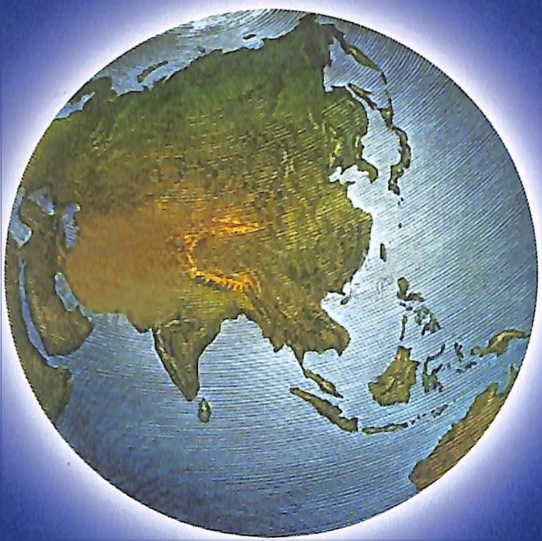
Biosecurity



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Foreword

India's preparedness and capability in the area of biosecurity is a serious concern, particularly after the detection of the H5N1 strain of avian influenza virus in many parts of the country. Agricultural biosecurity is of special significance in India, since it relates to the livelihood and health security of a major percentage of the population and also to the trade security of the nation. The National Commission on Farmers (NCF) in its report stressed the need for a systematic review of the present infrastructure and institutional framework in the area of agricultural biosecurity, including the World Trade Organisation specifications of sanitary and phytosanitary measures. It stressed the urgent need for a National Biosecurity System, with three principal goals:

i) To safeguard the income and livelihood security of farm and fishing families and the food, health, and trade security of the nation, through effective and integrated surveillance, vigilance, prevention, and control mechanisms to protect the productivity and safety of crops, farm animals, fish and forest trees.

ii) To enhance national and local level capacity for proactive measures in monitoring, early warning, education, research and international cooperation, combined with an integrated biosecurity package of regulatory measures, education, and social mobilisation.

iii) A coordinated national biosecurity programme on a hub-and-spokes model with effective home and regional quarantine facilities, able to insulate the major agro-ecological and farming zones of the country from invasive alien species of insects, pests, pathogens, and weeds. It is crucially urgent to take action on this.

Public awareness on various aspects of biosecurity is most essential to the defined tasks. Much research and development work is needed for a system of laboratories adequate to identify pathogens and disease and keep up a stockpile of vaccines. We must identify and review all existing acts related to biosecurity, and create a national biosecurity policy. Biosecurity should become not only the objective of the government and educational institutions but also the motto of each of us in India. This will vitally strengthen our ability to block the outbreak of disease pandemics and to initiate timely and effective control measures.

In November 2006, the National Institute of Advanced Studies, Bangalore and the M S Swaminathan Research Foundation, Chennai, organized a two-day Discussion Meeting on Setting up a National Agenda for Biosecurity, held at the J R D Tata Auditorium in NIAS. Many invited experts, leading policy makers, officials from key Government departments and other stakeholders participated. The presentations included overviews, current systems and procedures of defence, international comparisons and the international framework in which India's efforts must be set, pest-by-pest and disease-by-disease accounts of possible dangers, and salutary accounts of past and current accidental attacks. Speakers made clear that in today's global trade, even an infestation that is limited in area or in direct damage to crops can devastate the bio-economics of the entire country (via defensive import bans imposed by trade partners) unless a convincingly effective scheme of quarantine, assessment, control and eradication is in place.

Defence against these threats means defence of a complex, richly interacting system, and requires the understanding and integrated management of it that respects all its aspects. The impact of a plant disease varies with humidity, and a flood or drought brings ecological disturbance beyond its direct effects. For this reason, many speakers stressed the need for a unified body possessed of expertise and authority for biosecurity as a whole, rather than a fragmented set of agencies defending production of (*e.g.*) fish or cotton, lacking the obligation and skills to consider the broader impact on environment, human health and trade. A full network of secure and effective laboratories must exist for research and assessment of dangerous organisms, so that their danger can both be handled effectively and be seen internationally to be handled effectively, avoiding the economic multiplier effect of mistrust. Decisions such as eradication and quarantine measures must take into account not only their local impact on trade and livelihood, but also the wider impact of failure to act, both on trade in a specific crop and the national and international credibility of the system. The international organisations which address biosecurity must be embraced in mutually earned respect and partnership.

Evidently such a system must be multi-tier, allowing concentration of knowledge both bio-economic and geographical, down to the grass-roots level. Speakers made clear that it must have legislative, not merely administrative, authority, and the capacity to enforce needed measures. Individuals and groups need to avoid actions that put their own ecology at risk, and in some cases to take positive action for control and eradication of problem species. Thus, as many speakers pointed out, there is a vital need to build public awareness, involvement, and trust. The media must fully participate in spreading the sometimes complex knowledge needed, and the public — as much as international partners — must be convinced that government action is rooted in impartial scientific competence: this is as unending and vital a task as biological defence itself. The public must trust and follow their leaders in biosecurity defence, and must have strong reasons too. Good governance is indivisible. The key recommendations of the discussion meeting for ensuring bio happiness in our country, based on a scientifically sound and socially relevant agenda for biosecurity in appropriate areas of concern, are clearly set out in this book. They are a strong call for action.

My special thanks to Professor M S Swaminathan for his unstinting support to my colleague, Professor P K Shetty, and also to Dr Ajay Parida for helping them in preparing the text of the book. I take this opportunity to thank all the three editors in bringing out an important book on biosecurity.

K Kasturirangan
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Preface

Biosecurity needs a strategic and integrated approach that encompasses the policy and regulatory frameworks that analyse and manage risks in the sectors of food safety, animal life, plant life and health, including associated environmental risk. Currently, India has no effective system to detect, report and effectively mitigate outbreaks of new diseases or pests in crops and animals. We have no validated strategies to intervene in our food production, processing and distribution system after intentional contamination or biosecurity threat.

India is one of the countries most vulnerable to threats of bioterrorism. With growing concerns for the security of agriculture, the environment, and human health, in November 2006 the National Institute of Advanced Studies, Bangalore and the M S Swaminathan Research Foundation, Chennai, jointly organized a discussion meeting on Setting up a National Agenda Towards Biosecurity, focused on issues related to biosecurity, biosafety, biohazards and bioterrorism and its relevance to India. The discussion included biosecurity specialists, policy makers and individuals from various organizations, including the Indian Council of Agricultural Research (ICAR), New Delhi; International Crops Research Institute for the Semi-Arid Tropics (ICRISAT), Hyderabad; Department of Biotechnology (DBT), Government of India, New Delhi; National Bureau of Plant Genetic Resources (NBPGR), New Delhi; High Security Animal Disease Laboratory (HSADL), Bhopal; Central Food Technological Research Institute (CFTRI), Mysore; National Institute of Virology (NIV), Pune; National Institute of Nutrition (NIN), Hyderabad; National Centre for Integrated Pest Management (NCIPM), New Delhi; Bhabha Atomic Research Centre (BARC), Mumbai; and Food and Agricultural Organization (FAO), New Delhi. The outcomes include the following key recommendations on regulatory system, technical requirements and capacity building that need urgent attention.

Regulatory/Policy Issues:

i) India needs a biosecurity policy to safeguard the income and livelihood of the farm sector, to enhance national capacity and to monitor, warn, educate and build infrastructure for containment of any eventual pandemic.

ii) All departments and Ministries must converge effort to develop a coherent biosecurity strategy. Regulatory measures, education, and social mobilization are the three vital pillars in a biosecurity strategy.

iii) There is an urgent need to set up a National Agricultural Biosecurity System with three main components; the Union Minister for Agriculture must chair a National Agricultural Biosecurity Council whose four wings deal with crops, farm animals, living aquatic resources and agriculturally important micro-organisms, handling the analysis, averting and management of risk, and an early warning system. A National Agricultural Biosecurity Network will serve as the coordinating and facilitating scientific partnership between various institutions engaged in bio-monitoring and other biosecurity programmes.

Technical Issues:

i) India must update its risk classification of microorganisms, as the present one is outdated, and set up a network of high security labs (biosafety levels 3 and 4) across the country, with at least one national level 4 lab connected to level 3 regional labs each in the north, south, west and east.

ii) Biosecurity in aquaculture requires five main operational programmes: Pre-border quarantine certification and surveillance; Border quarantine; Regular post-border surveillance programmes; Incursion response control for exotic pathogens; and Disease management for established pathogens.

iii) A national surveillance system for exotic diseases and a Rapid Response Team to contain the problem is essential for India.

iv) Molecular epidemiology of nutrition deficiency/genetic susceptibility to degenerative diseases for early detection. Food and nutritional security issues in India demand a multidisciplinary blend of biotechnology, pharmacogenomics, molecular medicine and nanotechnology.

v) Classification of bioweapons by taxonomy, effects and mode of delivery.

vi) Radiation techniques give the most effective mode for protection from biohazards, with no residues even for pre-packed commodities. This would help quarantine meet the requirements of importers and exporters.

vii) Microchips can be used for quick and efficient detection of many viruses.

viii) There is a need for close collaborations in emergency scenarios, as in the cases of NIV (ICMR) and High Risk Security Lab (ICAR) for Avian flu.

ix) Lack of scientific information and proper database (especially of potentially dangerous viruses) increases biosecurity threats. There are five sophisticated and modernised plant quarantine stations in India, but we still need to meet international standards in several areas.

Capacity Building:

i) Biosecurity Literacy is essential. Each and every panchayat needs a trained man and woman as biosecurity managers.

ii) A focussed threat/risk analysis, followed by capacity building in diagnosis and preparedness, developing emergency action plan and an integrated National Bio-security Centre is the need of the hour. Some models on biosecurity set up in countries such as New Zealand, USA, Australia and Belize could be followed in India.

iii) A knowledge centre, to act primarily as a think tank for futuristic agricultural developments. This centre will use space sensing, geographic information and high science agricultural systems modelling to suggest land use options in different Agri-Export Zones (AEZs); frame policy/inter-institutional pathways to resource conservation; guidelines to embed IT and knowledge tools in agricultural research and development systems; and best response strategies to contain global change.

iv) It is essential to strengthen Plant Quarantine (PQ) facilities. We must train PQ officers in Pest Risk Analysis, surveillance and molecular diagnosis of pests, and develop 'Quarantina' and 'Phytopest' software and a PQ website to spread information on regulations/procedures/standards concerning import/export of agricultural commodities.

Addressing and implementing of the above concerns are vital to biohappiness in our country and will strengthen our ability to minimise the risk factors from any eventual bioattacks.

This book contains lead papers from the discussion meeting and also contributed papers, from distinguished biosecurity specialists. We thank all contributors to this volume. Our special thanks to Dr K Kasturirangan, Director, National Institute of Advanced Studies and Ms Radha Singh, Secretary, Department of Agriculture and Cooperation, Government of India for their support in organising the meeting at NIAS. We thank Advanced Research Institute, Bangalore for their help in organising the discussion meeting on biosecurity and also preparation of this book. We are very grateful to Prof Mahadevappa (former Vice Chancellor, UAS, Dharwad), Dr Ravi Khetarpal (Head, Division of Quarantine, National Bureau of Plant Genetic Resources, New Delhi) and Prof Tim Poston (Sir Ashetosh Mukherjee Professor, NIAS) for their valuable suggestions in preparing this text. We thank Ms K Shashikala, Indian Academy of Sciences, and Ms K G Sreeja, Research Scholar, NIAS for copy-editing this volume. We thank Dr G N Hariharan, MSSRF, Dr Sangeetha Menon, NIAS, and M Nanditha for their valuable contribution. Ms V B Mariyammal of NIAS deserves special thanks for her work at many stages of its preparation.

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Content

Preparedness for Ensuring Biosecurity

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The whole area of biosecurity is a very critical issue for national security. In the last several years the world has been concerned about the broad area of biosecurity. Biosecurity involves all kinds of threats to security from microbes to man, to the entire biological kingdom. It has been accentuated in the industrialized countries because of mad cow disease, then SARS, and now the H5N1 strain of avian influenza, many of them spreading largely because our world has become a global village, thanks to advances in communication including mobile phones. This has positive and negative implications. Among the negative implications is the probability of transmission of pests and diseases from one country to another or one region to another in a very speedy way. Transboundary pests pose a serious threat to food and health security. One of the early big epidemics, which led to changes in the course of history - the great Irish potato famine - was caused by the fungus *Phytophthora infestans*. In the 1840s when the potato famine occurred, suddenly a new strain of the fungus wiped out the entire potato crop. A large number of Irish settlers in the United States came from the Irish famine era.

One of the threats to human security is hunger. Recently I heard the World Food Day address by Robert Gates, who was then President of the Texas A&M University in the United States. He is now the new Defence Secretary of the U.S. in the place of Mr David Rumsfeld. He said the CIA of the United States collects reliable data on potential hunger hot spots around the world. They monitor the status of crops all over the world because hunger hot spots are also potential unrest areas. Where hunger rules, peace cannot prevail. This is why the CIA monitors the state of food crops. "A hungry person listens neither to reason, nor religion, nor is bent by any prayer" as pointed out by the Roman Philosopher Seneca over 2000 years ago. That is why food security and nutrition security are important not only for the health of individuals but also for human security in a broader sense of law and order, of peace and security. This is why biosecurity needs serious attention.

The National Commission on Farmers has proposed a National Agricultural Biosecurity System. Sometimes a lack of scientific information in the biosecurity area can lead to accusations. Recently in Libya, five Bulgarian nurses were about to be sentenced to death, accused that they had introduced HIV/AIDS into a hospital. Some of you might have read the book which deals with the whole origin of HIV/AIDS. It accused an American genetic engineer Koprowski, who did some experiments on African chimpanzees, of being responsible for the origin of HIV/AIDS. There was a meeting at the Royal Society of London to discuss the accusations in that book and it was found that Koprowski had done nothing scientifically unethical. But we know it came from chimpanzees in Africa. Why did HIV/AIDS suddenly become so important? Nobody had heard about it. So we are having new problems, new diseases and one does not know their origin. Sometimes there could be accusations based upon inadequate scientific information or suspicion. So this area has become a very sensitive area in many respects.

The global village has accentuated the possibility of rapid transmission. We currently import large quantities of wheat and other crops, and the danger of introducing invasive alien species of weeds, pests and pathogens has grown. Our infrastructure for sanitary and phytosanitary measures is still weak. Biosecurity needs a strategic and integrated approach that encompasses both policy and regulatory frameworks that analyze and manage risks relating to animal life and health, plant life, food safety and health, including environmental risks. For example, in northeast India, invasive alien species like eupatorium, mikania and lantana have affected animal biodiversity since these species are not edible. Biosecurity also covers the introduction of plant pests. The Protection of Plant Varieties and Farmers' Rights Act prohibits the introduction of genetically modified crops except through a prescribed regulatory procedure. So, biosecurity is a holistic concept with direct relevance to sustainable agriculture, food safety as well as protection of environment.

What we need is a national bio-security system, because of the linkages between human health and diseases like the Mad Cow Disease in cattle. The National

Biosecurity System should be capable of safeguarding the income and livelihood security of farm and fisher families as well as the food, health and trade security of the nation. Trade security is very important. Safety was one of the reasons why earlier many of our mangoes were prohibited. Irradiation can now sterilize some of them. But when importing countries place embargoes when they know of *salmonella* infection of fish or aflatoxin, mycotoxins, aspergillus infection in groundnut and so on, our trade is affected. For sustainable trade security, it is necessary to understand the import restrictions in the countries to which exports are to be made.

If Europeans come to know that a rice variety is genetically modified, they will not allow it to be imported. That is why traders are against experiments involving genetic modification of basmati rice since the European Union is not allowing any genetically modified food. We need a coordinated national agricultural biosecurity programme on a hub-and-spokes model, because ours is a large country. A well equipped National Institute for Biosecurity can service regional laboratories.

Alien invasive species are dangerous. The National Bureau of Plant Genetic Resources, National Bureau of Animal Genetic Resources and National Bureau of Fish Genetic Resources, all have important responsibilities to monitor the arrival of invasive species. If such species are found, effective steps should be taken to contain these threats.

Risk analysis is now a very detailed science. Risk prediction, risk analysis and risk management are components of biosecurity systems. The Disaster Management Authority is also concerned with the risk analysis techniques not only for natural risks like cyclonic storms, tsunamis and many others, but also for biological risks. We must standardize terminology and methodology while respecting the need for individual sectors to tailor the analytical procedures. Risk analysis procedures should be science-based and transparent. That is very important. They must be based on science, not just on intuitive feelings.

Our fast-expanding trade has intensified the need for effective risk analysis for bilateral and multilaterally agreed standards. In the last 15 years, after the Marrakesh agreement, there has been great interest in sanitary and phyto-sanitary (SPS) measures under the World Trade Agreement.

We should have done it in any case, but sensitivity has grown because of international pressures on SPS. We have developed national standards for pest risk analysis; we have also developed guidelines for certification for wood packaging material, quarantine treatment and application procedures, and also for assessment, audit and accreditation of fumigation agencies for undertaking methyl bromide fumigation. We have also established some pest-free areas for mangoes. These pest-free or disease-free zones are important for export. If we have a disease-free zone in animals then export becomes easy. In the case of seed potato, the crop should be grown during the aphid-free season.

After the WTO agreement we had to take steps to organise a single Central Government authority as responsible for implementation of SPS measures, reviewing and upgrading legislation and regulations relating to SPS. This is also very important to give effect to international agreements and for standardising national standards on SPS measures, notification procedures, risk analysis methods and so on, conforming as far as possible to international standards. This is where the FAO is playing an important role in developing broad international guidelines.

According to the National Bureau of Plant Genetic Resources, several alien, invasive species have been introduced in the country in recent years. In the nineties, for instance, sunflower downy mildew and coffee pod borer were very important problems in the Malnad area of Karnataka. There was a great deal of fear of what would happen, and a number of meetings were held. With increasing intensification of agricultural production, productivity and trade, invasive alien species will further threaten our crops. Crop security should hence receive high priority.

