units (more than one hundred) were established in Pune, Bangalore, Hyderabad and a few other places in the country with import of infrastructure for greenhouses, machinery, chemicals, pesticides, growing media, planting material etc. along with production technology as well as technical consultants from Holland and Israel. The import of greenhouse infrastructure, production technology and expertise was allowed in view of the non-availability of these within the country; and collaboration of foreign companies with Indian counterparts was allowed by the Government of India. Later it was observed that greenhouse technology including design and infrastructure and growing system brought in from the temperate countries was not fully adapted to our tropical conditions.
- There is a need to develop F_1 hybrids of traditional flowers like marigold, jasmine, carnation, aster, balsam, antirrhinum etc. suitable for growing under tropical/subtropical climates. In many

of the annual flowers, the varieties grown by the farmers for cut-flowers are old, obsolete, exotic varieties. Seeds of F₁ hybrids of these annuals imported by private companies are expensive and often not available to small growers because most of these seeds are utilized for landscaping large gardens or home gardens in cities.

- Basic biotechnology studies related to male sterility may be undertaken by molecular analysis of mtDNA and cp genomes and their interaction with nuclear genes. This will be useful in heterosis breeding projects in flowering annuals.
- Agro-techniques should be standardized for growing flowers in existing cropping systems as a diversified crop for higher or additional income generation.
- New and novel varieties/hybrids developed using biotechnology and molecular biology techniques will be a boon to floriculture industry.
- Pre-bred material developed by conventional breeding or molecular breeding will be a great help to private companies in their endeavour to develop F₁ hybrids or varieties.
- Sharing of germplasm pool is needed for strengthening flower breeding in private sector.
- Survey and collection of native species and varieties of flowers in the rich natural habitats of the country, if undertaken, will prove useful in introducing new flowers to the world; which is now an emerging enterprise. Many countries abroad are making efforts in this direction and a few new flowers have been introduced into international market, like *Protea*, *Banksia*, *Lisianthus*, *Bouvardia*, *Heliconia*, *Alostroemeria*, Oriental lilies and a few others.
- Public institutions having modern tissue-culture laboratories may provide such facilities and also supply tissue-culture plants and develop protocols for ornamental plants required by industry.
- Standardization of post-harvest management system and packaging methods of flowers will greatly assist in growth of industry-based domestic market of traditional flowers as well as export, particularly of orchids, anthuriums and oriental lilies.
- It is necessary to stress research on designing and construction of effective, adaptable and low-cost greenhouses and net houses suited to Indian environment/climate compatible with desired production technology in important flower-growing regions in collaboration with private companies; according to the requirements of the growing quality flowers for export as well as for domestic trade.
- Both contractual research and collaborative research with private companies may be taken up in public-research institutions for mutual benefits.

Human Resource Development

The private companies will always depend upon public institutions for their requirement of scientific, technical, field and extension staff. Reorientation of syllabus and curriculum in floriculture with emphasis on commercialization and trade aspects will be necessary for rapid expansion of floriculture industry. The private sector can be an important catalyst in providing forward linkage to take advanced scientifically-based production technology to farmers resulting in higher production and better quality of floricultural products.

- Besides highly qualified scientific staff, there are demands for short-term training courses for field and extension staff in growing flowers under field and greenhouse conditions.
- Equally important will be the development of technical manpower at managerial and operational levels for commercial greenhouse production.
- There is a necessity to upgrade teaching facilities in public institutions by providing highly qualified and experienced staff and modern advanced logistics for laboratories, greenhouses, net houses, mechanical equipment, chemicals, growing media, pesticides, irrigation, fertigation and drip-equipment in agricultural universities and research centres.
- Nowadays, horticulture including floriculture is considered a highly developed commercially-oriented discipline. Hence, there is an urgent requirement to initiate management courses (MBA) in horticulture including floriculture in agricultural universities and ICAR institutes. It will not only provide capable technically qualified managerial personnel to private entrepreneurs but also opportunity for self-employment to students after graduation. Presently greenhouse management and production of roses and a few other flowers mainly for export is looked after by MBA qualified and experienced managers, who unfortunately do not have scientific and technical knowledge and experience, which is very much desired in such capital- intensive commercial scientific and technology-driven ventures.

Private Sector

There are a few private companies in floriculture business in the country which have good R&D facilities. Hence, most of the companies will have to depend upon public institutions for scientific and technical support for their successful performance and growth in floriculture trade. Though there are financial constraints in providing adequate funds for floriculture research projects both in public and private sectors, yet it may be in the greater interest of private companies to support funding of research projects and offer research grants, fellowships or scholarships in public institutions.

A few private companies that have modern scientific equipment and infrastructure for tissue culture, biotechnology and molecular biology

techniques can share these facilities with public institutions where these may not be available. These companies having excellent climate-controlled greenhouses or net houses, especially for production of cut-roses and other flowers for export can be helpful to public institutions in designing and construction of greenhouses suited to specific locations or agri-zones.

The International Seed Testing Association (ISTA) accredited seed testing laboratories in the private sector may share their modern seed testing facilities with public institutions and also assist in training of their staff regarding international seed testing standards for issuing orange and blue tags required for seed export.

The private companies having expertise in commercial flowers growing and hybrid seed production in greenhouses and open fields can collaborate in practical training of students and extension staff of public institutions on these aspects.

The companies with strong R&D and Product Development Divisions may be willing to mutually share their highly qualified and experienced professionals in research and teaching as well as management of floriculture with those of public sector with a view to improving human resource development programmes.

The already advanced e-commerce and information technology systems available in the industry, as in case of flower auction centres in Bangalore and other places, can be adopted by public sector to help flower-growers of traditional flowers for local market in respect to market intelligence, farm equipment, agri-inputs (seeds plants, fertilizers, chemicals, pesticides, growing media etc.), desired flower quality, production technology, post-harvest management, packaging etc. It will be helpful in strengthening extension services in rural areas.

Aerobic Composting by Excel Process

S. Kundu

With pressure to produce more from a limited farm land-holding, farmers, in general, have been using indiscriminately only synthetic fertilizers. The practice of adding organic manure has lost its relevance. Burning farm waste is the easiest way to dispose rather than convert organic waste into stabilized organic manure. The general perception that organic waste is organic manure is dangerous, and has to be stopped. Proper understanding of the useful organic waste and its conversion into stabilized organic manure has to be promoted. The concept of organic farming itself has its limitations if standards of organic manures are not defined.

Excel Industries Limited, Mumbai, has developed an effective and eco-friendly aerobic composting technology for bioconversion of organic fractions from city organic waste and farm waste into a useful end product, i.e. Bio-Organic Soil Enricher “Celrich™”. This technology has been jointly developed by scientists and technologists of the organization. The technology consists of a controlled biological process and mechanical screening thereafter.

Excel Process has optimized aerobic composting process to degrade city organic waste and farm waste in the shortest possible time by adapting both microbiological technology and different streams of engineering technology. The three most important factors for making good compost are chemical make-up of the raw materials, the porosity of the pile, and the population of the organisms involved in composting process. Compost “happens” either aerobically or anaerobically when organic materials are mixed and piled together. Aerobic composting is the most efficient form of decomposition and produces finished compost in shortest time.

Microbes breakdown organic compounds to obtain energy for life processes. The “heat” generated in aerobic composting process or aerobic oxidation of organic matter to carbon-dioxide is the by-product of biologic “burning”. If proper amounts of carbon, water and air are provided, aerobic organisms will dominate compost pile and decompose raw organic materials most efficiently. Optimal conditions for rapid, aerobic composting include

carbon-nitrogen (C:N) ratio between 25:1 and 35:1, moisture content between 45% and 60% by weight, available oxygen concentration greater than 5%, bulk density less than 500-700kg per cubic metre and pH between 5.5 and 8.5.

Mesophilic bacteria, fungi, actinomycetes and protozoa (microorganisms comfortable at 10°C and 45°C) initiate composting process, and as temperature increases as the result of oxidation of carbon compounds, thermophiles (microorganisms comfortable at 45°C and 70°C) take over. Temperature in a compost pile typically follows a pattern of rapid increase to 49°C to 60°C within 48 to 72 hours of the windrow formation, and remains for several weeks. This is the active phase of composting, in which easily degradable compounds and oxygen are consumed, pathogens (e.g., *Escherichia coli*, *Staphylococcus aureus*, etc.,) and weed seeds are killed. During thermophilic active composting phase, oxygen must be replenished by turning of windrows.

As the active composting phase subsides, temperature gradually declines to around 38°C. The rate of oxygen consumption declines to where compost can be stockpiled without turning. During curing, organic materials continue to decompose and are converted to biologically stable humus substances. Curing is a critical and often neglected stage of composting. Immature compost can contain high levels of organic acids and have a high C:N ratio, extreme pH value, or high salt content; all of which can damage or kill plants when compost is amended to pots or soil. Compost is considered finished or stable after temperature in windrow core reaches near-ambient levels for several days. These measurements should be made when compost windrow has at least 40% moisture content and a minimum critical volume of 1 cubic metre to retain heat.

STAGES IN EXCEL PROCESS

The operations of aerobic process involve three vital steps: windrow-yard management; space management; end product recovery.

Windrow-yard management: This marks beginning of the treatment process, which involves all the aspects for smooth and efficient running of the process without affecting production economics. The following are important steps for windrow-yard management of the urban solid waste and rural farm wastes.

Treatment with culture "Bioculum™" [Significance]: The natural flora present in the organic waste will carry out decomposition at a fairly slow pace and may create some erratic problems for the process. Since biological process has to be completed within a limited time period, utmost importance has to be given to biological treatment. To accelerate process of decomposition and to reduce risk of erratic results, inoculation of waste with beneficial microbes is essential. Excel process provides a biological "Bioculum™" containing a consortium of beneficial microbes (bacteria and fungi), which can effectively degrade biopolymers like lignin, cellulose, etc., and which in turn will increase rate of decomposition. A proper dosage of

“Bioculum™” is required to have a maximum recovery. Any laxity in application or dosage of the culture can lead to losses, which may become noticeable only after mechanical screening is over. At this stage, no corrective steps would be possible. Hence, treatment of organic waste should be done religiously using correct dosage to derive optimum benefits from Excel technology.

Treatment Procedure [Preparation of slurry]: Bioculum™ is in powder form. For better spread, it should be mixed with water to form slurry. And pH of water should be 7 ± 0.5 . Quantity of water to be used will depend upon the moisture level of the organic waste.

Dosage: “Bioculum™” 800g is used to treat 1 tonne of organic waste. The dosages are made into 2 splits: 500g per tonne of fresh organic waste on the day one and 300g per tonne of organic waste at the time of second turning. Besides 200 g of “Phosphonitroculum™” per tonne of final product is added at the time of packing, which contains beneficial nitrogen fixers and phosphate solubilizers

Preparation of windrow: Once organic waste is treated with “Bioculum™” slurry and dry formulation, it is formed into a windrow in the designated space with a Backhoe front End loader or suitable turning equipment.

Aeration/moisture maintenance and turning of windrows: Aerobic bacteria need oxygen regularly. Regular turning of windrow is required to ensure availability of oxygen. Hence, turning of windrows at the fixed intervals is strictly followed. Besides, providing aeration, turning also helps in lateral movement of the organic wastes towards drying area of platform at the centre from where matured and decomposed organic wastes are taken up for mechanical screening. Planning of windrows is done in such a way that any backlog in turning will restrict area for acceptance of organic wastes in the yard. Also, due to high costs, there could be a natural tendency to reduce turning operation to gain economy. This may result in poor quality of end product, low product recovery and generation of greenhouse gases. The cost of the turning operation gets offset by improvement in quality and increase in the recovery percentage.

A Backhoe front-end loader is a suitable machine for turning. The machine may be stationed between windrow to be turned and the area where the turned material has to be formed into a windrow. By keeping machine on jacks, the Backhoe may be used to dig heap and drop material to new area. It may be dropped from maximum height so that interlocking is removed and the material is properly aerated. Top and outer portions of the old windrow may be dry and slow in decomposition process. This material should go to the core of the new windrow to have a speedy decomposition.

There will be a loss in moisture during each turning. This is maintained at an optimum level of 55% by spraying freshwater to material while turning windrow. Supplementary dosage of “Bioculum™” is given

while turning as per the inoculation schedule to ensure a uniform mixing.

Intermediate storage: Excess moisture present in the composted material can reduce yields of semi-finished material. To prevent this, the material is air-dried to reduce the moisture content to 30-35%. After giving composting for 42-48 days, the material is spread with the help of a Backhoe front-end loader over a demarcated area meant for intermediate storage. A composite sample is drawn from the material to estimate moisture content before subjecting it to mechanical screening. Intermediate storage will also remove foul odour, which may persist within material. It has following advantages.

- Biological activity still continues to reach perfection in maturity.
- Initial screening machines may accommodate higher levels of moisture (15-20%). Optimum level of moisture for final screening is below 10%. The storage allows excess moisture to evaporate due to heat generated and also due to natural air-drying. Proper ventilation with exhaust-fans can speed-up drying process.
- Recovery of end product is improved.
- Quality of end product is improved.
- A breakdown in upstream/downstream machines does not paralyze total screening operations.
- Interruption due to rains could be surpassed fairly.

Maturity test: The end product has to be fully matured and biologically stabilized to give better results in field. A composite sample is collected from final composted material, before passing it for mechanical screening. This test will help to understand degradation status of the material. A positive maturity test indicates that material is biologically stable and it can be processed further for mechanical sieving. If material tests negative then, it is recomposed till material stabilizes. If immature (maturity negative) material is taken up for screening, recovery will be reduced and quality of end product will be poor. Besides, end product after packing will keep on generating heat due to continuation of biological process, because of imperfect bio-stabilization at the yard.

Sieving: The spread-out material is sequentially passed out through a trammel of 65mm, 35mm and 16mm mesh size. Care should be taken so that moisture content of the material is not more than 30-35%. The material obtained after passing through 16mm trammel is called as “semi-finished product”.

Curing: The semi-finished product obtained after screening is formed into a windrow in semi-finished storage area. Material is subjected to sampling by trained supervisors using cup-and-cone method for testing its maturity in the laboratory. If material indicates generation of heat or if it indicates negative maturity from laboratory tests and also generates foul odour then it is allowed to cure till a maturity stage is reached. This is indicated by no rise in temperature of windrow, a maturity positive test, a pH range of 6-8, a blackish brown colour, free-flowing texture and an

earthy aroma. These indications can be taken as the criteria for packing of material as the final product. Normally, the curing of the semi-finished material can take around 7-15 days, depending on the nature of the semi-finished material. The cured final product should contain maximum moisture content of 25%. In case of excess moisture content, the material is dried in a clean area till expected moisture content is achieved. In-house quality parameters of the final product “Celrich™” are in Tables 1,2

Table 1. Specifications for different parameters

Parameters		Expectations
	Physical	
pH [range]		6.5 - 8.5
Moisture content [maximum %]		25
Bulk density [range](g/cc)		0.7 - 0.9
Maturity test [starch Iodine test]		Positive
Electrical conductivity [max](dS/cm)		4
Sand content [maximum %]		10
Particle size		4mm
	Chemical	
Total organic matter [minimum %]		30
Organic carbon [minimum %]		12
Total nitrogen [minimum %]		0.8
C : N ratio [range]		10:1 to 20:1
	Microbiological [cfu/g]	
Total bacterial count		10 ⁸ -10 ¹⁰
Total mould count		10 ⁴ -10 ⁶
Total actinomycetes count		10 ⁴ -10 ⁶
Total coliforms [maximum]		10 ³
Total <i>Salmonella</i> sp.		Nil
Total <i>Shigella</i> sp.		Nil

Note: The organic fertilizer may contain agriculturally useful beneficial bacteria, fungi and actinomycetes in varying proportions from time to time.

Table 2. Maximum permissible* limit of heavy metals

Sl No.	Parameters	Concentration not to exceed [mg/kg dry basis]
1.	Arsenic [As]	10.00
2.	Cadmium [Cd]	5.00
3.	Chromium [Cr]	50.00
4.	Copper [Cu]	300.00
5.	Lead [Pb]	100.00
6.	Mercury [Hg]	0.15
7.	Nickel [Ni]	50.00
8.	Zinc [Zn]	1,000.00

*Compost [final product] exceeding the above stated concentration limits shall not be used for food crops. However, it may be utilized for purposes other than growing food crops. [25th September'2000 notification in “The Gazette of India” by the Ministry of Environment and Forest].

Biopesticides and Biological Control for Crop Protection

T.P. Rajendran

Indiscriminate use of pesticides has eliminated several natural enemies from different crop ecosystems. This has led researchers in plant protection to think seriously about alternate pest-control technologies. Biological pest control is one such technology, which has gained in importance over the years.

The Project Directorate of Biological Control (PDBC) has, in its mandate, identified thrust areas of research to develop protocols for mass-scale production of natural enemies for key crop pests to facilitate commercial-scale production of key species of bioagents for large-scale utilization, and to popularize biological control as an important component of pest management for adoption by farmers.

Impact assessment of the technologies in the context of commercialization and field use is of utmost importance. The specific objectives of such an exercise should include identification of technologies on important biological control agents in terms of production technology for commercialization and field use, and assessment of socio-economic impact of technologies. These will help identifying methods to reduce cost per unit of output, minimize losses due to pests, sustain natural resources, and increase income and employment due to use of these technologies and suggest policy direction for priority-setting and future research on these technologies.

There is a need to assess impact and returns to investment on technologies and illustrate how technologies are serving society by raising income and employment, minimizing losses due to pests, sustaining natural resources and increasing commodity value.

The economic benefits of the technologies will have to be estimated, and these would be best done by developing public-private partnership in identifying suitable technologies for commercialization and identifying areas for joint validation of efficacy of technologies so developed. Production and consumption data for biological control agents could be effectively used to

estimate supply and demand elasticity, thus making an impact assessment of technologies and also economic benefits to the society.

STAKEHOLDERS' EXPECTATIONS

While identifying tools of crop protection like biological control agents, it is necessary to understand expectations of different stakeholders interested in the technology. The following points give some of the expectations of the stakeholders.

Expectations of the Farming Community

The farming community even though may not be entirely tuned to the use of biological control agents, but those who are aware and would like to use them are faced with difficulty of finding agents at the time when they need them. There is also the question of quality of bioagents; several times they turn out to be ineffective because of lack of quality checks. This results in farmers losing confidence in the agent and discontinuing of its use. Many times farmers also find application methods very cumbersome and impractical, like application in the evening hours for NPV and pinning trichocard bits in several spots; again prompting them to stop using technology. Ease of application and technology directed towards this end could go a long way in alleviating this problem and reducing drudgery.

Expectations of the Extension Agencies

Extension agencies have a strong role to play in popularizing these agents and increasing their uptake through demonstrations and other diffusion methodologies. In this process, the following points need to be addressed: Making available quality agents for demonstration; Capacity-building of extension functionaries to be convinced of the efficacy of the technology and possess a knowledge-base for effective dissemination; Synchronization of recommendations between different agencies.

Expectations of the Public-sector Research Organizations

The public-sector research organizations like ICAR institutes, SAUs and CIPMCs etc. also expect help in technology building, assessment, refinement and adoption by private industry and extension agencies. In this, it would be appropriate to empower KVKs to produce quality bioagents for demonstration. Some agents like *Trichogramma*, *Chrysoperla*, NPV could be starting points to develop a rearing-and-production unit which could form seeds for others in the region. There is a strong need to simplify registration protocols so that even small-scale entrepreneurs and co-operatives can take up task of producing agents and marketing them. There is also a need to explore possibility of attempting exclusive allocation of human, financial and infrastructural resources for this activity so that continuity and specializations are not lost. The government should also encourage joint research project collaborations with industry and other public-sector organizations.

Expectations of the Private Industry

The private industry expects efficient strains of bioagents amenable for mass production and mechanization, development of low-cost technology for production, formulation, long-term storage, transport and packing, data sharing on toxicology and registration and an efficient extension system in place for creating proper awareness and demonstration to enable a constant-and-assured demand.

Expectations of the Funding Agencies

Mandatory certifications on good agricultural practices (GAP) in the production of horticultural and other crops for fresh consumption, so that biological control agents find a niche in practices, and are promoted. This would also help in bringing more area under IPM technologies with biological control as an important component. Efficient and robust IPM technologies should be put in place to enable this.

Expectation of the Policy-makers

There is a need to find efficient technologies to manage crisis pests. Enhancement of agricultural growth through sustainable crop-protection technologies that will contribute to products for a globally competitive market is the need of the hour.

AREAS FOR JOINT VALIDATION OF EFFICACY OF TECHNOLOGY

The following areas could be identified for joint validation of technology in partnership.

Production Technology

- Scaling up processes for microbials and macrobials
- Cost-effective and quality production of bioagents
- Mechanization of production technologies

Commercialization

- Explorations of local and global markets for technologies
- Microbials – NPV, solid-state fermentation of antagonists
- Macrobials – *Trichogramma*, *Chrysoperla*

EXPLORATIONS FOR PARTNERSHIP

The explorations for developing this partnership could take into consideration the following.

- Developed technologies to be transferred on non-exclusive basis
- Greater use of biotechnological tools for strain identification, improvement and mass production and increased use of molecular markers in the process
- Design of the technology based on requirement of stakeholders
- IT to be used in helping diffusion process of the technology
- Validation of the efficacy of the technology

TERMS OF REFERENCE FOR TECHNOLOGY ASSESSMENT

The following terms of reference could serve in developing a framework for assessment and impact of the technology.

- Cost incurred in developing production technology
- Cost of production and application of the agent(s)
- Field application technology – ease, skill
- Adoption pattern
- Employment generation – raising the income level
- Anticipated minimization of losses due to pests
- Sustaining natural resources
- Increasing commodity value of crops

Technology Assessment

The developed technologies could be assessed in long-run using following parameters and would be useful in refining technology and finally prioritizing researches for efficient utilization of resources and manpower.

- Adoption rate of technology
- Depreciation rate of technology
- Expected life of technology
- Feedback to research system
- Refinement of technology

Economic Benefit of Technologies

Impact assessment of the technology needs to be done through estimation of economic/marketable surplus. This could be achieved by estimating supply and demand elasticity by finding production and consumption data for technology and agents.

AVAILABLE TECHNOLOGY FOR BIOLOGICAL CONTROL AGENTS

The technology for production is available for the following agents, and could be the examples to start a public-private partnership interface, to enable working out a strategy for building a lasting relationship.

Parasitoids

- *Trichogramma* spp. for different pests
- *Trichogramma chilonis*
 - pesticide tolerant
 - high host-searching ability
 - high temperature tolerant
- *Goniozus nephantidis* for *Opisina arenosella*
- *Telenomus remus* for *Spodoptera litura*

Predators

- *Cryptolaemus montrouzieri*
- *Chrysoperla carnea*
- *Cardiastethus exiguus*

Insect Pathogens

- Nuclear polyhedrosis viruses of
 - *Helicoverpa armigera*
 - *Spodoptera litura*
- Fungal pathogens
 - *Nomuraea rileyi*
 - *Beauveria bassiana*
 - *Verticillium lecanii*
 - *Metarrhizium anisopliae*

Fungal and Bacterial Antagonists

- *Trichoderma* spp.
- *Pseudomonas* spp.
- *Bacillus* spp.

Entomopathogenic Nematodes (EPN)

- *Steinernema* spp.
- *Heterorhabditis* spp.

Nematophagous Fungi

- *Paecilomyces lilacinus*
- *Pochonia chlamydosporia*
- *Arthrobotrys oligospora*

Bio-pesticides

Botanical Insecticides

- Among botanicals, neem is the most commonly exploited insecticide, available in different formulations and tested against more than 300 species of insect pests. However, other plant products like *Pongamia*, palmarosa and *Acorus calamus* have been proved to possess insecticide properties, at least in crude extract form. Through industrial partnership, identification of active principles and technology for commercialization may be attempted.
- The research efforts may be concentrated more on volatiles of plants such as limonene, pinene, myrcene, etc. through private-public partnership, which have potential to be used as attractants.
- IPR issues, especially for plants with insecticidal properties, must be addressed to retain our claims on these bioresources.

Pheromones

- Almost all commercially available pheromones are produced through technologies developed at laboratories from overseas. There is a need to develop low-cost technologies for synthesis of

pheromones for insects like *Helicoverpa armigera*, *Earias vitella*, *Pectinophora gossypiella*, *Chilo* spp. etc.

- Generally in India most of the private companies produce and sell a very few pheromone products relatively in high volume at low price, and mostly depended on the demand by state government's procurement. However pheromones for large number of insects for which technologies have been identified and their utility has been proved have not been produced by the private entrepreneurs.
- Already developed indigenous pheromone technology for insects like *Aproaerema modicella* and *Scirpophaga incertulas* may be commercialized by private entrepreneurs.
- With the discovery of the polymorphic *Helicoverpa armigera* populations showing differential responses to pheromones, it becomes necessary to develop blends suitable for different populations of the pest species. Such intraspecific behavioural responses also need to be studied in detail for other insect species.
- Combining pheromone technology with other attractants (synomones and kairomones) for e.g. pheromone in combination with basmati rice extracts for increased catches of *Scirpophaga incertulas* need to be attempted with emphasis on identification and synthesis of other plant-derived attractants.
- Export potential can also be tapped if pheromone technologies identified for pests like *Odoiporus longicollis* are fine tuned to capture World market.
- Capacity-building is an important component in pheromone technology. Most of the existing agrochemical laboratories under the ICAR and SAUs may be allowed to diversify the activities of their laboratories to develop technologies for synthesizing pheromones and other attractants with upgradation of equipments and trained manpower.
- The trap designs available presently need to be reinvented with proper technology on designs, trap numbers, dosage and their placement, which will increase their efficiency.

EXPECTED OUTCOME OF THE PARTNERSHIP

This exercise to synthesize partnership between public and private enterprises will become more meaningful if strategic relationship between this partnership is made sustainable with respect to clear deliverables, results and targets agreed upon. There is a need to have continued collaborations to refine technologies so as to enable addressing bottlenecks and hiccups on the continuous basis. The outcome of such a course will help research-managers and policy-makers to prioritize researches.

Biocontrol Agents: Problems and Perspectives

B. N. Vyas

The foodgrains production in the country, which was about 55 million tonnes in the early fifties of the last century, has increased to more than 200 million tonnes at present. However, Indian Agriculture faces a serious challenge to ensure food security for every individual in the country. As per the present estimates, India will have to increase its foodgrains production to 250 million tonnes by the end of 2025 to meet the requirements of an ever-increasing population. This is further challenged in view of the decreasing land productivity in many areas and also continued crop losses due to various pests. The extent of losses of crops is estimated to be nearly 30%, amounting to Rs 30,000 crore. Of these losses, weeds account for nearly 33%, insects and rodents 26%, plant diseases 26%, and birds and nematodes account for the remaining 15% (Table 1). Even if we are able to reduce losses by 25%, there would be a substantial saving of crops. Synthetic chemical pesticides have played an important role in reducing crop losses. Although crop losses due to insect pests are only 26%

Table 1. Status of crop losses

Pest	Crop loss (%)
Brown plant hopper (<i>Nilaparvata lugens</i>)	10-70
Rice gall midge (<i>Orseolia oryzae</i>)	15-60
Rice stem borer (<i>Scirpophaga incertulas</i>)	25-30
Maize pink borer (<i>Sisamia inference</i>)	25-75
Pulse stem fly (<i>Ophiomyzia</i> sp.)	50-72
Mustard aphid (<i>Lipaphis erysmi</i>)	30-70
Cotton bollworm (<i>Helicoverpa armigera</i>)	50-60
Cotton white-fly (<i>Bemisia tabaci</i>)	53-80

Rao and Murthy in 1983 reported losses worth Rs 6,000 crore.