We have strengthened our quarantine stations with the help of the FAO. Vizag has become a very important part now for importing wheat, and of course Kandla in Gujarat has been very important. So we must now strengthen them with a major investment in core plant quarantine stations, in both import and export. The 24 quarantine stations have been classified into three broad categories, based on the nature and volume of material received in each of these stations. The priority was given to Delhi, Mumbai, Kolkata, Chennai, and Amritsar.

We should promote an integrated pest surveillance system, and organize field inspection and pest surveillance activities. There is also a need for more *biosecurity literacy*. The National Commission on Farmers has recommended training programmes at the level of each Panchayat, electing one woman and one male member of each Panchayat trained as Biosecurity Managers. We should have a decentralized system, and make use of the Panchayat Raj institutions, because 1.2 million women and 2 million men are there in the Panchayats. If we develop some training modules and then train these people in suitable institutions on what is biosecurity, they can take it up in the Gram Sabha. This is participatory democracy. I believe that pest surveillance should include a very strong literacy movement, apart from diagnostic laboratories which we must strengthen.

Biosecurity is increasing in importance in the fisheries and aquaculture sectors. In fact, what was considered to be a sunrise industry suddenly became a sunset industry – aquaculture – as a result of diseases, all along the Andhra Coast. The Supreme Court had to intervene, everything had to be stopped and a potentially very important industry came into trouble because we did not make some minor investments in looking after the health of the seed used, examination and so on, which could have saved us from a very large disaster. These essential ingredients of bio-security are what we do not recognize in our country.

Not all alien species are bad. That is why I used the word 'invasive', because most of our important crops such as wheat and barley came from the Fertile Crescent (from Egypt to the Persian Gulf, around the Arabian desert). That area was the home of many of these cereals. So, we have introduced a lot of plants from outside, including the new world potato, tomato and maize – none of them are our plants. So, plant introduction is not a bad thing, but how to do it without endangering many of our native ones? This is the problem. So, the issue is not to ban alien species, nor to abandon regulations for their movement, but to assess the risks and benefits associated with their use and implement plans for their safe and responsible use. The safe and responsible use of bio-technology is the very basis of scientific ethics. J R D Tata suggested an institution like NIAS for the purpose of promoting scientific humanism and humanistic science, combining the two. This requires ethical principles of scientific management. So the issue is neither to ban alien species nor to abandon regulation but to assess the risks and benefits associated with their use and develop and implement plans for their responsible use. We should not insulate our country from any kind of introduction. How to do it in a responsible and safe way? That is the challenge.

There is a large debate on exotic species of fish, for example, if you take the pisciculture of grass carp and various kinds of native carp including katla, mrigal and rohu. But we have also introduced the silver carp and grass carp from outside. There are people who believe that such introductions are not good. There is also the question of seaweed cultivation in the Gulf of Mannar. There has been a large amount of debate on introduced brown algae into the country since they are very aggressive. The exotic weeds like *Parthenium, Lantana, Ipomea cornea*, etc. are everywhere because they are not our plants, but they have invaded. Also these invasive species are successful because they are non-edible to local animals. So evaluation of proposals for introduction should be objective, management of exotics should be present, and necessary infrastructure and human resources should be urgently provided for effective implementation of the above plan.

Biosecurity in livestock

The most acute problem is in livestock, with an estimated annual loss of about five thousand crores as a result of epidemic outbreaks in our country, and recently in the industrialized countries also. In the UK, at the height of mad cow disease, the whole area was stinking, because they were burning the animals. It was really a sad sight to see. Similarly our poultry birds were culled because of the threat of H5N1 strain of avian influenza. So the greatly accentuated livestock biosecurity problems are generally linked with unmindful industrialized production. Producers introduce from somewhere some material like hybrid broilers, and in that process sometimes new diseases come in, if there are not adequate quarantine measures. A very high-yielding Honey Bee strain from Italy was introduced but brought with it a serious disease. Good intentions can bring disaster in the longer run. Blue Tongue in sheep is a very important problem. I was there as the Head of the Indian Council of Agricultural Research. We had a lot of discussion on where did this Blue Tongue come from? How was it introduced? Marek's disease also come from outside.

Vaccination has also become a controversy, because a vaccinated animal can be a silent carrier. For example, the poultry industry in India, after H5N1 strain, was against vaccination, and there are a number of examples of this kind. This is why some believe culling is better than vaccination, because vaccines obstruct testing for the disease. They can also perpetuate and spread the disease and can also lead to the origin of a more virulent strain, as has happened with H5N1 in China.

Should there not be a decontamination policy? Will the Government allow import of any vaccinated animal into the country without quarantine? The United States doesn't allow it. The UK doesn't allow it. Even if you give certification that you have vaccinated, they won't allow it. The animal goes into a quarantine centre before it is released. Even with vaccination, we must have a quarantine arrangement also. This is where professional advice is very important. Migratory animals are also there. The Gujjars, for example in the Himalayas, take their animals high up for grazing. They go from Kutch to a number of places for fodder, although this is now becoming a problem because the other people are not allowing these animals to come. And so there is a problem of fodder and feed. Migratory animals also can transmit some diseases along with the dung.

High-quality, safe, potent, and efficacious vaccines require quality assurance procedures to ensure the uniformity and consistency of the production process. Worldwide harmonization of standards has become important as a result of the World Trade Agreement. This is where the FAO's role in standardization becomes important.

Policy and Regulatory Frameworks must have three important elements – education, regulation and social mobilization. Education is exceedingly important. That is why I said, in any Panchayat we must have one woman and one male trained as local biosecurity managers. Regulation is exceedingly important. And finally, unless people cooperate, regulations will not be effective. This is one of the problems in our country. So social mobilization as well as regulation and education – these are the three pillars for the successful implementation of any policy or regulatory framework.

In quarantine matters, there is need for both bilateral and multilateral agreements. For example, after Mr. Bush visited us early this year the US and India agreed that we can now export our mangoes to the United States. I still recall when Jawaharlal Nehru went in the fifties to the United States he wanted to include mangoes in his dinner for the President of United States. But the US customs wouldn't allow entry of mangoes. I was working at the Indian Agricultural Research Institute at that time. There were a lot of suggestions on how to allow the Prime Minister to take Alfonso mangoes with him. Finally, the US Authorities asked for the package to be handed over on arrival. They agreed to return the mango pulp immediately. All the rest was incinerated. That kind of precaution is exceedingly important for the purpose of ensuring the safety of agriculture.

A National Agriculture Biosecurity System has been recommended by the National Commission on Farmers to the Government of India. Agriculture is still the backbone of livelihood for 70% of our population. Rural India has 70% of our population and the major occupation of rural people is crop husbandry, animal husbandry, fisheries, forestry and agro-processing. Therefore, a National Agriculture Biosecurity System is important. It should have three components: a Biosecurity Council, which has to provide the political and policy overview; A National Centre for Agricultural Biosecurity, like an upgraded Bhopal Centre with four wings, for crops, animals, aquatic resources and micro-organisms; and a National Agriculture Bio-security Network, bringing together Agricultural Universities, ICAR and CSIR institutions, ICMR institutions and all other concerned institutions. We need all the three components - a Biosecurity Council for policy and political commitment, a very strong scientific centre, which must be the authority in the country in the biosecurity area, and also a network of the institutions involved in it.

There is also need for a National Agriculture Biosecurity Fund, because many times an urgent problem crops up. Suddenly disease outbreaks happen, like for example the H5N1 strain of poultry influenza. A biosecurity fund will help strengthen the infrastructure for sanitary and phyto-sanitary measures, upgrading facilities for plant, animal and fish quarantine and certification. Fish quarantine is an absolute necessity with such a large fishery industry.

Offshore genetic screening centre

When the poultry was being killed, the area possessed a lot of indigenous poultry. We don't know whether any of them were resistant or not. We were killing indiscriminately. If we had an offshore unmanned quarantine station (fortunately, in the Lakshadweep group of islands we have a number of islands where nobody is living, we can convert one of them into an offshore quarantine centre) we could take some of these wild birds over there and test them. If we identify a gene for resistance, immediately we have a new opportunity for disease management. On the other hand, by killing all the indigenous material, we are also foreclosing the option of trying to identify genes for resistance. It would not cost much to put up an offshore quarantine station. Even the Italian honeybee could first be introduced there and then taken to the mainland after six months, and so on. We must strengthen our infrastructure for offshore quarantine and genetic screening centers.

Eternal vigilance is the price of stable agriculture. Many times serious pests may be introduced unknowingly. Poinsettia is a very common Christmas plant. It is being imported in large quantities from outside. Now they have discovered that many of these Christmas poinsettias lead to a serious whitefly outbreak. Any quarantine of a plant should not be influenced by sentiment or by political pressure. A report of this is in *Nature* of 26 October 2006.

Bioterrorism is another kind of problem, which requires a different kind of expertise. Today, for example, genetically modified disease causing organisms could be developed. About 50 years ago, Bertrand Russell and Einstein started a movement called the Pugwash movement – I am the current President. The Pugwash manifesto says, "remember your humanity, forget everything else", otherwise you will end in a disaster. Today, science can be abused for wrong purposes. As the power of science grows, the ethical and moral responsibility of scientists for the consequences of their work also increases. That is why most scientific laboratories today have an Ethics committee to guide the design and implementation of recombinant DNA and cloning experiments.

Plant Biosecurity in India

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The introduction of new pests into a locality is brought about in various ways: (a) a host may be the carrier; (b) inert materials such as packing material may carry resting stages of the organism; (c) insect vectors and birds may transport them; (d) air currents may carry them long distances, or (e) deliberate, illegal introduction as bioweapons. The first two modes of distribution lend themselves to curtailment by quarantine measures. The next two are by and large beyond human control, and are a major limitation in the control of pests by exclusion. This creates the need for biosecurity. Biosecurity is a strategic and integrated approach that encompasses the policy and regulatory frameworks to analyse and manage risks in the sectors of food safety, animal life and health, and also plant life and health, including associated environmental risks. It covers the introduction of plant pests, animal pests and diseases, and zoonoses, introduction and release of genetically modified organisms (GMOs) and their products, and introduction and management of invasive alien species and genotypes (http://www.fao.org). Thus, biosecurity is a holistic concept of direct relevance to the sustainability of agriculture, food safety, and protection of the environment, including biodiversity. This theme paper confines itself to the phytosanitary aspects of biosecurity, with focus on dangers from exotic pests, state of preparedness and the need for a holistic approach to the issues.

The devastating effects of diseases and pests introduced along with international movement of plant material, agricultural produce and products are well documented (Khetarpal *et al.*, 2001; Khetarpal 2004; Gupta *et al.*, 2005). The historical Irish famine of 1845, caused by the late blight of potato introduced from Central America, coffee rust introduced in Sri Lanka in 1875 and its subsequent introduction in India in 1876, fluted scale on citrus introduced from Sri Lanka in 1928, San Jose scale in apple introduced into India in the 1930s, bunchy top of banana introduced from Sri Lanka in 1943, the dreaded golden nematodes infesting potatoes introduced in 1960s from the UK, and the noxious weed *Lantana camara* introduced in 1809 from Central America, are glaring examples that clearly demonstrate that introduction and establishment of quarantine pests, including weeds, into new areas can severely damage the crop production and economy of a region or country. Some instances of crop pests being used or threatened for agro-warfare are when Germany dropped the dreaded Colorado potato beetles (*Leptinotarsa decimlineata*) in potato fields of the UK during World War II; on several occasions Cuba accused the US of attacking Cuban crops through pests like tobacco blue mold, sugarcane rust and *Thrips palmi*; opponents of the Idi Amin regime threatened to poison Uganda's coffee and tea plantations to deny the government foreign exchange; and recently a Florida University Professor informed CIA that the outbreak of citrus canker in Florida was a result of the Cuban biological weapons programme.

Plant quarantining is a government endeavour enforced through legislative measures to regulate the introduction of planting materials, plant products, soil, living organisms, etc. in order to prevent inadvertent introduction of pests (including fungi, bacteria, viruses, nematodes, insects and weeds) harmful to the agriculture of a country/state/region, and if they are introduced, to prevent their establishment and further spread. After the Second World War, the FAO convened an International Plant Protection Convention (IPPC) in 1951, to which India became a party in 1956 along with Australia, Sri Lanka, UK, Netherlands, Indonesia, Portugal and Vietnam. At present, it has more than 160 signatory members. The IPPC aims to develop international cooperation among various countries to prevent the introduction and spread of regulated pests along with the international movement of plants and planting material (http://www.ippc.org). The IPPC requires that each country establish a national plant protection organization to discharge the functions specified by it.

National plant quarantine set-up

1. Legislation

The Government of India enacted the Destructive Insects and Pests (DIP) Act in 1914. This Act has been amended through various notifications issued from time to time and also has provision for domestic quarantine to restrict the movement of certain plant materials from one state to another state. In 1984, a notification was issued under this Act, namely the Plants, Fruits and Seeds (Regulation of Import into India) Order popularly known as the PFS Order which was revised in 1989 after the announcement of the New Policy on Seed Development by the Government of India in 1988, proposing major modifications for smooth quarantine functioning. This Order has now been superseded by the *Plant Quarantine (Regulation for Import into India) Order 2003*, which came into force as there was urgent need to fill the gaps in the existing PFS order regarding import of germplasm/genetically modified organisms (GMO's)/ transgenic plant material/biocontrol agents, etc., to fulfill India's legal obligations under the international agreements. Under this Order, the need for incorporation of additional/special declarations for freedom of import commodities from quarantine and invasive alien species (IAS), on the basis of standardized pest risk analysis (PRA), particularly for seed/ planting materials, is also taken care of. The other salient features of the Order include prohibition on import of commodities with weed/ alien species contamination as per Schedule VIII; and restriction on import of packaging material of plant origin unless treated. Besides, agricultural imports have been classified as: (a) Prohibited plant species (Schedule IV); (b) Restricted species where import is permitted only by authorized institutions (Schedule V); (c) Restricted species permitted only with additional declarations of freedom from quarantine/ regulated pests and subject to specified treatment certifications (Schedule VI); and (d) Plant material imported for consumption/ industrial processing permitted with a normal Phytosanitary Certificate (Schedule VII). So far, i.e., till March 2007, ten amendments of the Plant Quarantine (PQ) Order 2003 have been notified to the WTO, with revised requirements for crops under schedules V, VI and VII, of which schedules VI and VII now include 411 and 284 crops/ commodities, respectively. Issues related to IAS and GMOs are covered under the Environment Protection Act (EPA) 1986 but the Act does not state in clear terms the modality for restriction and prohibition of their potential threats to the environment (Khetarpal and Gupta, 2006b).

2. Infrastructure

The Directorate of Plant Protection Quarantine and Storage (DPPQS) of Ministry of Agriculture is the apex body for implementation of plant quarantine regulations. It has a national network of 29 plant quarantine stations at different airports (10), seaports (10) and land frontiers (9). In all, two categories of materials are now imported under the PQ Order, 2003: (a) bulk consignments for consumption and sowing/ planting, and (b) samples of germplasm in small quantities for research purposes. The Plant Quarantine stations under the DPPQS undertake quarantine processing and clearance of consignments of the first category (http://www.plantquarantineindia.org). The five major Plant Quarantine stations have been modernized recently under an FAO-UNDP funded project.

The National Bureau of Plant Genetic Resources (NBPGR) undertakes the quarantine processing of all plant germplasm and transgenic planting material under exchange for which it has well-equipped laboratories and greenhouse complexes, and a containment facility has also been established recently for processing transgenics (Khetarpal *et al.*, 2004). NBPGR also has a well-equipped quarantine station at Hyderabad, which mainly deals with export samples of the International Crop Research Institute for semi-arid tropics (Chakravarty *et al.*, 2005).

3. Risk associated with imports

Of the material being imported, bulk imports for sowing/planting carry maximum risk as thorough examination and treatment becomes difficult, and the planting area involved is also very large. Quarantine processing is often restricted to smaller derived samples, and based on results from these samples a whole consignment is rejected, detained or released after fumigation or fungicidal/ insecticidal treatments. The bulk consignments meant for consumption pose lesser hazards. However, certain small samples meant for research purposes are of immense quarantine importance. These samples usually comprise germplasm material, wild relatives or landraces of a crop, and are thus more likely to carry diverse biotypes/ races/ strains of the pest. Besides, in the case of true seeds, generally, risks are more due to deep-seated infections than with surface-borne contamination. However, import of vegetative propagules present a much higher order of risk than true seeds.

4. Interceptions in imported material

Over the years, during quarantine processing, a large number of pests have been intercepted in imported bulk consignments (http://www.plantquarantineindia.org) and in germplasm and other research material (Khetarpal *et al.*, 2001). The pests intercepted include many that are not known to occur in India, have different races/biotypes/strains not known in India, are present on a new host, are from a country from where they were never reported before or are an entirely new pest species hitherto unreported in science or reported to be present widely in India (Table 1). Several interceptions have also been made in imported transgenic material including downy mildew caused by *Peronospora manschurica* in Soybean from USA and *Cryptolestes ferrugenius* in paddy from Singapore, which are yet unknown or are not reported from India. These interceptions, especially of pests and their variants not yet reported from India signify the importance of quarantining in preventing the introduction of destructive exotic pests.