Jayaraj in 1993 reported losses worth Rs 20,000 crore.

Dhaliwal and Arora in 1996 reported losses worth Rs 29,000 crore.

Source: Sharma *et al.* 2000 (*Agrolook*, Aug. 2000)

of the total, the share of insecticides among crop-protection chemicals used in the country is over 70%. The large scale and indiscriminate use of such insecticides has resulted in the following environmental hazards.

- (i) Development of resistance to chemicals (more than 700 species of insects have recorded resistance).
- (ii) Toxicity to vertebrate/ invertebrate life-forms (WHO reports indicate one million people suffering from pesticide poisoning every year).
- (iii) Toxicity to natural enemies and beneficial insects like honeybees (significant reduction in natural predators against white-fly is a classic sample).
- (iv) Long persistent residues resulting in poisoning of food-chain.

MARKET POTENTIAL OF BIOCONTROL AGENTS IN INDIA

In view of the above, biological control agents (biopesticides) offer excellent opportunity for their use in pest-management programmes. It would not be out of place to assume that nearly 5% of the total market share of pesticides (Rs 3,500 crore) can easily be taken by biocontrol agents; this would amount to Rs 175 crore per annum as against the present market of approximately Rs 40 – 50 crore. From the date of first development till date, the off-take of the biocontrol agents has not been on the expected lines. Several constraints have been responsible for observed trends.

Constraints Responsible for Limited Market Growth

Different constraints responsible for limited success of biologicals can be divided into (i) Technological, (ii) Financial, (iii) Extension related (iv) Regulatory/ Statutory.

Technological aspects include lack of technological advancements relating to transfer of technology from pilot-plant scale to mega scale and lack of mass-rearing facilities; inconsistent field results; limited or very short life, say 6 months only, and existence of very crude formulations. Despite phenomenal growth in research and development of biologicals, the acceptance at the farmer's level has not been satisfactory. One of the reasons behind this phenomenon is that many private entrepreneurs have rushed into commercial production of biocontrol agents without creating adequate production and quality assurance facilities.

Similarly, financial aspects can be categorized as huge rates of taxes including excise at a par with chemical pesticides; benefits of economy of scale rather limited and lack of subsidy from the Government of India on the lines of fertilizers or drip irrigation etc. Some constraints related to extension are as follows.

- (i) Existence of mindset in farmers to compare results of biologicals vis-à-vis chemical pesticides, further complicated by understanding that chemicals vis-à-vis biologicals are complimentary or supplementary.

- (ii) Lack of field-demonstrations, distributors/ dealers training programmes
- (iii) Limited promotion through TV programmes
- (iv) Hardly any celebration of success stories
- (v) Many State Governments are yet to include their usage in package of practices
- (vi) Lack of awareness among farmers about all ill effects of chemical pesticides

Regulatory / Statutory aspects also need to be considered seriously, if biopesticides have to become a success. The major remedies that could help the process are as follows.

- (i) Creation of a separate cell for registering biologicals
- (ii) Liberalize expensive and time-taking registration process
- (iii) Strict quality control and standardized formulations
- (iv) Large number of nodal biopesticide testing laboratories

Future Outlook for Biocontrol Agents in Pest Management

- (i) Current growth rate of biocontrol agents market is close to 5% with an annual sales turnover close to Rs 50 crore (approximately 1.5% of the total pesticides market). World biopesticide market is recorded to be about Rs 2,000 crore (US\$ 400 million)
- (ii) Growth rate of 15% in next 10 years can easily result in turnover of Rs 200 crore which would be close to 5% of the pesticides market share.
- (iii) Bt and neem pesticides are major biocontrol agents used in India. The area covered with these plant-protection products is 0.1% of the net cultivable area. A ten-fold increase in area i.e. of cultivable land would raise turnover close to Rs 400 crore per annum.
- (iv) World demand for biocontrol agents is projected to be at US\$ 6 billion in the next 5 years. North America and western Europe will be the largest market, both accounting for 2/ 3 of the total demand.

It is obvious from the foregoing paras that in case we have to realise full potential of the biocontrol agents and at the same time ensure safety to our crops and environs, it would be necessary for all stakeholders to minimize above-mentioned constraints which would maximize use.

Agro-biochemicals in Agriculture

C. Devakumar¹ and Rajesh Kumar²

The term ‘agro-biochemicals’ includes all chemical-inputs in agriculture such as pesticides, fertilizers, plant hormones, plant-growth regulators etc.

India is among the largest agricultural societies in the world. Agricultural production has recorded remarkable growth over the past few decades. Though high-yielding varieties have contributed significantly towards improving production, these are highly responsive to inputs, and their intensive use has increased demand for irrigation, pesticides and fertilizers. However, the very agro-inputs, responsible for increasing agricultural production, are slowly showing signs of threats to environment, and health and socio-economic well-being of the community. Besides, monoculture and continuous cultivation of improved varieties, overlapping of cropping seasons, and excessive application of agro-chemicals have resulted in high incidences of pests and diseases in many parts of the country. It is now globally agreed that agricultural production can profitably be matched with growing demands of the population in terms of quality and quantity in a sustainable manner through effective public-private partnership (PPP).

CROP PROTECTION SCENARIO

Management of abiotic stresses in an ecologically sustainable manner will be one of the key determining factors in crop production that will become more knowledge-driven in the coming years. The pre-harvest losses due to pests are estimated at 42 % and post-harvest losses at 10% (Fig. 1).

Many innocuous pests of the previous decades have attained the status of serious pests in the recent years. In addition, problems of pest outbreaks, resistance and resurgence of insect pests demand more pesticides. The frequent crop losses, increased expenditure on agro-inputs, high debts, and fluctuations in market prices have put farming communities in deep economic and psychological distress.

Synthetic pesticides have become an inevitable input, and their consumption in India has not been uniform, which varies with cropping

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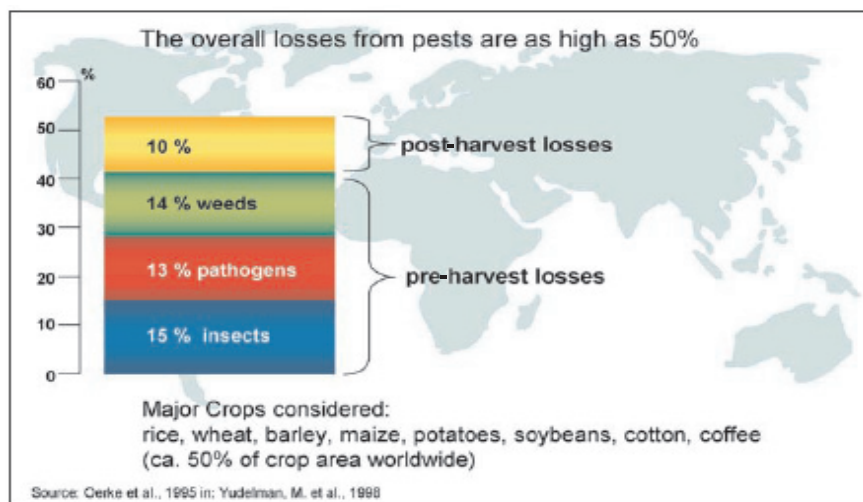


Fig. 1. Estimated yield losses due to pests

pattern, intensity of pests and diseases and agro-ecological regions. Pesticides use is particularly high in regions with good irrigation facilities and also in those areas where commercial crops are grown. An analysis of the pesticides-use pattern in the country has revealed that cotton, which accounts for just 5% of the cropped area, consumes about 52 to 55% of the pesticides. Rice grown over 24% of area uses about 18%, vegetables raised over 3% area, about 14%, plantation crops covering 2% of area, 8%, and cereals, millets and oilseeds extending over 58% of the area, 7%. Sugarcane uses 2% of pesticides and other crops grown over 6% of the cropped area account for another 2%. The unit area consumption of pesticides in the country is far lower than that in some of the developed countries. The use of chemical control cannot be dispensed with even in IPM, and is bound to increase in synchrony with the increased production.

PPP OPPORTUNITIES IN PESTICIDES

India produces pesticides valued Rs 41 billion, including that meant for exports worth Rs 25 billion, but the pesticides consumption in Indian agriculture is as low 288 g a.i. per hectare. India spends in dollar term US\$3 per ha as compared to China which spends US\$6 per ha. If the agricultural growth is set at 7-10% per annum in value terms, this will result in agrochemical sector growth of at least 10-12% per annum in value terms driven by higher usage of pesticides both at pre- and post-harvest stages. An explosive boom in consumer goods sector and with increasing affluent middle-class, demand for quality and processed foods is expected to increase. The Indian pesticides industries lobby through three associations (Table 1). The major industries have shown willingness in partnership with the ICAR institutions. In recently concluded NATP, Crop Life India partnered with the NCIPM in the validation of IPM of certain crops.

Table 1. Indian pesticides industries

Sl No.	Industry Name	Strength
1.	Crop Care Federation of India	70 members
2.	Crop Life India	12 MNC-members
3.	Pesticides Manufacturers and Formulators Association of India (PMFAI)	250 members

In the last decade, after scientometric analysis of the pesticides research conducted in India and in the developed world, the following are the conclusions.

1. Indian research is found dominated by adaptive research in terms of efficacy and environment-friendliness acceptability of pesticides developed elsewhere.
2. On the other hand, research in the developed world reflects importance of development of new molecules, novel approaches of pesticide management etc.

If one looks at the global scenario of pesticides use in 2004, top 10 agrochemical companies controlled 72% global sales revenues, amounting to US\$30 billion. These companies had spent US\$2.25 billion or 7.5% of sales in R & D, and they outsourced studies worth US\$260.7 million (Table 2).

Table 2. Agrochemicals R&D expenditure on external studies

Sector	Value (US\$million)
Biology	100.4
Chemistry	63.0
Environmental risk assessment	57.3
Total	260.7

With increased liberalization, the NARS can have a greater role in public-private partnership (PPP). The kind of external studies that can be undertaken by the ICAR scientists are given in Table 3.

Table 3. Studies outsourced by the MNCs

External expenditure	Includes costs for activities outsourced to carry out through joint ventures, alliances and research agreements with third parties
Synthesis	Laboratory-based synthesis, including combinatorial chemistry based methods, of new candidate products, analogues, metabolites and radiolabelled products
Sample and compound logistics	The storage, retrieval and archiving of chemical libraries for the purpose of discovery
Chemistry – other	Miscellaneous chemistry-based activities, such as computer modelling, structure-activity relationships (target-site), etc
Field biology	Includes field efficacy work, but excludes field demonstration trials done for commercial purposes
Laboratory biology	Includes high-throughput screening, genomics (for product discovery), molecular biology, combinatorial chemistry, biochemistry, profiling, etc.
Environmental risk assessment – other	Includes plant metabolism, soil metabolism, environmental fate, environmental modelling, water monitoring

The Division of Agricultural Chemicals at the Indian Agricultural Research Institute, has expertise to undertake synthesis of new molecules and metabolites, degradation and metabolism, computer modelling and quantitative structure-activity relationship. And field efficacy evaluations of new chemicals are now routinely undertaken by many SAUs. The ICAR may create an advanced centre under the Division of Agricultural Chemicals, in High-throughput screening (HTS), genomics for product discovery, combinatorial chemistry, biochemistry and gene expression profiling. Similarly a few centres under the NARS can be identified to undertake environment risk assessment. Thus, PPP with MNCs will open-up additionally revenue generation worth US\$50-250 million annually. Such an arrangement would strengthen on-going R & D efforts in bioprospecting of new active molecules from natural sources and by bio-rational synthesis also.

The committee on the Future Role of Pesticides in US Agriculture has predicted that the novel chemical products that will dominate in near future would most likely have a very different genesis from traditional synthetic organic insecticides; the number and diversity of biological sources will increase, and products that originate in chemistry laboratories will be designed with particular target sites or modes of actions in mind. Innovations in pesticide-delivery systems (notably, in plants) promise to reduce adverse environmental impacts even further but are not expected to eliminate them. There remains a need for new chemicals that are compatible with ecologically-based pest management and applicator and worker safety. It has exhorted the authorities to:

- Make research investments and policy changes that emphasize development of pesticides and application technologies that pose reduced health risks, and are compatible with ecologically-based pest management.
- Promote scientific and social initiatives to make development and use of alternatives to pesticides more competitive in a wide variety of managed and natural ecosystems.
- Increase ability and motivation of agricultural workers to lessen their exposure to potentially harmful chemicals and refine worker-protection regulations and enforce compliance with them.
- Reduce adverse off-target effects by judicious choice of chemical agents, implementation of precision application technology and determination of economic- and environmental-impact thresholds for pesticide use in more agricultural systems.
- Reduce overall environmental impact of agricultural enterprise.

According to the committee, the most promising opportunity for increasing benefits and reducing risks is to invest time, money and effort into developing a diverse toolbox of pest-management strategies that include safe products and practices that integrate chemical approaches into an overall, ecologically-based framework to optimize sustainable production, environmental quality and human health. Research topics that

should be targeted by the public sector include: (i) Minor-use crops, (ii) Pest biology and ecology, (iii) Integration of several pest-management tools in managed and natural ecosystems, (iv) Targeted applications of pesticides, (v) Risk perception and risk assessment of pesticides and their alternatives, (vi) Economic and social impacts of pesticide use.

Investment in basic research applicable to ecologically-based pest management must, according to this committee, aim at the following.

- Obtaining ecological and evolutionary biological information necessary for design and implementation of specific pest-management systems.
- Identifying ways to enhance competitiveness of alternatives or adjuncts by investing in studies of cultural and biological control.
- Elucidating fundamental pest biochemistry, physiology, ecology, genomics, and genetics to generate information that can lead to novel pest-control approaches.
- Examining residue management, environmental fate (biological, physical, and chemical) and application technology to monitor and reduce environmental damage and adverse health effects of both pesticides and pesticide alternatives.
- Basic research on public perceptions and on risk assessment and analysis would be useful in promoting widespread acceptance and adoption of ecologically-based management approaches.

Future Role of Pesticides in US Agriculture (2000)—Recommendations

1. There is no justification for abandoning chemicals per se as components in defensive toolbox used for managing pests. The committee recommends maintaining a diversity of tools for maximizing flexibility, precision and stability of pest management.
2. A concerted effort in research and policy should be made to increase competitiveness of alternatives to chemical pesticides; this effort is a necessary prerequisite for diversifying pest-management "toolbox" in an era of rapid economic and ecological change.
3. Investments in research by the public sector should emphasize those areas of pest management that are not now being (and historically have never been) undertaken by private industry.
4. Government policies should be adapted to foster innovation and reward risk reduction in private industry and agriculture. The public sector has a unique role to play in supporting research on minor use cropping systems, where inadequate availability of appropriate chemicals and lack of environmentally and economically acceptable alternatives to synthetic chemicals contribute disproportionately to concerns about chemical impacts.
5. The public sector must act on its responsibility to provide quality education to ensure well-informed decision-making in private and public sectors.

PPP OPPORTUNITIES IN PLANT NUTRIENTS

The demand for plant nutrients is bound to increase. With an estimated population of 1.4 billion by 2025 and minimum calories requirement of food, the country will need to produce at least 300 million tonnes of foodgrains, and this would require use of 30-35 million tonnes

Scope and Opportunities for PPP in Plant Protection

- Better pesticide formulations suiting to varied agroclimatic regions and cropping pattern
- Data generation on efficacy and safety of new molecules / formulations, analytical and bioassay services
- Improved pesticides delivery
- Development of biocontrol agents, biofertilizers, value-added fertilizers, phytonics etc.

of NPK from various sources. High-value crops such as horticulture, vegetables, plantation crops, sugarcane, cotton, oilseeds and potato, which also have high export potential and also claim high fertilizer use on priority basis; will need another 14-15 million tonnes of NPK. Thus, from both inorganic and organic sources the country will be required to arrange for 40-45 million tonnes of nutrients by 2025 from consumption of 18.07 million tonnes in 1999-2000. The projected requirements of Zn, Cu, Fe and Mn for 2025 following sufficiency approach are 323,777, 2,727, 32,571 and 5,591 tonnes/annum and in terms of zinc sulfate heptahydrate, copper sulfate, ferrous sulfate and manganese sulfate will be 15,417,952, 11,363, 171,426 and 18,331 tonnes. Nearly two-thirds of the total zinc sulphate is consumed in Punjab, Haryana and Uttar Pradesh. Presently, the production stands at 75,000-80,000 tonnes against installed capacity of 170,000 tonnes. These figures show poor performance of industry, and adequate supplies of zinc sulphate are not available. If we have to succeed in meeting projected requirements of zinc by 2025, urgent steps would be required to put industry on sound footing.

Involvement of public sector like the ICAR in development of value-added plant nutrients would ensure better quality of products. The ICAR has the requisite expertise in agricultural sector, and the industry has the better marketing network. A synergy between the two would usher in symbiotic growth leading to win-win situation. The IARI technology of neem oil coated urea (NOCU) has been enthusiastically picked up by a few fertilizer industries. Data generated by one fertilizer industry on the use of neem oil coated urea (NOCU) in rice amply demonstrate the utilization potential of first-ever indigenously developed product (Table 4). Production of NOCU involves a meagre cost of Rs 80-100 per tonne, but can save fossil fuel, labour and energy worth 100 times. The nitrogen-use efficiency (NUE) is abysmally low pegged at 35-40% in Indian agriculture. Taking into consideration of the current use, even 5% increase in NUE can lead to saving of about 8-10 billion rupees.

Table 4. Relative efficiency of NOCU for rice (*kharif* 2002-03) trials on farmers' fields

Districts	No. of trials	Paddy grain yield			CD 5%	CV%
		Urea tonnes/ha	NOCU	Increase(%)		
5	45	3.95	4.59	16.2	1.9	3.96

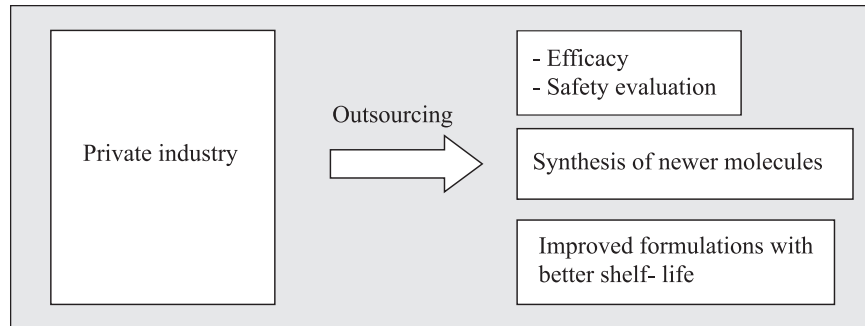


Fig. 2. Roadmap for registration data generation for pesticides

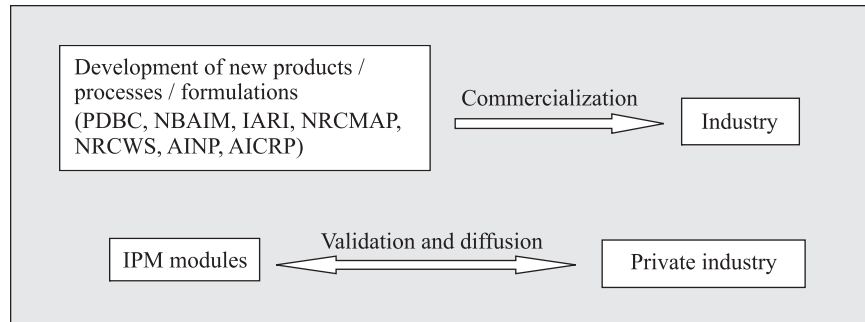


Fig. 3. Roadmap of PPP in pesticides R & D

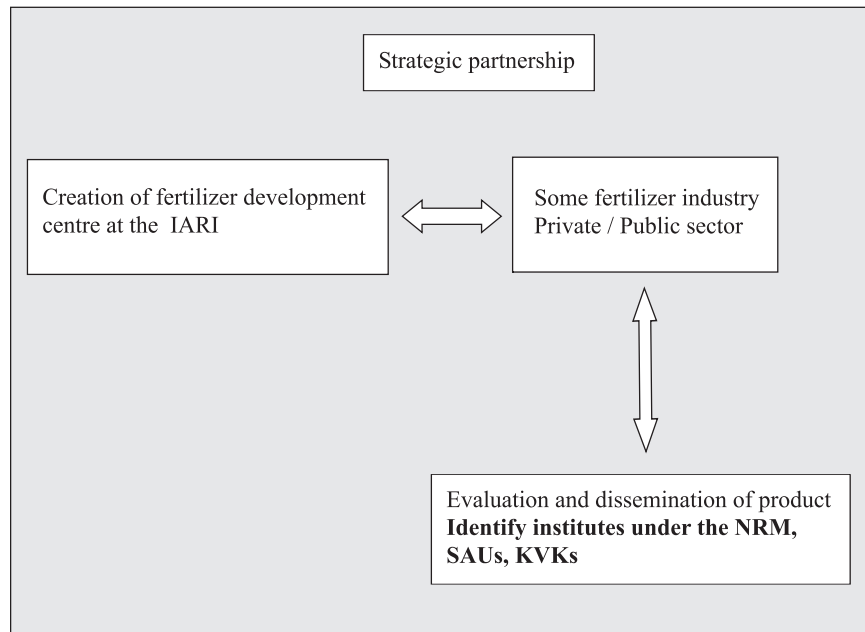


Fig. 4. Roadmap for PPP in value-added and custom-designed fertilizers

Unbalanced fertilizer usage is on the rise, and thus has led to low and declining crop yield responses. Continuing imbalanced use of N, P, K fertilizers (which was 8.5:3.1:1 in 1998-99 as against the desirable norm of 4:2:1) and increasing deficiency of micronutrients are major concerns. The rational use of fertilizers and manures for optimum supply of all essential nutrients for agricultural production simultaneously ensures efficiency of fertilizer use, promotes synergistic interactions and keeps antagonistic interactions out of crop production system. Balanced fertilization enhances crop yield, crop quality and farm profits; corrects inherent soil nutrient deficiencies; maintains or improves lasting soil fertility; avoids damage to environment and restores fertility and productivity of land that has been degraded by wrong and exploitative activities in the past. Widespread deficiencies of key micronutrients like Zn, B, Mo have been documented. Value-added fertilizers like zinc coated urea and sulphur coated urea have enormous market. Similarly phytohormones acting enzymes, amino acids as foliar supplements can be developed in small-scale sector.

Similar opportunities exist in R & D of botanical and biopesticides. In terms of value-addition of agricultural produce, the NARS can contribute to the development of biofuels, nutraceuticals, cosmeceuticals also. The Division of Agricultural Chemicals has over 30 products and improved processes available for commercialization.

Possible roadmaps for forging PPP in these areas are shown in figures 2-4. A consorted approach in a mission-mode would benefit for flagging of PPP in agro-biochemicals for maximizing returns in a sustainable manner.

Vaccines in Livestock Development

S.N. Singh

India has the largest livestock population in terms of 219 million cattle, 94 million buffaloes, 123 million goats, 50 million sheep, 16 million pigs and 750 million poultry. Public-private partnership is necessary to ensure Information Technology and Business Transformation (ITBT) merging to create Rural Knowledge Bio resource Centre in each Panchayat for providing active involvement of health-care Service Industry.

Unlike the western markets, which have very strong farm practices and where farming is conducted like an industry, the Indian scenario is very different. Farming in India is very much a cottage, household activity. The farm-holdings invariably are small, with a few exceptions, with major dependence on grazing and with a little effective health-care. Veterinary health-care is largely institution-driven in India with almost 90% of the facilities provided by the state. The concept of health insurance is yet to catch up in reality to become a practice. As the result, the farmers have to fend for themselves at very low levels; with most of the money spent on health and nutrition of livestock.

Due to low-income level of the marginal cattle farmers, the affordability becomes a major issue; very much like the mainline pharmaceutical industry, thanks to the absence of product patents and encouragement given to mushrooming small sector. The animal health market is thus highly fragmented with intense competition among companies with “me-too” products.

DRIVERS OF GROWTH

India represents one of the most promising animal-health markets in the world; that is because of its current sub-optimal state and given the fact that rural incomes can be bettered in India with the thrust on the dairy and poultry sectors. In fact, dairying with a base in the large cattle population of around 300 million and the vibrant poultry industry have helped animal husbandry contribute nearly 10% to the country's GDP. Apart from this, there is also realization that if India has to have sufficient export-led growth, more so from the farm sector, then there has to be a higher thrust on the health and nutrition in the animal health industry.

Competitive Industries in Animal Health

The major player in the industry, Glaxo (Agrivet Farm care), accounts for 9.5% of the market, credit goes to its strong presence in the poultry and cattle segments. This is followed by Zydus Sarabhai with 9% market share, Intervet and Pfizer with 8% and 6.7% market shares respectively, occupying third and fourth ranks. The top ten companies account for 63% of the market. Competition is intense not by the number of companies in the market, but more so due to the fact that most of these companies have competing “me-too” products. The two major FMD vaccine manufacturing companies, M/s Indian Immunologicals Limited and m/s Intervet rank among the first five companies in the industry.

The size of the Indian animal health market was estimated at US\$ 230 million (Rs 1,000 crore) in 2004-05, growing at a compounded annual growth rate of 5%; the cattle segment accounting for 51%, followed by poultry segment 40%, sheep/goats 4%, and the canines segment contributing to 3% of the total turnover.

The major therapeutic segments of the animal health market and their contribution are as follows.

Anti-infectives, 28%; Biologicals, 17%; Tonics, 15%; Anthelmintics, 10%; Feed additives, 10%; NSAID, 3%; Ectoparasiticides, 4%; Infusions, 4%; Antiprotozoals, 3%; Antiseptics, 2%; Steroids, 2%; Hormones, 2%.

The existing competition, scope and growth prospectus of the major therapeutic segments can be outlined as follows.

Anti-infectives: They constitute the biggest segment (28%) of the Indian Animal Health Industry. Poor level of farm hygiene and sanitary conditions coupled with traditional husbandry practices among the farmers across the country usually result in a number of diseases among their livestock due to high bacterial count. The therapeutic use of anti-infectives, therefore, is widespread in all sectors — Cattle, Poultry, Sheep and Goats—among farmers.

The anti-infectives' market in cattle and sheep/goat segment is dominated by the use of streptopencillins and tetracyclines. Pfizer's Terramycin (Oxytetracycline) and Zydus Sarabhai's DCR (Dicrystacin) are the leading brands in this segment, followed by Moxel (Amoxicillin+Cloxacillin) from Alembic. The use of 3rd and 4th generation cephalosporins is not yet widespread, and is limited to treating specific infections like mastitis, etc. Quinolones-Enrofloxacin and P-Floxacin are the most popular antibiotics being used in poultry sector. Enrocin-a brand from M/s Ranbaxy, continues to be the brand leader in poultry segment.

Indiscriminate and continued usage of tetracyclines and streptopencillins at the farmer's level for the last two decades, however, has led to the development of resistance to most of these antibiotics. The existing scenario offers a good opportunity and scientific rationale for one to come out with a new generation broad-spectrum injectable antibiotic for use in cattle. Marbofloxacin (quinolone) and cefquinome (a 4th generation cephalosporins) can be the best alternatives fitting into current

requirements. Similarly for the fast growing canine segment, a combination of Amoxicillin+Clavvulanic acid can be an antibiotic of choice.