Table 1: Examples of different categories of pests intercepted in quarantine

Category of pest intercepted	*Pest / host / source country*
Not known to occur in India	*Peronospora manschurica*/ soybean/ USA *Uromyces betae*/ sugarbeet/ USA and Italy *Fusarium nivale*/ *wheat*/ UK *Cowpea mottle virus*/ cowpea/ Philippines *Tomato black ring virus*/french bean/ CIAT (Colombia) *Heterodera schachtii*/ sugarbeet/ Denmark *Anthonomus grandis*/ cotton/ USA *Quadrastichodella eucalyptii*/ eucalyptus/ Australia
Known to occur but the race/ biotype/strain intercepted is not known to occur	*Helminthosporium maydis*/ *race T*/ sorghum/ USA *Pea seed-borne mosaic virus*/ broadbean *Burkholderia solanacearum* biovar 3/groundnut/ Australia
Intercepted on a host on which it was never reported before	*Alternaria zinniae*/ tobacco/ Japan *Pseudomonas syringae* pv *syringae*/ *Hibiscus cannabinus*/ Bangladesh *Aphelenchoides besseyi*/ *Stylosanthes hamata*/ Australia *Aphelenchoides besseyi* on *Fraximus Americana, Merobruchus columbinus*/ *Samanea saman*/ UK *Bruchus ervi*/ *Acacia brachustachva*/ Australia *Pachymerus lacerdae*/ *Orbygnya phalerata*/ Italy

Category of pest intercepted	*Pest / host / source country*
Intercepted from a country from where it was never reported before	*Peronospora manschurica*/ soybean/ Malaysia *Heterodera zeae*/ *Vetiveria zizanioides*/Tanzania *Bruchus ervi*/ *Acacia brachustachva*/ Australia
A new species hitherto unreported	*Drechslera pluriseptata*/*Eleusine coracana*/ Zambia *Tylenchorhynchus neoclavicaudatus* on potato tubers from USA *Polenchus minutus*/palm plants/UK
Known to occur in India but possess a wide host range	*Collectotrichum graminicola, Drechslera turcica* and *Gloeocercospora sorghi*/ sorghum/ Nigeria *Drechslera siccans*/ soybean/ USA *Claviceps purpurea*/ *Avena sativa*/ USA *Drechslera sorokiniana*/ *Carthamus tinctorius*/ Italy, USA

Source: Khetarpal and Gupta, 2006a

5. Safe movement of transgenics

The rules for safe use and release of GMOs have been notified under the EPA. The Department of Biotechnology (DBT) of the Ministry of Science and Technology reviews, permits and monitors the experiments utilizing GMOs and recombinant DNA products, while the MoEF implements their large-scale commercial use through its Genetic Engineering Approval Committee (GEAC). The biosafety guidelines prepared by DBT in 1990 which have subsequently been revised, requires that every organization involved in work on GM plants to set up its Institutional Biosafety Committee (IBSC) for interaction with the Government. Various committees have been formed by DBT with well-defined objectives for implementing the biosafety guidelines. The Review Committee for Genetic Manipulation (RCGM), a national committee under the DBT, reviews the ongoing R&D projects on GMOs, undertakes field visits of experimental sites and issues clearance for import/ export of GMOs for research and training. The RCGM has also constituted a Monitoring-cum-Evaluation Committee to monitor the limited field trials for which permission for multi-locational field-testing has been accorded. In addition, the concerned committees of each state and district are also involved in the monitoring of the experiments at their respective field sites (Khetarpal and Pandey, 2001). By the PQ Order 2003, the NBPGR is responsible for ensuring that imported transgenic materials are free from pests and terminator gene technology.

Potential threat of biowarfare

The potential for misuse on mishandling of dangerous pests not so far reported from India causing harm to human beings and ecosystems on a large scale is also an issue of national concern. The agricultural economy is vulnerable to threat from exotic pests/ diseases that could be used as bioweapons (Table 2). Besides, a large number of destructive agricultural pests have strains/ isolates/ biotypes reported that could be used as bioweapons, which includes viruses such as the *Rice tungro bacilliform virus* with four variables isolated from South Asia; *Rice tungro spherical virus* whose Indian isolate is different from South-East Asian isolates, *Cotton leaf curl virus* which causes severe damage in Pakistan but has a limited distribution in India, *Groundnut bud necrosis virus* having a wide host range, *Banana bunchy top virus* with five identified strains and *Tobacco streak virus, Citrus tristeza virus* and *Mungbean yellow mosaic virus* with several strains reported. The pathogens causing serious diseases, where variability has been reported, are cereal rusts caused by *Puccinia triticina* (whose spores are air-borne, and of which a number of virulent pathotypes are known), Rice blast *(Pyricularia oryzae*, with a high degree of variability), *Bulkholderia solanacearum* (whose race 2 is not known in India) and *Xanthomonas campestris* pv *malvacearum* (of which the most virulent pathovar in Africa, XcmN, is not known in India). The insects whose biotypes have been reported include *Bemisia tabaci*, (a highly polyphagous pest which attacks more than 600 host plant species and has 16 known biotypes); brown plant hopper *(Nilaparvata lugens*, whose biotypes in India differ from those in other Asian countries); rice gall midge *(Orseolia oryzae*, has six biotypes known from India), red-flour beetle *(Tribolium castaneum*, whose strains show variability in level of pesticide resistance). Several races are also reported for nematodes like *Meloidogyne incognita, M. javanica/ M. arenaria* and *Heterodera avenae.*

Ethically, the potential for harm must be weighed against scientific, or commercial freedom for research and to develop microbes for useful reasons. Given the invasions of ecological systems by alien species, as well as the potential for bioterrorism, we need to foster policies and technological capabilities to prevent, detect, and respond to incidents involving such acts

(Rana *et al.*, 2004). Lack of genetic diversity in certain cases limits natural defenses to disease and to biological agents that are intentionally introduced into an environment.

Table 2: Major threats from devastating exotic plant pests/diseases

Bacterial and Fungal Pathogens • Bacterial wilt and ring rot of potato (*Clavibacter michiganensis* sub sp. *sepedonicus*) • Fire blight of apple and pear (*Erwinia amylovora*) • Black pod of cocoa (*Phytophthora megakarya*) • Powdery rust of coffee (*Hemelia coffeicola*) • Sudden death of oak (*Phytophthora ramorum*) • South American leaf blight of rubber (*Microcyclus ulei*) • Vascular wilt of oil palm (*Fusarium oxysporum* f sp. *elaedis*) • Soybean downy mildew (*Peronospora manshurica*) • Blue mold of tobacco (*P. hyocyami* sub sp. *tabacina*) • Tropical rust of maize (*Physopella zeae*)
Viruses, Viroids and Phytoplasma • *Barley stripe mosaic virus* • Coconut cadang cadang (Viroid) • Palm lethal yellowing (Phytoplasma)
Nematodes • Pine-wood nematode (*Bursaphelenchus xylophilus*) • Red-ring nematode of coconut (*Rhadinaphelenchus cocophilus*)
Insects • Mediterranean fruit fly (*Ceratitis capitata*) • Cotton boll weevil (*Anthonomus grandis*) • Russian wheat aphid (*Diuraphis noxia*)

Introduction of naturally occurring or manmade genetically modified (e.g., recombinant DNA) viruses and experimental biotechnology into weaponry, livestock, crops and medicine is controversial because, if not adequately controlled, these may threaten the well-being of entire populations and ecosystems. The new biological strains of plant pathogens can easily cause significant harm, as often observed in the case of livestock, because they rapidly infect elements of ecosystems that have not yet developed immunity.

Issues to be addressed

The National Plant Protection Organization needs to be upgraded in terms of manpower, infrastructure and capabilities to bring it up to international standards, as the increase in imports and the stipulation of WTO under its SPS Agreement has brought additional challenges to be faced by plant-protection personnel (Khetarpal and Gupta, 2002). Strengthening would be not only for prevention of attack by exotic pests, but also to check the interstate spread of indigenous pests by effective implementation of domestic quarantine regulations against certain important pests, which have been introduced/ detected in the country in recent years and which are likely to spread fast.

The Pest Risk Analysis Unit established under the DPPQS needs to be strengthened to carry out risk analyses for each commodity under import, be it plant/ animal/ GMO/ microorganism/ biocontrol agent to minimize or eliminate the utilization of techniques for detection of pests and would facilitate the quick and safe transboundary movement of material. It should also recognize that the risk analysis procedures should provide a basis for biosecurity and not create barriers to trade (Gupta and Khetarpal, 2004).

There is a need to reprioritize our research projects based on critical gaps identified in meeting the requirements for export and import. A few that need immediate emphasis are survey and surveillance of disease/ pests of national and international importance to exercise endemic pest data; generation of comprehensive epidemiological data on important pests, in order to be able to fix *tolerance limits,* to develop PRA and identify PFAs as per WTO norms. It is also a top priority to develop diagnostic protocols using molecular techniques for detection of exotic pests and their variables not easily detectable otherwise, but of grave economic concern and evaluation of the biosafety risks in import of transgenics and beneficial biocontrol agents. Methods also need to be developed to detect the presence of transgenic/GM contamination (deliberate or inadvertent mixing of GM seeds with non-GM seeds) in unknown samples during quarantine processing.

There is also a dire need to develop an accessible platform for obtaining information on biosecurity for policy makers, administrators and industry groups. A website http://www.plantquarantineindia.org consisting of a national database on legislation, quarantine procedures, methodologies, etc., designed by DPPQS is available. Compilations on potential quarantine pests of various crop groups are being created at NBPGR (Dev *et al.*, 2005). However, an internet-based portal mechanism needs to be developed for easy accessibility of information, and exchange of official information on food safety, and animal and plant health and the environment (like the International Portal for Food Safety and Animal and Plant Health, http://www.ipfsaph.org/En/default.jsp), to facilitate communication among countries in these sectors. Awareness about biosecurity is urgently required among the scientific fraternity and the general public to generate respect for regulations in the interest of national security.

Need for a holistic strategy on biosecurity

In the light of the above information, there is an urgent need for a holistic concept to address the problem of biosecurity. Internationally, the Agreement on the Application of Sanitary and Phytosanitary Measures of the WTO, disciplines SPS measures in relation to international trade. The Codex Alimentarius Commission (Codex), the IPPC and the Office International Des Ppizooties (OIE) provide international standards for food safety, plant health, and animal health, respectively. Further, the Cartagena Protocol of Convention on Biological Diversity (CBD) applies to the transboundary movement, transit, handling and use of Living Genetically Modified Organisms (LMOs). Guidelines on the management of invasive alien species have been developed under the SBSTTA of CBD (Khetarpal *et al.*, 2006). This group of international agreements, organizations and programmes is part of a loose international framework for biosecurity, and reflects the sectorial approach to regulation in this area. Also, it is clear that under the present international scenario, plant protection specialists have a major role to play not only in promoting and facilitating the export and import of biomaterial in the interest of their respective nations, but also in protecting the environment from the onslaught of invasive alien pests and unforeseen ill-effects of introduction and trading in GMOs. Besides, the possible threat to national biosecurity from the use of instruments such as bioweapons to create agroterrorism requires preparedness.

The holistic approach to ensure biosecurity seeks to use the synergies of various existing sectors at the national level, without necessarily creating new structures. It further recognizes the need for integration of various aspects of biosecurity and the institutions involved. There is need to establish a National Plant

Biosecurity System comprising a National Plant Biosecurity Centre (NPBC) to deal with plants, animals, living aquatic resources, and agriculturally important microorganisms as its four major divisions, with the Ministry of Home Affairs (MoHA) at the helm of affairs. MoHA has the National Disaster Management Authority that can properly monitor and regulate the biosecurity issues. Besides, MoHA is also the nodal point of the National Crisis Management Plan 2003. Therefore, if we are to have an effective biosecurity system in the future, it has to be under the MoHA so that matters related to both biosecurity and bioterrorism (agroterrosim) can be dealt with more effectively, and funds can be routed in the correct direction. The emergency-action plan and the rapid-response team that are critical in case of outbreak of an epidemic also need to be with MoHA. The MoA under the Indian Council of Agricultural Research (ICAR) has excellent researchers and laboratories in the field of plant protection, which would support and work in a networking mode for diagnostics and control of diseases/pests in case of emergent situations. Hence, a network of various ministries like MoEF, Ministry of Health and Family Welfare (MoHFW), Ministry of Defence (MoD), Ministry of Food (MoF) and Ministry of Science and Technology (MoST) could work in close collaboration with the MoHA for developing an effective Plant Biosecurity System at the National level.

Perspectives

Biosecurity will be ensured only when there is an integrated approach to deal with its various components. Models to rationalize regulatory functions among sectors in a quest for improved effectiveness and efficiency have appeared in a number of countries. For example, New Zealand has had a Biosecurity Act since 1993 and a Biosecurity Minister and Council since 1999. In US, the Department of Homeland Security was created in 2002 with as many as 22 agencies, including the US Department of Agriculture's Animal and Plant Health Inspection Service. Likewise, the Australian government has established Biosecurity, Australia. In Belize, food safety, and animal and plant quarantine and environmental issues are dealt with by a single authority, the Belize Agricultural and Health Authority. For a biosecure India, there is a need to establish a National Biosecurity Centre, which would deal with biosecurity in a comprehensive manner to achieve food safety, protect animal and plant life and health, and also protect the environment. Risk analysis and early warning systems are the most important unifying concept cutting across different biosecurity sectors that would help in tackling emergency situations. What we need is a synergy of expertise from various organizations under the Ministries of Agriculture, Science and Technology, Home Affairs, Commerce and Industry and Defence. Most of all, we need the political will to take comprehensive action.

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Biosecurity in Aquaculture

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Disease outbreaks are increasingly recognized as a significant constraint on aquaculture production and trade, and seen to affect the economic development of the sector in many countries of the world. Disease is now considered the most limiting factor in the shrimp culture sub-sector. Diseases due to viral infection are not easily treated with current technology, and have caused significant economic losses. Potential economic losses from disease outbreaks are significant, and can affect the survival of the industry. Some figures are available on direct economic losses, which indicate the significance of the problem. Social and other related impacts, such as trade and employment issues, chemical and drug use, and environmental costs, have never been properly quantified. It is estimated that India loses an annual revenue of Rs. 300 crores due to shrimp viral disease outbreaks alone (mainly due to white spot disease), and during the last one decade, the accumulated losses have been estimated to be about Rs. 3000 crores (Vijayan *et al.*, 2005). According to a World Bank report, global losses due to shrimp disease are around US$3000 million and the Bank recommends investment of US$275 million in shrimp disease research over the next 15 years (Lundin, 1996).

Asia is the hub of aquaculture and India is one of the major producers of fish. Around 80% of the world's aquaculture production comes from Asia. Disease is considered to be the most limiting factor on shrimp culture. Most outbreaks can be linked to introduction of aquatic organisms (OIE, 2003). In 1989, six viruses were known to affect penaeid shrimps, but by 1997, more than 20 viruses were identified as having affected wild stocks and commercial production. The OIE now lists seven viral diseases of shrimp in the Aquatic Animal Health Code (OIE, 2003), which are considered to be transmissible and of significant socio-economic and/or public health importance. These viral diseases are: White Spot Disease, Yellow Head Disease, Taura Syndrome, Spawner-isolated Mortality Virus Disease, Tetrahedral Baculovirosis, Spherical Baculovirosis, and Infectious Hypodermal and Haematopoietic Necrosis (OIE, 2003). In India, the prevalence of WSSV is well established, but reports on the occurrence of yellow head virus and monodon baculovirus in shrimps need further confirmation.

In fin fishes, India is still fortunate that none of the OIE notifiable diseases have been reported, except for epizootic ulcerative syndrome and some reports on the noda virus. However, the recent outbreak of Koi herpes virus in the South-East Asian countries is a cause of worry for the country. Koi herpes virus (KHV), a highly contagious viral disease in fish, may cause significant morbidity (sickness or disease) and mortality in common carp, *Cyprinus carpio* (Hedrick *et al.*, 2000). This species is raised as a food fish in many countries and has been selectively bred for the ornamental fish industry, where it is known as Koi. Historically, the first outbreak of KHV was reported in 1998 and confirmed in 1999 in Israel. Since then, other cases have been confirmed in the United States, Europe and Asia. KHV disease may cause 80–100% mortality in affected populations, and the virus disease affects fish of various ages. As large numbers of ornamental fishes, especially Koi, are being imported to India, there is a high risk of KHV entering the country.

It is thus clear that a significant challenge to the expansion of aquaculture production is the outbreak of disease. Potential economic losses from disease outbreaks are significant, and can affect the survival of the industry. The occurrence of disease results from a combination of the health of the animal, the condition of the environment, and the presence of a pathogen. The most effective way to deal with viral infection is to prevent it from occurring, through proper biosecurity measures. The key elements of biosecurity are a reliable source of stocks, adequate detection and diagnostic methods for excludable diseases, disinfection and pathogen eradication methods, best management practices, and practical and acceptable legislation.

There are two major platforms for implementing biosecurity measures, at national level and at production level.

Biosecurity in aquaculture at national level

The elementary definition of "Biosecurity conditions" by OIE is as follows: "A set of conditions applying to a particular disease or infection, and a particular zone or country, required to ensure adequate biosecurity", namely:

- the disease is compulsorily notifiable to the Competent Authority;
- an early detection system is in place within the zone or country;
- no vaccination against the disease is carried out;
- infection is not known to be established in wild populations;
- import requirements to prevent the introduction of disease or infection into the country or zone, as outlined in the Aquatic Code, are in place

The scope of aquatic biosecurity is summarized in its definition, "Protection from the risks posed by organisms to the fisheries economy, environment and aquatic animal health through exclusion, eradication and control".

Biosecurity provides scientific quarantine assessments and policy advice that protects the country's favorable pest and disease status and enhances its access to international markets. An important component of biosecurity is import risk analysis. The process of developing a new quarantine policy, where no policy exists, begins with Import Risk Analysis (IRA), which is undertaken by a team of scientists and technical specialists.

Biosecurity in aquaculture not only protects the aquaculture production system but also safeguards human health and consumer confidence in aquatic animal products. It also preserves the aquatic environment and promotes sustainable production. Diseases in aquatic animals are among the major threats to increasing aquaculture production, and most of these diseases are the consequence of unregulated movement of live aquatic animals, resulting in unintentional transfer of pathogens. The implementation of biosecurity measures provides a strategic framework and integrated approach to assess the risks associated with movement of live aquatic animals. The three main aspects of biosecurity in aquaculture are:

- introduction of exotic or alien fish species,
- aquatic animal pathogens/ diseases,
- genetically modified organisms (GMOs).

Exotic species have had a role in increasing aquaculture production in some countries, but can have negative effect to the rich aquatic biodiversity of our country. To respond to emerging needs, introduction and management of exotic fish species should be done in a controlled manner after careful assessment. Introduction of exotic pathogens can be avoided in aquaculture through the implementation of pre-quarantine and post-quarantine measures. One key pre-quarantine measure is Import Risk Analysis (IRA). IRA of live aquatic animals and aquatic animal products would prevent the spread of pathogens through imported consignments.