The Indian Annual Health (AH) Market is essentially a dairy-oriented market since beef and pork do not find much acceptance in the society due to socio-religious issues. India has the largest cattle population in the world of 219 million. However the main focus in cattle rearing continues to be getting more productivity from animals in the form of milk. Mastitis in milch animals continues to be one of the major diseases of livestock. There is a very good market and scope for coming out with a novel combination of anti-mastitis infusions for treatment of mastitis in dairy cattle. A combination of Cefaperazone Sod + Procaine Pencillin G + Predrusolone can be a good alternative. As per our information the anit-infective market will continue to grow at an average annual compounded growth rate of 5%.

Biologicals: Biologicals contributed 17% to the total revenue of the AH Industry during 2003-04. In fact, the biological segment has witnessed the fastest growth during the last one decade. The contribution of poultry sector continues at 53% in terms of volume, followed by cattle at 37%, canines at 7% and sheep and goats sector at 3%. In cattle segment, the FMD vaccine continues to be the biggest revenue earner with a contribution of 32% (Rs 51 crore). The introduction and implementation of FMD-Disease Free Zones concept in the country and continued support to the states under ASCAD programme by the Central Government have helped expanding this market tangentially. With increased competition and awareness at the farmer's level during the last few years there has been virtually a paradigm shift. More and more number of farmers/cattle owners now are switching over to the adoption of prophylactic measures for prevention of diseases in their livestock. There has been increased emphasis on preventive health-care than going for curative treatment.

The Ministry of Agriculture, Government of India, had earmarked a sum of Rs 1,000 crore for creation of FMD disease free zones during the tenth five year plan (2002-03 to 2007-08). Out of this, the vaccine component is expected to be Rs 600 crore over the five-year period (200 million doses per annum at Rs 6 per dose).

Put together all the three manufacturers M/s IIL-45 Mio, Intervet-20 Nio and IVRI-2 Mio, the country can produce a maximum of 67 million doses against the annual requirement of 200 million doses. A new manufacturer on the horizon- B.V. Biologicals (Venkateshwara Hatcheries) is planning 40 million doses capacity. This means that once the FMD-Disease Free Zones programme becomes fully operational, there will be excellent opportunity and scope to participate in this market.

There has been an increased thrust by the Government on exports sector by way of livestock exports to Middle East, Gulf and SAARC countries. As a signatory to WTO agreement, there is increased onus that all the livestock to be exported should be free from diseases like FMD, Brucellosis, IBR etc. The market for FMDV, HSBQ, Brucellosis, IBR, Anti

Tick Vaccine in cattle and PPR, ET, Multi component Vaccine for sheep/goats holds a tremendous business potential for a very promising future.

Anti-parasitics: The anti-parasitics constitute the second biggest therapeutic segment with 17% contribution to the total turnover of Indian Animal Health Industry. The anti-parasitics can be further classified into three main groups as: (a) Anthelmintics- 10% MS, (b) Ectoparasiticides- 4% MS (c) Anti-protozoals- 3% MS. The existing size of the anti-parasitic market is about Rs 161.5 crore, and this market is estimated to be growing at a healthy rate of 10-12% per annum.

Anthelmintics: Regular use of anthelmintics for deworming their flocks is quite popular among nomadic population of shepherds across the country. The sheep/goat segment accounts for around 28% of the anthelmintic market whereas cattle segment contributes about 70% of the total anthelmintic market. Benzimidazoles/Fenbendazole/Mebendazole/Triclabendazole, Imidothiazoles Tetramisole/Levamisole and Pyrantel, Pamoate are the most popular anthelmintic salts being marketed by many companies. However Panacur (Fenbendazole) by Intervet, Banminth (Morantel) by Pfizer and Albomar (Albendazole) by Glaxo continue to occupy leadership position of preferences. For controlling fasciolosis, the salicylanides (Oxyclozanide) are the most preferred formulations. Nilzan (Tetramisole+Oxyclozanide) by Glaxo and Tolzan (Oxyclozanide) by Intervet and Fascinex (Triclabendazole) by Novartis are the most popular brands.

Ectoparasiticides: The Indian ectoparasiticides market has grown phenomenally during the last one decade. The market has evolved from the use of chlorinated hydrocarbons to organo phosphorus compounds to pyrethroids and formamidines (Amitraz). At present the market is dominated by synthetic parathyroid formulations like Deltamethrin, Cypermethrin and Flumethrin etc. However Butox (deltamethrin) from Intervet with about 33% market share is undoubtedly the market leader in this segment. The use of Ivermectins is quite popular and growing up in canine segment.

The temperate climate of the country, uncontrolled grazing pastures, poor farm hygiene and sanitary conditions will continue to pose a big challenge and a menacing threat of ecto and endoparasites to the livestock. Moreover it has been observed that due to indiscriminate and excessive use of ectoparasiticides at farmer's level has led to resistance development to these molecules. The ectoparasiticides market today is cluttered with a number of me-too packs.

To tap potential of this fast growing market, it will be quite innovative to come out with a vaccine for control of ticks. Such a vaccine if launched successfully can be a real money-spinner besides attaining leadership position in the Indian ectoparasiticide market.

Similarly coming out with a formulation like (Fenbendazole + Urea Molasses)- mineral bricks can be a very good dewormer for dairy cattle.

Anti-protozoals: With increasing crossbred population of cattle across the country has always been under constant threat from the protozoal diseases

like Babesiosis, Theileriosis and Trypanosomiasis. Beranil (diminazene diacetate) from Intervet is the drug of choice and a brand leader for treating Babesiosis in cattle. However for treating Theileriosis there are not much alternatives/and the drug of choice continues to be Butalex (an original research product of Pitman Moore-UK); being marketed by Zydus Sarabhai. The camel population in the country is expected to be around 1.1 million. However for treating the most frequently occurring Surra (*Trypanosoma evansi*) infections in camels, hardly there are alternative drugs available which can be rated very effective. As we foresee, there is a good opportunity to participate in this market, since the market is growing, and there is not much competition at present. If introduced successfully a drug like "Isometamedium Chloride" can be the drug of choice for treating Trypanosomiasis infection in animals. Similarly the combination of Diminazene diacetate + Vit-B 12 can be a good product for anti-Babesiosis market.

Tonics: The tonics segment comprises allopathic as well as ayurvedic/herbal preparations, which are used regularly in cattle and poultry segments. The tonics market is dominated by the presence of ayurvedic rumenotonic preparations like Himalayan Batisa in cattle segment and Liv-52 like herbal formulations in poultry sector. There are a number of injectable liver extract preparations available in the market which are being used as the supportive therapy. Similarly injectable organic phosphorus preparations like Tonophosphan/Tonoricin are quite popular for supplementing phosphorus deficiency in animals as the supportive therapy. The market for tonics is quite attractive, and there is a good scope for a novel combination like (Toldimphos Sod + Vit-B12) to be positioned in this market for use in dairy cattle. Similarly in rumenotonic category too, there is ample scope for a unique combination (Vit B complex + Choline Chloride + Cobalt + potassium + Sodium chloride) as a rumen stabilizer. The tonics market segment is estimated to be growing at a rate of 8-10%.

Hormones: One of the major reasons of infertility in dairy cattle, besides nutritional deficiency, is found due to hormonal imbalances. Though the present size of the market is only about 2% (Rs 19 crore) of the total AH Market but the biochemical nature of the products/hormones and their scientific way of promotion makes this segment a special product category to be associated with companies who have a good knowledge base. This helps in improving the image of the company in the market place. The efficacy and utility of GnRH analogues and PGF2 alpha (Prostaglandin's) in day-to-day regular urge animal practice particularly in cattle and equines have been established beyond doubt. There is not much competition in this segment excepting of a few MNC players. The market is sound to expand and there is a good scope to come out with GnRH analogues and Prostaglandin's. Similarly coming out with estradiol for regularizing heat/oestrous in bitches can be a novel introduction besides becoming a blockbuster in hormonal

preparations.

For a new start-up biological company in animal health business, we would recommend some of the corporate strategies as follows. We are confident that these will help secure a bright future for the enterprise on a sustainable basis.

CORPORATE STRATEGIES

Broad product range: It is obvious that a wide product range will create depth in the product offering and help capture significant share of the overall market. FMD, Brucellosis, IBR, Calf Scour, Sheep Pox, PPR, ET and Blue Tongue are some of the proposed vaccine candidates which can offer a very promising future for any start-up new biological company.

Produce low cost: Vaccine business is generally seen as a tender driven business. Such tender driven business may place high emphasis on price rather than quality, and we must be prepared to continuously drive costs down.

Build strong technology and create entry barriers: At present, there are only three established players in the market manufacturing biologicals. However to be among the top players calls for significant technology capabilities and a dedicated team of professionals who have thorough understanding of biologicals business. Since it is only the advanced technology that can help us achieve both-cost leadership and developing differentiated products. To create entry barriers, it is proposed to develop various products through recombinant DNA technology such as DNA vaccines for rabies, FMD, Brucella, Tick vaccine and White Spot Disease Vaccine etc. Similarly monoclonal antibodies can be developed for a field test for diagnosis of FMD virus sero-types after an infection.

Techno-commercial backup as a differentiating tool: Having a strong techno-commercial back-up for any biological company, aiming for leadership position, has come to be identified as the key to success. Technical services and support provided to farmers/cattle owners at the field level can give us much-needed platform to differentiate our services from competitors.

Get global: To be a leading player, it is obvious that not only the Indian domestic market, but also other regions of the world have to be our markets as well. Export to the SAARC, Middle East and CIS countries for FMD and other cattle biologicals offer a very good business potential. We need to have a strong presence in most of the international markets.

Indian Poultry Industry Perspective

O.P. Singh

Global Scenario

Globally, chicken meat and egg industry has been characterized with the fastest consumption and trade growth among all the major agricultural commodities during the last 2 decades. The trend may continue in the next decade also due to: (i) Growing disposable income, (ii) Urbanization, (iii) Increasing Market Access to poultry products, (iv) Improved awareness about chicken and egg products

Indian Scenario

India is No. 2 in egg production, No. 5 in meat production, and is most competitive in production among 150 poultry-producing nations (Table 1)

Table 1. Competitive ranking of Indian poultry industry

Country	Cost rank	Margin rank	Egg pr. rank	Sum	ICR*
India	1	4	2	7	1st
USA	4	32	5	41	4th
China	15	38	8	61	15th
Japan	44	13	41	98	44th

*ICR means "International Competitive Ranking"

Source: FAO, Fairhurst et al.

The poultry sector provides employment to more than 2 million families; most of them are from small rural entrepreneurs. It is the highest contributor to the growth of agri-economy and is expected to double in the next 6 years. Besides it will have additional employment for 1.6 million people (Table 2)

Table 2. Growth potential of Indian poultry industry

Expected growth (next 5 years)	
Overall GDP	7%
Agriculture sector	4%
Poultry industry	12%
Layers	10%
Broilers	15%

Chief Executive Officer, M/s Venkateshwara Pvt. Ltd, Unit No. 3/303, 3rd Floor, Sharada Centre, 11/1, Erandwane, Pune 411 004 (Maharashtra)

Future Projection

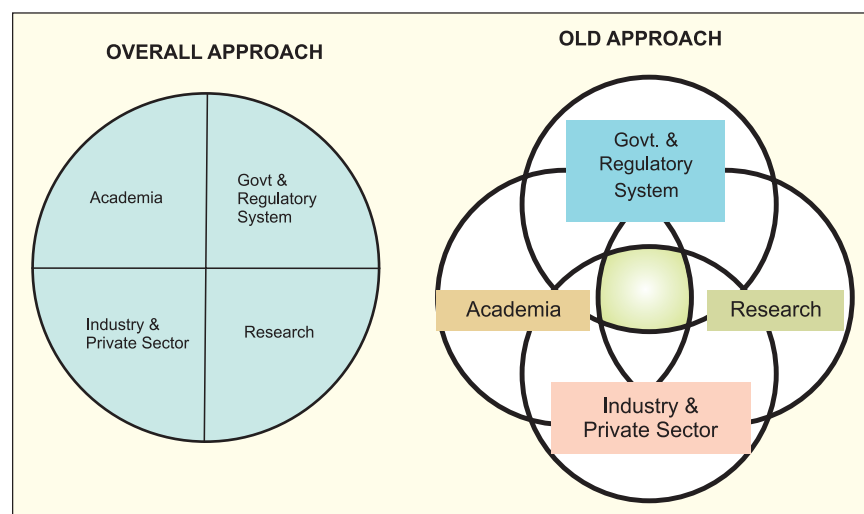
Table 3. Vision 2020 for the Indian poultry industry

Segment/ Parameter	Year 2005	Year 2010	Year 2020
Breeders	11 mil.	18 mil.	30 mil.
No. of broilers	1,440 mil.	2,400 mil.	3,900 mil.
Broiler meat (tonnes)	2.5	4.0	7.6
Layers	140 mil.	230 mil.	350 mil.
Employment	2.0 mil.	2.8 mil.	3.7 mil.

Source: All India Poultry Breeders Association, Industry Sources

Overall Development

It has been envisaged that public-private interactions and academia-industry interventions are inevitable for effective technical and sectoral development.

*INDUSTRY FOCUS – ACADEMIA SUPPORT*

- Research and training on meat science needs to be strengthened at the university level with practical approach.
- Research on “Value-addition” of poultry products needs to be based on *consumer need* and *market competitiveness*.
- Poultry science should be introduced as the graduate-level programme.
- Nutrition and *food ingredients bio-availability* need to be taught in educational institutes.
- Education about *food safety among academia and students is a must*.
- Special emphasis is needed on teaching practical animal nutrition in academia during Veterinary Graduation programme.
- Curriculum on bio-security and quarantine needs to be strengthened.
- Well researched sound ethics on international trade are to be installed.

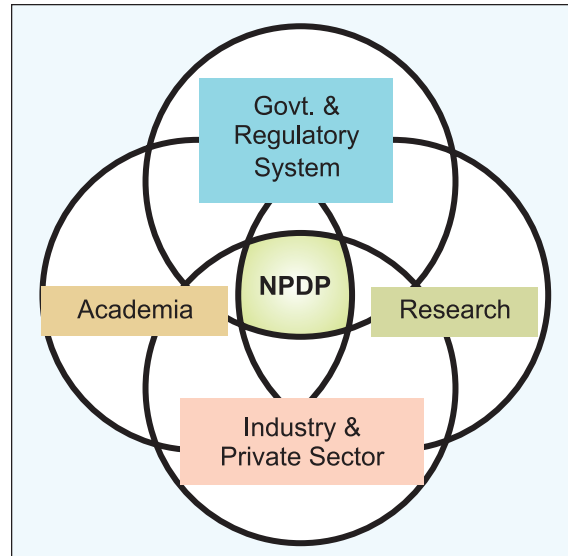
INDUSTRY FOCUS – PUBLIC RESEARCH SUPPORT

- Rapid and economical lab/field-based disease diagnostics/kits
- Development of molecular probes for food pathogens and food intoxicants for finding adulteration and for food safety; eliminating contamination ensuring food safety
- New generation vaccines, thermo-stable vaccines and bio-therapeutics
- Bio-security and rodent control programme – uniform and applicable at the farm level
- Development of non-conventional source of feed materials as viable option for animal nutrition
- Research on development and usage of probiotics and prebiotics in the Indian context
- Research on bio-safety, quarantine and bio-security for transboundary trade and movement
- Research on food safety and public health studies
- Farm waste management
 - Litter management – for energy and biofertilizers
 - Feather and butcher-shop waste management
 - Processing plant offal management
- Water management
 - Hardness
 - pH
 - Mineral impurities
 - Microbial contamination
- Food market reform
 - Standardization of channels
 - SOPs for all levels of production and marketing
 - Making better and wider availability of animal products hygienically
- Development and maintenance of *cold chain infrastructure* for distribution of processed food
- Ensure easy access to all vital facilities
 - inputs,
 - credit and
 - marketing
- Help in minimizing cost of essential inputs for growth of industry
 - Essential amino acids production
 - Vitamins production and excise duty
 - Improving quality and productivity of soya and maize
 - Prebiotics and Probiotics production

INDUSTRY FOCUS – PUBLIC SECTOR PARTICIPATION

- Evolving and formulating “**National Poultry Development Plan**” (NPDP)
- Involving Industry–Academia – Regulatory System /Government – Research Institutes

- Lay down guidelines and support aimed at bringing national governance and poultry health legislation inline with the international standards



“National Poultry Development Plan” (NPDP). The NPDP has following responsibilities.

- Identifying strategies and processes that should create public-private partnership
- Preparation of emergency plan and systems for early detection, rapid response and surveillance for priority diseases
- Will help in improving consumption of animal protein as human diet
- To standardize production, distribution and marketing with SOPs
- Supervise and inspect different channels for health and hygiene point of view for end-consumers
- To make standard test procedures for diagnosis of different diseases and raw material analysis
- To certify products, processes, farms and channels
- To make national disease surveillance and have database management
- To promote participation of different stakeholders in disease control and consumer health awareness
- To make uniform standards for national bio-security and sanitation programmes
- To certify products free from specific diseases like *Salmonella* etc.
- To help in making policy for animal and animal trade across the border
- Developing a more efficient use of land-energy and resources in

poultry production through establishment of superior “Industrial ecologies”

- To make standard bio-security and sanitation procedures like
 - Flock sanitation
 - Hatching egg sanitation
 - Hatchery sanitation
 - General farm cleaning and disinfection
- Planning and developing strategies for future change in poultry agriculture and natural resources
- Creating sustainable basis of *poultry production*
- Strengthening competitiveness of poultry produce and ensuring *strong domestic and global food supplies*

Biologicals in Animal Husbandry

M.P. Yadav

The human endeavour to fight diseases has a long history. The initial scientific application of biological products was established by Jenner's work on the effectiveness of cowpox in immunization of human-beings against smallpox. The science of immunology and evolution of biological products then remained dormant for about a century, but thereafter microbiologists started probing into various microbes fatal to man and animals. The last decade of the 19th century proved to be the golden era of bacteriology and immunology. During this period appeared the classic works of Pasteur on anthrax, fowl cholera and rabies; Salmon and Smith on swine paratyphoid; Koch on tuberculosis; Behring and Kitasato on diphtheria antitoxins; Ehrlich's exposition on the principles of immunity and of Metchnikoffs on the immunological studies. These studies opened up a new lease of life to the suffering humanity and animals.

Definition of biologicals: By definition, biologicals are vaccines, cultures and other preparations made from living organisms and their products, intended for use in diagnosing, immunizing or treating humans or animals, or in related research (www.nsc.org/ehc/glossary.htm). Biologicals have also been defined as products derived from living organisms that detect, stimulate or enhance an animal's immunity to infection (www.ahi.org/resources/glossary.asp). The first definition covers all components of biologicals, and the second deals only with detection, stimulation and enhancement of immunity with no mention of diagnosis (or diagnostic reagents) and use of biologicals in research.

The advent of recombinant DNA (rDNA) and associated technologies have enabled development of (i) synthetic peptides, (ii) recombinant proteins expressed in heterologous expression systems, (iii) synthetic RNA molecules as drugs in antiviral therapy and, (iv) vectored vaccines. These products are not directly derived from animals or their products but have tremendous potential in animal husbandry and medical field. Such biologicals make an exception to both the above definitions.

R&D ON BIOLOGICAL PRODUCTS IN INDIA

The research work on the development of biological products in India

was taken up at the Imperial Bacteriological Laboratory, established at Pune in 1889 by Government of India, for systemic study on rinderpest, anthrax and surra (trypanosomiasis), which caused enormous losses to farming community. The functions of the laboratory originally were to investigate diseases of domesticated animals in all provinces of India and to ascertain, as far as possible, by biological research in the laboratory and when necessary, at the places of outbreak, the means for preventing and curing such diseases. After two years, it was realized that the climatic conditions at Pune were not quite suitable for carrying out finer operations of biological research and eventually the laboratory was shifted to Mukteswar at the foothills of Himalayas in 1893. In 1901, a branch laboratory was built at Kargainia about 4 km from Bareilly, and subsequently moved to Izatnagar in 1913, better known as Imperial Veterinary Serum Institute, Izatnagar, which eventually became the Biological Products Division of the Indian Veterinary Research Institute (IVRI), and the main biological production unit of the country.

PRODUCTION OF BIOLOGICALS IN INDIA

In India, production of veterinary biologicals was started in 1898 at the IVRI, Izatnagar. The major activity of the institute in the early 20th century was production of various antisera against rinderpest, haemorrhagic septicaemia, anthrax, tetanus and black quarter and mallein at Mukteswar. By 1913, large-scale production of biologicals had started in the newly established laboratory at Izatnagar. At present, there are about 29 units with the centre and state governments and the private sector.

OLD WORLD/NEW WORLD BIOLOGICALS

The old time biologicals were produced in animals or derived from animal products employing less stringent processes and hence they were crude, comparatively less pure and homogenous. Such biologicals were also liable to produce adverse reactions in recipients. Technologies for production of new generation biologicals employ better production substrates (like chicken embryos, cell culture), improved down-stream processing methods, and recombinant DNA technology approaches. Use of cell cultures in biologicals production has resulted in comparatively pure and homogenous biologicals preparations. Biologicals prepared in cell cultures are also amenable to downstream processes for concentration, purification, and can be prepared free of microbial contaminants. The recombinant DNA technology has now made it possible to produce biologicals tailored to specific applications. Such technologies have also made it possible to generate biologicals from microorganisms, which are either non-cultivable in cell cultures or have poor growth leading to uneconomic production of biologicals. The overall cost of production of biologicals using cell cultures and employing downstream processes suitable for high throughput product purification has also gone down significantly. The products are of international standards as most of the biological production facilities are

now GMP/GLP compliant. The mass-scale use of the new generation biologicals has significantly reduced adverse reactions in recipients. Cell culture vaccines have helped in eradication of animal diseases like rinderpest, and have been helpful in controlling many diseases of livestock and poultry. The livestock and poultry products are now traded internationally in higher proportions. Similarly, ready availability of new generation diagnostic reagents, tests and kits has helped in implementing infectious disease control and eradication strategies at the national level.

CATEGORIES OF BIOLOGICALS

Biologicals for veterinary use can be categorized in the 7 following categories.

Vaccines: Many bacterial, viral and parasitic vaccines are now available in the country. Most of the bacterial vaccines are killed vaccines. Viral vaccines are either killed/inactivated or live attenuated cell-culture based vaccines. At the IVRI technologies for gamma-irradiated lung-worm vaccine, cell-culture *Theileria annulata* schizont vaccine and MASP culture derived *Babesia bigemina* vaccine were developed and tested. At the moment, efforts are being made to develop a subunit vaccine against tick infestation.

Immunodiagnostic reagents: Immunodiagnostic reagents being produced include mainly two broad categories of reagents–antigens and antibodies.

Antigens: Antigens could be

- crude and partially purified antigens,
- cell-culture grown and purified viral antigens,
- Recombinant (expressed) protein antigens,
- synthetic peptides as antigens, and
- coloured or plain antigens.

Antibodies: Antibodies could be

- polyclonal antibodies like hyperimmune serum, infected serum, convalescent serum or monospecific serum,
- monoclonal antibodies, and
- purified immunoglobulins intended for immunotherapy.

Immuno-modulatory cytokines: A number of immuno-modulatory cytokines are now commercially available which have the potential as novel adjuvants when administered along with the conventional, as well as, the new generation vaccines to modulate immune response.

Drug delivery matrices: Systemic antibiotic delivery has certain drawbacks such as systemic toxicity and poor penetration into ischemic and necrotic tissues. Local antibiotic therapy offers advantages of a high local concentration without systemic toxicity as well as dead space management, early primary wound closure and better eradication of infection. Various vehicles have been used for drug delivery but biological materials include a handful of items like collagen, implant prosthetics etc. Of late, it has been suggested that fibrin-antibiotic compounds can be used both prophylactically and therapeutically in treating infected sites that are difficult to reach with

systemically administered antibiotics. Since fibrin blood clots are naturally subjected to fibrinolysis as part of the body's repair mechanism, implanted fibrin may also rapidly degrade. Further, pattern of output from a resorbable carrier system is of great practical importance clinically, and is most often the only variable to achieve expected pharmacological activity. The release rate of drug must be reproducible, be unaffected as much possible by physiological factors to provide therapeutic plasma concentration. The use of fibrin as a site-directed drug delivery system has several potential clinical applications; as fibrin is a naturally occurring, haemostat and scaffold, guiding direction of wound contraction and closure in humans. Small molecules generated during fibrinogen clotting, such as fibrinopeptides and kallikrein, thrombin, plasmin, etc are chemokinetic and chemotactic for almost all cells in the fibro-proliferative phase. Fibronectin which is usually present in fibrinogen concentrate prepared from plasma is a primary matrix for organizing collagenous proteins, which appear early in granulation tissue generation. Therefore, a porous biodegradable disc prepared from fibrin glue components will form a mechanical support into which blood penetrates and holds the tissue at the site. The uniqueness of the fibrin clot matrix is that it can be made available in an easy, ready-to-use, lyophilized form that has a good shelf-life. Such drug delivery matrices have been studied and used with a promise in mice and humans, suggesting similar refinement of the technology for use in animal husbandry; as such a device will help in avoiding systemic medication, which may be unnecessary in most circumstances.

Biomolecules in antiviral therapy (RNA as drug): The mass vaccination approach has contributed significantly towards controlling and eradicating many human as well as animal viral diseases. However, of late, siRNA-mediated reduction in viral production in mammalian cells seems to offer a plausible approach towards antiviral therapy especially in human viral disease control. Some of the economically most important animal viruses include FMDV, PPRV, Blue tongue virus, Newcastle disease virus, sheep pox and goatpox viruses and Classical swine fever virus. RNA interference studies have been conducted in the Division of Virology with PPRV as an RNA virus model and buffalopox virus (*Orthopoxvirus* genus) and goatpox virus (*Capripoxvirus* genus) as DNA virus models for studying RNA potential of interference in antiviral therapy. RNAi treatment resulted in >98% inhibition of PPRV in cell culture.

Effect of individual siRNAs on *Orthopoxvirus* replication was studied in vero cells. The significant inhibition of virus replication observed with pox (buffalopox, goatpox), PPR and duck plague viruses indicates that RNA interference, using synthetic RNA molecules, could be a promising approach for antiviral therapy.

Probiotics: In addition to antibiotics, a wide variety of feed additives, many of biotechnological origin, are known to modify rumen fermentation. They include components that can reduce methanogenesis, enhance propionic acid production, reduce protein degradation, improve microbial protein synthesis and inhibit protozoa. Among such additives are antibiotics,

microbes (probiotics), and specific substrates like oligosaccharides (prebiotics). Probiotics are live, microbial feed supplements that improve intestinal microbial balance. The term prebiotic refers to substrate selectively stimulating probiotics.

Microbial (including rumen fungi) enzymes for degradation of cellulose and hemi-cellulose (microbe translocation): The transfer of rumen microbes from Indonesian goats to Australian sheep has enabled Australian ruminants to degrade hydroxypyridone (HDP), a metabolite from mimosine that is commonly present in the tropical legume *Leucaena leucocephala*. Another successful application from a technological point of view is the development of recombinant bovine somatotropin (rBST) hormone. Its effectiveness and safety have been confirmed by the Food and Drug Administration (FDA) in the USA, but are still under dispute by various groups. Consumers tend to be wary of the use of hormones, and widespread application in developing countries is not without danger, particularly because its effective application requires high-quality feed and proper management.

FACTORS INFLUENCING QUALITY OF BIOLOGICALS

Microbial contamination of cell cultures used in production of biologicals: Bacteria, fungi, parasite, viruses, invertebrates and mycoplasmas are main causative agents of the cell-line contamination. Contamination effects are categorized into three classes (i) minor disturbances by which several plates or flasks are occasionally lost by contamination, (ii) serious problems by which entire experiments or cell cultures are lost; and (iii) major catastrophes that affect validity of past or current works.

Most of the viruses contaminating cell cultures cause cytopathic effects (CPE), and can be presumptively identified after visual inspection. However, the best way to detect is to inoculate the cell culture supernatant to a few other cell lines. It may take one or a few passages before CPE is evident, thus a quarantine period of 21 days should be followed, till then new cell cultures should be kept isolated. The bacterial and fungal (including moulds and yeast) contamination of cell lines (except mycoplasmas) can readily be detected by visual observation of: (i) turbidity, (ii) shift in medium pH, resulting in change in colour of medium, and (iii) cell destruction. However, putative pathogens such as nanobacteria cannot be detected by visual observation. Also the antibiotic-resistant bacteria developed, which are slow-growing, are very difficult to detect by visual observation. Such cryptic contaminants usually persist indefinitely in cultures, cause subtle but significant alterations in cell behaviour and morphology, and are transferred frequently from one laboratory to another by exchange of cell cultures. Similarly, mycoplasma contamination is also undetected for many passages. Mycoplasma contamination of cell cultures alters function, metabolism, growth, morphology, attachment, membranes, chromosomal aberrations and many other properties of the cell lines. And

mycoplasma contamination spreads quickly to other cell lines and laboratories after exchange of cell cultures.

Sources of cell culture contamination may include: (i) contaminated cells, (ii) glassware, apparatus including storage bottles and pipettes, (iii) culture media and reagents (basal culture media, serum, basic salt solutions and enzymes viz. trypsin/pronase/collagenase, etc), and (iv) airborne contamination including other additives. The most serious is the original contamination of cell culture used as seed cells.

FCS contamination: Most cell culture production processes involve culture media that are supplemented with bovine foetal serum (FCS). It has been known for a long time that FCS may be contaminated with adventitious viruses, and BVDV is the most common contaminant. Use of vaccines made using medium supplemented with FCS contaminated with BVDV may result in (i) outbreak of BVDV in cattle, (ii) cause disease in pigs, or (iii) result in induction of antibodies that might interfere with serological surveillance programmes for the eradication of hog cholera. Now serum-free cell cultures are being used for large-scale production of vaccines under serum-free conditions. However, complex requirements for *in-vitro* growth seem to be cell-type specific, and it cannot be guaranteed that large scale serum-free production processes can be developed for all biological products. Therefore, it has to be accepted that the use of FCS during production of biologicals is presently still routine, and will continue to be so in the near future.

NEW GENERATION PRODUCTION PROCESSES AND ASSAYS OF BIOLOGICALS

New generation assays for quality assurance of biologicals: Nucleic acid Amplification Technology (NAT) has revolutionized detection and molecular characterization of pathogens. However, complexity of NAT, comprising sample preparation, amplification and detection methods, requires specific design considerations for both the laboratory and the procedure utilized in such testing. Technical considerations for performance of the NAT to address the detection of human infectious agents in blood, plasma, serum and other components by the NAT have been described.

Improved down-stream processing methods: These methods have allowed production of biologicals of superior quality, which have helped in minimizing adverse reactions due to comparatively impure biologicals used in the earlier times. Incidence of disease outbreaks (like FMD, rabies, etc) due to the use of inactivated viral vaccines in the field has gone down significantly. Adverse reactions due to use of vaccines produced in animal-host like rabies in sheep brain, many viral vaccines in embryonated chicken eggs and Japanese encephalitis virus vaccine in mouse brain have now been reduced due to use of cell culture for production of these vaccines.

New fractionation assays for removal of TSE agent from products: Prion diseases have recently become a focus of intense research

interest. The level of concern surrounding potential contamination of therapeutic products with prion, coupled with difficulty in destroying agents of transmissible spongy form encephalopathy disease has opened a new market to TSE removal processes. A lot more processes are now being tested for plasma product purification and in-process simultaneous prion removal. Gradiflow is such a technology, which has recently been tested for prion removal and has proved effective.

Inactivation of viruses in biologicals: Manufacturing processes of all plasma derivatives required comprise dedicated virus inactivation/removal steps for enveloped and non-enveloped viruses. Virus inactivation procedures include solvent/detergent treatment, acid treatment, heat treatment in solutions at 60°C and heat treatment in lyophilized state. These operations have proved effective against lipid-enveloped viruses such as HBV, HCV and HIV. However, suitable procedures for inactivation of non-enveloped viruses HAV, human parvovirus B19 remain to be developed. UV irradiation can inactivate a wide variety of microorganisms including enveloped and non-enveloped viruses but existing UV-irradiation processes have some difficulty especially large volumes cannot be irradiated. Of late, a new UV irradiation process “Continuous flow design” has been developed, which is found sufficiently effective.

THERMOSTABILITY OR THERMO-RESISTANCE OF FINISHED PRODUCTS

Improved freeze-drying techniques and machines, use of proven stabilizers, and airtight sealing of vials and ampoules have improved thermostability of the finished products. Use of accredited stabilizers like sucrose, trehalose and many other combinations have improved shelf-life of biologicals. Deuterated water may further enhance stability of products, especially virus preparations like vaccine seed viruses, viral vaccines, purified protein antigens and antibodies; especially monoclonal antibodies; as has been seen by better stabilization of oral polio vaccine and yellow fever vaccine.

ENDOGENOUS RETROVIRUSES IN CELL LINES USED FOR BIOLOGICAL PRODUCTION

It has long been established that rodent cell lines contain retrovirus elements that may be expressed as particles detectable by electron microscopy. Such particles may be infectious, as in murine leukemia virus (MLV); or defective and non-infectious, as in Chinese hamster ovary (CHO) cell retroviruses. Despite lack of evidence for such an association between murine retrovirus and disease in man and animals, the potential contamination of biologicals with agents associated with oncogenicity and immunosuppression in biological products is a cause of regulatory concern. Detection and characterization of retroviruses in master and end of production cell banks is recommended by regulatory agencies using electron microscopy, reverse transcriptase assay and appropriate infectivity or co-cultivation assays. Detection of nucleic acid of these viruses in cells by RT-

PCR could be another sensitive and specific test for certifying cells. In addition, determination of retrovirus particles load and experimental demonstration of appropriate removal or inactivation of retroviruses during purification are also required for each product.

GMP/GLP COMPLIANT BIOLOGICAL PRODUCTION UNITS

In the wake of the WTO and the international trade, the GMP/GLP compliance by biological production units has become mandatory. Almost all biological production units under private management in India have either complied to GMP/GLP facilities and/or are in the final stages of creating such facilities essentially required for production of veterinary biologicals of international quality. The biological production units of State Government sector have also geared up for GMP/GLP compliance. The Institute for Animal Health and Veterinary Biologicals at Bangalore has GMP/GLP facilities, while IAHVVB, Kolkata, has ISO certified production facilities. Other institutes are already in the process of creating such facilities. Veterinary biologicals produced in GMP/GLP compliant facilities will not only ensure the product of superior quality but also give a competitive edge in the world market.

The diagnostic tests for international trade have to use internationally accredited diagnostic reagents and follow internationally accepted diagnostic procedures. GLP facilities will help in ensuring development and use of such tests and therefore, most diagnostic labs in the country are going for ISO certification. Central Disease Diagnostic Referral Laboratory (CDDRL) at the IVRI has already been given ISO 9001:2000 certification in 2004 for diagnostic laboratories.

The National Institute of Biologicals (NIB) at the NOIDA has GMP/GLP compliant biological production facilities. Department of Animal Husbandry, Dairying and Fisheries (DAHD&F), Government of India, is also setting up a GMP/GLP compliant facility at Baghpat in Meerut on the lines of the NIB for production of veterinary biologicals. Establishment of such a facility will ensure availability of quality biologicals of international standards and acceptance, which, in turn, will help in augmenting the productivity of livestock, enhancing income generation by animal husbandry sector in India. This will also help in marketing of livestock and livestock products in the international market.

NEW GENERATION TESTS/ASSAYS FOR VACCINE POTENCY ESTIMATION

Potency is a key indicator for quality of any live attenuated vaccine. Potency is estimated by virus titration calculating median tissue culture infectivity dose (TCID₅₀) or median cell culture infectivity dose (CCID₅₀), or plaque forming unit (PFU) assays. These assays measure amount of infectious virus particles in vaccine by counting plaques or observing CPE that, at times, becomes difficult. Further, potency estimation of a single component virus vaccine by conventional methods is easier but difficult for multivalent vaccines due to various reasons including CPE complexity and

magnitude. Potency estimation by counting tiny or too big plaques may result in invalid assays. Moreover, these conventional assays are dependent on the observation of the CPE and take a longer time before plaque or CPE becomes visible in a cell monolayer.

New generation assays like quantitative RT-PCR (qRT-PCR) in combination with a short-term virus replication step, also known as qRT-PCR infectivity assay, overcomes this problem, and has proven effective in potency estimation of measles virus in trivalent MMR vaccine. q-RT-PCR infectivity assay precision is comparable to plaque assay and is able to provide quantitative information on the growth characteristics of vaccine viruses. This assay has been used for potency estimation of many viruses in live attenuated vaccines like measles virus in trivalent MMR vaccine, measles, mumps and rubella viruses in trivalent MMR vaccine, Japanese encephalitis and many others.

COMMERCIAL SUPPLIES OF CONSUMABLES

Commercial supplies of safe and sterile consumables like (i) plastic-ware (including centrifuge tubes, tissue culture flasks, micro-well tissue culture plates, tissue culture petri dishes), (ii) minor instruments (syringes, vacutainers, storage vials) and (iii) other lab accessories used by workers (gloves, face masks, overall wear, head covers, disposable shoes) have definitely improved the quality and safety of biologicals being produced now-a-days. Clean and sterile collection and processing of samples especially blood and serum has been possible because of the availability of disposable vacutainers, needle and syringes, centrifuge tubes, vials for cryo-storage and ampoules and vials for freeze-drying. Commercial availability of accessories for dispensing, packing, freeze-drying and storage has helped in production of safe and quality biologicals.

ALTERNATE PRODUCTION SUBSTRATES AND METHODOLOGIES

Production of biologicals in olden times depended heavily on animals and animal-derived products. Availability of chicken eggs, chicken embryos and cell cultures has offered an alternate suitable substrate for mass-scale quality production of biologicals, especially for viruses. Specific pathogen-free eggs and embryos, defined cell culture media, serum certified free of viruses, serum-free cell-culture media have further improved quality and overall cost of production of biologicals. Thus, the transition from animals to cell culture as substrate has been the great stride in improving quality and reducing cost of production of biologicals at mass-scale.

Advent and subsequent advancements in rDNA technology, chemical synthesis processes and newer downstream processing methods have made it possible to identify target region in the genome, design oligonucleotide primers for PCR amplification, cloning, high throughput sequencing and technology for optimal expression of foreign proteins in heterologous systems (prokaryotic, mammalian, yeast or insect expression systems), and chemical synthesis of peptides have paved the way for producing much-

more refined and specific immunobiologicals against bacteria, viruses and parasites, which may not be amenable to easy cultivation. Many vaccines like sheep-brain rabies vaccine had resulted in severe adverse reaction when used for vaccination. Further, large number of injections had to be given. The cell-culture produced rabies vaccines are currently available, which can be used even as a single dose vaccine or else 3-5 injections may have to be taken, instead of 14 injections, as was the case earlier. The post-exposure adverse events reporting has also come down significantly, and now it is unheard of that such reactions occur after rabies vaccination.

IMPACT OF VETERINARY BIOLOGICALS ON ANIMAL HUSBANDRY SECTOR

The veterinary biologicals have been the backbone of present-day animal husbandry in India. The potent immunobiologicals including conventional immunoprophylactics, diagnostic antigens and vaccines have played vital role in providing effective animal health coverage. More than 40 immunobiologicals were produced in India in early 1990s. The total production of different biologicals in Government sector in 1985 was approximately 400 million doses. The old production methods have been upgraded from time-to-time and now GMP/GLP compliant facilities are coming up very fast. Realizing potential market economics of immunobiologicals including vaccines, the private sector companies have invested huge sum of money, and private sector production units already have GMP/GLP compliant facilities in place. Government production institutes have geared up and will have GMP/GLP compliant facilities not only for production of immunobiologicals but also for disease diagnosis in a very near future.

Judicious application of veterinary disease control measures and use of biological products have enabled (i) eradication of African horse sickness and rinderpest from India, (ii) control of poultry diseases like Ranikhet disease, fowlpox and spirochaetosis, making poultry industry a viable enterprise in India. The other diseases which could be controlled effectively include black quarter, pasteurellosis in cattle, brucellosis and clostridial infection in sheep. The vaccination of cattle has brought down disease significantly over many plan periods. The disease has now been eradicated from the country. The latest veterinary biologicals (vaccine and diagnostic kits) for diseases like PPR, sheep-pox and goat-pox have provided the impetus to launch national disease control programmes for PPR, sheep-pox and goat-pox. The monoclonal antibody based rinderpest competitive ELISA (RP cELISA) kit, developed at the IVRI, for detection of rinderpest virus antibodies has been internationally validated, accepted by OIE/FAO and ultimately approved for field use under the National Project for Rinderpest Eradication (NPRE) in India. This kit has been produced in-house at the IVRI and has been supplied throughout the nation since 2002. The kit has successfully been used in the country and has served as import substitution item. Similarly, the PPR sandwich ELISA kit (for detection of

PPRV antigen) and PPR competitive ELISA kit (for detection of PPRV antibodies) are produced in-house at the IVRI and are supplied throughout the nation (Table 1). The PPR kits are also being used extensively in the country and are in very high demand. These kits have also served as the means for import substitution. The overall savings due to development of these kits via import substitution could be more than Rs 10 million in the last 3-4 years (Table 2).

Table 1. Total number of rinderpest and PPR kits produced in-house and distributed nationally during 2002-05

Sl No.	Kit	Year-wise distribution of kits			Cumulative total of kits distributed
		2002-03	2003-04	2004-05	
1.	Rinderpest c-ELISA kit	12 (1,800)	27 (40,500)	69 (103,500)	108 (155,800)
2.	PPR c-ELISA kit	06 (3,000)	27 (13,500)	76 (3,800)	109 (54,500)
3.	PPR s-ELISA kit	03 (300)	21 (2,100)	39 (3,900)	63 (6,300)

Figures in parentheses indicate total number of samples tested.

Table 2. Cost factor analysis for PPR s-ELISA and c-ELISA kits

Kit	Year	Total samples	Cost of analysis by BDSL kit (INR)	Cost of analysis by indigenous kit (INR)	Revenue saved (INR)
PPR c-ELISA kit	2001-2005	66,530	1,663,250	332,650	1,330,600
PPR s-ELISA kit	2001-2005	13,298	9,973,500	332,450	9,641,050
	Total (INR)		11,636,750	665,100	10,971,650

Bluetongue is another serious disease in sheep in India, where 20 serotypes of bluetongue virus (BTV) have been reported to be present based on the serology as well as on the isolation of the viruses from the field. There are no kits available, and India imports these kits from abroad. These kits are not available freely, and are expensive. Cost of testing each sample works out to be Rs 50/sample. The IVRI has recently developed an indirect ELISA based on cell culture grown purified BTV antigen for detection of BTV antibodies in field serum samples. This ELISA has diagnostic sensitivity (DSn) and diagnostic specificity (DSp) equivalent to the imported kits. The indirect ELISA developed at the IVRI costs Rs 10 per sample. Recombinant BTV VP7 truncated gene has also been expressed in prokaryotic expression system, and this protein works well in place of cell culture grown purified BTV. Efforts are on to express this protein in yeast in large quantities. In the mean time, research continues to develop recombinant BTV VP7 protein-based indirect ELISA (Table 3).

INSTITUTIONS INVOLVED IN MANUFACTURING OF ANIMAL BIOLOGICALS (SOURCE: www.indiadairy.com)

The institutions involved in manufacturing vaccines and other biological products in India are as follows.

- Institute of Veterinary Biologicals, Guwahati, Assam
- Veterinary Biologicals and Research Institute, Hyderabad, Andhra Pradesh

Table 3. Antigen and antibody detection kits at different stages of development at the IVRI

SI No.	Kit	Antigen/ antibody used	Test sample capacity	Diagnostic specificity	Diagnostic sensitivity	Samples tested so far	Validation
Field diagnostic kits for detection of antibodies in clinical serum samples							
1.	Rinderpest competitive ELISA (c-ELISA)	Anti RPV H MAb	1,500 samples in duplicate	93%	89%		Internationally validated and accepted by OIE
2.	PPR competitive ELISA (c-ELISA)	Anti PPRV HMAb	500 samples in duplicate	98.84%	92.2%	58,700	Validated nationally by more than 25 laboratories
3.	Indirect ELISA for detection of PPR antibodies	Cell culture purified PPRV vaccine antigen		100%* (388/388) 98.4%** (952/967)	79%* (195/247) 92.2%** (676/733)	1,544	Validated internally. To be validated by outside laboratories
4.	Indirect ELISA for detection of BTV antibodies	Cell culture purified BTV antigen					
5.	Indirect ELISA for detection of capripox virus (CaPV) antibodies	Cell culture purified goat-pox virus (CPV) antigen					
Field diagnostic kits for detection of antigen from clinical samples							
6.	PPR sandwich ELISA (s-ELISA)	Anti PPRV N MAb	100 samples in duplicate			5,983	Validated nationally by more than 25 laboratories

* Compared with VNT using 967 samples (952/967); ** compared with PPR c-ELISA using 733 samples (676/733)

- Poultry Viral Vaccine Production Unit, Samalkot, Andhra Pradesh
- Institute of Animal Health and Production, Patna, Bihar
- Animal Vaccine Institute, Gandhinagar, Gujarat
- Haryana Veterinary Vaccine Institute, Hisar, Haryana
- Anti-rabies Vaccine Laboratory, Jammu, Jammu and Kashmir
- Institute of Animal Health and Biological Products, Srinagar, Jammu and Kashmir
- Institute of Animal Health and Veterinary Biologicals, Bangalore, Karnataka
- Institute of Animal Health and Veterinary Biologicals, Palode, Kerala

- Institute of Animal Health and Veterinary Biologicals, Mhow, Madhya Pradesh
- Institute of Veterinary Biological Products, Pune, Maharashtra
- Orissa Biological Products Institute, Bhubaneswar, Orissa
- Punjab Veterinary Vaccine Institute, Ludhiana, Punjab
- Regional Veterinary Biological Unit, Jaipur, Rajasthan
- Institute of Veterinary Preventive Medicine, Ranipet, Tamil Nadu
- Institute of Veterinary Biologicals, Lucknow, Uttar Pradesh
- Indian Veterinary Research Institute (IVRI), Izatnagar, Uttar Pradesh
- Institute of Animal Health and Veterinary Biologicals, Kolkata, West Bengal

VETERINARY BIOLOGICAL PRODUCTS

Number of licensed veterinary biological products available globally include (a) Vaccines (155), (b) Bacterins and bacterial extracts (106), (c) Antibody products (19), (d) Vaccines with bacterins/bacterial extracts/toxoids (185), (e) Diagnostic products (86), (f) Antitoxins (8), (g) Bacterin-toxoids (54), (h) Toxoids (11) and (i) Miscellaneous (11) (Source: www.aphis.usda.gov).

BIOLOGICALS AND MANUFACTURERS

Major animal biologicals available in India include: (a) FMD vaccine (cattle and sheep), (b) Gumboro vaccine-IBD (poultry), (c) Newcastle disease vaccine, (d) Marek's vaccine, (e) Rabies vaccine (cattle and canine), (f) Canine multi-component vaccine.

LEADING INDIAN PLAYERS IN ANIMAL BIOLOGICALS

Leading players in animal biologicals in India include: Fort Dodge, Hester Pharma, Indian Immunologicals Ltd, Intervet, Indovax, Ventri Biologicals, Zydus Cadila.

INTERNATIONAL PLAYERS PRESENCE IN INDIA

International players in India include: Akzo Nobel (Intervet), Fort Dodge (American Home Product), ABIC (Zydus Cadila), CEVAC (Ranbaxy), Merial (Hester Pharma), Factro (Stellan), and TAD (Indo Bio Care (IBC)).

GOVERNMENT OF INDIA INITIATIVES

Animal wealth in India has increased manifolds and animal husbandry practices have changed to a great extent following introduction of newer technologies particularly for crossbreeding and upgradation of indigenous breeds. More recently, with the liberalization of trade after the advent of World Trade Organization's Sanitary and Phytosanitary (SPS) agreement, the chances of ingress of exotic diseases into the country have increased.

For ensuring disease-free status and to be compatible with the standards laid down by the Office International des Epizooties (OIE) - World Animal Health Organization; major health schemes have been initiated to support animal health programmes in the states.

Further, to control economically important livestock diseases and to undertake obligatory functions related to animal health in the country, the Central Government is implementing a centrally sponsored macro-management scheme called "Livestock Health and Disease Control". The scheme is being implemented with an outlay of Rs 525 crore. It has several components – Assistance to States for Control of Animal Diseases (ASCAD), National Project on Rinderpest Eradication (NPRE), Foot-and-Mouth Disease Control Programme (FMD-CP) and Professional Efficiency Development (PED). In 2005-06, the department of animal husbandry, Ministry of Agriculture, allocated about Rs 99.95 crore for livestock health. The outlay included Rs 55 crore for animal disease control, Rs 7 crore for National Project on Rinderpest Eradication, and Rs 2.95 crore for professional efficiency development and Rs 35 crore for Foot-and-Mouth Disease Control Programme.

For control of major livestock and poultry diseases by way of prophylactic vaccination, the required quantities of vaccines are produced in the country at 26 veterinary vaccine production units. Of these, 19 are in public sector and seven are in the private sector. Import of vaccines by private agencies is also permitted as and when required. According to the annual report 2004-05 of the Department of Animal Husbandry, Ministry of Agriculture, a network of 26,540 polyclinics, hospitals and dispensaries and 25,433 veterinary-aid centres, supported by about 250 disease diagnostic laboratories, are functioning in states and union territories for quick and reliable diagnosis of diseases.

ANIMAL HEALTH-CARE *VIS-à-VIS* BIOLOGICALS MARKET

According to various reports, the worldwide sales of biotech-based products for use in animal health had generated US\$2.8 billion in 2003 (out of a total market for animal health products of US\$18 billion). The share of biotechnology-based products and services in 2004 was US\$4.1 billion, out of the total animal health-care market of US\$21 billion. This was expected to grow to US\$5.1 billion by 2005 in a total animal health-care market of US\$23 billion. Animal biotechnology market is projected to be worth US\$12.5 billion by 2010. According to the USDA, there are different licensed biotech products available for animals. These products include veterinary vaccines, biologics and diagnostic kits. The animal health industry invests more than US\$400 million a year in research and development.

The global animal biological market is one-sixth of the animal health market of US\$18 billion, and it is growing at 7% against animal health market growth rate of 2%. In India, the animal health-care market is Rs 1,000 crore, growing at the rate of 10%. The major segments include cattle

(45%), poultry (40%), canine (6%), sheep (4%) and others (5%). The animal biologicals, market in the country is one-fifth of the health market (Rs 200 crore) but it is growing faster than the health market at 15%. Segments in animal biologicals include cattle (42%), poultry (45%), canine (7%), sheep (3%) and others (3%).

The animal health-care industry in India has been increasing from about US\$200 million in 2000, rising up to US\$215 million in 2003, US\$230 million in 2004 and US\$246 million (estimated) in 2005. However, as per the latest report of CLFMA of India (an Association of Livestock Industry), the animal health-care market is Rs 1,350 crore. There are 250 companies in this space. The market is growing at 8-10%. Although biologicals contribute about 15% (i.e. about Rs 200 crore) of the animal health-care market, it is growing at the rate of 25%. The estimated proportion of animal biologicals can be 63%, 24% and 13% for poultry vaccine, FMD vaccine, and vaccine for companion animals, respectively, contributing approximately Rs 200 crore (Rs 128 crore by poultry vaccine sector; Rs 47 crore by cattle vaccine sector; Rs 25 crore by pet animal vaccine sector). Besides the private sector, there are many organizations in cooperative or public sectors. These are running at no profit-no loss basis. However, as per the Chairman of CLFMA of India, the Indian animal biologicals market is about Rs 400-500 crore. The major contribution is from public and cooperative sectors. The public sector mainly consists of Government institutes as all the state governments have one or two veterinary institutes to manufacture the basic vaccines for animals like sheep, goat and cattle. These institutes supply animal biologicals at very nominal price or free to farmers. Hence, it is difficult to calculate exact size of animal biologicals market. Besides, there are companies in private sector too contributing (roughly about Rs 200 crore) to animal biologicals market.

The leading private players in large animal biologicals sector include Indian Immunologicals Limited, Intervet (India) Limited, and BAIF group. The leading companies in poultry sector include Venkateshwara Hatcheries group (Ventri Biologicals), Hester Pharmaceuticals, Indovax, while Intervet, Serum Institute of India, GlaxoSmithKline Beecham, and Zydus Sarabhai are the main players in companion (pet) animal sector. Most of the vaccines for pets are imported and supplied through distributors. The market is small compared to other two segments but is picking up and growing at 10-12%.

There is relatively higher growth of vaccines in animal health market in India due to new initiatives undertaken by the Government for control of animal diseases. The vaccines for poultry and FMD vaccine for cattle have been the fastest growing sector. Bulk proportion of poultry vaccines and FMD vaccine are produced by companies in private sector as well as public sector companies. The size of the vaccine market is over Rs 400 crore. Venkateshwara Group and Srimi Biologicals dominate poultry vaccine market. They have a captive market. Other important vaccine manufacturers are Indovax, located at Hisar, that has collaboration with Vineland, USA.

Hester Pharmaceuticals Ltd is mainly into poultry vaccines but is eager to enter animal biologicals space.

The Indian poultry vaccine market is about Rs 150 crore. The market share of poultry vaccine manufacturing companies is approximately 10% of Hester Pharmaceuticals, 50% of Venkateshwara Hatcheries (Group Company of Western Hatcheries) and 9-14% of Indovax, while the imported vaccines meet the rest. Intervet does imports from parent company, American Home Products and Zydus Sarabhai from ABIC, Israel. Except one or two types of poultry vaccines, all other poultry vaccines are manufactured in the country. The strong domestic industry with technology capabilities and sound cost structure has supported the growth of animal biologicals market; making us to witness more of exports (Rs 20 crore) with little of imports (Rs 10 crore).

PARADIGM (STRATEGIC) SHIFT

There are about 30 companies in animal biologicals both in public and private sectors but only a few companies are currently exporting vaccines. The country has to look at import of vaccines to meet indigenous demands. India imported 445 kg of antiserum in 2004-05 and 6,870,000 (vials/unit/doses) of vaccine while exported 71.9 kg of antiserum and 330,950 vials/unit/doses (vaccine export figures up to 31 October 2004) in 2004-05. The opportunity is opening up further, and Indian Government has been making all-out efforts to bridge gap between supply and demand.

Foot-and-Mouth Disease (FMD) has been widespread in India, creating massive economic losses. Existence of FMD in India is not only limiting beef export opportunities but also hitting farmers hard as milk production in FMD infected animals reduce drastically. The Government of India has earmarked FMD control as the top priority and has put in place livestock improvement programmes. FMD eradication programme has been in place in 54 specified districts of the country in the first phase with 100% central funding as cost of vaccine, maintenance of cold chain and other logistic supports to undertake vaccination. The state governments are providing other infrastructures and manpower. Five rounds of vaccinations are to be done during the tenth plan comprising mandatory vaccination of 40 million animals annually for a five years, and the allocation for this is around Rs 200 crore. About 270 lakh vaccinations were carried out under this programme during the first round in 2003-04 and about 550 lakh vaccinations are expected to be carried out in the second and third rounds. Once the vaccination drive is completed, the region will be declared "FMD-free zone". Eventually "disease free zones" will be extended to the entire country.