Disease surveillance and reporting are considered to be another fundamental component of any national strategy on aquatic animal health, and form an integral part of aquatic animal biosecurity. Active surveillance helps in rapid detection of new pathogens. Accurate description of the distribution and occurrence of diseases provides evidence for freedom from disease and assessment of control measures. Besides, active surveillance programmes will facilitate health certification for our aquatic animal exports, giving a much-needed credibility to our exports in the international markets, and help the country to facilitate import and export without harm to either our native fish population or our aquatic ecosystem.

As a World Trade Organization (WTO) member, our country is obliged, under the Agreement on the Application of Sanitary and Phytosanitary Measures (SPS Agreement), to consider all import requests from other countries concerning agricultural products, just as other member countries are obliged to consider our requests. Decisions to permit or reject an import application can be made only on sound scientific grounds. Biosecurity works with the main international agencies that set standards for animal and plant health, and food. Biosecurity safeguards the country's economy and aquatic environment from the risks of introduced pests and diseases. In addition to trying to prevent the arrival of new pests and diseases, and unwanted aquatic animal species, biosecurity involves getting rid of, and controlling those that are already here. Biosecurity is as strategically important as national security, by protecting key economic and environmental assets. Biosecurity helps in protection of aquatic animal health, the natural environment that is unique and special to this land, native flora and fauna, our biodiversity, our marine areas and a range of resources uniquely important to the country. These measures involve a delicate balancing act that requires sound judgment, expert science, compliance with international obligations, community engagement and coordinated action with many other agencies and partners.

Biosecurity can mean different things to different stakeholders. Consumers want to have the assurance that the product is safe for use, which means that processors should follow Hazard Analysis and Critical Control Point (HACCP) guidelines to ensure that their products are safe for human consumption. At the production level, workers need to know what practices decrease or increase the risk of a disease outbreak occurring. In general, the entire aquaculture industry is concerned about disease outbreaks.

The occurrence of disease is the result of a combination of the health status of the animal, the condition of the environment, and the presence of a pathogen. Klesius *et al.*, (2003) used the disease continuum model to illustrate how outbreaks of disease were the result of a weakened immune system of the culture animals, caused by neuro-immune changes resulting from stresses and infection. Therefore, excluding infectious agents and reducing stress are important in preventing disease outbreaks.

At the National level aquatic animal biosecurity is achieved through five main operational programmes:

(i) Pre-border quarantine,
(ii) border quarantine,
(iii) post-border surveillance,
(iv) incursion response, and
(v) disease management activities.

These are supported by research and other scientific inputs, awareness building and the education of stakeholders and the public, and enforcement activities.

The planning of aquatic biosecurity measures should include technical evaluation of the optimal balance of the application of specific pre-border and border surveillance, and response procedures to ensure prevention of entry, early detection of entry, and post-entry and cost-effective eradication of potential exotic organisms.

Pre-border Surveillance: Pre-border biosecurity measures are designed to prevent threats from reaching its borders. These include the following.

- Procedures for the identification of risk consignments and the definition of procedures which minimize the associated risks prior to arrival of consignments at ports of entry. These are determined through processes of risk analysis, development of import health standards (IHS) and statements of conditions of import on import permits.

- Procedures to ensure that the conditions on import permits are met. Conditions might relate to the health status of aquatic populations of source countries, quality systems used in production or inspection and testing of the samples prior to dispatch. Commonly, certification that the requirements have been met ("official assurance") is required from the government of the country of origin.

The desired outcome from pre-border biosecurity measures is that aquatic imports reaching our country are free of biosecurity threats.

Border Surveillance: Border security measures include all measures applied to aquatic consignments arriving at the country's border, which aimed to prevent organisms that present biosecurity risks from entering our national borders. These measures include:

- requiring declarations by importers, regarding biosecurity risks;
- inspection of incoming consignments;
- requirements for live aquatic animals, to be held in secure locations for varying periods of time (quarantine);
- testing random samples of imports for specific risk organisms prior to release.

The purpose of biosecurity border management is to prevent, as far as practicable, the entry of potential aquatic organisms.

Post-border surveillance: Post-border biosecurity surveillance programmes aim to monitor aquatic exotic species and their disease status, and detect any changes. Surveillance programmes include systems for the confirmation of the absence of specific pathogens and disease from another country, detection of organisms new to our country and monitoring of established pathogens in order to detect changes. The desired outcomes from disease surveillance systems are the following.

- Detection of significant organisms new to the country early enough to allow cost-effective eradication responses to be mounted;
- detection of changes in the behaviour and/or distribution of established exotic species with sufficient sensitivity to allow cost-effective management procedures to be implemented, if required; and
- acceptance by our trading partners of official assurances about our country's aquatic exotic species and their disease status.

Incursion response: Incursion responses are activated when exotic organisms are suspected to have somehow passed through the border security systems. A response to a suspected incursion includes all the processes that contribute to identification of the suspect pest, decisions on response procedures and implementation of control or eradication strategies. The desired outcome from a response to an incursion of a new organism is the most cost-effective eradication or control of the organism.

The marine environment is one of the sectors for which a pro-active biosecurity programme is required. A major priority is the definition of the current range of flora and fauna as the baseline against which "incursions" can be determined. Biosecurity measures, such as border security through management of ballast water in ships and a basic surveillance programme are essential. Hence, the major focus should be on establishing a rational approach to marine biosecurity and marine surveillance programmes. There is growing recognition that biosecurity in the marine environment is a tough challenge. Prevention of entry of organisms in ballast water or as part of the fouling flora/fauna on ships may not be possible. Surveillance can be targeted at high-risk areas but there is little international experience to give confidence that an incursion can be met by an effective eradication response. It is probable that most incursions of marine organisms will result in programmes to minimize their impact.

Pathogen/Exotics Management: This deals with the management of aquatic exotics and their diseases which have established themselves in our country.

Biosecurity at production level

(A) In shrimp farming: Biosecurity measures in the shrimp industry can be grouped into two categories based on (i) excluding, and (ii) eliminating pathogens, if present.

Excluding pathogens from entering the production system: Common ways of excluding pathogens from the stock (i.e. post-larvae and broodstock) are through the use of quarantine and specific pathogen-free (SPF) certified stocks, and restrictions on import of live and frozen shrimp. Excluding vectors and external sources of contamination, and preventing internal cross-contamination are suggested methods for excluding pathogens from hatcheries and farms (Lightner, 2003).

Horowitz and Horowitz (2003) described physical, chemical, and biological precautionary measures to be taken as a second line of defense against potential disease outbreaks.

- Physical measures aim to prevent the intrusion of disease-carrying vectors at the farm site. They include physical barriers, water treatment, and quarantine.

- Chemical measures are used to treat materials before they enter the facility. Chlorination and ozonisation are often used to treat incoming water, while iodine and chlorine are used to treat other potential vectors such as tools, footwear, and clothing.

- Biological measures include the use of SPF shrimp, which are readily available commercially. A second line of defense for the shrimp industry is to use specific- pathogen-resistant shrimp. In addition to being disease-free, these are resistant to particular diseases. Since shrimp do not develop a specific immune response, common immunostimulants, such as β-1-3 glucan, lipopolysaccharides, and peptidoglycans are used to improve their ability to withstand infection.

Eliminating pathogens from the production system: During a disease outbreak in a particular pond, effective biosecurity measures can prevent the complete loss of the crop and the spread of disease to other ponds. To eliminate pathogens in post-larvae and broodstock, affected tanks and ponds should be depopulated, disinfected, and restocked with SPF shrimp. It may, however, be necessary to depopulate the entire stock and to leave the entire facility fallow if partial disinfection (using lime, chlorine, or drying) is not successful. Other measures include providing better environmental and biological conditions to the infected population, to increase its ability to resist diseases. These include the following measures.

- Physical measures (increase aeration, control temperature, improve the feeding regime, remove sludge and organic matter, and treat wastewater) to improve the environmental conditions;

- chemical measures, including control of pH and salinity, reduction of ammonia and nitrite, and application of antibiotics; and

- biological measures, consisting mainly of the use of probiotics containing a mix of bacterial species to establish beneficial microbial communities under culture conditions.

(B) In finfish culture: Breuil *et al.*, (2003) has classified the risk factors associated with the rearing of fish in various systems, and grouped them in four categories: (i) meteorological events, such as storms and ocean swells, (ii) ecological events, such as plankton blooms and water pollution, (iii) pathological events, and (iv) other factors, such as mechanical problems. A recycling production system greatly reduces the risk of meteorological and ecological events, except mechanical problems. Implementing biosecurity reduces the risk of pathological events. Yoshimizu (2003) has outlined some common biosecurity measures used against viral diseases in finfish. These control strategies include both physical and biological aspects.

- The physical aspects start with cleaning and disinfecting measures in hatcheries and production facilities. The next step is to disinfect incoming water and wastewater. Fish viruses, which are sensitive to either UV or total residual oxidants (TRO), are inactivated by a treatment of 10^4 to 10^5 μ sec/cm^2 UV or 0.1 to 0.5 mg/mL TROs for 1 min. Ozonated seawater that contains TROs, however, is toxic to fish and should be removed with charcoal. Dedicated equipment, nets, brushes etc., can be disinfected with ozonated or electrolyzed seawater containing 0.5 mg/L of total residual oxidants (TROs) or chlorine for 30 min.

- The biological aspects of disease control include health inspections of broodstock to ensure they are pathogen-free: the health of the fry is also routinely monitored. Larvae cultured in disinfected water may need to have their normal intestinal flora restored. Immunizing stocks, using commercially available vaccines, is the most effective method for controlling diseases that cannot be excluded.

Some of the other biosecurity measures adopted in developed countries for finfish are the "eggs only" policy of Atlantic salmon in USA which eliminates the introduction of many pathogens. Any eggs that are imported into the area must have originated from certified specific disease-free sources, to ensure that diseases are not transmitted vertically. The methods used to disinfect Atlantic salmon eggs usually consist of 100 ppm iodine for 10 min. For other species with eggs that require limited incubation periods, eggs are disinfected with chlorine (0.6 mL 4–6% sodium hypochlorite/L) for 5 min., and then hatched in sterile water. Hatched larvae can be shipped under these conditions. Along with this policy, other biosecurity measures include screening broodstock, disinfection, quarantine, and treatment of the effluent from quarantine facilities (5 ppm chlorine for 10 min and discharge to ground).

Aquaculture biosecurity policies

Aquaculture biosecurity policies vary from farm-level to the international level, and between areas at each of these levels, but several characteristics are essential if aquaculture biosecurity polices are to be successfully implemented. These common characteristics include: (a) scientific decision-making, (b) economic and sociopolitical rationales, (c) standardized and uniform methods, (d) relative ease of application, (e) wide recognition, (f) vertical and horizontal integration, application, and agreement, (g) consistent enforcement, and (h) primary focus on prevention, but with contingencies in place for control and management, or eradication. Scientific methodologies have been developed and applied to risk analyses to form the basis of aquatic animal import health standards. These methodologies should be aimed at:

- decreasing the probability of risk organisms reaching our shores (pre-border measures);
- preventing the entry of organisms that do reach ports of arrival (border security);
- detecting aquatic pathogens and organisms that evade pre-border and border measures, sufficiently early to allow cost-effective eradication (surveillance); and
- having systems and resources in place to allow exotic organisms to be eradicated following their detection (response planning).

International efforts

Some international bodies dealing with biosecurity at a global level that set standards for animal and plant health, and food security are (i) the World Trade Organization and the Agreement on the Application of Sanitary and Phytosanitary Measures (SPS Agreement), (ii) the Food and Agriculture Organization of the United Nation's Codex Alimentarius Commission, which sets international standards relating to food additives, veterinary drugs, and pesticide residues, and codes of conduct, (iii) the International Council for the Exploration of the Sea's (CICES) Code of Practice on Introductions and Transfer of Marine Organisms, (iv) The Office International des Epizooties (OIE), which informs member countries of aquatic animal disease outbreaks throughout the world, studies new ways of controlling aquatic animal diseases and sets international standards; and (v) the International Plant Protection Convention (IPPC) which provides a framework for international cooperation, sets international standards and exchanges information on plant health.

The primary focus of all these bodies is on enhancing or protecting trade through biosecurity. OIE performs the role of informing governments of the occurrence and course of aquatic animal diseases throughout the world, suggesting ways to control them, coordinating studies devoted to the surveillance and control of animal disease, and harmonising regulations for trade in aquatic animals and animal products among its 158 member countries. The OIE "International Aquatic Animal Health Code" and "Diagnostic Manual for Aquatic Animal Diseases" set international guidelines to prevent the movement of aquatic animal pathogens and diseases.

Countries like Australia and New Zealand have a separate Biosecurity Division of the Ministry of Agriculture and Forestry (MAF) that has the lead role in preventing unwanted pests and diseases being imported, and in controlling, managing or eradicating those that do manage to enter. Australia is one of the countries with a very effective policy on biosecurity for aquatic animals. Also, has a comprehensive biosecurity program (AQUAPLAN) in place that provides overall management strategy for aquatic animal health (Findlay 2003). This programme applies integrated management strategies right from the borders to individual farms or specific areas, using OIE guidelines that have helped Australia to gain a trustworthy reputation in trade. The Australian Quarantine and Inspection Service (AQIS) and Biosecurity Australia manage the quarantine programmes in the country. Biosecurity Australia has an *Import Risk Analysis Handbook* (AQIS, 1998) that details the process of import risk analysis, which is pivotal to every programme within AQUAPLAN. In descriptive terms, AQUAPLAN is a very conservative approach to quarantine risk, i.e., it permits only a very low risk for imported aquatic animals. Its success can be measured in improved aquatic animal health management in Australia, increased productivity and improved sustainability of its aquaculture, improved market access, and better protection for Australian aquatic ecosystems.

Efforts of NBFGR on biosecurity at national level

One of the important mandates of the National Bureau of Fish Genetic Resources (NBFGR) is "monitoring the introduction of exotics in Indian waters". In this regard the Exotics & Fish Quarantine Section of NBFGR has prepared two important documents, *viz.* "National Strategic Plan for Aquatic Exotics and Quarantine" and "Aquatic exotics and quarantine guidelines". These documents were prepared after a brainstorming meeting involving all the ICAR fisheries institutes, universities, fisheries experts, the Ministry of Agriculture, and the industry. The purpose of these documents are to promote the introduction of exotics for aquaculture, while safeguarding our biodiversity and preventing economic loss. These documents address the effective tackling of exotic species invasion and their disease problems, by improving our understanding and awareness of them, enhancing our knowledge and research efforts, strengthening management response and building the appropriate institutional mechanisms. The Ministry of Agricuture has approved the plan and the guidelines for regulation of the fish trade in our country.

NBFGR is an active member of the National Committee on introduction of exotic aquatic species. A proforma to evaluate proposals for introduction has also been prepared by the Bureau, which serves as an application form for importers. All the import proposals for aquatic finfishes, ornamental fishes, crustaceans, etc., are directed to NBFGR by the Ministry of Agriculture for evaluation with respect to their disease and ecological risks. Import proposals for the introduction of broodstock of crustaceans, fin fishes, and freshwater and marine ornamental fishes are evaluated and the inputs given to the Ministry. A list of 59 ornamental fish species has been cleared by NBFGR, based on ecological risks.

Introduction of exotic aquatic species can lead to disease outbreaks and unintentional introduction of new pathogens into the aquaculture system. Previously, India did not have facilities for the detection of exotic pathogens; now, NBFGR has developed a diagnostic capability for a number of OIE-listed pathogens based on molecular techniques, which can help in the screening of fishes. Recently, NBFGR has come out with two important publications on "Fish Introductions and Quarantine: Indian Perspective" and "Field guide for OIE and FAO/NACA listed aquatic animal disease". Both the publications provide information on quarantine policies in India.

Conclusion

Biosecurity can be applied to aquaculture production systems through a variety of management strategies and by following internationally agreed upon policies and guidelines. An important biosecurity measure is to develop an effective quarantine system in our country, so as to avoid the introduction of exotic pathogens. Besides, the development of a standardized surveillance and reporting system will assist in the identification of the range and distribution of pathogens of interest that affect the aquaculture industry. This would allow better targeting of efforts to control and reduce the risk of spread of diseases. Surveillance at the national level informs the competent authority about the disease situation in the country, absence or presence of disease in the country; and provide, early warning of disease emergence, facilitates more specific contingency planning, and strengthens international confidence in the health status of fin fishes and shellfish exported from the country.

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Biosafety and Biosecurity for Human and Animal Health

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Infectious diseases have always affected humans and animals, and always will. Biologists have recognized a great variety of pathogenic organisms and the hazards of dealing with them. Special precautions are necessary for protection of both laboratory workers and the environment. Due to the wide variety of research and diagnostic work carried out in biological laboratories, no single set of biosafety guidelines can be framed to fit all situations. However, it is up to the institutions/laboratories to establish and enforce sets of guidelines tailored to the safety requirements of each laboratory. A safety programme is not something that is imposed on the organization. It must be an integral part of every technique used in the laboratory. Neither biosafety nor biosecurity should be overlooked. The difference between biosafety and biosecurity lies in whether the system is designed to protect against unintentional escape (biosafety) or intentional removal (biosecurity). The term biosecurity also refers to preventing the spread of infection by various means.

Now world-wide there is a growing importance for Biosafety and biosecurity concepts. Some countries have been able to establish biosafety laboratories, but many have not. Recent incidents of SARS, avian influenza, and Nipah virus infections have created awareness among scientists and general public, and many countries are now planning such facilities so that high risk pathogens can be handled safely, without risk to workers or danger of environmental pollution.

Biological containment, which ensures that infectious micro-organisms remain in the laboratory, is the principal feature that distinguishes containment laboratories from basic laboratories. A variety of overlapping integrated engineering systems installed in a containment laboratory prevent the uncontrolled escape of infectious micro-organisms from the building, to safeguard the health of the surrounding community, to prevent unintentional spread of disease among humans and animals by person-to-person, animal-to-animal, animal-to-human or human-to-animal transfer, and to prevent false laboratory reports due to cross-contamination.

In addition to engineering systems, a positive attitude among employees towards biological safety, and their adherence to approved guidelines, are essential to total biocontainment. To summarise, biological security is the end product of the interaction of the built-up facility, together with its management and operational philosophies and the environment in which it operates.