The FMD-CP has led to manifold increase in demand for vaccines. The production units under public sector cannot fulfill this growing demand for FMD vaccine. Further, Government agencies are supplying vaccines either free of cost or levying minor amount for each dose. As the current vaccine manufacturers are unable to meet this increasing demand, there is a

scope for 2-3 more companies in the market. The highly technical nature of FMD vaccine sector (in terms of people and regulatory compliance), high entry cost barriers and the edge of Government companies over private companies (in terms of reach as Government companies have a very good network to reach to the micro levels) deter small-time players to enter this segment. However, companies like Bharat Biotech (one of the leading names in human biologics), Brilliant Industries (mainly dealing pet vaccines) and Venkateshwara Hatcheries/Hester Pharmaceuticals (mainly dealing poultry vaccines) are entering into large animal vaccine market also.

INDIAN IMMUNOLOGICALS LIMITED (<http://www.indimmune.com/businessoverview.html>)

Indian Immunologicals Limited (IIL) is a wholly owned subsidiary of the National Dairy Development Board (NDDB), and was established in 1983. The facility was initially set-up to manufacture Foot-and-Mouth disease (FMD) vaccine with technical know-how obtained from The Wellcome Foundation, UK. Subsequently, IIL has developed and introduced several veterinary biologicals through its own R&D efforts. Today, IIL is a market leader in veterinary biologicals in India, and operates world's largest plant for veterinary vaccines. The IIL's manufacturing facilities for both animal and human vaccines are WHO-GMP and ISO-9002 certified. The IIL is also India's largest veterinary products exporter. Exports of animal health products contributed to 30% of its total turnover of Rs 55 crore in 2002-03.

Of late, the IIL has diversified and set-up Human Vaccines Plant and R&D Centre at a total cost of approx. Rs 50 crore in Hyderabad. The new state-of-the-art Human Vaccines plant has been designed to manufacture various human vaccines like recombinant hepatitis B, hepatitis A, measles, diphtheria, pertussis and tetanus. This plant also has plans to produce new combination vaccines in future. The plant has a capacity to produce 200 million doses per annum of each vaccine. With the new vaccine plant, IIL will contribute significantly towards making India self-sufficient in modern vaccines, and also help the country emerge as a leading vaccine manufacturer in the world. The IIL already markets a modern tissue-culture rabies vaccine, Abhayrab, for human-beings.

Along with the manufacturing unit, a modern R&D Centre with highly qualified staff consisting of post-graduates and doctorates in various fields has also been set-up. The main objective of this Centre is to develop various animal and human vaccines and biologicals. Attention would also be focussed on the development of glycoconjugate vaccines. It is expected that many new products will roll-out of this R&D Centre in the coming years and these products should be available to Indian farmers and the public at affordable prices; which is in line with the NDDB's mission "affordable immunity with technologically superior biologicals".

The market potential for human vaccines is immense; with over one-quarter of the world's children still outside the protection of common

vaccine preventable diseases. Nearly three million people, two million of them children, who die every year from killer diseases, could have been saved by vaccination. Currently, the size of the global human vaccines market is about US\$ 6 billion and is growing at about 9% annually. This is expected to reach to about US\$10 billion by 2010-11. With new therapeutic vaccines being developed for HIV, malaria etc, it may even go to US\$ 25 billion. Despite this large business potential, there is still acute shortage of some critical vaccines. The UNICEF, which meets around 40% of the global demand for children's vaccines, is seeking urgent global response in sourcing these vaccines to prevent what can become a crisis. The IIL hopes to emerge as the major supplier to UNICEF for their global immunization programme.

The global market for animal vaccines is about US\$ 2 million, growing at 4% p.a. The IIL hopes to be the major vaccine player in both animal and human vaccines, and plans to target about 1 % share of the global market for human vaccines by 2010.

Transformation through Public-Private Partnership—An Interface on the Dairy Sector

Animesh Banerjee

Dairying was among the first commercial endeavours in agriculture. Knowledge of the farming and subsequent domestication of the bovine, cattle, had led to the value-added products from its milk, and the initial foray into business from the sale of these products. The bovine animals, therefore, became the epicenter of agriculture, and civil societies harnessed them as the key input to agribusiness. Their multipurpose usages have been for milk, meat, tilling, drafting, skin, hide, etc.

With the passage of time, the industrial nations adopted practice of technology-driven agriculture including livestock to optimize their resource and manpower, whereas the rest of the world continued to depend on the home-grown labour-intensive system.

GLOBAL MARKET AND PRODUCTION TRENDS

The global milk output rose by approximately 1.6% in 2004-05, driven mainly by increased production in Asia, US and Eastern and Central Europe (Fig. 1). The overall trend of higher production in developing countries is expected to continue. It is therefore not unacceptable to assume that if the current trend in the international milk product markets is to continue, the developing nations would increasingly be responsible for a larger chunk of the market in future. This is becoming more prudent in the post-liberalized environment when distortion-free global trade is truly emerging!

INDIAN DAIRY SCENARIO

Production

Dairying is an integral part of Indian agribusiness. The livestock sector, in particular, dairying is one of the fastest growing sectors in India, with a total size of about Rs 1,160 billion (Rs 116,000 crore) or US\$ 26.5 billion. In 2003-04, contribution of the livestock sector to Indian GDP was at 6.56%, while the dairy sector contributed at 4.39%.

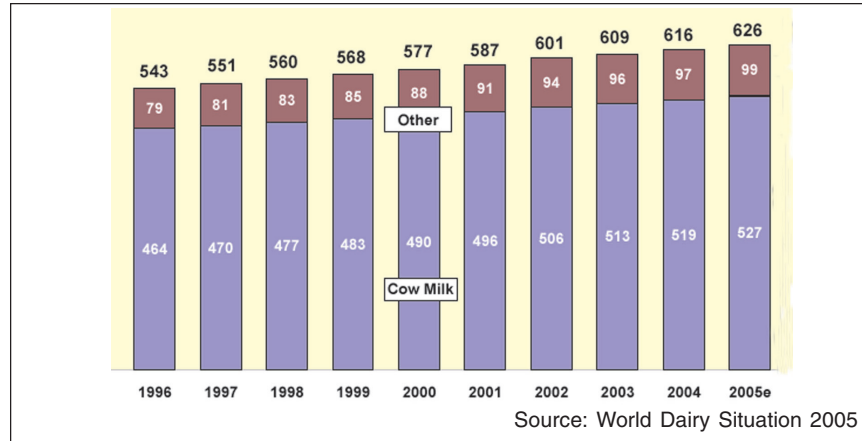


Fig. 1. Global milk production trend (in million tonnes)

Milk production in India is still dominated by small and marginal land-holding farmers and landless labourers. Annual production, which had in fact stagnated between 17.5 and 22 million tonnes during 1960s, steadily increased at 7.8% in 90s, and has subsequently been maintained around 5% per annum. India is the largest milk producer in the world, which at present is estimated to be 93.6 million tonnes, growing at an average rate of 4-4.5% per annum. And the milk availability is at present 232 g per person per day.

About 11 million workers are employed in principal status and 8 million in the subsidiary status in livestock sector, women constitute 71% of the labour force in livestock farming. In dairying, 75 million women are engaged as against 15 million men, while in case of small ruminants, the sharing of work with men is almost equal.

Supply Chain

In traditional and unorganized dairy system in India, milk producers directly supply milk to consumers or through a marketing channel, and through milk producers supplying milk to consumers through

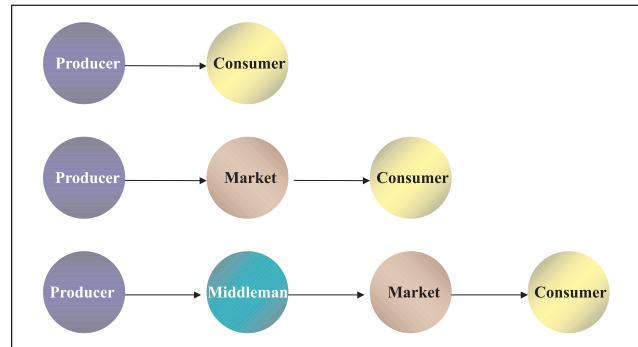


Fig. 2. Supply chain (Unorganized)

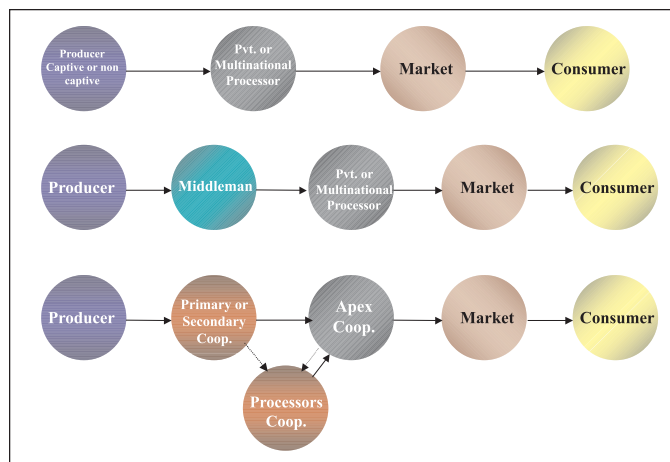


Fig. 3. Supply chain (Organized)

intermediaries like middlemen and/or milk contractors via marketing channels (Fig. 2).

In the organized sector, (i) Producers' milk reaches private processors either directly and/or through middlemen/milk contractors. After processing and/or value-addition, milk reaches consumers through marketing channel. (ii) Producers' milk reaches private processors directly and/or through producers' association. After processing and/or value-addition, it reaches consumers through the marketing channel. (iii) Milk producers supply their milk to primary co-operative society, which *inter alia* supplies to secondary co-operative (Fig. 3). The milk, after processing and/or value-addition in the secondary co-operative, reaches consumers via marketing channel, either directly or through apex co-operative. The apex co-operatives for bulk marketing sometimes operate through national federation of co-operatives.

Dairy and Food Market

The food market in India is growing at 15% per annum owing to faster growth of the urban population. According to the study jointly conducted by McKinsey and Confederation of Indian Industry, the food market was expected around US\$ 140 billion in 2005.

The demand for hygienically processed and packed Indian dairy products has been increasing in the urban demand centres (study by Rabobank International). This is because of the economic and demographic changes, including rising disposable income, growing proportion of working women as well as the greater awareness to global trends. The findings of Robobank International are briefly presented in Fig. 4, Table 1.

PUBLIC-PRIVATE PARTICIPATION

In developed dairying nations, the role of State or Parastatal organization is confined primarily to policy formulations and policy support. Therefore, the investments in the developed nations from the State

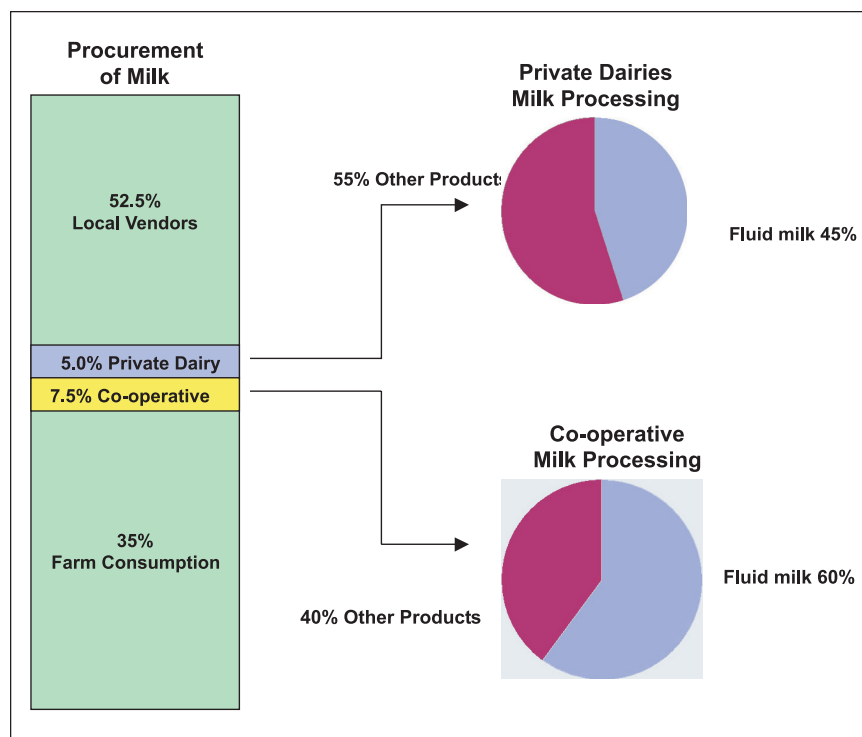


Fig. 4. Milk utilization

Table 1. Dairy products and expected market sizes

Product	Market Size 2005 Est. in INR bn (USD mn)	Expected CAGR
High Growth		
Liquid milk-packaged	98 (2040)	8%
Ethenic sweets	1.3 (27)	
Paneer (Cottage cheese)	1.0 (21)	
Curd (yoghurt)	0.8 (17)	40%
Shrikhand (Flavoured yoghurt)	1.0(21)	20%
Cheese	3.1(65)	15%
Infant milk foods	71 (1479)	30%
Flavoured milk	0.4 (8)	10%
Ice creams	10.5 (219)	15%
Mature Products		
Butter	8.2(171)	6%
Ghee (butter oil)	236 (4917)	3%
Milk powder	17 (354)	3%
Dairy whitener	8.1 (169)	3%
Condensed milk	1.2 (25)	3%

Indian Food and Dairy Product Market

- Indian food market is growing at 15% p.a.
- Indian food market's segmental growth
 - Subsistence level at 14% p.a.
 - Basic level at 100% p.a.
 - Premium level at 150% p.a.
- Organized Dairy Industry of India grew over 13% CAGR, from US\$ 3 billion in 2001 to US\$ 5 billion in 2005.
- The market size of traditional Indian milk products, which was US\$ 4.4 billion in 2001, was expected at US\$ 5.0 billion in 2005.
- The market size of other Indian dairy products, which was US\$ 1.3 billion in 2001, was expected at US\$ 2.5 billion in 2005.

or Parastatal institutions are minimal, other than providing production and/or export subsidies, besides tariff supports, as far as the production, processing and marketing of milk and milk products are concerned. The investments primarily come from producers for all grassroots activities including milk production. However, the investments for various components of the value-chains are generally by the milk producers' co-operative institutions. In some of the developed countries, particularly after globalization, investor-owned firms are making substantial private investments, especially in processing and value-addition.

In contrast to the above, the state plays a pre-dominant role in dairying in most of the developing countries, including India. With the success of the Anand model of co-operative dairy development and its replication through the Operation Flood programme, however, the milk co-operatives have commanded the organized dairying in India. Around 12-15% of milk produced in India is being handled by organized sector, and the balance remains with unorganized sector. In post-liberalized era, there has been a quantum jump in private investments from investor-owned organizations, especially in milk processing and value-addition (Tables 2,3).

Table 2. Processing capacities in different sectors in India

Sector	Registration Granted	Capacity LPD
Private	267	25,761,000 (9.402 MT/year)
Co-operative	194	24,357,000 (8.890 MT/year)
Government	61	7,160,000 (2.613 MT/year)
Total	522	57,278,000 (20.906 MT/year)

Source: IRMA

Table 3. Throughputs and value of the dairy industry over the decades in India

	1951	1970	1998	1999	2000
Milk processing throughout (million litres/day)	0.2	2.5	20	21	22
Value of Dairy Industries (Rs in billion)	10	50	1,050	1,102	1,158

Source: IRMA

Broad areas of PPP			
Animal Health-care and Disease Control System		Production System	
AREAS	INVESTMENTS	AREAS	INVESTMENTS
Control of Infectious Diseases	Public	Breeding AI/ET/ Biotechnology	Public/Private/Co-operatives/NGOs
Control of Systemic Diseases	Public	Fodder Seeds (grass/tree)	Public/Private/Co-operatives/NGOs
Pharmaceuticals	Private	Green Fodder/ Drying Briquetting	Private/Co-operatives/NGOs
Vaccine Production	Private/ Co-operatives	Straw Treatments and Supply of Minerals	Private/Co-operatives/NGOs
		Feed Manufacturing and Milling	Private/ Co-operatives
		Animal Housing for Individual Farmers	Private
		Large Milk Farming	Private
		Milking Machine and Parlours	Private/Co-operatives/NGOs
Collection System			
AREAS		INVESTMENTS	
Milk Cans/ Milk Tankers		Private	
Milk Cooling, Chilling, Pasteurization System		Private	
Milk Testing Equipments the Emphasis on Testing Bacterial and Other Contaminants in Milk		Private	
Processing and Marketing			
AREAS		INVESTMENTS	
Mechanized and Hygienic Production of Indian Milk Products		Private/ Co-operative	
Production of Various Value Added Milk Products including Cheese, Butter, Powder, Cultured Products, --Transfer of Desserts, Ice Cream Technology, Equipments for Such Products		Private/ Co-operative	
Ethnic/Traditional Value added Milk Products		Private/Co-operative	
Long Shelf-life Milk Products		Private/Co-operative	
The Milk and Milk Product Packaging		Private/Co-operative	
The Buy-back Arrangement/Consultancy		Private/Co-operative	
Manpower, Training and Research and Development			
AREAS		INVESTMENTS	
Education		Public/Private	
Training --Management and Manpower --Job Oriented		Public/Private/Co-operative Private/Co-operative	
Research --Fundamental --Applied		Public Private/Co-operative	

In the developed world, technology-driven dairy development with a hard-core commercial approach is being propagated whereas in developing countries, particularly in India, dairying still continues to remain as a socio-economic tool with severe constraints of low-yield, low-quality, inadequate infrastructures like cooling facilities, connectivity, etc. Besides, it is now being exposed to emerging challenges of highly subsidized milk products, subsequent to globalization.

In the present scenario, Indian dairy sector needs an overall restructuring, particularly in animal breeding and feeding, health-care, disease control, milk production and its value-addition. The farm-oriented technology-driven milk production is becoming very relevant to come up to international standards. But, with limitations like small holder-driven-cum-fragmented landholdings, it would not be possible to completely resurrect existing system. Nevertheless, with growth of niche market and demand of high-quality milk, the production system can be segmented commensurating with different market segments. All these new situations call for a massive investment at every tier of the value-chain of the Indian Dairy Sector. It is obvious that to sustain it, public/private investments, organizing through different institutional mechanisms, including joint ventures, would be desirable. The education, management and manpower training, research and development in the dairy sector continue to remain a domain of the State or Parastatal institutions. It is no doubt that the fundamental research should continue to be supported by the state either directly or through institutional arrangements. But, applied research, which has to be need-based, should gradually be reinstated as a commercial tool for dairy development. This can be organized in the form of projectizing as well as developing incentive schemes either through equitable partnerships or joint ventures so that all stakeholders including state can play a proactive role in optimizing resources.

The broad areas, wherein scope of public and private investments have been identified and accordingly focussed are presented in a box on p. 97.

The Indian Dairy Sector despite having several competitive advantages is yet to become a leading global player. The comparative advantages are getting nullified, as stated earlier, due to lower density of production vis-à-vis high haulage cost, lack of infrastructure, quality, etc. The multi-faceted and multi-disciplinary sector like dairying, which has high job-generating potential, particularly at the grassroots, needs strong policy support as well as proactive and participatory roles from all stakeholders, whether they are in public or private sector or in co-operatives.

Public-Private Partnership in Fisheries and Aquaculture

S. Ayyappan

India is a major maritime state and an important aquaculture country in the world. Our country stands fourth in the world with regards to total fish production, with an annual production of about 6.4 million tonnes; with the marine and the inland sectors contributing 3.0 and 3.4 million tonnes. Aquaculture is increasingly becoming important, with an annual growth rate of over 6%. The country is the second largest producer of fish through aquaculture in the world, next to China. The annual per caput fish availability in the country is 9 kg, sustaining domestic market price of fish over years. The annual export earnings from fish and shellfish is more than Rs 6,700 crore, accounting for nearly 20% of the agricultural exports and 3% of the total exports. Producing about 4.7% of world's fish, India trades to the extent of 2.5% in the global fish market.

India is the home for more than 10% of global fish biodiversity, with 2,200 species of fish and shellfish, 1,440 of marine, 143 of brackishwater, 544 of freshwater and 73 of coldwater. The potential fish production from marine and inland is estimated at 3.9 and 4.5 million tonnes, totalling to 8.4 million tonnes. Over 7 million people are directly engaged in different fisheries and aquaculture activities in the country. The contribution of the fisheries sector is estimated at around Rs 31,534 crore annually, amounting to 1.4% to the GDP and 6.2% to the agricultural GDP. The annual growth rate of marine fisheries during the IX Plan period was 2.1%, and that of inland fisheries was 6.6%, with an average of 4.4%. The corresponding projected rates during the X Plan are 2.5%, 8.0% and 5.4%.

With varied agro-ecological zones, the country possesses immense potential ranging from marine fisheries to coldwater fisheries in mountains including coastal aquaculture, riverine fisheries and pond aquaculture. The aquaculture practices of integrated fish farming, inland saline aquaculture, ornamental fish culture and prawn farming are highly compatible with other farming systems and flexible with regard to scale of operations, both in size and investments. Globally, aquaculture is recognized as an important tool

for ensuring domestic nutritional security and rural development. A virtual blue revolution is happening in the country; with states like Andhra Pradesh, Punjab, Haryana taking to aquaculture in a big way, along with West Bengal, Orissa and Assam. Thus fisheries and aquaculture have become important enterprises across the country, in both the coastal and inland states, for adding to food basket, to employment generation as well as economy of different regions.

MARINE FISHERIES

The marine fisheries resources of the country are in terms of 8,129 km long coast line, 0.5 million sq. km of continental shelf and 2.02 million sq. km of exclusive economic zone. Contributed by major fish species like oil sardine, mackerel, bombay duck, pomfrets, shrimp, the catches have gone up from 0.53 million tonnes in 1951 to 2.99 million tonnes in 2004.

The fish production from the open-seas has stagnated since the last decade, and marine fisheries is still restricted to nearshore areas. Against estimated potential of 3.9 million tonnes, the sector has already reached 2.99 million tonnes mark, thus leaving a balance resource of around one million tonnes for deeper waters and oceanic zone. To fish those resources for increasing fish production from marine sector, the industry needs ocean-going vessels and highly sophisticated on-board facilities which are capital-intensive. The strategies proposed for marine fisheries management are regulated and diversified fishing, targeting under-exploited and non-conventional resources of the exclusive economic zone, identification of potential fishing zones, stock enhancement through sea ranching, installation of fish aggregating devices and artificial reefs, community-based resource management, responsible fishing including closed seasons and mesh regulations, assessment and exploitation of resources available around Islands and infrastructural support in terms of deep-sea vessels, on-board and on-shore facilities.

Open-sea farming or mariculture is an alternative, being proposed to stagnating marine fish production, by utilizing vast areas of lagoons and bays available along the Indian coast, that have a good potential of finfish and shellfish species, seaweeds, sea cucumber, etc., for which eco-friendly hatchery and grow-out systems are being developed. Seed production and culture of shrimps, *Penaeus monodon*, *Penaeus indicus* and *Penaeus semisulcatus*; soft-shelled crab, *Scylla serrata* and sea crab, *Portunus pelagicus* have become economic enterprises. Lobsters and sea cucumbers with export market are the prime species for sea ranching and farming in coming years. Sea bass and groupers have been identified as important candidates for finfish culture, with excellent possibilities of cage culture. The estimated production potential from mariculture is about one million tonne with high value species.

Marine ornamental fishes are a valued resource of the country's marine biodiversity. Nearly 200 species of ornamental fishes such as sturgeon fish, trigger fish, butterfly fish, wrasses, squirrel fish, goat fish, damsel fish,

parrot fish, rock cod, lizard fish, cardinal fish, file fish, angels, rabbit fish, puffer fish, along with corals and echinoderms have been recorded around Lakshadweep islands. Damsel fish, clown fish and sea horse have been bred indoors with commercial propositions.

Molluscan culture is a major diversification, happening in the sector. Edible oyster farming is spreading fast with women self-help groups involved in this small-scale aquaculture enterprise. Mussel farming provides for food and employment to a large number of people living along the coasts. Marine pearl culture using *Pinctada fucata* has become an industry in the country with round pearls and also the images being produced. Cultivation of agar-yielding seaweeds is another economic enterprise.

The marine environment provides immense biodiversity that is being catalogued for commercial use. This includes several microorganisms, algal forms, invertebrates, that can serve as the potential sources of bioactive substances including antimicrobials, anaesthetics, anticarcinogens, etc. as well a wealth of valuable genetic materials for transgenics, and thus present a huge opportunity for both Foods and Drugs from the sea. Identification of suitable sites along the Indian coast line of over 8,000 km, hatcheries and grow-out systems for finfish, shellfish and other organisms, possibilities of cage culture in island ecosystems are the strategies for realizing these potentials.

Research thrusts in the next five years pertain to studies in shelf, slope and oceanic realms of the EEZ to assess and map resource potentials, upgradation of mariculture technologies, socio-techno-economic aspects of marine fisheries and brackishwater aquaculture, design and fabrication of modern fuel-efficient fishing vessels, development of cost-effective and responsible fish-harvesting systems, diversification and value-addition for utilization of low-value fishes and quality assurance and management systems.

INLAND FISHERIES

India is blessed with huge inland water resources in terms of 29,000 km of rivers, 0.3 million hectares of estuaries, 0.19 million hectares of backwaters and lagoons, 3.15 million hectares of reservoirs, 0.2 million hectares of floodplain wetlands and 0.72 million hectares of upland lakes. The annual fish production from these waters is about 0.8 million tonnes, mainly comprising carps and catfishes. The rivers provide one of the richest fish faunal resources of the world.

The reservoirs form the largest inland fisheries resources in terms of resource size; with 56 large reservoirs (>5,000 ha), 180 medium reservoirs (1,000-5,000 ha) and 19,134 small reservoirs covering water area of 1.14 million hectares, 0.527 million hectares and 1.485 million hectares. The average national production level obtained from small reservoirs of the country is about 50 kg/ha/year, and the technologies of stocking reservoirs with fish fingerlings for achieving higher production levels are available. Floodplain wetlands or beels are other potential fisheries resources in

Assam, West Bengal and Bihar, which offer tremendous scope for culture and capture fisheries, with production levels of 100-150 kg/ha/year.

FRESHWATER AQUACULTURE

Carp form the mainstay of culture practice in the country, which is supported by the strong traditional knowledge base and scientific inputs in various aspects of management, and contribute as much as 87% of the total aquaculture production. The three Indian major carps catla (*Catla catla*), rohu (*Labeo rohita*) and mrigal (*Cirrhinus mrigala*) contribute as much as 2.4 million tonnes. Two technologies of 'Induced fish breeding' and 'Composite carp culture' have brought about 'blue revolution' or 'aquaplosion' in the country in the last two decades.

The private enterprise in over 700 hatcheries is of a high order in the country, producing over 19 billion carp fry, and West Bengal and Assam produce more than their requirement. With the adoption of technology of carp polyculture or composite carp culture, the mean production levels from the still-water ponds of the country have gone up to over 2.2 tonnes/ha/year, and several farmers are even demonstrating higher production levels of 8-12 tonnes/ha/year.