Recent developments in molecular biology, including recombinant DNA technologies, have changed the age-old scenario of microbiology. Incorporation of foreign genes in a host organism, utilizing prokaryotic or eukaryotic cells, might pose several problems of biosafety. An increasingly important consideration in biotechnology research and applications is that workers in these fields are not necessarily trained in microbiological techniques, including the safe handling of pathogens.

The plan of this paper includes risk-based classification of micro-organisms and general guidelines for handling micro-organisms, genetically engineered organisms, personal and environmental procedures, experimental animal handling and decontamination procedures. Special emphasis is paid to handling the avian influenza virus, which is a potential bioweapon.

The scheme for classification of micro-organisms provides a method for defining the minimal safety conditions necessary when using these agents. It designates five classes of hazardous agents: risk groups I, II, III, IV and V. Each country should draw up a risk group classification of the agents encountered in that country. The organisms not encountered in the country are a special category (risk group V).

The following classification conforms to the classification of human and animal pathogens:

Risk group-I: Low individual and community risk

Agents of no risk or minimal hazard under ordinary conditions of handling that can be used safely in the laboratory without special apparatus or equipment, using techniques generally acceptable for non-pathogenic materials.

Risk group-II: Moderate individual risk and limited community risk

This class includes agents that may produce diseases of varying degrees of severity, resulting from accidental inoculation or infection or other means of cutaneous penetration. Known effective treatment and preventive measures must be locally available, and the risk of spread limited. These agents can usually be adequately and safety contained by ordinary laboratory techniques.

Risk group III: High individual risk and low community risk

A pathogen that usually produces serious human/animal diseases but does not ordinarily spread from one infected individual to another.

Risk group IV: High individual risk and high community risk

Agents that usually produce serious human or animal diseases and may be readily transmitted from one individual to another, directly or indirectly. These need stringent conditions for their containment. Precautions are needed when entomological experiments are conducted in the same laboratory areas.

Risk group V: Special category

Foreign human/animal pathogens that are not present in a country and need stringent containment facilities for handling are included in this group. There are over 43 animal diseases exotic to our country.

Avian influenza, first diagnosed in 1878 in Italy, has assumed significance because of its ability to mutate and infect humans. The disease recently caused havoc in 1997, affecting humans directly from birds in Hong Kong, and subsequently since December, 2003. As many as 62 countries are now affected, in ten of which 151 human deaths have been reported. The disease has caused economic and social disruption in many countries. There are not yet any reports of human-to-human transmission. If such transmission occurs, there could be a pandemic. India was free from this disease till January 2006. The disease was first diagnosed in February 2006 in Maharashtra State, and subsequently in Gujarat and Madhya Pradesh. However, the disease was controlled successfully. As per international norms, avian influenza virus should be handled in a biosafety level-3 laboratory. However, if a country is free from the disease it should be handled in a biosafety level-4 laboratory.

The biologics derived by recombinant DNA techniques or developed from hybridomas may be classified into three broad categories, based on the biological characteristics of the new product and the safety concerns they present.

Category-I

This category includes inactivated recombinant DNA-derived vaccines, bacterins, bacterin-toxioids, virus subunits or bacterial subunits. These non-viable or killed products pose no risks.

Category-II

This category includes products which have been modified by addition of one or more genes. Precautions must be taken to ensure that the deletion or addition of genetic materials does not impart increased virulence, pathogenicity or survival of these organisms, greater than those found in natural or wild-type forms. The genetic information, added or deleted, must specify characterized DNA segments including base-pair analysis, aminoacid sequence, restriction enzyme sites, as well as phenotypic characterization of the altered organisms.

Category III

This category includes live vectors which carry foreign genes that code for immunizing antigens and/or immunostimulants. A live vector may carry more than one recombinant-derived foreign gene, since it can carry a large amount of new genetic information. This is also efficient for infecting and immunizing target animals. Currently used live vectors are vaccinia, pox viruses, bovine papilloma virus, adenoviruses, simian virus-40 and yeasts.

Animal experimentation

Animal experimentation with pathogens requires facilities to ensure appropriate levels of environmental quality, safety and care. Laboratory animal facilities are extensions of the laboratory, and in some institutions are integral to and inseparable from the laboratory. Biosafety levels recommended for working with infectious agents *in-vivo* and *in-vitro* are comparable.

Containment laboratories

Three basic elements of containing microorganisms in a laboratory are laboratory practices and techniques, safety equipment (primary containment barrier) and facility design (secondary containment barrier). Incorporation of these elements into a laboratory is required for safe handling of human and animal pathogens, including recombinant organisms of various risk groups. These form the basis for classification of laboratories. Four biosafety levels (BSL), in ascending order, are described for laboratories dealing with micro-organisms of risk groups I, II, III and IV. These laboratories are designated biosafety levels 1, 2, 3 and 4. The descriptions of biosafety levels 1–4, parallel to those of P1-4 in the National Institute of Health (NIH, USA) guidelines for research involving rDNA technology, are consistent with general criteria used in assigning agents to classes 1–4 in classification of pathogens on the basis of risks.

Biosafety Level-1

The laboratory is suitable for handling risk group I organisms and is referred to as a basic laboratory. Undergraduate and teaching laboratories come under this category. The laboratory is not separated from the general traffic in the building. The work is generally carried out on open bench tops without the use of primary containment equipment. However, good laboratory practices and techniques should be followed while handling organisms.

Biosafety Level-2

The laboratory is suitable to carry out work on risk group II organisms. The level of biosafety is similar to that of biosafety level-I. Besides following good laboratory practices and techniques, some additional aspects like closing the doors when the work is in progress and adherence to biosafety norms should be adopted. Safety equipment like biological safety cabinets (Class I or II) or other protective devices, should be used when procedures involved could create aerosols.

Biosafety Level-3

The laboratory is suitable for undertaking work with risk group III organisms. The laboratories under this category include clinical, diagnostic, research or production facilities, where infectious agents which may cause serious lethal diseases are used. Laboratory workers have special training in carrying out the work and are supervised by scientists. Infectious materials are handled in biological safety cabinets (class I, II cabinets). The laboratory has special design features of negative air pressure with an access zone, sealed penetrations and directional air flow.

Enforced biosafety guidelines, including decontamination of contaminated materials in the laboratory, are critical elements in the handling of pathogens. The safety equipment used in this category of laboratory are biosafety cabinets (class I,II,III) or combinations of personal protective or physical containment devices, e.g., clothing, masks, gloves, respirators, centrifuges with safety cups, sealed centrifuge rotors and animal isolators. For a BSL-3 laboratory the design features should be such that infectious agents handled in the laboratory do not escape to the environment. The laboratory is separated from unrestricted traffic within the building. Physical separation of the laboratory from access corridors shall be provided by clothing changes, showers, airlocks and other access facilities. Table tops should be impervious to water and resistant to acid, alkali, solvents and heat. A sink must be located near the laboratory exit which is elbow or foot-operated. Exhaust air filtered through the HEPA filters of biosafety cabinets should be discharged directly to the outside or through the building exhaust system with thimble connections.

Biosafety Level-4

The laboratory is suitable for carrying out work with risk groups IV and V (exotic) pathogens which pose a serious threat to human and animal populations. Personnel working in the laboratory have specific training in procedures of handling high risk pathogens, and understand the function of various biosafety equipments and design of the laboratory. A safety department must exist, which formulates the biosafety rules and regulations to be strictly followed. Good laboratory practices must be followed to ensure safe handling of organisms at the work place to avoid spillage, aerosol generation, cross-contamination and accidental infection of the workers. In addition to these, the two-person rule should apply, whereby no individual works alone within the laboratory. A system should be set up for reporting laboratory accidents and exposures, employee absenteeism and medical surveillance of laboratory associated illness.

All procedures within the facility shall be carried out in class III biological safety cabinet or in class I or II biological safety cabinets in conjunction with ventilated life-support system.

The biosafety level-4 laboratory has specific design features. It should be such that organisms handled in the laboratory do not escape to the environment through human material, air or water (effluent). To achieve this, the laboratory should be under graded negative air pressure, and should have arrangements for showering out, sterilization of outgoing materials by autoclaving (both steam and ethylene oxide), formalin fumigation (air locks), surface decontamination (dunk tank), effluent treatment (steam sterilization) and air filtration system through HEPA filters.

When pathogens of a high risk group with zoonotic importance are handled, the personnel should wear one-piece positive pressure suits, ventilated by a life support system. A specially designed suit area shall be provided in the laboratory facility. Entry to this area shall be through an airlock fitted with airtight doors. A chemical shower must be provided to decontaminate the surface of the suit before a worker leaves the area.

Bioterrorism

The use of nuclear bombs is against the survival of mankind and other species. This threat may be overshadowed by bioweapons. Intelligence sources estimate that there are over 50 countries world-wide with bioweapon programmes. Bioweapons can be designed and used to injure and kill not only humans but also animals and plants. In fact, it is possible that biological weapons may be used by terrorists or criminals to wage economic warfare, by destroying animals and/or plant population important in agriculture. By rough estimates, it is over ten times easier to construct a highly contagious organism than it is to enrich uranium. Moreover, the number of people with technical knowledge in microbiology and genetic engineering is much higher than of those in nuclear and missile technology together. Biological weapons can more easily be produced, at much cheaper cost, and smuggled to delivery to strategic areas. From a small point of release, a bioweapon can jump from person to person or from animal to animal in an explosive chain of lethal infection. Potential bioweapons are anthrax, smallpox, ebola virus, botulinum, plague, tularemia, viral hemorrhagic fever, glanders, brucella, Q fever, Nipah etc. Some people speculate that the avian influenza which hit India in February 2006 could be a bioterrorist activity of some agencies, but this is known to be untrue. The virus was introduced to the country through migratory birds. However, avian influenza virus could be used as a bioweapon. The knowledge gained by mapping the human genome will allow unscrupulous people to turn genetic therapies into bioweapons of mass destruction, capable of targeting specific ethnic population. This type of genocidal "Neutron bomb" would be capable of reaching a diverse urban population and killing only those whose genome has DNA sequences that code for certain sequences and leaving others untouched.

It is now felt that national security on agriculture, animal and human health is at stake. The recent outbreaks of avian influenza, causing a loss of Rs.700 crores, and the SARS episode are examples which remind us of our deficiencies. Besides these, possible threats from bioterrorism should not be taken lightly. To find solutions to these and to protect the nation, it is desirable to establish a chain of biosafety laboratories to effectively control emerging and exotic diseases of humans and animals. In addition, it is desirable that each state should have atleast one biosafety level-3 laboratory and at the national level there should be 4–5 biosafety level-4 laboratories on zonal basis.

Improving Food, Health and Nutrition Security in the Backdrop of Biosecurity

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The focus of the seminar being Biosecurity, I have added some aspects of Health and Nutrition to this agenda. In all of them is embedded the word 'Food'. When we look at food, we look back all the way to the first Green Revolution and the first Milk Revolution that we had; today, we find a large threat in the Biosecurity of food, public health and nutrition. How does one address this today in terms of prevention of food losses, capacity building, and contribution of science to society, as well as bringing an evergreen revolution at the village level in the area of nutrition and agri-business security, ultimately to give the consumer a cost-effective product with a focus on employment empowerment?

All this can be addressed by adopting some scientific discoveries. These can also generate new technologies, make possible basic research, pave the way for high-end technologies, and ensure that the fundamental work takes us a quantum leap forward. The prevention of food loss also means total availability of more nutrition. The nutrition available to the overall food pool of the country is very critical, and one has to always balance this very carefully on a commodity-to-commodity basis, with the fundamental goal of value addition.

From this angle, one has to really define the networking (especially the important network of food and nutrition) with the clear objectives of eliminating malnutrition on the one side and providing enough food to the consumer on the other side, from pediatric to geriatric nutrition. Nutrition throughout the life cycle is vital, and not only for the under-privileged. A large percentage of even the affluent population of India is micronutrient-malnutritive, and many are also anaemic. Cognitive development in school-children is a major problem related to nutrition and intake of adequate nutrients at the right age.

Therefore, nutrition and health are integral to each other, and just cannot be separated.

What are the major cascading issues in this arena? Food fortification is one. How does one bring about micronutrient food fortification and ensure that the macro economics is not disturbed? We are presently looking at organizations such as CSIR, ICMR, ICAR, DRDO, DOD, DAE, etc., to cascade networking and the capacity to build, and make sure that the fortification system thus built in the backbone of the country is with a clear basis of economic investment and cost to the consumer. Coarse cereals are another area on which we need to focus. Flavonoids, anthocyanins, vitamin E, calcium, and diet fibre have all assumed very high priorities as nutraceuticals, with a clear mandate of value addition to traditional foods. All these ingredients are observed to add to the long run preventive aspect of health care, rather than the curative aspect of disease.

In genes and diets, the specialized role of ingredients is very important. How good diet prevents onset of diseases is an important question. It is not easy to determine, but has to be identified through newly prominent scientific disciplines, such as nutrigenomics for health. Food obviously represents nearly an ideal channel through which one can realize the promised benefits of nutrigenomics. For example, custom-made food for individuals, gene mapping and food, avoidance of certain foods which for the individual are allergenic and unsuitable at the cellular level, functional foods, foods based on genetic mapping acceptance and so on and so forth. Can we call it a phyto-diet based on gene background? All this means that there is tremendous interaction needed between every discipline; biology, biotechnology, food and information technology. This is where nano and biotechnology, and bioinformatics play a major role. Utilized completely, nutrition technology not only prevents diseases but also looks at the diet, both in geno and pheno types in terms of both single-gene and multi-gene polymorphic interaction.

When we look at ingredients in food and food processing, and natural foods with contaminants such as pesticides, fungicides etc., we worry about the safety of food. Here we must together also address a very important aspect of food safety and security, as we talk about biosecurity. It is here that biotechnology plays a major role in biosecurity, with molecular markers today identifying some contaminants at very low concentrations, of almost parts per billion. Where one should really interface and make sure that biotechnology gives us answers to our concern for the Biosecurity of food.

When we talk about nutrition and food we cannot exclude obesity. Nowadays everybody wants to be slim, thin and trim. Why not? But how does really one look at lifestyle and standard of life? Will daily exercise be only in the history books? Will it be a part of our life? Will we be able to sustain and maintain our immune systems to fight diseases when we convert ourselves from an active physical life to more of desk work; what we term typical office work? The activity requirement of a human being should just not be forgotten. We must also realize here the 'food guide' or 'balanced food' concept of the 1950's. Perhaps we need our own documented highly complex network of traditional foods, with functional applications that ultimately encompass those customs, traditions and practices, and regional-agro-availability of raw materials. The way we cook and eat, and the way we enjoy our food, is very vital. Complications of dietary supplements, medical foods and functional foods have confused us sufficiently today and perhaps we need to clarify the situation. As scientists we have the responsibility to bring more awareness in the consumer world and the public at large.

Many of us may be thinking that hunger is always in rural areas and not a part of the urban agenda. This is not true. Our agenda must shift gears from global to national and from national to household. This is where agri-productivity and accessibility is very important. Here, I would like to quote Prof. Swaminathan that "good food production does not always mean good accessibility". It has its own problems of transportation, storage, buying power, sustainability and livelihood. The right to adequate food, millennium development goals and all these areas attract us towards certain important phases of policies, but we also need to address especially the holistic approach to nutrition. As we progress in science, we also want a healthy society, where each one of us is a partner in eliminating hunger and poverty and minimizing nutrition-related diseases. I am also sure that we all believe in an optimistic way that we can eradicate malnutrition, provided we take the decision. This is not easy to achieve, but it requires the participation and commitment of individuals, communities, clusters, families, institutions, policy makers and, of course, the local self-help groups and many others who could play a major role. That is where partnership and networking will work. Information and communication technology in sustainable development is what we look forward to when we address this issue.

We cannot forget the consumer. Nutrition is also defined by how convenient and how affordable a food item is, and perhaps I may also say, how much of grandmother's touch it has! This reminds me of the tsunami episode that India unfortunately faced. CFTRI and its dedicated team of scientists, technologists and engineers and all the staff went all out to produce nearly 67 tonnes of food and supply it directly to the tsunami victims through our own system. By integrating into the crisis by self-motivation, we made sure that at least a few hungry people got the best of foods, and did what we could in the calamity. This means that if we plan we can do it, but how do we bring in sustainability to such activities? Perhaps it is a very long drawn out agenda, but I am very positive that if we can address a part of one tsunami, we should be able to address millions of children who undergo the pangs of hunger and malnutrition every day. With all the science that we have in our hand today, it is a question of our confidence and determination. The speed and direction in which we want to move to eliminate hunger, poverty and malnutrition at the national level is very important. It often looks very huge in terms of the problem, but perhaps there is always a solution to it.

Biological Warfare and Terrorism

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Sickness and disease have exercised human thought since the dawn of human consciousness. It was realised that some diseases occur in crops and spread from the afflicted to the healthy. The concept of 'contagion' developed, and the earliest societies devised methods and actions that could influence the spread of such diseases and ensure a reasonable state of health for the populace. The spread of agriculture and domestication of animals led to economic development and the realisation that diseases of crops and livestock could also affect communal well-being. The subsequent "...story of the human race is war. Except for brief and precarious interludes, there has never been peace in the world", as Winston Churchill said in "*The World Crisis and My Early Life*". It was then a short step to when military commanders tried to use the knowledge of infectious diseases to influence their tactics. Till the rise of bacteriology and vaccinology, it was not possible for infectious agents to be used in situations where the combatant armies were in contact, as, their own and the enemy troops were usually equally susceptible to a disease. There were, however, certain circumstances when this was not the case and the use of biological agents in combat conditions was feasible. These are considered in subsequent sections. Thus, there could be both natural and artificial spread of infections, leading to the definition of biological warfare (BW) as put forward by Prof. Joshna Lederberg in his testimony to the Committee on Foreign Relations of the US Congress (Lederberg, 2001). Lederberg defines BW "as use of agents of disease for hostile purposes". This essentially simple definition is good for dealing with the subject. The operative aspects are volition and exclusion of natural forces.

BW as a Weapon of Mass Destruction (WMD)

Whether naturally acquired or artificially introduced, highly virulent agents have the potential of infecting a large number of susceptible individuals and in some cases establishing infectious chains. The destructive potential of BW is nearly as great as that of Nuclear Weapons and, therefore, included in the triad of WMD: Nuclear, Biological and Chemical (NBC). The low cost and widespread availability of dual technology (of low sophistication) makes BW attractive even to less developed countries. BW agents, in fact, are more efficient in terms of coverage per kilogram of payload than any other weapons system. In addition, the advances in biotechnology have made their production simpler and have also enhanced the ability to produce more diverse, tailor-made agents. Excluding countries which have dismantled their BW programmes, e.g. USA, UK, France etc., 11 other countries are believed to have developed the capability to produce biological weapons (US Committee on Armed Services, 1993). Biological weapons are different from the other WMD in that their effects manifest after an incubation period, thus allowing the infected (and infectors) to move away from the site of attack. The agents used in BW are largely natural pathogens and the illnesses they caused simulate existing diseases. Diagnosis and treatment would be carried out by the medical care system, rather than by a specialized agency as in the case of the other two WMDs. Another characteristic of some of these attacks is their proclivity to set up chains of infection.

The use of biological agents is simple enough to be handled by individuals or groups aiming to target civilians. Thus bioterrorism is defined by the Centre for Disease Control and Prevention (CDC) as, "the intentional release of bacteria, viruses or toxin for the purpose of harming or killing civilians" (Centers for Disease Control and Prevention, 2001).

History

Introduction of a communicable disease into the enemy camp as a tactical manoeuvre has exercised military commanders from the earliest times. Apart from prayers to gods to shower pestilences on the enemies, active measures were also adopted. These were based on the observed association between filth, foul odour, decay and disease or contagion. Filth, cadavers and animal carcasses were used to contaminate wells, reservoirs and other water sources in antiquity and even up to the 20th Century (Christopher *et al.*, 1997, Stubbs 1962). In the Middle Ages, military leaders recognized the strategic value of bubonic plague and used to catapult infected bodies into besieged forts. Two such episodes, at Kaffa (1346) and Carolstein (1422), have been identified as events that initiated and perpetuated the infamous Black Death which killed off a third to a half of the population of Europe. This illustrates the long-term effects of biological warfare and bioterrorism. Another documented use of biological weapons occurred during the French and Indian wars in North America (1754–1767) when the British General Sir Jeffrey Almhirst authorised the distribution of smallpox infested blankets to Indians (Red) and the French (Khardori, 2006). While these attacks were directed to the vulnerable enemy, there was no method by which inadvertent spread to 'own troops' could be prevented.

In the twentieth century, use of bioweapons became more scientific as vaccinology and the technology for cultivation of pathogens developed. Early in World War (WW) I Germany developed a biowarfare programme and used bacteria to infect or contaminate livestock or feed. There are also accusations of German bioattacks on Italy (cholera) and Russia (plague). It was after World War I that many nations undertook development of bioweapons. Significant research efforts were made by both sides in World War II. On the Allies' side, the British developed *B. anthracis* and tested it on Guinard Island off the Scottish coast, making the island incapable of supporting livestock for nearly half a century. The US programme, started in 1942, looked at a variety of agents including human pathogens like *B. anthracis, Botulinum* toxin, *Fracisella tularensis, Brucella suis*, etc. and crop pathogens like rice blast, rye stem rust, etc. The Axis powers had their own programmes, which they tested on Jewish concentration camp inmates in Germany, and the Chinese inmates of unit 731. Japan probably did use these weapons in China (Harris, 1992).

The post-WW II cold war saw the two sides take up bioweapons programmes seriously. Major research establishments, such as the US Army Medical Research Institute for Infectious Diseases at Fort Detrick, MD, the British complex at Porton Down and Biopreparat in the Soviet Union, are some examples of state efforts by major countries. The US (and most of its allies) terminated their offensive programmes after President Nixon's executive orders of 1969 and 1970 but continued to maintain 'defensive' research. The Soviet programme started early in its history (around the 1920's) and continued unabated till the break up of the Soviet Union, despite the nation being a signatory to all the Biological Weapons Conventions. The status of the major facilities in Russia and other successor countries to the Soviet Union is posing a major problem. Evidence from defectors who were quite high up in the organization hierarchy, notably Vladimir Pasechnik and Kanadjan Alibekor, indicates that the programme was on-going till the final years of the 20th century (Davis, 1999). Another extensive and aggressive programme was that of Iraq. Starting in 1974, the state established a research group and manufacturing facilities. The programme was probably active up to 1995(Davis, 1999). In fact, despite international agreements, there has been a proliferation of this modality. The number of countries working on biological weapon is estimated to be between 11 and 17 and the list includes sponsors of terrorist activities (US Committee on Armed Services 1993, Bartlett 1999). In addition, smaller groups have acquired bioterrorist capabilities.

Bioweapons are particularly attractive to terrorist groups because of their ease of production and low cost. They have been termed "the poor man's nuclear bomb" (Lesleor and Koran, 1993). In testimony to a UN panel in 1969, a group of chemical and biological experts estimated: "a large scale operation, against a civilian population with casualties, may cost about $2000 per sq km with conventional weapons, $800 with nuclear weapons, $600 with nerve gas weapons and $1 with biological weapons". There have been numerous documented attempts at bioterrorism. Table 1 summarizes some of those attempted between 1970 and 2001(Khardori, 2006). The collation by Khardori and Kanchanapoom has an interesting mix of episodes. On the one hand, there is the accidental release of anthrax bacilli from a bioweapon unit at Sverdlovsk (in the former USSR). The leak was never acknowledged by the Soviet government. Suspicions were confirmed only when Boris Yeltsin acknowledged the episode after the collapse of the Soviet Union. The lethality of leaked material was amply demonstrated and the spread of casualties emphasized the role of atmospheric factors. On the other hand, the 1984 outbreak of salmonellosis in Dalles, Oregon could be traced to the perpetrators (Rajneesh cult) only when the insiders confessed. The incident used a common food pathogen in order to influence a local election – a bad precedent. The danger of jumping to conclusions based on scanty evidence is well illustrated by the postal anthrax spore dissemination that followed. The episode, which caused 22 cases including 5 deaths, "ushered in the transition from table top bioterrorism exercises to real world investigation and response" (Perkins 2002, Hughes and Geberding 2002). This outbreak brings out well the crucial role of well-trained, alert health care providers like Larry Bush, the infectious disease physician from Florida, USA, who diagnosed his first case promptly.

Despite extensive programmes and stockpiling of bioweapons, there are no established instances of their use in combat. Apart from an ethical reluctance to use this modality, the time gap between onset of morbidity and the attack (incubation period) renders bioweapons of little tactical value. Strategic attacks are still cost-effective, but, even in the Iraqi wars, have not occurred. The situation is somewhat different in the case of bioterrorism. Here, events in the recent past have shown that the threat is real. The arguments advanced to defer consideration of the issues related to bioterrorism have been 'without validity' and we cannot delay the development and implementation of strategic plans for coping with civilian bioterrorism" (Henderson, 1998). The reconstructed scenarios in the case of attacks by the more likely bioterror agents reveal two types of pattern. In the case of anthrax and botulinum toxin, which have high initial effects but no secondary cases, the scenario is similar to chemical attacks. However, when the pathogen used has the ability to set up secondary cases, and, probably an epidemic, the scenario is far more complex. The action and preparations have to be tailored appropriately.

Table 1: Examples of attempts at bioterrorism

Year	*Group*	*Attempt*	*Outcome*
1970	Weather Underground	A US revolutionary group intended to obtain agents from Ft. Detrick by blackmail and to incapacitate US cities temporarily to demonstrate the "impotence of the federal government"	Report originated with a US Customs informant. The case later appeared to be apocryphal
1972	R.I.S.E.	A group of college students influenced by ecoterrorist ideology and 1960s drug culture planned to use agents of typhoid fever, diphtheria, dysentery, and meningitis, initially to target the entire world population, but later narrowed the plan to five cities near Chicago	The attack was aborted when cultures were discarded
1978	Unknown	Bulgarian defector Georgi Markov was assassinated in London when a spring-loaded device disguised in an umbrella was used to implant a ricin-filled pellet in his thigh	Similar device used against a second defector in the same area was unsuccessful

Year	Group	Attempt	Outcome
1979	Accidental	Accidental release of anthrax spores from a bioweapons facility in Sverdlovsk, Russia, caused an epidemic of inhalational anthrax	At least 77 cases and 60 deaths
1980	Red Army Faction	Members of a Marxist revolutionary ideology group allegedly cultivated botulinum toxin in a safe house in Paris and planned attacks against at least nine German officials and civilian leaders	This probably was an erroneous report, later repudiated by the German government
1984	Rajneeshee Cult	An Indian religious cult headed by Rajneesh plotted to contaminate a restaurant salad bar in Dalles, Oregon, with *Salmonella typhimurium*. The motivation was to incapacitate voters, win local elections, and seize political control of the county	The incident resulted in a large community outbreak of salmonellosis involving 751 patients and at least 45 hospitalizations. The plot was revealed when the cult collapsed and members turned informants
1991	Minnesota Patriots Council	A right-wing "Patriot" movement obtained ricin extracted from castor beans by mail order. They planned to deliver ricin through the skin with dimethyl sulfoxide and aloe vera or as dry aerosol against Internal Revenue Service officials, US Deputy Marshals, and local law enforcement officials	The group was infiltrated by Federal Bureau of Investigation informants
1995	Aum Shinrikyo	A New Age doomsday cult seeking to establish a theocratic state in Japan attempted at least 10 times to use anthrax spore, botulinum toxin, Q fever agent, and Ebola virus in aerosol form	Multiple chemical weapon attacks with sarin, Vx, and hydrogen cyanide in Matsumator and Tokyo and assassination campaigns were conducted. All attempts with use of biological weapons failed. The nerve gas sarin killed 12 and injured 5500 in a Tokyo subway

Year	*Group*	*Attempt*	*Outcome*
1997	Disgruntled employee in Texas	Intentional contamination of muffins and donuts with laboratory cultures of *Shigella dysenteriae*	Caused gastroenteritis in 45 laboratory workers, 4 of whom were hospitalized
2001	Unknown	Intentional dissemination of anthrax spores through the US Postal System led to the deaths of 5 people, infection of 22 others, and contamination of several government buildings	Investigation into the attacks so far has not reached any conclusion

Use of biological weapons

The most convenient method for delivering BW agents would be by small particle aerosols. They have the advantage of being silent, odourless and invisible. The dilution factor in the atmosphere would make detection by most currently available methods difficult.

Biological agents (like normal pathogens) may enter the body by the following routes.

a) As *aerosols*. The particle size should be such that the infecting agent reaches the alveoli. For this, the ideal size of particles would be 1–20μ. Particles larger than 20μ would be filtered off in the upper respiratory tract or settle down rapidly. Those of size less than 1μ would float away and not be captured by breathing. Practically all BW agents can be processed to produce aerosols with infectious potential.

b) Along with *food* or *water*. Agents such as botulinum toxin or enteric pathogens like *Salmonellae* or *Shigellae* can be transmitted by water or food. This method is not used often but instances of successful use, *e.g.* the outbreak caused by the Rajneeshee cult, are available.

c) By *injection* through the skin. This method is used to deliver agents that would not withstand processing for aerosols or would get degraded in the alimentary tract, *e.g.* ricin attack against a Bulgarian defector (*loc.cit*).

d) Through the intact *skin*. This is probably the least effective method and is useful in very few cases.

Aerosol preparations processed from bacterial cultures, tissue culture growths or toxin preparation require special technology, which however is readily available in the food processing, pharmaceutical, cosmetic and allied industries. The preparation may be dispersed by a spray device such as an industrial insecticide sprayer. Even a smaller cosmetic sprayer can be used. When used in a moving conveyance, a sprayer creates a *line source*. A terrorist vehicle can spread the aerosol and drive away, allowing atmospheric factors to spread the contagion as far as the stability of the organisms/toxin permits.

The second method of release would be *point sources*. Here stationary sprayers, or bomblets from a missile or artillery shell, are used. Packing the infective material in an explosive shell is an inefficient method of delivery. The heat of explosion and unpredictability of the exact site of impact would result in only a small fraction of the bioweapon reaching its target. It is estimated that around 2% of anthrax spores packed in an exploding artillery shell survives (Patrick, 1994). This, however, may be a large enough amount to infect quite a few persons if enough were packed in. It is believed that Iraq had quite a few such shells, which could have ensured devastation if fired into populated areas.

Other clandestine means of delivery are available to terrorist or Special Forces units. These include darts coupled to syringes, pellets or penetrating devices. Methods of contaminating food or water supplies would also be not easily observable. A typical example, as mentioned earlier, was the contamination of salad by the Rajneesh cult members.

Dispersal experiments have been attempted using the non-pathogenic *Bacillus globigii* which has physical characteristics similar to *B. anthracis*. The variables in dissemination have been worked out and the impact of bioterrorist attacks estimated. The experiments showed that an attack on the New York subway system would kill at least 10,000 people. WHO studies showed that 50kg dispersal on a population centre of 500,000 would result in up to 95,000 fatalities with over 125,000 people incapacitated (Piles *et al.*, 1998). Other experiments have shown similarly disastrous results.

In the case of smallpox, the emergence of secondary cases at the rate of 10 times the numbers of primarily infected subjects would add to the burden (Henderson, 1999). There would also be a demand for large scale vaccination, from meager stocks and no on-going production. Inevitably epidemics would break out and social disruption would result.

The economic impact of bioterrorism would be a major burden transcending the medical consequences. It has been estimated that the use of a lethal agent like *B.anthracis* would cost $26.2 billion per 100,000 persons exposed, while a less lethal pathogen, *e.g. Brucella suis*, would cost $477.7 million (Kauffman *et al.*, 1997). The study also showed that a post-attack prophylaxis programme would be cost effective, thereby justifying expenditure on preparedness measures (Kauffman *et al.*, 1997). When bioterrorism attacks agriculture the economic costs are paramount and can hurt as severely as attacks on human beings (Thompson, 1999; Dunn, 1999). The spread of the imported weed *Parthenium hysterophorus*, which entered India in the late 1950's with imported wheat and spread all over, affecting the yield of fodder crops and becoming a crop pest, is an excellent case study. It shows how subtly bioterrorism could work, though in this case there has been no evidence of malicious action (Joshi, 1990). In concrete terms, a simulation exercise of an overt bioterrorist attack after a threat two days earlier over San Franscisco demonstrated that a major airborne release over the bay could result in two different scenarios. In the first scenario, where the city is unprepared, more than a million of the 6.5 million populations would die, there would be widespread panic with people fleeing the city, the hospital facilities would be choked, healthcare would break down and ill-equipped emergency crews would be of little help. In the other scenario, where an interval of two days available after the threat is used to educate the public on domestic preventive methods, assemble properly equipped emergency crews, collect designated meteorological experts, stockpile prophylactic and therapeutic antibiotics and swing to emergency mode, the total estimated causalities would be reduced to between 5–10% of the earlier figure. This analysis succinctly expresses the need for and the value of a proper response to bioterrorism (Henderson, 1999).

Biological threat agents

Theoretically any human, animal or plant pathogen can be used as a biological weapon. The deliberate intent and action to cause harm defines a biological attack. An outstanding example is the gastroenteritis caused by the use of *Salmonella typhimurium* by members of the Rajneesh cult. The organism causing the illness is such a common natural pathogen that only the confessional statements of the perpetrators (when the cult broke up) revealed the facts. However, the characteristics that have already been discussed need to be present for an organism to become a serious candidate. Table 2 (U S Army Medical Research Institute of Infectious Diseases, 1998) gives a list of biological agents that could be used in warfare and terrorism attacks. Of these, anthrax, smallpox, plague, tularemia, brucellosis and botulinum toxins can be considered leaders in the field, with the first two taking pride of place. These agents have to be worked against at all times. Also, as already mentioned, the use of agents that target livestock and crops could be as devastating as human pathogens in terms of their economic impact (Dunn 1999).

By using the increasing sophistication in biology, 'tailoring' of classical biological warfare agents could make them harder to detect, diagnose and treat". A more sinister spectre in the fourth generation of BW agents could be the production of 'stealth' viruses that "could be introduced covertly into genomics of a given population and triggered later by a signal, and also a 'designer' disease such as one that produces apoptosis by multiple pathways (Fraser and Dando 2001).Sometimes inadvertent results of legitimate research may produce novel bioweapons that could be misused by unscrupulous parties (Nowak, 2001). This also has a bright side. The weaponisation research can also generate information that can be used to develop counter-measures. Thus, if protective research keeps pace with offensive efforts, detection and definition methods would be in place to combat the bioattack. At the same time, genetic information could yield many more vaccine targets, e.g., the MedImmune research in the development of six new vaccine targets from the genome of *Streptococcus pneumoniae* (Wizemann *et al.*, 2001). Likewise genomic studies of pathogens (natural and artificially modified) in relation to the human genome would reveal new proteins and pathways that could be used to treat/prevent infections (Cummings and Relman, 2000).

Detection of a biological attack would start with (particularly in the civilian context) suspicion that an outbreak of disease could be due to such an event. As mentioned earlier, the information would largely emanate from the primary health care contact points and be collated and interpreted by the disease surveillance mechanism(s). Clues to a potential bioterrorism attack have been enumerated (Khardori, 2006) and are reproduced as Table 3.

Starting from large vehicle- or helicopter-mounted manned mobile laboratories that examine the physical characteristics of clouds emitted from moving objectives (without the capability to identify the infectious agent) to biosystems based on biochemical, biological or mass spectrometry, detectors have been developed that sample air and identify the DNA present. Another method being tried is the Bead Array Counter based on magnetic fields. Antibody-based detection systems can be coupled to beads that can pick up the pathogens and show the reaction by flow cytometry. However, these methods require a putative identity to work with. Tissue-based sensors based on the biological basis of toxin activity can sense the presence of an agent, but still require knowledge of its identity. Nanoscience holds the promise that it may be possible to detect and identify agents simultaneously (Astron, 2001).