The different culture systems that have been standardized with optimum achievable production rates are composite carp culture (4-6 tonnes/ha/year), sewage-fed fish culture (3-5 tonnes/ha/year), weed-based carp polyculture (3-4 tonnes/ha/year), biogas slurry-fed fish culture (3-5 tonnes/ha/year), integrated fish farming with poultry, pigs, ducks, horticulture, etc. (3-5 tonnes/ha/year), intensive pond culture with supplementary feeding and aeration (10-15 tonnes/ha/year), pen culture (3-5 tonnes/ha/year), cage culture (10-15 kg/m²/year) and running-water fish culture (20-50 kg/m²/year). Catfish, freshwater prawn and ornamental fish species have provided for the diversification of practices in freshwater aquaculture.

Clarias batrachus (magur) and *Heteropneustes fossilis* (singhi) are two air-breathing catfishes that have received attention over the years, though commercial culture of these species is yet to start. Researches with regard to development of grow-out technologies of several other non-air breathing catfishes *Mystus seenghala*, *M. aor*, *Pungasius pungasius*, *Wallago attu*, *Ompak pabda* are given greater importance in recent years due to their high consumer reference in different parts of the country.

The success in breeding and larval rearing of giant freshwater prawn *Macrobrachium rosenbergii* and Indian river prawn *M. malcolmsonii* and assured supply of seeds of these species have provided scope for farmers to diversify cultural practices into more rewarding farming systems. Monoculture of *M. rosenbergii* has shown production levels of 1.0-1.5 tonnes/ha in a culture period of 7-8 months. During the last three to four years, the freshwater prawn farming sector has witnessed quite impressive growth; recorded a production of over 30,000 tonnes in 2002-03 from about 35,000 ha water area, mostly by this species. As in case of carps,

Andhra Pradesh dominates the sector with over 85% of total production of the country from about 60% of water area under prawn farming. At present, there are 35 freshwater prawn hatcheries established mainly in the Andhra Pradesh, Tamil Nadu and Kerala, producing about 200 million seeds per annum.

BRACKISHWATER AQUACULTURE

Brackishwater aquaculture in India though is an age-old practice in *bheries* of West Bengal and *pokkali* fields of Kerala, but the modern and scientific brackishwater farming in the country is only a decade old. The country possesses huge brackishwater resources of over 1.2 million hectares suitable for farming. However, the total area under cultivation is just over 13% of the potential water area available, i.e. 157,400 ha (2001-2002). Shrimp is the single commodity that contributes almost the total production of the sector. The production levels of shrimp recorded marked increase from 28,000 tonnes in 1988-89 to 115,000 tonnes in 2002-2003. The black tiger prawn *Penaeus monodon* contributes lion's share. The other shrimp species being cultivated are *P. indicus*, *P. penicillatus*, *P. merguensis*, *P. semisulcatus* and *Metapenaeus* sp. Culture of crab species like *Scylla serrata* and *S. tranquebarica* has also been taken up by a few entrepreneurs. Besides, there are several other finfish species viz., *Mugil cephalus*, *Liza parsia*, *L. macrolepis*, *L. tade*, *Chanos chanos*, *Lates calcarifer*, *Eetroplus suratensis* and *Epinephelus tauvina*, which possess great potential for farming, though commercial production of these species is yet to be taken up in the country.

The studies on maturation and breeding of shrimps were initiated by the Central Marine Fisheries Research Institute in the early 70s, and later by the Central Institute of Brackishwater Aquaculture. At present about 226 shrimp hatcheries (about 90% in private sector) are operational with a total production capacity of 12 billion post larvae-20/year. Though the brackishwater farming in India is an old practice, the scientific and commercial aquaculture is mainly of shrimps; owing to high export potential of shrimps. Demonstration of semi-intensive farming technology at Nellore, Andhra Pradesh, showing high returns, coupled with credit facilities from commercial banks and subsidies from MPEDA, helped development of shrimp farming. The semi-intensive culture practices with black tiger prawn demonstrated production levels of 3-4 tonnes/ha in a crop of 4-5 months.

Production of shrimps is mainly contributed by small farms. It has been estimated that about 91% of the shrimp farmers in the country have a holding of less than 2 ha, and 6% between 2 to 5 ha

FISHERIES EXPORTS

Indian exports are nearly five lakh tonnes every year, valued at over Rs 7,000 crore. More than 12% of fish landings are exported, comprising 32% shrimp, 68% lobster, 13% crabs and 75% molluscans like mussels and

oysters. The exports are largely of shrimp, the break-up in terms of value being 64% of frozen shrimp, 11% of frozen fish, 7% of cuttle fish and 7% of squids. The export destinations are Japan to tune of 18% of the total exports, 23% to the USA, 28% to the European Union and 10% to China. India has global competitiveness in shrimp and carps, with potentials in trout, catfish, oysters, mussels, cephalopods and ornamental fishes. Technological developments in fish processing have led to the production of a large number of value-added products, apart from the traditional methods of drying and freezing, such as individual quick frozen foods, accelerated freeze-dried products, heat processed products, extruded products, battered and breaded products, fish mince and mince and mince-based products, surimi and surimi-based products. A large number of byproducts like isinglass, shark fin ray, squaline, chitosan, glucosamine hydrochloride, gelatin and collagen are high-value products from wastes in fisheries. The products are being diversified in terms of surimi and ready-to-eat products, and markets are also being enlarged in the recent years. The industry is also well equipped to address emerging issues of the residues in the processed products, SPS measures and other standards being applied from the importing countries.

CONTRIBUTIONS FROM PARTNERS

The public sector has been contributing to the growth in fisheries, in research, education, extension, as also in development through Fish Farmers' Development Agencies (FFDAs) and Brackishwater Development Agencies (BFDAs), fishing harbours and jettys. The private sector is involved in a big way in boat building, fish-net making, fishing and fish processing, with over 1,800 boat building yards, 400 fish-net making plants, 297,000 fishing boats operating on the Indian coasts, 1,500 registered exporters, 362 freezing plants, five canning and 12 fish-meal plants. Most of the fish-seed production, whether of carps or shrimp, is with the private sector and in the recent past, it has taken to fish-feed manufacture and disease diagnostics.

Disaster management and rehabilitation in fisheries and aquaculture, whether in cyclones, floods or tsunami, was organized by the NGOs in a big way in the recent years.

In the context of high growth rates in the sector, issues that have emerged pertain to unregulated fisheries in open-waters like seas and rivers, seed quality and required quantities in different regions, dependence on a few species and need for diversification, uncontrolled introduction of exotic species and absence of an effective quarantine mechanism, low feed utilization, lack of proper cold chains and unhygienic markets. Lack of captive breeding technique in shrimp has been a major problem in brackishwater aquaculture, which is operating on almost a single species of shrimp. Quality assurance in fishery products is an R&D issue to be addressed. There exists a great scope for integrating aquaculture with tourism.

POTENTIAL PARTNERSHIPS

Potential partnerships in fisheries and aquaculture could be categorized into Public-Public, Public-Private and Private-Private. Aspects of fisheries management in open-waters (seas and the rivers), quality assurance in fish landing centres of harbours and jettys, seed certification and greater applications of biotechnology in aquaculture call for greater Public-Public partnerships; among different institutions in the ICAR, Universities and Development Departments.

Public-Private partnerships can address areas of deep-sea fishing, open-sea cage farming, seed certification, feeds, diagnostics and facilitation of processes of technology incubation and access to facilities by the students in the above areas. Issues of evaluation and introduction of exotic fish and shellfish species, particularly the ornamental fishes, reservoir fisheries management, markets and cold chains and market intelligence can also be effectively addressed in this mode. Manufacture of fishing boats and nets, aquaculture implements and establishment of aqua-shops, as a single window facility for aquaculture inputs, as also aqua-tourism stand for profitable Private-Private partnerships.

The fisheries and aquaculture sector in the country is poised to play a major role in the lives of the people in the coming decades with increasing population pressure on the land and alternative food production systems being increasingly projected from the aquatic resources. The challenges can be faced better with partnerships at different levels to make the blue revolution a reality.

Small Bugs, Big Business

Ratul Saikia¹ and Dilip K. Arora²

Today we face many critical issues in agriculture: (i) An exponentially growing human population; (ii) Recurrent famine in many developing/underdeveloped countries; (iii) Destruction of natural landscapes such as tropical rain forests to extend agriculture to previously unused lands; (iv) The exodus of human civilization from rural communities to cities; (v) The destruction of environmental quality resulting from exposure to agrochemicals, erosion of soils and salinization of soils as well as exhaustion and contamination of freshwater resources; (vi) Loss of biodiversity through monocropping and destruction of natural habitats; (vii) Reliance of agricultural production, transport and storage systems on fossil fuel; (viii) Acquisition and concentration of agricultural wealth by multinational corporations; and (ix) An issuant lack of knowledge by a growing proportion of human civilization on how to cultivate, prepare and preserve food. The United Nations Food and Agriculture Organization has predicted that agricultural productivity in the world will be able to sustain growing human population by 2030 but hundreds of millions of people in the developing countries will remain hungry and environmental problems caused by agriculture will remain serious. By 2025, 83% of the expected global population of 8.5 billion will be in the developing world. The social consequences are obvious. Food is the basic human need and right. How can we sustain the food needs of the earth's biotic community in the 21st century and beyond while preserving environmental quality and diversity and quality of the life on the earth? What solutions can microbial agricultural biotechnology provide to address these problems?

Disciplinary crossovers of biochemistry, genetics, microbiology, nutritional sciences, engineering and emergence of microbial agricultural biotechnology have set the stage for reconsidering the paradigm of agriculture from traditional breeding of food plants. The strongest impact on agriculture in this area has occurred after the discovery of *in-vitro* genetic engineering and use of transgenic plants. Microbial agricultural

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biotechnology as a new era, 20 years into its development, is also showing its positive impacts in agricultural production and new food crops.

Thus we can expect many new developments with regard to this field in the next decade. Furthermore, despite public concern about transgenic crops, the global adoption of transgenic crops continues to increase, particularly in the United States, where 74.8 million acres were planted with transgenic crops including corn, soybean, cotton and canola in 2002. This represented about 50% of the total soybean and cotton acreage planted in that year. The International Service for the Acquisition of Agri-Biotech Applications predicts that world market for genetically engineered plants will be US\$8 billion in 2005 and US\$25 billion by 2010 (<http://nature.biotech.com>). Plant pathogens cause US\$30-50 billion of loss annually in crop productivity, thus justifying this investment in biotechnological approaches to crop protection. The reduction in use of the agrochemicals for disease control is another important incentive for this technology. Japanese growers spend more than US\$600 million a year to control diseases on rice. Already, the reduction in insecticides use in China through use of Bt transgenic crops has impacted farmer income and health.

Because microorganisms are small, they are least known, and this gap in knowledge is particularly apparent for bacteria and other small organisms. Current evidences suggest that perhaps 1.5 million species of fungi exist, yet only 5% are described. For bacteria there may be 300,000 to 1 million species on earth yet, only 3,100 bacteria are described in Bergey's Manual, the treatise of described bacteria. A gram of typical soil contains about 1 billion bacteria, but only 1% of those could be cultured. Similarly low fractions of microorganisms have been cultured from freshwater and ocean environments. Hence, most microbes yet remain to be discovered. Microorganisms colonized earth a long time before humans did. They have been evolving for nearly 4 billion years and are capable of exploiting a vast range of energy sources and are thriving in almost every habitat. For 2 billion years, microbes were the only form of life on earth. During this long history, all of the basic biochemistries of life evolved, and all life-forms have developed from these microbial ancestors. It is estimated that 50% of the living protoplasm on this planet is microbial.

Microorganisms represent by far the richest repertoire of molecular and chemical diversities in nature. They underlie the basic ecosystem processes such as biogeochemical cycles and food-chains as well as maintain vital and often elegant relationships between themselves and higher organisms. Microbes provide fundamental underpinning of all ecosystems. Without microorganisms, all life on earth would cease. Exposure to bacteria, parasites, microbes and viruses has played an important role in human evolution. The research of microorganism has, therefore, always been an important branch of microbiology. The main focus lies on those microorganisms, which play a role within soils and marine ecosystems. Almost all material cycles on the earth are influenced by microbial processes that occur within soils and marine environment. The climate of our planet and its atmosphere is also largely dependent on these processes.

KNOWLEDGE IN MICROBIOLOGY AND ITS APPLICATIONS

Modern Agricultural Biotechnology

Microbes dominate our world as plant and animal pathogens, as sources of food and other useful products, and as critical components of natural and agricultural ecosystems. Presently, they have contributed much to the development of various industrial materials and processes, agri-food commodities and human-health products. Thus, knowledge in microbiology and its pursuit through modern agricultural biotechnology have led to practical applications in broad sense to many spheres of human enterprise. Microorganisms are primary degraders of organic materials, but can also be pathogens and parasites of other microorganisms, invertebrates, plants and animals. In food and drink arena microorganisms are historically important as mushrooms, in fermented foods, and as yeasts for baking and brewing. These roles are supplemented by the use of microorganisms to provide food processing enzymes and additives, and more recently the development of protein-based foodstuffs from filamentous microorganisms. In agriculture and horticulture, certain mycorrhizal microorganisms may be necessary for seed germination and plant health, or may be used as biocontrol agents against weeds and invertebrates. Outside of the broader food and agriculture areas, microorganisms have proved particularly significant in pharmaceutical industry, where, since the discovery of penicillin, many microbial metabolites have showed potentially exploitable levels of biological activity. The degradative activities of microorganisms have also been harnessed in programmes for bioremediation of contaminated land, for treatment of industrial wastes, and for biotransformation of specific compounds.

Microorganisms that serve tropical or temperate forests and serve as mycorrhiza, endophytes, phytopathogens, entomopathogens, or simple saprophytes to turn over biological matter are a significant and unknown resource. This could be the source for many bioproducts including secondary metabolites, antibiotics and catabolic enzymes of enormous impact. Compared to terrestrial microorganisms, those in aquatic habitats are some of the most neglected yet important in applied mycological and biotechnological researches. Knowledge of microbial genomics is the area for new pioneers of mycology, microbiology and allied sciences that are worth exploration and mining.

An obvious group of foods in this cross-cut is the large-scale production of fermented foods, edible mushrooms, so called single cell proteins (SCP) and fermented beverages. Microbial agricultural biotechnology in future will enjoy being the primary driver of world food production technologies.

Microbes in Agriculture and Food Production

Microbes, which make-up most of the earth's biomass, have evolved for some 3.8 billion years. For thousands of years, microorganisms have been

used to supply us with products such as bread, beer, wine, distilled spirits, vinegar, cheese, pickles and other fermented materials. The processes were originally developed for preservation of fruits, vegetables and milk, but developed into producing sophisticated products. A second phase of biotechnology began during World War I which resulted in a quantum jump in economic importance of microbes. In England, Chaim Weizmann developed acetone-butanol fermentation and in Germany, the glycerol fermentation was formulated by Neuberg. Both acetone and glycerol were needed for manufacture of armaments to support war efforts of the respective opposing nations. These events were followed after the war by the development of fermentation, bioconversion and enzymatic processes yielding many useful products with large annual markets. These included amino acids, nucleotides, vitamins, organic acids, solvents, vaccines and polysaccharides. Ever since the discovery of penicillin in 1929 and its commercial development starting at the beginning of the World War II, antibiotic molecules have had major beneficial effects on human and animal health. In early 1970s, a phenomenal third phase began with the birth of recombinant DNA technology. In the recent year, recombinant DNA technology has impacted production of primary and secondary metabolites; bioconversions playing a significant development, especially in the enzyme industry.

Changes in functional features of the starting materials leading to food products and processes are the other side to the microbial agricultural biotechnology. It is expected that efforts in the public and private sectors research establishments should provide new inputs for food production. From various estimates, the values of sales of mycology-based products can run into tens of billion of dollars, projected by this decade; certainly not an insignificant figure.

In recent years much is emerging in developed countries of the world that will serve as new learning opportunities in application of microbial agricultural biotechnology for food and environment.

ORGANIC INGREDIENTS PRODUCTION

Fermented Foods and Beverage

Industrial yeasts are involved in production of many foods and drinks. The edible products, cheese and bread and potable alcohol products, beer, wine and spirits depend on yeast-based fermentations. The potential use of various agri-food enzymes in processing raw materials for production of novel foods and drinks represents an untapped resource for microbial agricultural biotechnology.

Fermentation Technology

Yeasts (mainly *Saccharomyces*) have been used worldwide for brewing and baking for thousands of years. Likewise, filamentous microorganisms have been traditionally used for preparing mould-ripened cheeses (mainly

Penicillium spp.) in Europe and soybean-based fermented foods (mainly *Aspergillus* spp.) in the Orient. On the other hand, edible mushrooms (such as *Agaricus*) have been used worldwide for direct consumption since time immemorial.

Microbial Pathogens and Mycotoxins

Thousands of microorganisms reduce or threaten availability and safety of foods and agricultural products. Huge challenges are posed by mycotoxins (aflatoxins), trichothecenes and fumonisins — that can be addressed by microbial agricultural biotechnology. Identification of mycotoxins biosynthesis and their genes, mycotoxin catabolism and biotransformation and their genes could have tremendous value.

Saprophytic and pathogenic microorganisms are a major detriment to freshness of fruits and vegetables and safety. Application of antimicrobial peptides could significantly change our options in management of spoilage microorganisms. A new avenue for applied research is the application of genomics, proteomics and bioinformatics towards intervention with microbial developmental genes for enhanced functionality, for controlled ingredient delivery or for spoilage of foods. As the knowledge of the regulation of the microbial gene expression advances, it is expected that strains will be designed for expression of commodities of high impact in the world trade.

Recent advances in diagnostic agricultural biotechnology have revolutionized procedures used in identification of food microorganisms. Biochemical identification assays have been miniaturized, and thorough automation and uses of robotics have become faster, reliable and cost affordable. Rapid identification of microorganisms and yeasts from foods has become less cumbersome because of the ease in sequestering of target microorganisms from food ingredients and interfering compounds. In addition, biochemical tests which traditionally have been used in the identification of yeasts and filamentous microorganisms have been greatly aided by the introduction of the PCR technology.

AGRICULTURALLY IMPORTANT MICROORGANISMS

Besides above, the Agriculturally Important Microorganisms (AIMs) play an important role in various applications.

- Microbial biotechnological applications in plant protection
 - Marker-assisted breeding and map-based cloning of genes
 - Role of microbes for development of transgenic plants for better disease resistance and defense response
- Role of entomopathogenic microbes for development of biopesticides
- Biotechnological potential of microbial alkaloids, enzymes, toxins and antibiotics and biomicrobicides

- Use of microbes as plant-growth promoters and disease suppressor
- Development of microherbicides for management of weeds
- Discovery and use of potential biocontrol agents against diseases of economically important crop plants, vegetables and post-harvest diseases
- Development of AM-based or other microbial based biofertilizers
- Use of microbes in agri-food industry e.g. anti-microbial food additives, amino acids beverages, dairy products, digestive aids, other ethnic foods and fermented food
- Commercial production of edible mushrooms
- Study of spoilage microorganisms in seed deterioration
- Discovery and use of microbes in degradation of cellulose, lignin and other waste materials and bioconversion of distillery wastes and dyes
- Biomineralization of heavy metals, bioremediation of degraded soils
- Commercial application of microbes in agriculture
- Microbes in brewing, bioactive metabolic carotenoid production

Useful Microbes and Agri-based Fermented Food

Acid fermented foods, Bread and pancakes, Fermented milk products, Alcoholic food and beverages, Fruit-based beverages, Cereal-based fermented foods, Legume-based fermented foods, Tuber crop-based fermented foods, Fermented fish products\fermented meat products.

Food Production through Microbial/Biotechnological Applications

Amino acids, Beverages, Dairy products, Digestive aids, Dough, Ethnic foods (*kefir*, *koji*, *miso*, *tempeh*, etc.), Food pigments, Food enzymes, Mushrooms, Organic acids, Single-cell protein, Vitamins

Functions of Beneficial Microorganisms

Following are the beneficial functions of microorganisms. Fixation of atmospheric nitrogen, Decomposition of organic wastes and residues, Suppression of soil-borne pathogens, Recycling and increased availability of plant nutrients, Degradation of toxicants including pesticides, Production of antibiotics and other bioactive compounds, Production of simple organic molecules for plant uptake, Complexation of heavy metals to limit plant uptake, Solubilization of insoluble nutrient sources, Production of polysaccharides to improve soil aggregation

Functions of Harmful Microorganisms

They are as follows. Induction of plant diseases, Stimulation of soil-borne pathogens, Immobilization of plant nutrients, Inhibition of seed germination, Inhibition of plant growth and development, Production of phytotoxic substances

Cleaning-up Environmental Pollution

Pesticides or fertilizers, Toxic by-products of industrial processes that yield a factory discharge or accidental industrial spillage, while others (e.g. dioxin) are dangerous even at very low concentration in the environment, Waste disposal or bioremediation, microorganisms that are known to be able to degrade the pollutant, can be added to the contaminated soil or water, or the contaminant can be flushed out of the soil into large tanks, Phytoremediation and the rhizosphere microorganisms and Designer microorganisms.

Microorganisms Producing Active Useful Biomolecules

These may be used for biotechnology or agriculture and food-based industry such as follows.

Microbes used for baking and brewing, Ethanol/hydrocarbon production, Hydrogen producing microbes, Drug production, Enzymes, Bioactive polysaccharides and polysaccharopeptides, Lipids, Acids, Carotenoids, Antibiotics, Fermented foods and feeds, Edible fungi, Flavours and aroma, Food additives, Antitumor and antimodulatory compounds, Microbes useful for developing vaccines against chronic diseases

Novel Microbes

- Other organisms that could be of great genetic and biochemical interest are present in extreme surface environments but are almost impossible to grow in the laboratory.
- To identify and determine the abundance and activity of novel hard-to-cultivate organisms in two extreme surface environments.
- These collections offer a rich resource for identifying and isolating novel species with potentially unique sets of genes as well as proteins with environmental, energy, biotechnological and other applications.

MICROBIAL BIOTECHNOLOGY AND FOOD PROCESSES

In food production, enzymes have many advantages and they are welcomed as alternatives to traditional chemical-based technology, and can replace synthetic chemicals in many processes. This can allow real advances in environmental performance of production processes, through lower energy consumption and biodegradability; they are also more specific in their action than synthetic chemicals. Processes which use enzymes, therefore, have a fewer side reactions and waste by-products, giving higher quality products and reducing likelihood of pollution; they allow some processes to be carried out which would otherwise be impossible. An example is the production of clear apple juice concentrate, which relies on use of pectinase (Table 1).

During fermentation processes, microbial growth and metabolism (the biochemical processes whereby complex substances and food are broken down into simple substances) result in the production of a diversity of

Table 1. Some uses of enzymes in food production

Market	Enzyme	Purpose / function
Dairy	Rennet (protease)	Coagulant in cheese production
	Lactase	Hydrolysis of lactose to give lactose-free milk products
Brewing	Protease	Hydrolysis of whey proteins
	Catalases	Removal of hydrogen peroxide
	Cellulases, beta-glucanases, alpha-amylases, proteases, maltogenic amylases	For liquefaction, clarification and to supplement malt enzymes
Alcohol production	Amyloglucosidase	Conversion of starch to sugar
Baking	Alpha-amylases	Breakdown of starch, maltose production
	Amyloglycosidases	Saccharification
	Maltogen amylase (Novamyl)	Delays process by which bread becomes stale
	Protease	Breakdown of proteins
Wine and fruit juice	Pentosanase	Breakdown of pentosans, leading to reduced gluten production
	Glucose oxidase	Stability of dough
	Pectinase	Increase of yield and juice clarification
	Glucose oxidase	Oxygen removal
Meat	Beta-glucanases	
	Protease	Meat tenderizing
Protein	Papain	
	Proteases, trypsin, aminopeptidases	Breakdown of various components
Starch	Alpha-amylase, glucoamylases, hemicellulases, maltogenic amylases, glucose isomerases	Modification and conversion (e.g. to dextrose or high fructose syrups)
	dextranases, beta-glucanases	
Inulin	Inulinases	Production of fructose syrups

metabolites (products of the metabolism of these complex substances). These metabolites include enzymes which are capable of breaking down carbohydrates, proteins and lipids present within the substrate and/or fermentation medium; vitamins; antimicrobial compounds (e.g. bacteriocins and lysozyme); texture-forming agents (e.g. xanthan gum); amino acids; organic acids (e.g. citric acid, lactic acid) and flavour compounds (e.g. esters and aldehydes). Many of these microbial metabolites (e.g. flavour compounds, amino acids, organic acids, enzymes, xanthan gums, alcohol etc.) are produced at the industrial level in both developed and developing countries for the use in food-processing applications. A considerable volume of current research both in academia and in industry targets application of microbial biotechnology to improve production, quality and yields of these metabolites. Fermentation is globally applied in preservation of a range of raw agricultural materials. Commercially produced fermented foods which are marketed globally include dairy products (cheese, yogurt, fermented milks), sausages and soy sauce. Certain microorganisms associated with fermented foods, in particular, strains of the *Lactobacillus* species, are probiotic, i.e. used as live microbial dietary supplements or food ingredients

that have a beneficial effect on the host by influencing the composition and/or metabolic activity of the flora of the gastrointestinal tract.

In developing countries, fermented foods are produced primarily at the household and village levels. Microorganisms and metabolic pathways associated with the production of fermented foods are the subject of considerable research, targeting strain isolation and identification; improvement of the efficiency of fermentation processes and the quality, safety and consistency of fermented foods.

IMPORTANCE OF MICROORGANISMS USED IN INDUSTRY

Although microbes are extremely good in presenting us with an amazing array of valuable products, they usually produce them only in amounts that they need for their own benefit; thus they tend not to overproduce their metabolites. The fermentation microbiologist, however, desires a 'wasteful' strain which overproduces and excretes a particular compound that can be isolated and marketed. Once a desired strain is found, a development program is begun to improve titres by modification of cultural conditions, mutation and recombinant DNA technology. The microbiologist actually modifies regulatory controls remaining in the original culture so that its 'inefficiency' can be further increased, and the microorganism excretes tremendous amounts of these valuable products into the medium. The main reason for the use of microorganisms to produce compounds that can otherwise be isolated from plants and animals or synthesized by chemists is the ease of increasing production by environmental and genetic manipulation. Thousand fold increases have been recorded for small metabolites. Of course, the higher the specific level of the production, the simpler is the job of the product isolation.

Molecular methodologies, commonly the PCR, ribotyping (a method to determine homologies and differences between bacteria at the species or sub-species (strain) level), RFLP analysis of rRNA genes and pulsed-field gel electrophoresis (PFGE), can be used to characterize and monitor the presence of spoilage flora, normal flora and microflora in foods. RAPD or AFLP molecular marker systems can also be used for the comparison of genetic differences between species, subspecies and strains, depending on the reaction conditions used. Monoclonal and polyclonal antibodies can also be used for diagnostics, e.g. in enzyme-linked immunosorbent assay (ELISA) kits. Microarrays are biosensors which consist of a large number of parallel hybrid receptors (DNA, proteins, oligonucleotides). They can be used for detection of pathogens, pesticides and toxins and can offer considerable potential for facilitating process control, the control of fermentation processes and monitoring of the quality and safety of the raw materials.