In the meanwhile, it is necessary to develop an Emergency Response Capability such as the National Disaster Medical System in USA, with designated emergency beds equipped to treat BW or BT casualties and mobile teams to set up peripheral treatment facilities. Complementing this would be a Laboratory Network across the country with designated microbiological handling capability from Level 1 through Level 4. This infrastructure is still in a rudimentary state. In fact, for this country of nearly sub-continental dimensions, no Level 4 facilities exist. This needs to be remedied and the infrastructure has to be built soon.

Drug and vaccine repositories require to be located at convenient locations throughout the country. This is a stupendous task considering that despite being the last country to have seen *Variola major*, and having once had production capability beyond national requirements, India has hardly any smallpox vaccine supply at present (Raghunath, 2002). Similarly human anthrax vaccine is not available. In the course of its preparation to tackle bioterrorism, the USA has now built up a stock of smallpox vaccine capable of immunizing its entire population (Le Duc, 2002).

Table 2: Characteristics of Biological Warfare Agents

Disease	*Transmissible Person to Person*	*Infective Dose*	*Incubation Period*	*Duration of Illness*	*Lethality*	*Persistence (aerosol exposure)*	*Vaccine Efficacy*
Inhalation Anthrax	No	8,000-50,000 spores	1-6d, possibly longer	3-5 d (usually fatal if untreated)	High	Very stable, spores remain viable for years in soil	2-dose efficacy against 200-500 LD_{50}s in monkeys
Brucellosis	No	10-100 organisms	5-60 d	Weeks to month	<5% untreated	Very stable	No vaccine
Cholera	Rare	10-500 organisms	4 h to 5 d	≥ 1 wk	Low with treatment, high without	Unstable in aerosols and fresh water; stable in salt water	
Glanders	Low	Assumed low	10-14 d via aerosol	Death in 7-10 d in septicemic form	>50%	Very stable	No data on aerosol
Pneumonic Plague	High	100-500 organisms	2-3 d	1-6d (usually fatal)	High unless treated within 12-24 h	For up to 1 y in soil; 270 d in live tissues	No vaccine
Tularemia	No	1-50 organisms	2-10 d (avg 3-5 d)	≥ 2 wk	Moderate if untreated	For months in moist soil or other media	3 doses not protective against 118 LD_{50}s in monkeys
Q Fever	Rare	1-10 organisms	10-14 d	2 - 14 d	Very low	For months on wood and sand	80% protection against 1-10 LD_{50}s
Smallpox	High	Assumed low (10-100 organisms)	7-17 d (avg 12d)	4 wk	High to moderate	Very stable	94% protection against 3,500 LD_{50}s in guinea pigs
Venezuelan Equine Encephalitis	Low	10-100 organisms	2-6 d	Days to weeks	Low	Relatively unstable	Vaccine protects against 30-500 LD_{50}s in hamsters
Viral Hemorrhagic Fevers	Moderate	1-10 organisms	4-21 d	Death between 7-16 d	High for Zaire strain of Ebola, lower for others	Relatively unstable	No vaccine

Diseasae	*Transmissible Person to Person*	*Infective Dose*	*Incubation Period*	*Duration of Illness*	*Lethality*	*Persistence (aerosol exposure)*	*Vaccine Efficacy*
Botulism	No	0.001µg/kg is LD_{50} for type A	Variable (hours to days)	Death in 24-72h; lasts months if not lethal	High without respiratory support	For weeks in non-moving water and food	3 doses give efficacy of 100% against 25-250 LD_{50}s in primates
Staphylococcal Enterotoxin B	No	0.03 µg /person incapacitation	3-12 h	Hours	<1%	Resistant to freezing	No vaccine
Ricin	No	3 - 5 µg / kg is LD_{50} in mice	18-24 h	Days; death within 10-12 d for ingestion	High	Stable	No vaccine
T-2 Mycotoxins	No	Moderate	2-4 h	Days to months	Moderate	For years at room temperature	No vaccine

LD_{50}: a dose that is lethal for 50% of the subjects

Source: *Medical Management of Biological Casualties Handbook*. Fort Detrick, Md: US Army Medical Research Institute of Infectious Diseases; 1998.

Table 3: Clues to a potential bioterrorism attack

Epidemiologic clues

1. Greater caseload than expected of a specific disease
2. Unusual clustering of disease for the geographic area
3. Disease occurrence outside of normal transmission season
4. Simultaneous outbreaks of different infectious diseases
5. Disease outbreak in humans after recognition of disease in animals
6. Unexplained number of dead animals or birds
7. Disease requiring for transmission, a vector previously not seen in the area
8. Rapid emergence of genetically identical pathogens from different geographic areas

Medical clues

1. Unusual route of infection
2. Unusual age distribution or clinical presentation of common disease
3. More severe disease and higher fatality rate than expected
4. Unusual variants of organisms
5. Unusual antimicrobial susceptibility patterns
6. Single case of an uncommon disease

Miscellaneous clues

1. Intelligence report
2. Claims of a release
3. Discovery of munitions or tampering
4. Increased numbers of pharmacy orders for antibiotics and symptoms relief drugs
5. Increased number of 911 calls
6. Increased number of visits with similar symptoms to emergency departments and ambulatory healthcare facilities.

International response

Humanity retains memories of scourges of infectious diseases that spread across populations and decimated them. The use of these contagions for personal gain has been abhorrent to most people. This abhorrence was first expressed in the Geneva Protocol of June 1925 which prohibited biological (and chemical) methods of warfare. A mutually agreed new convention proposed by the United Kingdom to supplement the Geneva Protocol was signed on April 10th 1972 by the three depositories, UK, USA and USSR. This was a historic move since it was the first time that an entire class of WMD was voluntarily abjured by agreement. This remarkable piece of arms control has the following components.

1. States promise not to produce BW-agents or toxins in quantities that cannot be justified for peaceful purposes, and also promise not to produce weapons or dispersal equipment.
2. All stockpiles of bioweapons shall be destroyed.
3. States promise not to transfer weapons or technology for production of BW-agents and toxins.
4. States shall ban production and development of bioweapons within their territories.
5. States pledge to cooperate in order to solve any problems that emerge.
6. States can raise complaints against other states through the Security Council of the United Nations. They shall cooperate with the UN in investigations of non-compliance with the Convention.
7. When requested, states should assist another state that has been exposed to attacks or threats with this type of weapon.
8. Nothing in the Convention restricts the obligations according to the Geneva Protocol.
9. States should work for a corresponding CW-convention.
10. States should contribute to the transfer of technology and knowledge within the biological sector that can be used for peaceful purposes, e.g. for disease control. The Convention must not limit the technical and economic development of states.
11. Each state shall have the right to propose additions.
12. After 5 years, a review conference will be held.
13. The Convention is valid for an unlimited period. States can withdraw from the Convention by giving 3 months notice to the other state parties and the UN.
14. (Relating to depository powers and signing, etc.)
15. (Relating to the translation in 5 authentic languages and its transmission to the governments of signatory and acceding states.)

Unfortunately, this landmark Convention was made ineffective by a lack of agreement on verification procedures. The biggest blow to it was the rejection of the verification procedures by the USA (Kanth, 2001). There is a widespread feeling that even if there were an agreement, there would be numerous transgressions. In any case terrorist individuals or groups would be beyond its scope. Nevertheless, the review process of the Biological and Toxin Weapons Convention 1972 was undertaken in 2006 and could, hopefully, yield better results (Meng-Kim, 2005). Ultimately, like other powerful technologies, biotechnology could benefit or destroy humanity depending on the behaviour, ethical or otherwise, of those handling it. A code of ethics for the life sciences has been promulgated, and if followed would improve the safety of humanity. The cases of Bedson (Raghunath, 2002) and Butler (Somerville *et al.*, 2005) show that there would be transgressions that only the ethics of the community can resolve.

Biological warfare has been discussed in military circles and considered in strategic planning ever since the cultivation of pathogens was achieved in the closing years of the 19th century. However, the arsenals have not been used during military operations. This is not true for bioterrorism. The subject was initially dismissed by national policy makers and academia because of prevailing notions, which have now proved to be invalid. This has led to open discussion, and raised awareness which it is hoped will not have a negative impact. Open debate and ethical behaviour on an international scale, unconfined by "narrow domestic walls" will possibly save humanity from the biological equivalent of "nuclear winter" (Shalala, 1999).

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Developing Options for Agricultural Biosecurity: Assessing progress and evaluating comprehensive mechanisms

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Scientific advancements have offered opportunities for revolutionizing human welfare, activities primarily through improvements in the quality and quantity of lives. Enriched with the knowledge-based inputs in the form of molecular biology and genomic research, biotechnology has emerged as a major work force for the developments in food and agriculture, environment and human and animal health. Biotechnology and the life sciences contribute to solving global problems like food and water insecurity, enhancement in crop productivity, advent of new diseases of humans and animals and re-emergence of pests/pathogens of crop plants that impede national development in many parts of the world and threaten peace in the developing countries (Sharma, 1999). Without them, slow solution to these problems damages the environment, weakens social infrastructure and constitute a threat to normal life. The UN Human Development Report "Making New Technologies Work for Human Development" (UN, 2001) identifies biotechnology as a potential avenue for the socio-economic advancement of the developing world. This area of science is a motor of technological advancement, a driving force for rural livelihood, poverty alleviation, conservation of the environment and biodiversity, and sustainable development at a new capacity in scope and content. The simple production of cheese and fermented foods, the industrial production of antibiotics, metabolic bioengineering to produce secondary metabolic products, the genetic elaboration of biopharmaceuticals, molecular farming to produce nutraceuticals and genetic engineering for production of novel crops and beneficial microbes: all these success stories illustrate the breadth and depth of biotechnology endeavour and practice worldwide (DaSilva *et al.*, 2002).

Entwined with the cultural, ethical and socio-economic contributions of the major scientific advancements in the present era are the dangers of unmanaged, unscientific or even revengeful science. The whole story starts with a question: Is there a minimum feasible safe scale of science? A technically trained person with a poor or vengeful understanding of experimentation may cause considerable damage unknowingly or with intent. The world has observed a number of examples, such as the methyl isocyanate disaster in Bhopal, India in 1984 (Browning, 1993), sarin gas delivered to the Tokyo subway system (Olson, 1999). Biotechnology brings with it a number of potential risks. With our current knowledge, the potential risks largely associated with biotechnological advancements are identified as health risks to humans, plants and animals; risks of invasive species; pests and pathogens in agriculture; food and environment contamination; threats to biodiversity; and ethical and socio-economic risks.

Biosecurity in jeopardy

We live in an environment that we share with a number of biological entities including microbes, flora and micro-fauna. During the 20th Century, scientific developments and advancements extended to the extent that we became able to force these microorganisms to match our exact and preferred conditions for the relationship. The life science community, in ever-cleverer ways, is still regularly altering our microbial environment in the name of innovations in industrialization, but in doing so, life scientists are increasingly realizing how little they know about the microbial world, how little able and equipped they are to control the chain mechanisms initiated by a wrong introduction and how much damage they and others, even less wittingly, can do there. Most life scientists working in the microbial ecology basically focus on its individual components: organisms themselves, their genes and by-products. Few among them are concerned about the interactions of the biological entities or chemicals with other organisms in their environment, including microbes themselves, plants and animals, as well as human beings. In fact, this comparatively narrow microbe or chemical-mediated ecological response capacity may amount to a particular biosecurity breach, that would be understood rather less quickly than might be hoped. This thinness actually is all the more worrisome as the ability to create, select and now, stabilize novel organisms is accelerating in the agricultural biosciences sector, where an "intention to release" is typically fundamental to the economics of genetic-engineering initiatives (Selifonova *et al.*, 2001).

In such a situation, the life science community to a certain extent shares moral and managerial responsibility and culpability (although scientists are uniquely professional and thus cannot escape them) with governments, public and corporations (Frazer and Dano, 2001, Kwik *et al.*, 2003). Governments and corporations can make this responsibility rather easier or harder to meet (Epstein, 2001), but this community may act in ways governments and corporations can not credibly match (Sprinkle, 2003).

The scientific community's aim in this age of bio-risks should be "biosecurity". This would mean: an assurance that our environment would neither intentionally nor recklessly be made more dangerous to us and to other living-being living in our surroundings, than the ongoing evolutionary processes and continuous environmental changes that might have made it. Scientists should work legitimately to understand those dangers, to minimize the impacts on species and to modulate, utilize or even magnify the harmful effects to have a check on deleterious microbes, pests and pathogens (Sprinkle, 1992). Conversely, scientists can compromise biosecurity by creating a working environment where they intentionally work to enhance the potential bio-risks to human being or where they enhance such dangers recklessly through their work (Sprinkle 2003).

The term *biosecurity* accommodates the treaty language and is generally understood to mean all policies and regulatory frameworks to manage the biological risks associated with food, agriculture and human health (Draft of National Biosafety Policy prepared by National Biosafety Committee, Oct.08, 2006). It encompasses environmental, agricultural and commercial incidents, as well as epidemiological and eco-regional, and addresses an asset whose degradation could be actionable civilly or criminally (Sprinkle, 2003). Any kind of scientific or unscientific act, whether carried out unknowingly, unintentionally or intentionally, may destabilize socio-economic advancements through engagement in bioeconomic warfare and seeding of food insecurity, and decimate the human resource capital of developed or developing countries through contamination of food and water supplies. For example, an outbreak of smallpox, the causative virus of which is extinct in the wild and is specially kept in the known repositories, would be a direct indication of a biosecurity breach (Breman and Henderson, 2002).

Describing Biosecurity / Biosafety

Definition of "biosecurity threats": those matters or activities which, individually or collectively, may constitute a biological risk to the ecological welfare, or to the well-being of humans, animals or plants, of a country (World Conservation Union (IUCN), 1999).

Biosecurity objectives: In accordance with the precautionary approach contained in Principle 15 of the Rio Declaration on Environment and Development, the objective of this Protocol is to ensure an adequate level of protection in the field of the safe transfer, handling and use of living modified organisms resulting from modern biotechnology that may have adverse effects on the conservation and sustainable use of biological diversity, taking also into account risks to human health, and specifically focusing on trans-boundary movements (Cartagena Biosafety Protocol, 2000).

Biosecurity treaty rationale: The biosecurity treaty rationale is a needed international biosecurity convention, distinct from the bioweapon treaty but complementing it by primarily addressing the threats of bioterrorism. In addition, the biosecurity convention should build on the ongoing implementation of the 1992 Biological Diversity Convention (CBD) and its 2000 Cartagena Protocol on Biosafety, which includes provisions for the safe handling, transfer, and use of genetically modified organisms (Barletta, Sands, Tucker, 2002).

Articulation of the biosecurity concept: Biosecurity is a strategic and integrated approach that encompasses the policy and regulatory frameworks (including instruments and activities) that analyse and manage risks in the sectors of food safety, animal life and health, and plant life and health, including associated environmental risk. Biosecurity covers the introduction of plant pests, animal pests and diseases, and zoonoses, the introduction and release of genetically modified organisms (GMOs) and their products, and the introduction and management of invasive alien species and genotypes (FAO, 2003).

Cooperation and the Biosecurity Portal (IPFSAPH): The FAO's Biosecurity Portal is officially known (awkwardly) as the "International Portal for Food Safety, Plant, and Animal Health" (IPFSAPH). Since its debut in early 2004, the Biosecurity Portal has the potential to pull together access to an enormous range of information relevant to biological weapons control. The FAO is planning to train government officials in how to use its resources. The Portal will use a controlled and consistent vocabulary, and is planned to be available in English, Spanish, French, Chinese, and Arabic (FAO, 2004).

Agricultural biosecurity: major threats

1. Life Sciences and Biotechnology

Outstanding technological advances in the past few decades in biotechnology include genetic engineering, genomics, proteomics and bioinformatics with dual-use research potential (i.e. knowledge and techniques that have or may have, potential civilian and military applications) (Block, 2001, Carlson, 2003). They are materializing worldwide at a very rapid pace. Knowledge obtained in the life sciences and techniques holds the potential to improve human and animal health and welfare, agriculture, and economic development all over the world. Over the next one to two decades, the developed world will likely remain the most powerful global players in the life sciences. Many other nations are also in the queue of developing powerful and well-equipped scientific bases, technological infrastructure and human capabilities, to emerge as regional and global leaders in such fields. India, China, Brazil, and Russia are among those expected to become stronger economic, political, scientific, and technological global powers of the future in the field of biotechnological advancements.

There exist a multitude of diverse, intermingled and mutually interacting social, economic and political forces that drive innovations and novelties in life sciences-related frontier technologies. Rapid globalization has resulted in the fast dispersion of these technologies in a number of areas including pharmaceuticals, nutraceuticals, agriculture, biomaterials, microbiology and computing. Among the prominent drivers of frontier technologies in science, economic forces (i.e., national investments in terms of manpower cost in research and development and geographic trends in consumerism and purchasing power), social forces (i.e., efforts to utilize health and agricultural biotechnology and nanotechnology to improve the well-being of national population, and efforts to develop pro-environment agricultural and consumption practices) and political forces (i.e., commitment of governments to make research and development flourish in the nation through investments). In order to allow all these drivers to play their role in the development of a country through technological innovations and scientific advancements, we must search out a biologically secure workplace for health safety and well-being implying inherent protection and safeguarding of the human labour forces against biohazards, chemical toxicants and biogases, and biochemical entities detrimental to human and animal health, food, environment and agro-ecology.

The most significant factor fueling the dispersion of advanced technologies throughout the world is basically the profit motive, the desire and quest to enter, succeed and stand in the global marketplace. Over the next five to ten years, all sectors of the life sciences industry – including agricultural biotechnology and food technology, the industrial and environmental sector, and homeland defence and national security—are expected to continue to benefit from and thus drive the rapid growth of new biological wisdom and advanced technologies (DaSilva, 2005). The dual role of information technology as an advanced science, and as a driver of other advanced technologies is very noteworthy. However, the potential impacts of all these factors governing advanced science and society remains in their safe and secure use. There is an emergent need to create a balance between an open science research program and the national biological security; to avoid a restrictive action concerning the growth of scientific advancements in the biosciences in the near future, and at the same time, create a safe and secure environment for science workers, the whole society and the nation.