MICROBIAL GENOMICS AND FOOD PRODUCTION

In recent years, genome sequences of many food-related microorganisms have been completed (e.g. *Saccharomyces cerevisiae*, the first eukaryote to have its genome sequenced - in 1996), and large numbers of

microbial genome sequencing projects are also underway (*see* <http://www.ncbi.nlm.nih.gov/entrez/query.fcgi?db=Genome> for an update). Functional genomics, a relatively new area of research, aims to determine the patterns of gene expression and interaction in genome, based on the knowledge of extensive or complete genomic sequences of an organism. It can provide an understanding of how microorganisms respond to environment at the genetic level (i.e. by expressing specific genes) in different situations or ecologies, and should, therefore, allow adaptation of conditions to improve technological processes. For a range of microorganisms, it is now possible to observe expression of many genes simultaneously, even those with unknown biological functions, as they are switched on and off during normal development or while an organism attempts to cope with pathogens or changing environment. Functional genomics can shed light on the common genetic mechanisms which enable microorganisms to use certain sugars during fermentation, as well as on the genetic differences allowing some strains to perform better than others. It holds great potential for defining and modifying elusive metabolic mechanisms used by the microorganisms. Moving from gene to protein level, it should also be mentioned that proteomics, an approach aiming to identify and characterize complete sets of proteins, and protein-protein interactions in a given species, is also a very active area of research, which offers potential for improving fermentation technologies. The industrial production of enzymes from microorganisms involves culturing microorganisms in huge tanks where enzymes are secreted into fermentation medium as metabolites of microbial activity. Enzymes thus produced are extracted, purified and used in the food industry and for other applications. Purified enzymes are cell-free entities and do not contain any other macromolecules such as DNA.

Through protein engineering, it is possible to generate novel enzymes with modified structures that confer novel desired properties such as improved activity or thermostability or ability to work on a new substrate or at a higher pH. Directed evolution is one of the main methods, currently used for protein engineering. This technique involves creating large numbers of new enzyme variants by random genetic mutation and subsequently screening them to identify improved variants.

RECOMBINANT DNA TECHNOLOGY AND INDUSTRIES

Many enzymes are produced by using gene technology (Table 2). Biopharmaceuticals (recombinant protein drugs, vaccines and monoclonal antibodies) have a market of US\$15 billion; in the US alone, there are about 1,600 biotechnology companies, employing 153,000 people, with a total revenue of US\$19.6 billion and sales of US\$13.4 billion. Europe has almost 1,200 companies, 45 000 employees and revenue of US\$3.7 billion; the UK and Germany are the major players. Japanese biotechnology has been conducted predominantly in major pharmaceutical, food and beverage companies with only a few small biotechnology companies in existence.

Table 2. Some enzymes produced using gene technology

Principal enzyme activity	Application
Alpha-acetolactate decarboxylase	Brewing
Alpha-amylase	Baking, brewing, distilling, starch
Catalase	Mayonnaise
Chymosin	Cheese
Beta-glucanase	Brewing
Alpha-glucanotransferase	Starch
Glucose isomerase	Starch
Glucose oxidase	Baking, egg mayonnaise
Hemicellulase	Baking
Lipase	Fats, oils
Maltogenic amylase	Baking, starch
Microbial rennet	Dairy
Phytase	Starch
Protease	Baking, brewing, dairy, distilling, fish, meat, starch, vegetable
Pullulanase	Brewing, starch
Xylanase	Baking, starch

The most well-known products of the modern biotechnology industry are the mammalian polypeptides such as erythropoietin (EPO) with US\$2.9 billion market; interferon- α , with US\$1.6 billion; human growth hormone (HGH; human somatotropin), with US\$1.1 billion; human insulin, with US\$1 billion; granulocyte colony stimulating factor (G-CSF) with US\$720 million; and tissue plasminogen activator (tPA) with US\$290 million. Another important product is recombinant hepatitis B vaccine (US\$725 million). These polypeptides are mainly made in bacteria such as *Escherchia coli* (US\$2.9 billion) and mammalian cell culture (US\$3.3 billion), but yeasts, filamentous fungi and insect cells are also important. In very near future, it is expected that many products will be made in transgenic animals and plants. Recombinant DNA technology has revolutionized agriculture; where, in 1998, the farm market included insect-resistant corn, potato, soybean; herbicide-resistant canola, cotton, soybean and corn; virus-resistant squash; and canola containing speciality oils and tomato with increased pectin.

Scientist as well as enzyme companies, realizing that their products were encoded by single genes, rapidly adopted recombinant DNA techniques to increase enzyme production and to make new enzymes. As the result, today's industrial enzyme market has annual sales of US\$1.6 billion with applications in food and starch processing (45%), detergents (34%), textiles (11%), leather (3%) and pulp and paper (1.2%). The protease subtilisin, which is used in washing powders, accounts for US\$200 million of this market. Over 60% of these enzymes are recombinant products. Significant markets exist for speciality enzymes such as recombinant chymosin for cheese-making (US\$140 million), restriction enzymes for molecular techniques (US\$100 million) and Taq polymerase for PCR applications (US\$80 million). A huge market (US\$2.3 billion) exists for therapeutic enzymes.

Recombinant DNA technology has been applied to antibiotic production. Many genes encoding individual enzymes of antibiotic biosynthesis have been cloned and expressed at high levels in heterologous microorganisms. Antibiotic biosynthetic pathways are often encoded by clustered chromosomal genes, especially in bacteria, which facilitate transfer of an entire pathway in a single manipulation. Even in fungi, pathway genes are sometimes clustered, such as the penicillin biosynthesis genes in *Penicillium*.

The most industrially important primary metabolites are amino acids, nucleotides, vitamins, solvents and organic acids. Millions of tonnes of amino acids are produced each year with a total multibillion dollar market. Many synthetic vitamins production processes are being replaced by microbial fermentations. In addition to the multiple reaction sequences of the fermentations, microorganisms are extremely useful in carrying out biotransformation processes. These are becoming essential to fine chemical industry in production of single-isomer intermediates. Secondary metabolites produced by microorganisms are extremely important to our health and nutrition. They have tremendous economic importance. The antibiotic market amounts to almost 30 billion dollars and includes about 160 antibiotics and derivatives such as β -lactam peptide antibiotics, the macrolide polyketide erythromycin, tetracyclines, aminoglycosides and others. Other important pharmaceutical products produced are hypocholesterolemic agents, enzyme inhibitors, immunosuppressants and antitumor compounds; some having markets of over 1 billion dollars per year. The modern biotechnology industry has made a major impact in the business world, biopharmaceuticals (recombinant protein drugs, vaccines and monoclonal antibodies) with a market of US\$15 billion. Recombinant DNA technology has markedly increased markets for microbial enzymes. Molecular manipulations have been added to mutational techniques as means of increasing titres and yields of microbial processes and in discovery of new drugs. Today, microbiology is a major participant in global industry. The best is yet to come as microbes move into environmental and energy sectors.

MICROBIAL BIOTECHNOLOGY AND BIOREMEDIATION

Bioremediation is use of biological agents, bacteria, fungi and plants to remove, degrade or detoxify pollutants from contaminated environmental sites. Scientists are identifying naturally occurring organisms that may be useful for bioremediation. They are also genetically modifying these as a way to expand list of treatable contaminants and to maximize their efficiency and safety. Bioremediation encompasses both commercial/industrial and governmental market places. The risk of exposure plus severity of the exposure itself is the principal factor in determining remediation standards. Risk assessments are based upon the proposed uses of the property upon which the contamination is discovered. Changed uses or changing scientific health data regarding danger associated with particular exposures may also change remediation standards.

MICROBIAL BIOTECHNOLOGY AND SOCIO-ECONOMIC DEVELOPMENT

For socio-economic development, some important points should be fulfilled. These are: (1) characterization of production system for crop intensification; (2) nutrient management; (3) waterlogging and land degradation; (4) farmers' perception about improved technologies; (5) assessment of financial and economic feasibility of improved technologies; (6) constraints to adoption of improved technologies; and (7) modelling to extrapolate research information.

Biotechnological research as applied to the bioprocessing in majority of the developing countries, targets development and improvement of traditional fermentation processes. Some areas specifically relevant to developing countries which can be summarized are as follows-

- a. Socio-economic and cultural factors-* Traditional fermentation processes employed in most developing countries are low input, appropriate food processing technologies with minimal investment requirements. They make use of locally produced raw materials and are an integral part of the village life. These processes are, however, often uncontrolled, unhygienic and inefficient and generally result in products of variable quality and short shelf-life. Fermented foods, nevertheless, find wider consumer acceptance in developing countries and contribute substantially to food security and nutrition;
- b. Infrastructural and logistical factors-* Physical infrastructural requirements for manufacture, distribution and storage of microbial cultures or enzymes on a continuous basis is generally available in urban areas of many developing countries. However, this is not in most rural areas of the developing countries. Should research be oriented to ensure that individuals at all levels can benefit from applications of biotechnology in food fermentation processes, i.e. should logistical arrangements for starter culture development be integrated into biotechnological research targeting improvement of traditional fermentations? What is required for the level of fermentation technologies and process controls to be upgraded to increase efficiency, yields and the quality and safety of fermented foods in the developing countries?
- c. Nutrition and food safety-* Fermentation processes enhance nutritional value of foods through biosynthesis of vitamins, essential amino acids and proteins, through improving protein and fibre digestibility; enhancing micronutrient bioavailability and degrading antinutritional factors. Many bacteria in fermented foods also exhibit functional properties (probiotics). The safety of fermented food products is enhanced through reduction of toxic compounds such as mycotoxins and cyanogenic glucosides, and production of antimicrobial factors such as bacteriocins, carbon-dioxide, hydrogen peroxide and ethanol, which facilitate inhibition or elimination of food-borne pathogens. Are the nutritional characteristics (and safety aspects) of fermented foods adequately documented and appreciated in developing countries? Is there a need for consumer education about the benefits of fermented foods?
- d. Intellectual property rights (IPRs)-* The processes used in more advanced areas of agricultural biotechnology tend to be covered by IPRs, and these rights tend to be owned by the parties in developed countries.

This applies also to biotechnology processes used in food processing. On the other hand, many of the traditional fermentation processes applied in developing countries are based on traditional knowledge.

In addition to biotechnology processes, microbial strains may also be the objects of IPRs. Many of the microorganisms associated with traditional fermentation processes in developing countries are unique. Issues of ownership will become increasingly important as bacterial strains are characterized and starter cultures are developed in developing countries. How should food scientists, researchers, industry and governments in developing countries approach these issues? A considerable volume of research into the development and improvement of fermentation processes is currently taking place worldwide. Are research results from developing countries adequately documented? Who owns this information? Are cell banks being developed to protect microbial strains characterized in developing countries? *e. Commercial opportunities-* biotechnological innovations have greatly assisted in industrializing production of certain indigenous fermented foods. The results of biotechnology research will lead to fermented foods of improved quality, safety and consistency. Should biotechnology developments in developing countries target commercialization? Should they target diversification into new value-added products? *f. Appropriateness of food processing biotechnology in developing countries-* As with any commitment of resources, investments in biotechnology for food processing should be weighed up against other potential uses of these resources in developing countries. How relevant and worthwhile can such investments be for the developing countries?

Knowledge of the genomes of the agricultural microorganisms is expected to underpin future advances in the agriculture into the next quarter century. It is anticipated that microbial genomics will lead to an accelerated understanding of beneficial and pathogenic microorganisms that will lead to more rapid advances in metabolic engineering, development of sensitive and specific diagnostic tools, marketing of improved therapeutics and efficacious vaccines, and conversion of agricultural materials into high-value products such as fuels and chemicals. The modern biotechnology industry will be made to play a major role in the world's business. However, some issues like socio-economic and cultural factors, infrastructural and logistical factors, nutrition and food safety, intellectual property rights, commercial opportunities, appropriateness of food processing biotechnology in developing countries will arise, and these issues should be overcome.

Public - Private Partnership in Mechanizing Indian Agriculture for Second Green Revolution

M.M. Mehta

In the First Green Revolution, the growth in the farm power (tractors, engines, motors, etc) played its supporting role magnificently, as it enabled farmers to:

- Achieve important factor of timeliness of field operations for maximizing yield potentials of HYV seeds.
- Provide timely irrigation to crops with tractor PTO powered pumps without awaiting power supply.
- Hasten on-farm crop threshing and bagging of grains to save harvest from vagaries of nature.
- Quickly transport harvest for sales to adjoining *mandis* of choice.
- Prepare vacated land for the next crop – to achieve gains in cropping-intensity.
- The Net Gain from this phase of tractorization, being gain in production and productivity.

The Second Green Revolution requires that:

- We service specific needs of each and every agroclimatic zone/ State, be it plains or hills, be it grains or horticulture, be it flowers or vegetables, etc.
- We optimize use of each input for further gains in productivity and production for achieving rural prosperity and global competitiveness.

The move from tractorization to farm mechanization for the second green revolution requires developing crop-wise implements and equipment for mechanizing total crop production cycle. For example, to mechanize, develop:

- Equipment/implements for planting, interculture, harvesting, transport of vegetables, pineapples, etc.

- Equipment/implements for planting, interculture, harvesting and haulage of cotton, sugarcane, pulses, oilseeds, etc.
- Suitable power-units and matching implements for hill agriculture and wetlands.
- Equipment giving consideration to operator safety, comfort and other ergonomic factors (including gender considerations).
- Equipment for value-addition to harvest for additive rural employment and rural prosperity.

For the above to be achieved in the shortest time-span to provide well-designed and mass-produced good-quality products, backed by dependable after-sales service, it will make national and commercial sense to:

- Draw upon existing national resources in public and private domains.
- Develop a formal and transparent structure for adopting R&D mandates, protecting IPRs, technology fees and service rates, etc.

At present annual investment in India on agri-machinery including tractors, power-tillers, combine-harvesters, straw-choppers, tillers and cultivators, engines, irrigation pumps and sprinklers, plant-protection equipment is estimated to be more than Rs 50,000 crore. This level needs to be increased considerably for profitable farming. And the power availability is 1.5 kW/ ha that needs to be increased for greater productivity, as indicated by the international experience (Tables 1-4)

Table 1. Farm power availability in India

Year	Total farm power (kW/ha)	Source-wise (%)			
		Human	Animal	Mechanical	Electrical
1951-52	0.25	97.40	2.10	0.50	
1961-62	0.31	94.90	3.70	1.40	
1971-72	0.30	15.11	45.26	25.86	13.77
1981-82	0.47	10.92	27.23	44.10	17.70
1991-92	0.76	8.62	16.55	53.93	20.90
2001-02	1.23	6.49	9.89	62.36	21.26
2005-06*	1.50	5.77	8.02	65.47	20.74

*estimated

Table 2. Comparison of mechanization with other countries, 2001

Country	Farm power (kW/ha)	No. of tractors per 1,000 ha	No. of combine-harvesters per 1,000 ha
India	1.23	9.43	0.026
Japan	8.75	456.24	234.42
UK	2.50	88.46	8.32
France	2.65	68.52	4.93
Italy	3.01	201.90	6.24
Germany	2.35	87.26	11.43
Pakistan	—	14.92	0.074
Egypt	—	31.32	0.8311

Table 3. Farm machinery availability in India

Agricultural operations/ machine	No. in lakh*		Command in percentage of net area sown
	1992	2003	
Tractors	12.22	23.61	25.0
Seed-drill			
(i) Tractor drawn	3.90	73.50	11.25
(ii) Animal drawn	51.03	23.77	12.06
Threshers			
(i) Wheat	10.76	7.26	17.0
(ii) Paddy	0.35	1.61	2.21
(iii) Multicrop	1.68	6.81	5.76
Plant protection equip.	29.56	58.31	48.39

Table 4. Growth of agricultural machinery

Equipment	Population (Hundreds)		No. per 1,000 ha net area sown		Percentage growth
	1992	2003	1992	2003	
Horticultural tools (power-operated)	NR	12,681	—	8.9	Not calculated
Tractors	12,218	23,612	9.3	16.7	93.3
Power-tillers	3,297	2,799	2.5	2.0	(-) 15.1
Tractor-operated disc-harrow	6,456	9,330	4.9	6.6	44.5
Tractor-operated cultivator	NR	17,715	—	12.5	Not calculated
Tractor-operated rotavator	NR	1,330	—	0.9	Not calculated
Potato digger	975	2,955	0.7	2.1	203.1
Straw reaper	NR	26,605	—	18.8	Not calculated
Forage harvester	NR	25,739	—	18.2	Not calculated

* *Livestock Census* 1992, 2003; NR, Not reported

Focussing on the aspects of agricultural transformation through public-private partnership, the above mentioned data bring out the following.

- The R&D programmes have so far served mainly rice-wheat system.
- The range of the equipments (i.e. the agricultural implements and machinery) are not wide enough to facilitate diversification of agriculture.
- Equipments including tractors and prime-movers for mechanization of hill agriculture and production of fruits and vegetables are not commonly available.

The R&D programmes in future should focus on the development of farm machinery and power units for precision and protected agriculture; hill agriculture; horticulture, cash and plantation crops; non-farm applications like efficient rural transport, maintenance of village roads, etc.

The ICAR has a number of institutes having related technologies,

manpower and research facilities, and the private sector has its own strengths of production technologies, R&D, marketing and sales-reach and after-sales-service infrastructures; all of which can provide the interface for achieving desired objectives. The ICAR institutes have well-equipped labs, high calibre manpower, exposure to modern science and technologies, developing functional prototypes, testing standards, and methods, interface with related areas of specializations, knowledge of soil types and agroclimatic parameters. However, these institutions require support in designing for production with maximum parts commonality, designing for ease of maintenance and life-cycle enhancement market reach and sales networks, and getting market feedback for further improvement; these all are private sector strengths.

But private sector does not have the R&D infrastructure and trained human resource that the ICAR institutes have. Clearly, it is a fit case for bringing synergy through the public-private partnership.

It is suggested that ICAR may, with suitable modifications, adopt a structure like that of the 'Automotive Research Association of India' (ARAI), Pune, for Agricultural Mechanization Programmes, where the ICAR already has established vibrant institution, the 'Central Institute of Agricultural Engineering' with a number of AICRPs located in various states/SAUs. Agricultural mechanization holds the key not only to the second green revolution but also to the multiple growth of agri-equipment business. The surest path to this is to provide an effective interface between the ICAR institutes and the related private domains.

Processing and Value-addition

P.L. Kaul

Dr A.P.J. Abdul Kalam, President of India, in his presentation on the transforming vision into missions enumerated the following five areas for integrated action plan to be achieved by 2020.

- Providing Urban Amenities in Rural Areas (PURA)
- Greater Emphasis on Agriculture and Agro-food Processing
- Increase in GDP growth rate from the present level to 10%
- To eradicate totally Below Poverty Line (BPL) status of 26% of Indian Population
- Food and Nutritional Security for all

Total of 700 million people (mainly farmers), constituting approximately 70% of the population of India, live in about six lakh villages. According to the recent estimates, about 260 million people (mostly from villages) are classified as those Below Poverty Line (BPL). There are 36 million unemployed people, again mostly rural-youth. One needs to realize that the processing in value-addition activities should directly benefit consumers, in general, and provide an overall boost to the national economy. When implemented in the right spirit and with appropriate technological back-stopping, processing of farm produce has the capacity to pull farmers out of the perennial economic despondency. Besides, huge post-harvest losses estimated to be about Rs 50,000 crore annually can be minimized. This activity will generate employment opportunities for rural-youth, thereby, stepping rural prosperity and stopping rural to urban migration. A comparison of the value-addition activities in agriculture and food processing among a few nations of the world clearly indicates that the value-addition in food processing sector in India at present is only about 6% as compared to 21% in Brazil, 30% in Thailand, 42% in New Zealand and 53% in the USA. Even though when enormous volumes of fruits and vegetables for handling, storage and processing for preservation are available in India.

PROCESSING AND VALUE-ADDITION CONSIDERATIONS

To ensure cost competitiveness and quality of the product, there are appropriate scales of operations, which need to be considered for setting-

up processing and value-addition facilities. India produces about 25 million tonnes of potato annually, and is the third largest potato producer in the world. Today, potato processing in India is negligible and it is surprising that the products such as frozen french-fries are totally imported by the MNCs for their chains of restaurants. Potato cultivation in India needs to be necessarily integrated with potato-processing activities.

Let us consider a multi-product potato processing plant. It has been observed that an optimum plant capacity is 47,000 tonnes per annum (TPA) of raw potatoes. The estimated cost of the plant is likely to be Rs 75 crore that includes Rs 44.7 crore for plant and machinery. The plant with a capacity of 6,000 TPA for frozen french-fries, 1,200 TPA for potato crisps, 2,400 TPA for meshed potato products and 2,700 TPA for potato granules will yield 27.7% returns on investments with an estimated annual turnover of Rs 50.9 crore.

To sum up, processing and value-addition activities in India will be beneficial for producers, processors, marketers and consumers alike besides, enormous benefits to the national economy and the environment.

Post-harvest Technologies in Agriculture

S. M. Ilyas

India produces more than 750 million tonnes of food items of plant and animal origin, and is next to China's 830 million tonnes. The agricultural commodities are mostly of perishable nature. While some are highly perishable like fruits, vegetables, livestock and fish products; the others are relatively less perishable like foodgrains, oilseeds, certain tuber crops, cotton, jute and kenaf, etc. It is estimated that the losses of the food commodities roughly vary from 10% for cereal, pulses and oilseeds to more than 25% for perishable commodities. The monetary value of the losses is more than Rs 50,000 crore per year. This losses could be reduced by using appropriate post-harvest technologies and equipment, and thereby providing Rs 38,000 crore decentralized addition to rural economy.

The expending economy has opened new vistas for post-harvest processing and value-addition for ensuring high quality safe raw and processed produce at competitive prices. In this, development and strengthening of linkages are utmost essential for improving gain at each node of the value-chain. This task being gigantic, the involvement of all stakeholders is a must, and this entails total paradigm shift ensuring a strong partnership with the private sector. The processes of conversion of weakness into strength and threats into opportunities can be smoothened through this coalition.

PROCESSING AND VALUE-ADDITION FOR EMPLOYMENT GENERATION

Presently processing levels are very low in our country (2% fruits and vegetables, 2% meat and poultry, 14% milk, 4 % in fish and 21% meat deboning) and value-addition to commodities is only 7% as against 30% in Thailand, 70% in Brazil, 78% in Philippines and 80% in Malaysia. It is roughly estimated that to increase the level of food processing from 2% to 10%, an investment of more than Rs 140,000 crore would be required. And this investment would generate direct employment for 7,700,000 persons and indirect employment for 30,000,000. And would reduce wastage by Rs 8,000 crore.

Apart from these advantages, the value-addition of food products will go up from 7% to 35%, which will be reflected in corresponding increase in the GNP. The bad reputation concerning post-harvest quality losses can result in loss of market opportunities and little overseas interest for export, and the recovery of losses can help expansion of consumer markets and profits. The farm-gate price available to farmers is only 25% of the retailed price in India as compared to 60-70% in the developed countries, where more efficient marketing system is in place.

The two major objectives of post-harvest technology are loss prevention and value-addition of raw food commodities through preservation and processing. For the resource-poor farmers and women, it is important that economic benefits of agro-processing and agri-business are taken to rural areas.

India's food processing mainly involves primary processing, which accounts for 80% of value. As much as 42% of the food industry is in the organized sector and 33% in the small scale, tiny and cottage sectors, which are beset with problems of inefficiencies of high cost, economics of scale and inadequate logistic support. According to CII- Mc Kinsey Report, the size of the India's food industry (estimated as Rs 25,000 crore) was expected to double by 2005. Of this, value-added processed foods were forecast to rise three times from Rs 80,000 crore to Rs 225,000 crore. This should give a fair idea of opportunities for employment generation particularly in rural areas. Obviously this vast potential can be tapped only with the active participation of the private sector.

Under the auspices of the National Agricultural Research System (NARS), including ICAR Institutes and State Agricultural Universities, a large number of equipment and technologies have been developed, which have also been rigorously evaluated and many of them are already commercialized. Apart from these institutions, other research and development organizations, co-operatives and also industrial sector have also evolved many useful technologies and have come out with the agro-processing models (Table 1).

AGRO-PROCESSING CENTRES (APCs)

Agro-processing centre is an enterprise where required facilities for primary and secondary processings, storage, handling and drying of cereals, pulses, oilseeds, fruits and vegetables are made available on the charge basis to people. Value-added agro-based products and processed food items are also prepared and marketed by the centre. An individual/co-operative/community organization/voluntary organization may manage this type of centre.

The centre meets processing, preservation, handling and marketing needs to surplus produce available in a production catchment (village or a cluster of villages). Thus, the centre is a means of providing income and employment to rural people through agro-based processing activities for various produces.

Table 1. Different agro-processing models

1	Amul Pattern Co-operatives	Production of milk by large number of cattle owners, processing and marketing network by organized co-operatives
2	Tea Industry Model	On-farm primary processing, blending and marketing in an organized sector
3	Sugar Industry	Organized industry located in production catchments with loose tie-up with growers; government playing moderating role like deciding support price for sugarcane
4	Gur and Khandsari	On-farm cottage industry catering to an ethnic need and lately to health conscious people competing with sugar industry and giving better dividends to cane-growers
5	Cotton Textile Industry	Pre-cleaning/ginning and baling in production catchments, spinning and weaving in an organized sector
6	Power looms	Decentralized, efficiently managed units, no labour problems or shutdowns, catering to certain range of consumers
7	Mills (<i>Atta Chakkis</i>)	Small, low capital units, doing custom processing to satisfaction of customers
8	Lijjat Papad	Traditional product, using underutilized, mostly female human resource, organized as co-operative, availing established marketing network
9	Mobile Door to Door Service	Craftsmen and mechanics moving on bicycle or cart (and now tractor trolley) with necessary equipment for door-to-door processing service

The components of agro-industrial complexes are location-specific, so generalized agro-industrial models cannot be suggested for the country. The agro-industrial model for the area could be developed in a manner, which provides sufficient job opportunities and to an entrepreneur unit adequate profit margin. The APCs also provide good opportunities to women. The R&D institutions as well as commercial houses have developed agro-processing machines for the entire sector suiting various operations.

For developing an agro-industrial model for a particular area, following points should be considered.

- Existing potential demand of the processing produce
- Availability of raw material i.e. produce
- Technology/process to be used for processing
- Volume of production (based on the assessment of demand through market survey)
- Identification of suitable technologies, plants and machinery for desired volume of production
- Training facility for operation, repair and maintenance of equipment
- Credit availability at soft rates/subsidies given by financial institutions
- Facility for packing, storage and marketing
- To derive maximum benefit, the APCs should be properly laid out

to optimize available space and to utilize energy efficiently. The selection of equipment (capacity, power requirement etc.) is of utmost importance. Since most post-harvest operations are seasonal in nature, two/ three technologies/ products may be taken up to develop an agro-industrial complex to provide regular employment throughout the year. It is estimated that an investment of Rs 3.00 lakh will create job for 2 persons and generate decent income for the entrepreneur. With an investment of Rs 5.00 lakh, it will create employment opportunities for 4 persons and annual income of Rs 90,000 to 100,000.

ROLE OF STAKEHOLDERS

Farmers/producers are, of course, the biggest stakeholders. The problem lies in that they are still not very sensitized about latest technologies. Hence our agriculture continues to be: low input, low technology, less productive, low quality, less competitive and thus less remunerative. Farming community is being served by the extension agencies of the government-line departments ICAR Institutions and State Agricultural Universities, but that is not enough. Private sector has also entered in this, where services provided are chargeable.

NGOs have evinced interest in post-harvest sector lately, who try to embed technology in private and community-based production systems. Many of these groups are exclusively formed by women, and are run successfully. The model of agro-processing centres has been catching up especially in Punjab, Karnataka and Maharashtra. In some cases religious trusts have also joined hand. World Bank and Indian financial institutions especially the NABARD and large co-operative like IFFCO have also showed interest.

Private sector has always been an important stakeholder and has kept commercial activity in this sector alive. Most of the processing is done in unorganized sector; more than 60% units are small and tiny. Established private food processing like ITC, Hindustan Lever, Pepsi Foods, Nestle, etc have also entered the market with much success. Mother Dairy is emerging as an important player. Most of these have strong linkages with producers through contact farming, which is taking firm roots in the country. A strong R&O farmers-industry-trade and consumer partnership is in the nascent stage, but has good prospect for creating win-win situation for all stakeholders.

Post-harvest Technologies: Key Issues and Strategies for Effective PPP

- Adoption/development of proven technologies for reduction in post-harvest losses of cereals, pulses, oilseeds, minor millets, fruits, vegetables, floriculture, livestock, aquaculture and poultry products, produce of forest origin, dairy produce, fibre crops and commercial crops with specific goals for loss reduction through

extensive Good Agricultural Practices, safe harvesting-handling-storage and transportation movement.

- Technology upgradation in processing cereals, pulses and oilseeds for higher recovery, better quality and energy efficiency. Better economic utilization of agri-residues, wastes processing and by-products.
- Undertaking joint research in frontier areas of post-harvest technology such as application of biotechnology, cryogenic processing, system dynamics simulation and modelling, super critical temperature liquefied gases for extraction of high-value oils, fabricated foods and feed through extrusion processing, modified atmosphere packing (MAP) for enhanced shelf-life of fruits, vegetables, meat and so on.
- Equipment design refinement, prototypes production and manufacturing promotion through industries.
- Development of area-specific agro-processing models for value-addition and higher employment opportunities and agro-processing/agro-business-based development.
- Development of better nutrition and high acceptance products and processes specifically for low-income groups and mid-day meal programmes through involvement of peoples' organization and NGOs, even religious trusts.
- Contract research for industry and consultancy projects.
- Better linkages between R&D labs, farmers, industry and development agencies.
- Holistic system approach in analysing problem situations, and operating a problem solving project.
- Ergonomics in equipment design, worker's safety, creating healthy work environment in food processing industries.
- Promotion of group/community processing to gain benefits of economy of scale through active involvement of farmer groups, co-operatives and Panchayati Raj institutions, line departments of government with emphasis on higher income to farmers/producers.
- Development of high quality food products (including improvement of traditional foods) - healthy, hygienic, cost-competitive, using locally available resources.
- Standardization of unit operations-product and machine parameters, Hazard Analysis and Critical Control Points and Good Manufacturing Practices for food processing industries for domestic and export requirements.
- Processing of non-traditional grains, oilseeds, fruits vegetables, especially benefiting dryland areas, weaker section, tribals and women.
- Development of comfortable shades/structures for livestock for safe living and higher productivity.

- Development of efficient storage system including CA and MA storages, and work on ultra-low oxygen storages for high-value crops.
- Improvement in efficiency of oil and pulse milling processing and equipment, energy auditing and reduction in pollution.
- Use of biotechnology in development of novelty foods, for improvement in effectiveness of existing processes and for enabling longer shelf-life.
- Studies on effect of chemicals at post-harvest stages and work on reduction of use of chemicals through use of botanicals and safe chemicals.
- Development of effective packaging for perishable products for long-term haulage and storage.
- Transfer of post-harvest equipment and technology through documentation, training and demonstration.
- Human resource development (national, international) for scientists, engineers, technologists, operators and managers for processing industries.

ACTION PLAN

- A fair assessment of work done anywhere in the World, ICT will come handy, and patent search should be undertaken since only best can compete.
- This is an era of customized production; mass production, instead of production by masses. Hence group/contract farming and economic scale processing needs to be promoted.
- To come out of the mental block of serving landless and marginal farmers only. Here the clientele is much wider which includes everyone from farmers/producers to handlers, transporters, storage, packaging, processing, quality evaluation to consumer. The consumer/user needs to be retained rather than only attracted satisfied. And only surplus can be traded, processed, stored and marketed.
- Promoting processing and value-addition, to ensure only processed products (even if primary/minimally processed), rather than raw materials, are sold for further processing/consumption. Better income to producers, reducing clout of middlemen, giving a boost to rural agro-processing, enabling more inputs to production agriculture.
- The equipment/process developed needs to be the best state of art, which should help in reducing/eliminating losses, reducing costs at different stages and should provide incremental advantage through increasing competitiveness. With existing technology, one can't think of competing with the world. It is clear that competition will come from low-cost innovations. The product should have all possible advantages. The quality and safety should

have prime consideration from raw materials to different stages of processing, implementing all relevant codes and standards. All participants of value-chain should be thoroughly sensitized about quality and safety.

- Promoting agro-processing and value-addition through establishment of large number of APCs. Self-help groups and co-operatives need to be promoted. Specialized processing in mode of “One Village One Product” be encouraged.
- Strengthening backward and forward linkages through intensive liaisoning. Everyone should know what the other needs.
- Documentation, software development of package of practices: commodity based, also unit-operation based, and regular updation. Consumption of processed food needs to be promoted. It will help in boosting agro-processing and will fight gluts.
- Training human resource and capacity-building of human capital to compete with the best.
- Pilot-scale evaluation of equipment/processes/products, appropriate packaging and safe storage.
- Complete beneficiation of biological materials: roots, stems, leaves, flowers and fruits, hides, blood bones etc. with special emphasis of making waste into wealth. Increasing application of biotechnological tools.

ROADMAP

- Product of high quality; safe produce pre-cleaning grading and drying to be done by producers. Development of quality testing lab in public/private institution to serve maximum areas.
- Non-destructive estimation of yield of orchards by using artificial intelligence neural network models, fuzzy logic, machine vision etc., and determination of fruit quality by using NIR spectroscopy.
- Development of safe and efficient handling and specialized transport system for perishable produce, including horticultural produce, meat, egg, fish etc.,
- Modernization of food-processing industries should be for higher outturn, better quality, lower losses; by-product utilization; efficient energy use; improved work environment through drastic reduction of pollution
- Mechanization of all *mandis*/markets especially for perishables to be done on priority.
- Development of effective post-harvest technology for medicinal and aromatic plants including handling, drying, storage and extraction of active ingredients, construction of appropriate structures/sheds for livestock and poultry and their environment control.

- Establishment of packing houses in production catchments for appropriate packaging of food, feed and fibres using natural and man-made fibres and locally available materials.
- Movement for implementations of codes and standards for equipment, processes and products for agriculture, horticulture and livestock including fishery sectors to be initiated with lead by private sector.
- Utilization of high pressure technology, hurdle technology, irradiation, reverse osmosis for enhancing shelf-life of products by processing industries.
- Installation of high capacity dryers for high moisture produce like paddy, mushroom and vegetables in products areas by co-operative and food-processing industries.
- Construction of a large number of CA and MA storages for high-value crops and products in the country especially near dry ports, air and sea ports for export promotions by the APEDA, MPEDA, commodity boards and corporates.
- Development of package of post-harvest practices for spices, condiments, coconuts and cashewnuts.
- Modernization of slaughterhouses, meat and fish processing and preservation with joint effort of public and private sectors.
- Large-scale demonstration of equipment and technologies for their adoption by large number of stakeholders.

Global food business is more than US\$ 1 trillion but the share of developing countries is extremely low. India has huge potential in term of its 1,000 million plus population and a large number of Indian diasporas spread throughout the globe. Further the Indian food snacks and savories have started tickling taste buds of foreigners as well.

Apart from its vast potential for meeting domestic and export food demand, food business has another redeeming feature namely it provides enormous opportunities for changing rural scenario. If tapped properly, this activity can do wonders to rural economy, creating, unlimited jobs—more than one can perhaps handle.

The development of technology should be followed by merciless testing and quick transfer to perspective users. The role of private sector in jointly developing and transferring technologies is very crucial. The potential entrepreneur who has the aptitude to enter in exciting world of food processing can make use of these and other technologies, release his untapped energy, and sky will be the limit. A strong producer-handler-trader-processor- consumer linkage is extremely desirable as that has the potential to generate more agro-rupees and dollars than any other financial activity in the country.

Public-Private Partnership — Context HRD

J. C. Katyal

PPP – Backgrounder

- HRD involves education (formal and non-formal) and training
- PPP structures – outsourcing to private agencies (infrastructure development), outsourcing by private partners (product/process development), joint (Crop Co-ordinated Projects)
- PPP – Rationale with respect to relevance, efficiency, effectiveness, equity and sustenance
- Need analysis a must to identify areas and sectors with maximum potential benefit

PPP in Training - Status

- FET of Agricultural Research Scientists with NGOs
- Practical training of NGO functionaries by SAUs/ICAR institutes/ EEIs/MANAGE/ NIRD/SIRDs
- RAWE – student placement with farmers
- Practical training of farmers by KVKs
- Rare examples of joint PPP in training like the NVTs for industrial workers

HRD – Perspective Agriculture

- To sustain an economic growth rate of 8%, country must diversify its agriculture, it must broaden its agricultural export basket, and must prepare to compete even more in global markets
- To sustain new heights of economy, India needs a hierarchical brigade of 'knowledge and skilled workers'

PPP – Rationale

- Public institutions enhance use efficiency of infrastructure and manpower; and need to shift from input culture to output mindset, from inventions to innovations and from degree holders to market-relevant professionals.

- Private organizations enhance productivity, reach and profitability; and need to minimize fixed costs; look for enterprise-relevant agri-business managers and product-pushing marketers.
- Country's development goals – reduce poverty, expand employability and employment; conserve and make efficient use of added and native resources for reducing cost of cultivation, increasing market competitiveness and environmental security.
- Availability of right quality and number of HR is a must; single entity approach found wanting in producing that kind and number of HR
- Need is for a more robust system of education and training to produce need and market appropriate human resource
- Technically qualified (graduates⁺). Number: ~625,000; kind: professionals (200,000 alone in food processing). Para-professionals (matric⁺); number: 1,250,000 (?)
- Knowledge and skill empowered farmers and farm-workers. Number: 127 million farmers and 107 million farm-workers
- Multi-organizational function and diverse-mode delivery of knowledge and skills are must to fill HRD needs to ensure flow of benefits of economic growth to those most in need

HR – Need is for Knowledge and Skilled Workers

- More programmes are needed to promote technical skills among farm-workers and build entrepreneurship spirit among graduates. A large pool of agri-business managers need to be developed
- Both public institutions and private organizations have stakes in K&S workers. This is what precisely defines need for PPP
- Market orientation to training programmes brings private sector close to public sector

Market Orientated E&T

- Enhances employability, income earning opportunities of professionals and mobility in the labour market
- Helps farmers to get more income and thus alleviating from poverty
- Enables private sector to reap more rewards through improved productivity per worker and compete successfully in increasingly integrated world markets

PPP – Basics

- Goal commonality (shared vision)
- Strength complementarity (I need you)
- Costs and funding (no free lunch)
- Credits, risks and responsibility sharing (we are partners)
- Conflict resolution (we decide)

PPP – Alliance Enabling Links

- Strengthen and update regulations and procedures to encourage PPP
- Aim for creating synergies from PPP; jointly script and deliver course curricula based on pre-defined knowledge and skill profile of farmers, para-professionals and professionals
- Experiment with new partnership models, where best of public and private sectors can come together without compromising stated mission of either partner
- Launch educational programmes to create a cadre of professionals who will be structuring, implementing and monitoring PPP initiatives
- Resonate a process to forge alliance

PPP – Alliance Process

- Establishing PPP involves soldering together a series of independent but interrelated sequential steps and activities
- Partnership building is, thus, a process. It follows a cyclic path
- Cycle begins with exploration of a partnership subject and ends with a logical conclusion or re-begins with search for new options based upon the experience and confidence built during previous partnership

PPP – Process Steps

- Exploration of HRD subject
- Outlining aim and objectives
- Identification of potential partners, MOU
- Fine tuning HRD subject, aim and objectives
- Detailing HRD activities and delivery plans
- Evaluation of results and outcome
- Conclusion of partnership or re-begin

PPP – Strategic Training Initiatives

- India has developed a coherent systemic PPP framework for training industrial workers
- ITIs are main component of NVTs
- Of 2,720 ITIs, 1,700 belong to private sector
- Annually 450,000 workers are trained
- Apprentice Act 1961 makes it obligatory for private enterprises to engage a certain proportion of ITI trained personnel
- NVTs thus serves organized industrial sector; covers merely 10% of total economically active labour force
- Agricultural workers remain excluded
- Education and training of farmers is the single largest contributor for growth and development in developing countries (WB). Pay

offs are far greater if access of education and training is improved to girls and women

- Strategic training initiative involving PPP on the lines of NVTs will be highly desirable.

National Training System for Agricultural Workers (NTSAW)

- Necessary to strengthen and develop skilled human resource that can make most out of the emerging opportunities in place of over-emphasized misgivings
- Basic to L3 to respond rapidly to changing technologies and labour market demand
- Required to minimize (i) shift from artisans to unskilled employment, (ii) unemployment due to seasonal factors and (iii) migration from rural to urban areas
- Needed to promote science and market-driven agriculture. This trend ropes in increasingly prominent role of private sector

NTSAW – Structuring Proposal

- A statutory body may be created to frame policies, lay down standards, plan, co-ordinate and manage NTSAW
- A PP supported nodal institute needs to be established with mandate for: curricula, media and training material development; advancing research and policy advice; making training need assessment and repository of information on farm labour and developing materials and standards for instructor training
- ICAR institutes; SAUs and their RRS; State Departments of Agriculture and KVKs based upon mandate and capabilities provide instructor training and farmers' training.
- Firm partnership of and linkage with private training institutes and agro-business industry needs to be integrated to enhance reach, connectivity and market linkages.

Moving PPP from Rhetoric to Reality

- Prepare a National Policy on PPP in HRD, which *inter alia* lays down clear guidelines and regulations governing PPP
- Identify subjects and areas
- Establish PPP processing cells in the institutes of NARS. Define structure, drawing (preferably) members from existing institute, research and management bodies
- Set-up an monitoring and evaluation unit to guide and facilitate PPP initiatives

ANNEXURE

Proceedings of the 'ICAR-Industry Meet— Agricultural Transformation through Public- Private Partnership: An Interface'

The 'ICAR-Industry Meet—Agricultural Transformation through Public-Private Partnership: An Interface' was inaugurated by Hon'ble Shri Sharad Pawar, Union Minister for Agriculture, Consumers Affairs, Food and Public Distribution on 19 January 2006. The session was chaired by Dr Mangala Rai, Secretary (DARE) and Director-General (ICAR). Twenty-three invited experts from private and public organizations, out of 24, presented a wide spectrum on agriculture.

Dr Mangala Rai welcomed the Chief Guest as well as the participants from different public and private organizations. He focussed on the large number of technologies generated by the ICAR Institutes and Agricultural Universities, which need to be transferred to different end-users in a participatory mode with the industry. He requested the industry to come forward to work in collaboration with the National Agricultural Research System, so that both can benefit from mutual exchange of ideas and technologies. He also suggested industries to benefit from the infrastructure available with the ICAR for carrying out need-based research in important areas through contract research and contract services. He said that misconceptions, if any, in the minds of anyone, need to be removed at the earliest. The partnership has to be on one-to-one basis. Dr Mangala Rai also appreciated the presence of a large number of experts/officials from various organizations for attending this important meeting. He thanked the Hon'ble Union Minister for Agriculture for encouragement and support received in organizing for the first time this important event in the ICAR at such a scale.

Shri Sharad Pawar, Hon'ble Minister for Agriculture, delivered the inaugural address. He complemented the ICAR, and said, a good beginning has been made, and said that all should join hands in addressing problems and potentials in a holistic manner. He highlighted the advantage of forming alliances. The Public-Private Partnership (PPP) will help in reducing cost of development of processes and technologies. The partnership can be successful only if both the sides agree on the scope of the alliance, viz. strategic, economic and operational. There should be no mistrust in partnership, as otherwise, it will result in failure; and the profit needs to be shared equally between stakeholders. In the past we had fruitful interactions between the public institutions and the private sector in several areas of agriculture. While public-funded organizations have significant

research results and the ability to observe uncertainties of pay-offs, the private sector seems to have an edge in factoring clients into design of technologies and in diffusion process. In view of the changing framework of the research and development processes in agriculture and the high potential of the Public-Private Partnership to enable a faster technological change in a more sustainable, socially and ethically responsive manner, this interface was convened. The specific outcome of the interface would be road map for developing strategies for the three P's i.e. Public-Private Partnership in agriculture. He was confident that this Interface would help in forming alliances and set the tone for continued dialogue between the public and private sectors for mutual exchange of ideas. Shri Sharad Pawar ji also released 5th revised and enlarged edition of *Handbook of Agriculture*, brought Out by the DIPA, ICAR, New Delhi.

Dr B R Barwale (Chairman, M/s MAHYCO Research Foundation, Pune) in his address on 'Partnership for Prosperity' mentioned that MAHYCO and ICRISAT had joined hands to form a consortium with half-a-dozen organizations, which proved to be a success. He suggested that the MAHYCO, ICRISAT and the ICAR should join hands to solve problems of *Helicoverpa* in pigeonpea and develop good hybrid pigeonpea, which shall double production of the crop in the country. He said, there is a need for having bilateral agreement between the public and private sectors, and in that its secrecy be maintained with respect to technologies to be developed. He said, partnership may be initiated on this important crop as it has tremendous potential and needs solution for increasing yields. The Director-General (ICAR) agreed for forging an effective partnership.

Dr N K Singh (Principal Scientist, National Research Centre on Plant Biotechnology, New Delhi), talked on 'Capabilities in Agricultural Biotechnology', and emphasized on the need for attaining Ever Green Revolution and enumerated strengths of public and private sectors. He also listed major achievements made in biotechnology and suggested the mode of public-private partnership model to be adopted in this important area.

Dr S N Singh (Managing Director, M/s Biovet Pvt. Ltd, Pune), gave lecture on 'Vaccines in Animal Health' and listed a large number of vaccines developed in the area of Animal Health to control various diseases. The world is paying greater attention towards animal health. Due to a large number of emerging diseases, there is a need to prevent spread of these diseases by developing suitable vaccines through public-private partnership. India is fortunate that its livestock are free from various diseases, and there is a good export potential of its animals and its products. Proper hygienic environment needs to be provided and standard abattoirs need to be established to meet standards set-forth by other countries. The Director-General assured that ICAR is ready to join hands with interested parties in this strategic area.

Dr O P Singh (Chief Executive Officer, M/s Venkateshwara Hatcheries Pvt. Ltd, Pune), briefed about the poultry industry, and informed that its contribution to Gross Domestic Product is 12%. He emphasized on the need

to protect local germplasm; as 85% of the egg production is from the local germplasm. Breeding programmes, value-addition, food safety and public health, quarantine, food and nutrient bio-availability, practical animal nutrition, graduate programme in poultry science, feed production, farm-waste management and its safe disposal, insurance plan, industrial ecology, credit availability, cold chain are some of the areas, where according to him, there can be partnership between the public and private sectors. Research support is needed for production of amino acids production, vitamins production, reduction of excise duty, improved quality of soy and maize as feed for birds and prebiotics and probiotics production. He showed willingness to take active part in collaborative research in identified areas, and stressed for formulation of 'National Poultry Development Plan'. The Director-General (ICAR) appreciated the presentation and said that all angularities in implementation of the joint programme need to be removed, if we have to move forward in public-private partnership.

Shri Suresh A Kotak (Chairman, M/s Kotak Industries, Mumbai) presented a brief overview and status of textile industry in India and abroad, and dwelt on shortcomings and strengths of the textile industry. He emphasized the need for development of value-chain in textile sector at different stages of production of textile fabric and yarn, and said that our strength is that the Indian cotton varieties are of good fibre strength. China imports approximately 1 million bales from India, and it is expected to increase to 3 million in future. From 25 to 30% world export trade is from India, and textiles contribute 3% to the GDP, which is expected to double in future. The extra long staple bales, eco-friendly short-to-medium cotton and supply of improved seed of long staple cotton to Gujarat were also discussed. There is a need for technology-upgradation fund, market development assistance and market-area initiatives.

Dr P L Kaul (President, Food Processors' Association, New Delhi) gave a brief account of different post-harvest facilities and technologies available in India and compared the processing capabilities with other neighbouring countries. He also highlighted generation of rural employment through setting-up of agro-processing centres in villages and reduction of post-harvest losses. The post-harvest management contribution to GDP could be enhanced from 6 to 10%. He emphasized on high levels of investments in food-processing sector, as also on the forward and backward linkages to realize full potential. Three models of processing — large, medium and small — to suit different commodities and investment potentials were also discussed through potato processing.

Dr A Banerjee (President, Indian Dairy Association, New Delhi) presented global scenario of the Dairy Industry and brought out diversification that can be achieved in the sector. He dwelt on cattle improvement, health-care and feed, and on needs for public-private partnership in this area. Value-addition and waste handling and disposal were also discussed. He suggested development of technology parks that can serve as the vending source of information and material.

Dr G Kalloo (DDG, Horticulture, and with Additional charge of Crop Sciences, ICAR, New Delhi) made a presentation on the 'Crop Varieties and Horticulture Planting Material' and listed various potential areas : exchange of germplasm, seed, disease diagnostics, *in-vitro* multiplication and sensitive viral detection techniques for public-private partnership.

Dr D K Arora (Director, NBAIM, Mau) highlighted diversity of microorganisms and their potential that can be harnessed in different aspects of agriculture. He briefed about biofertilizers, biocontrol agents, bioprocessing and waste recycling and sources of valuable genes.

Dr S Kundu [General-Manager (Technical), M/s Excel Industries, Mumbai], presented the process of aerobic composting and benefits of organic manures in agriculture, and underlined the need for development of standards for certification of organic manures.

Dr J C Katyal (Director, School of Agriculture, Indira Gandhi National Open University, New Delhi) presented immense possibilities of public-private partnership in human resource development in agriculture. He talked about the wealth of trained manpower that India possesses in agriculture, including Information Technology and Biotechnology. He gave the example of the Industrial Training Institutes and called for the National Training System for Agricultural Workers (NTSAW). He emphasized movement of researchers between public and private systems to harness best of the two sectors.

Dr S Maiti (Director, National Research Centre on Medicinal and Aromatic Plants, Anand) made a detailed presentation on the potentials of the market with US \$5 billion in the world. Top 100-traded medicinal plants of India were listed. The capacities of private sector in extraction and formulation were emphasized.

Dr S Ayyappan [DDG (Fisheries), ICAR, New Delhi], gave an overview of fisheries and aquaculture in the country, including export status. Issues of marine and inland fisheries that are being managed by the public and private sectors as also the cooperatives and NGOs were highlighted. The future possibilities in marine fisheries management, in seed production, feed and health sector, quality assurance, and boat-and net-making, processing, for public-private partnership were discussed.

Dr Vishnu Swarup [Director (Research and Development), Indo-American Hybrid Seeds (India) Pvt. Ltd, New Delhi] gave a brief account on the public-private partnership possibilities in floriculture and horticulture, and in India's share in global market worth US \$ 9.4 billion, from the present 0.18%. He suggested areas of post-harvest management and packaging of flowers, design of low-cost greenhouses and net-houses for Indian conditions, and human resource development for public-private partnership.

Dr T P Rajendran [ADG (Plant Protection), ICAR, New Delhi] emphasized the biological control methods and suggested public-private partnership areas as designs of applicators of biocontrol agents, identification of active principles of different agents and large-scale production of hormones.

Dr M P Yadav (Director, IVRI, Izatnagar), presented an account of 'Biologicals in Animal Husbandry'. He presented briefly different diagnostic kits developed for different diseases of livestock. He emphasized the need for standards for vaccines as also the need for uniform pricing of vaccines.

Dr B N Vyas (Vice President, M/s Godrej Agro-Vet, Mumbai), deliberated on the biocontrol agents, and brought out the need for harmonization of standards, introduction of pesticides and biocides in a systematic manner with awareness programmes for farmers, quality assurance in herbal formulations and registration of formulations being produced by the Government Institutions.

Dr S M Ilyas (Vice-Chancellor, Narendra Dev University of Agriculture and Technology, Faizabad), gave an overall account of post-harvest technology and its scope in agriculture. He briefed on the reduction of post-harvest losses, value-addition in different commodities, food safety and quality and related aspects. Human resource development in terms of inclusion of the subject in the Industrial Training Institutes was also emphasized, along with job potentials.

Prof M M Mehta (Former-Vice President, M/s Escorts Pvt. Ltd, Faridabad), gave a brief account of farm mechanization in India, and the accomplishments through public-private partnership in the area. Farm machinery worth Rs 500,000 million is being manufactured in the country annually. He suggested that the ICAR should send all the publications in the relevant areas through registered associations to have a wide reach in the country.

Dr C Devakumar (Principal Scientist, Indian Agricultural Research Institute, New Delhi), spoke on the global scenario of agro-biochemicals and suggested development of database on available chemicals and their use in different crop systems, and indicated industries that can be targeted for public-private partnership along with the issues.

Dr Mruthyanjaya (National Director, National Agricultural Innovative Project, New Delhi), presented the institutional views on the public-private partnership in agriculture, and highlighted the likely problems and means of overcoming them for successful partnership. Potential areas for public-private partnership were listed and organization of match-making workshops was suggested. He also suggested formulation of a policy for the purpose.

Dr R D Kapoor (Regulatory Lead, M/s Monsanto India Ltd, New Delhi), presented the Industry views on public-private partnership in agriculture. According to him public institutions need to help private sector for testing and evaluation of products and processes. The aspects of proprietary products, equated subsidy and self-certification were discussed. Alliances for empowerment, joint helpline, support to social programmes and joint Intellectual Property Rights management were suggested. The need for joint monitoring and mid-course correction in projects as also the facility of sabbatical for staff members was also highlighted.

Dr N Srinivasan (Chief General Manager, National Bank for Agriculture and Rural Development (NABARD), Pune), explained various

programmes of the NABARD, with case studies and detailed procedure of project formulation and evaluation and offered the assistance of the NABARD in facilitating public-private partnership.

There were detailed discussions on the presentations made in different sessions, and also at the end of all the sessions on 20 January 2006. They were mainly on-farm testing of new technologies, seed quality improvement, one window for commercialization of technologies, soil-testing laboratories, value-chain in different aspects, water, weedicide, smaller machinery and appropriate technologies, custom-hiring, mobile feed dryers, use of fertilizers and micronutrients, extension systems and mobility of researchers between public and private sectors.

ACTION POINTS

The Action points emerged from the ICAR-Industry Meet are enumerated as follows.

1. A Network project on 'Pigeonpea improvement through transgenics for resistance to *Helicoverpa* between ICAR and M/s MAHYCO, Pune, and ICRISAT, Hyderabad, to be developed, for funding by the ICAR.
2. A day's meet on 'Dairy, Cattle and Buffalo Improvement' to be organized in the next 3 months and a Roadmap for Public-Private Partnership in the area to be developed.
3. Four Working Groups, would deliberate on issues of Public-Private Partnership in (i) Diagnostics and vaccines, (ii) Processing, value-addition, farm implements and machinery, (iii) Seed and planting material; and (iv) Biocontrol agents.
4. Joint efforts by the public and private sectors in the areas of poultry germplasm identification and protection, food safety and feed production including amino acid production, cold chain and NPDP
5. Technology upgradation and incubation for scaling up food-processing methods and enabling higher investments for setting-up pilot plants.
6. Establishment of technology parks in institutions for hands-on-exposure to farmers and entrepreneurs and circulation of relevant ICAR publications through registered associations.
7. Collaborative work between fisheries institutes and private shrimp hatchery operators for developing protocols for captive broodstock development of shrimp.
8. Enabling mechanisms of mobility for researchers between the public and private sectors in different areas, as also representations on each others' management to be developed.
9. The guidelines for Memorandum of Understanding for public-private partnership would be developed, for facilitating public-private partnership in agricultural research and education in a more effective manner.
10. The ICAR-Industry Meet to be an annual event.
11. Full Proceedings of the Meet to be published.

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