Although life science and biotechnology have progressed vastly through opportunities and applications in public health, social welfare, medicine, agriculture and food sector, this progress has generated many important legal, social and ethical implications (WHO, 2005). Research, knowledge and technologies in the life sciences can be used for both legitimate and illegitimate purposes. This therefore, raises the problems of how best we can manage the risks associated with such research, techniques and knowledge without hindering their beneficial applications in social and human welfare.

Research and development in life sciences that can be of potential risk includes the new techniques, processes and knowledge of molecular biology, non-engineered microbiology, engineered microorganisms and their toxins, functional genomics and food technology. Recent advancements in life science R&D differ from conventional R&D techniques in that, firstly the new techniques are rapidly involving the deeper understanding of genes and exploring their functions in relation to infectious disease mechanisms (pathogenesis), immune responses and defence systems, and biological and physiological pathways. This knowledge, unknowingly or intentionally, may lead to modification or manipulation of the genetic materials of beneficial or harmful microorganisms, to give birth to potential hazardous microorganisms and their bio-products. Secondly, being very simple, easy and economical cost-wise or knowledge-wise, these potentially problematic techniques can easily be adopted by anti-social elements in a region and/or can rapidly be made available worldwide, via the internet or other fast means.

Genetic engineering involves the modification of the genomic properties of an organism or, the transfer of genetic material between living organisms. From the perspectives of public health and of livestock well-being, the transfer of genetic material can lead to potentially novel and new therapeutic agents and treatments such as gene therapy. However, genetic engineering can deliberately be misused in several ways. Insertion of new properties into the microbes could, *inter alia*:

- facilitate large scale production of biological toxins or unwanted harmful biochemicals that were previously difficult to produce;
- make a pathogen resistant to the immune system or to antibiotics, hence rendering defensive measures ineffective;
- modify the stability of an organism in the environment;
- create bacteria and viruses of greater virulence or making previously harmless organisms pathogenic;
- change the host specificity of microorganisms; or
- render the identification and detection of engineered pathogens difficult (i.e. make them by-pass current techniques); and
- result in viruses or immunotoxicants through Gene Vector techniques that could be misused to create vectors carrying specific diseases.

Laboratory Biosafety and Biosecurity

"Laboratory biosafety" describes containment principles, technologies and practices implemented to prevent unintentional exposure of pathogens and toxins, or their accidental release.

"Laboratory biosecurity" describes the concept, process and objectives of managing biorisks associated with a laboratory, holding valuable biological materials, increasing their protection, control and accountability in order to prevent their unauthorized access, loss, theft, misuse, diversion or intentional release.

WHO – biosecurity adds to institutional biosafety programs, for better responsibility and accountability of working in the biological laboratories:

- Public health laboratories
- Agricultural and animal laboratories
- Research and academic laboratories
- Pharmaceutical and biotechnological laboratories
- Health-care facilities

To promote the use of safe practices in the handling of pathogenic microorganisms

- in laboratory
- during transportaion
- in field investigations
- in manufacturing facilities
- in health-care units

Source: Laboratory Biosafety Manual, 3rd edition, 2004, WHO

2. Genomics, functional genomics and proteomics

Genomics is the "study of the genome and its action". Functional genomics refers to the "development and implementation of technologies to characterise the mechanisms through which genes and their products function and interact with each other and also with the environment" (WHO, 2002). Among the advents and developments in genomics, the genomes of many microbes including bacteria, fungi, viruses, animals and humans have been sequenced, with the help of molecular biological tools. Techniques used in genomics have fundamentally improved our understanding of the roots of pathogenesis and enhanced our knowledge about the treatment of infectious diseases. This has further resulted in wider applications of this science, including improved vaccines, antibiotics and antiviral agents. Conventional approaches of developing vaccines in the past are lengthy, and take many years to produce a successful vaccine. Through genomics, however, it is now possible to design and develop a vaccine much faster and more effectively with the help of computer analysis of the entire genome sequence of the pathogen. Target specificity of genomics has enormously helped in producing new drugs by identifying ion channels and proteins and has led to the understanding of the structures of cell receptors and their interactions with the ligands upon binding. This new knowledge about the behaviour of receptor sites and their proteins now makes it possible to develop designed drugs by "reverse molecular pharmacology" (WHO, 2002).

Proteomics, another important area of molecular biology, is defined as "the development and application of techniques to investigate the protein products of the genome and their interactions to determine biological functions" (WHO, 2002). This area complements genomics and makes it possible to identify the proteins expressed during microbial infection and disease spread and its interactions in the cells. Proteomics holds the promise to identify and characterize new proteins and pathways that will help in early detection and diagnosis of diseases and further improve the methods of drug design and search for new vaccines and antimicrobial substances. Rapid methods for the detection and identification of pathogens (either of human, animal or plants) are being developed with molecular techniques using polymerase chain reaction and DNA arrays.

However, the above facts about the genomics and proteomics also have a darker side. One reason is self-evident. These techniques and methods can be used intentionally to cause harm to civilization. The other reason, less obvious, is that a harmful environment or products may be created accidentally in the laboratory, by a single mistake at any stage of experimentation. The same knowledge that can be used to identify new drugs and vaccines can also be misused to cause harm. The knowledge, techniques and their applications associated with pathogenesis, for instance, can be misused to make drugs and vaccines ineffective or to overcome immune system. Knowledge about receptors and ligand-binders can be used to produce imitation ligands and pseudo-bioreceptors that harm the immune system and nervous system (WHO, 2002). Increasing knowledge about the bioregulators, neurotransmitters, peptides and cytokines that are produced in very small quantities to regulate physiological functions is also a risk. Increasing understanding about the innate immune system can provide information on generic protection against broad class of microbial agents but can also be utilized to disrupt the immune system. In a similar manner, the dual-use research and development activities in the life science can be of major harmful consequences if misused.

This is why activists in the biosecurity community now speak of the "moral norms" operating against development and employment of the risk-associated biological research.

3. Molecular farming and Genetically Modified Organisms (GMOs)

Humans require diverse, well-balanced food containing a complex mixture of both macronutrients and micronutrients in order to maintain optimal health. Macronutrients – usually carbohydrates, lipids and proteins including peptides and amino – acids are the primary sources of growth and energy, and make up the bulk of the food. Micronutrients, being essential (inorganic) or non-essential (organic) in nature, are not used for energy but are equally important for good health and well-being. Although present in minor quantities, nonessential micronutrients encompass a vast group of unique organic phytochemicals that are not strictly needed in the diet but, their presence at sufficient levels in the food is certainly linked with good health promotion (Morris and Robbins, 1997, DellaPenna, 1999).

Modifying the nutritional composition of plant foods is urgent worldwide need, in order to meet the basic nutritional needs for much of the world's population. A large number of people in the developing world are fighting hunger through a very simple diet, primarily composed of a few staple foods like wheat, rice, corn, cassava. Consequently, the diets of over 800 million people do not contain even sufficient macronutrients: micronutrient deficiencies are rather more prevalent (Calloway, 1995). Even in industrialized nations, where both food abundance and variety are excellent, and daily calorie intake is excessive, micronutrient imbalances are common owing to poor food habits.

With a view to increase the consumption of health promoting phytochemicals in the diets, researchers have turned with renewed interest in manipulating plant secondary metabolism. A central focus has been on the identification and isolation of genes required for the synthesis and accumulation of a target compound, so that its level can be modified in staple crops to obtain desired dietary change. Plant molecular farming (PMF) or biofarming, a step forward in the ongoing research and development of transgenic plants, involves the use of genetically enhanced plants to produce pharmaceuticals and industrial products, e.g., lycopene (in tomatoes), lutein (kale, spinach), glucoraphanin (broccoli), genistein (soybeans) and resveratrol (red wine, red grapes) (Einsiedel and Medlock, 2005). The first pharmaceutical protein made in plants was human growth hormone in tobacco in 1986 and since then a number of other proteins including vaccines, antibodies and industrial proteins have been produced.

Nutritional genomics is a general approach to gene discovery that is currently most applicable to plant compounds of nutritional importance. Identifying the genes needed for increasing levels of essential micronutrients and non-essential phytochemicals in staple food crops is an immediate goal that would have a significant impact on human nutrition worldwide. Nutritional genomics has recently been applied to the vitamin E biosynthesis pathway in plants.

Although molecular farming has the potential to resolve the nutritional imbalances in the human population, it also raises social, environmental and regulatory challenges that need to be addressed while considering how these products might be successfully and responsibly commercialized. The key concerns concern the commodity handling systems, environmental safety issues, contamination of the food supply and the emergence of new allergens or biotoxicants in the plant tissues undergoing genetic changes. The potential for cross pollination and contamination of food crops can be felt from the facts that the modified products would get into the food chain through direct cross-pollination or through wind, animals, birds or insects. At the same time, humans can also contaminate food crops either by error (e.g., by accidentally taking plant material from a greenhouse and sowing it in a field) or by malicious intent (e.g., bioterrorism, or by modifying a food crop to produce toxins and introducing such plants into the food supply). The issues of safety, regulatory and policy-making are also critical. Regulatory authorities should strictly monitor these technologies from being well planned and adequately accurate. However, there is a fairly widespread perception that activity of regulatory bodies, especially governmental bodies, may be hampered due to the lack of proper resources in the form of equipment, chemicals and expertise to appropriately oversee the research to ensure that all biosafety measures have been taken and biosecurity parameters are fully met. The scope of the existing rules, standards and guidelines and the policing capacity should also be considered to minimize risks, ensure transparency and avoid uncertainty. Finally, the potential long-term side effects, especially impacts on human and animal health should also be taken into consideration in public interest. The unforeseen impacts of such technologies on the environment and human health may not be detectable in short duration, although it may be revealed after years. Scientific practices for molecular farming that have been carried out under strictly controlled experimental conditions may not be reproduced and necessarily followed by the farmers/growers and commercial interests may supersede the public interest in biosafety. By doing so, the risk of contamination and risk of impacts on humans may increase. It would, therefore be of greater implications if molecular farming applications are carried out with non-food crops than with food crops. Further, molecular farming products grown in the outdoors are perceived as riskier than those grown indoors, under controlled environmental conditions.

Opportunities and constraints in agricultural biotechnology around the world, especially in the developing nations, are of significance in responding to the challenges of poverty in the 21st century (Persley and Lantin, 1999) as they can influence the development of national strategies that address the nutritional needs of poor-resource farmers and at the same time minimize ecological as well as social and health risks. Profit-oriented agricultural biotechnology is now addressing major national and international issues including poverty, food insecurity, conservation of the environment and sustainable agriculture. Genetically modified organisms (GMOs) also known as Living Modified Organisms (LMOs) are obtained from parent animals, plants and microorganisms. The worldwide expansion of transgenic crops can be considered as one of the most important agricultural trends of the future associated resulting from the biotechnological advancements. Potential benefits of transgenic agriculture can be observed in terms of the development of disease-resistant crops (which may obviate the need for ecologically hazardous pesticides), drought-resistant varieties and crops with better nutritional and food values. Recent growth and global dispersion of biotech crops or transgenic crops, better known as genetically modified (GM) crops, suggests that these techniques are the powerful drivers to improve and maximize agricultural productivity. Transgenic food crops have already entered and occupied a significant part of the global marketplace. In this age when food productivity has become an important socio-economic concern for all nations, due to the huge pressure of rapidly increasing population, about 45% of the world food crops are lost due to diseases, pests, drought and other natural calamities. In such a situation, agriculturists and biotechnologists are recognizing GMOs as high yielding and more productive crops that are solutions to the global food crisis. However, biosafety and biosecurity related concerns, fears and promises to GM crops have been expressed worldwide. Biosecurity issues and public fears concerning GM crops result from a number of events including the occurrence, spread and ignorance of *Mad Cow Disease* in Europe, reported presence of the chemical Dioxin in foods, beverages and sludge in animal food, and the concentration of seeds in a few hands, especially hands in the developed world. The national losses in the form of threats to genetic diversity and biodiversity, use of generic medicinal plants, indiscriminate appropriation of native intellectual property resources, monoplastic trends, and non-conformity with social, ethical and cultural issues are certain other important arguments that are presented against GM crops (DaSilva, *et al*, 2002). There is a continuing need for the assessment of GM crops and the food products obtained from them to address possible health risks from the release of the GMOs in the environment (WHO, 2000). Nutritional food safety assessments are integrated stepwise approaches in quality control, random trials and periodic updates in laboratory techniques, and man power expertise. Biosecurity protocols will help assure and secure the safety of GM crops and foods in the public sector (Anonymous, 2003).

4. Invasive alien species

Biological invasions by non-native species constitute one of the major threats to natural environment and biodiversity including forestry, livestock and agro-ecosystem (Wittenberg and Cock, 2000). Subsequently they can also impose huge cost on agriculture, forestry, fisheries, and other human activities including social organization and human health. Rapidly expanding and accelerating trade, travel, transportation and tourism all across the world over past century have dramatically exposed the risks of invasive alien species, allowing them to surmount the natural geographical barriers. In fact the majority of the species being used in agricultural, forestry and fisheries across national boundaries are non-indigenous, and therefore may be referred to as alien species, but their impacts are usually not harmful. Thus, the first and foremost step is to distinguish among beneficial, harmless and harmful alien species and to identify the impacts of the latter on native biodiversity and agricultural productivity in our eco-regional context.

The ways in which invasive species affect the native species and natural ecosystems are numerous, some times massive and usually irreversible. Non-indigenous species often consume or prey on native ones, attack and overgrow, infect them or act as insect/disease vectors, compete with nutrition or some times hybridize with them. Invaders can change eco-regional biodiversity as a whole and may alter hydrology, fire regimes, nutrient cycling, wild life, pests/diseases, indigenous microorganisms and natural pests/predators (Pimentel, 2002). They not only cause threats to agriculture and ecosystems but also damage natural resource industries. *Lantana camara*, zebra mussel (*Dreisenna polymorpha*), *Pueraria lobata*, Brazilian pepper (*Schinus terebinthifolius*), *Parthenium* and rats (*Ratuus* sps.) are examples from all over the world that have caused economic and ecological catastrophes. Invasive species are taxonomically diverse, and thousands of native species have been extinguished or are at the verge of extinction due to heavy bioinvasions. Weeds alone cause almost 25% loss in agricultural productivity and degrade agricultural fields and food quality. Chemicals used as weedicides work in a similar manner in degrading the agro-ecosystem and affecting native crop species and beneficial flora and fauna. Further, environmental degradation including global climatic changes, disrupted rain patterns, temperature rise in many parts of the world, habitat fragmentation, and contamination of natural water bodies extends the range of invading species and increase the risks.

However, it is not that all non-indigenous species have a harmful impact. During the course of the journey of the human civilization and along with the expansion of geographical boundaries, a great majority of plants, microbes and animals have been introduced as food, feed and fodder. Many productive industries using plants, microorganisms (fungi, bacteria and cyanobacteria), algae, fisheries and livestock are based on introduced species. Similarly, many microorganisms are being introduced in non-native environments in the form of biological control of crop pests and diseases, which has resulted in savings in pesticide use and crop loss. But, it is equally true that the agronomic originality, horticultural variety, microbial profile and zoological novelties of the natural agro-ecosystems have become destructive and invasive due to un-intentional and un-managed introduction of invaders. Many of the invasive insects have become pests, microbes like bacteria and fungi have become pathogenic, fishes introduced for human consumption have extirpated many native species, and even biological control introductions have gone awry. The rapidly developing science of invasion biology is now paralleling or even competing the biology of natural organisms. The growing worry for the present day agriculture is that the intentional introduction of harmful invasive alien species into the agro-ecosystem with the help of growing technologies can create major threats, so the scientists, public and the policymakers must be aware of them. The events of September, 11, 2001 and the subsequent anthrax attacks brought this bioterrorism to the forefront of world consciousness (Meyerson and Reaser, 2002).

Biological invasions – the routine importation (both accidental and deliberate) of harmful non-native organisms (Meyerson and Reaser, 2002) occur daily, and are estimated to cost more than $100 billion per year worldwide (Inderjit, 2005). Nonetheless, the scientists, policymakers and public over the whole world including India are paying considerably less attention and spending far fewer resources than needed to identify and address bioinvasions and their manifold impacts that include chronic damage to societal infrastructure, agro-ecology, fisheries, the environment and human health (Pimentel, 2002). It is therefore, a formidably challenging task for the scientists all over the world to convince policy makers, industry and the public to produce and subsequently adopt a comprehensive approach to biological security at the time when the prominent threats and the tangible benefits from the protection are not readily apparent.

Thus, looking into the potential threats of the bioinvasions, there is an urgent need to raise multifold awareness dedicated to substantial resources to address daily biological incursions in the country, as these have a substantial impact on human and animal well-being. Scientific communities can help to identify and develop a comprehensive biosecurity system to combat the chronic problems posed by the threats of bioinvasion and bioterrorism. It is our contention that a strong national strategy based on the evaluation of the human dimensions of the invasive alien species problems and an assessment of the current situation should be needed to identify the process at the very beginning and to ensure the responsibilities of all stakeholders involved in all phases of preparing the strategy. The very initial step towards a national strategy should be to identify a competent scientific group who will have to collect, assess and present the evidence as to that how invasive alien species are a major threat to the biodiversity and the economy and what actions should be needed to avoid, prevent or eradicate bioinvasion and even if it has taken place, how the associated risks will be minimized. Besides this, an inventory of existing invasive species along with their molecular, phylogenetic and biochemical taxonomic profile, ecological and economic impacts and the ecosystem they have invaded should also be prepared. The next step is to involve the stakeholders, policymakers and public to make them aware through nation wide campaign about conspicuous invasive species problems in the country.

Explicit objectives are a basic need to provide a national strategy framework conceptually to develop set priorities, and build awareness regulatory guidelines. Among the main objectives are-

- Protection of animals, plants and human health against alien species including pests, disease and pathogens.
- Protection of native species, including lower taxa and microorganisms, against contamination, hybridization, local eradication or extinction.

An invasive alien species may be found in any taxonomic group, from prokaryotes to the higher plants and animals. These groups include blue green algae, green algae, bacteria, fungi, plants, invertebrates, fishes, amphibians, reptiles, birds and mammals. In different eco-regional domains of the same country or in other countries, the definitions, terminologies and the peculiarities of such alien species may vary widely, but the general terms used by the scientific community, their definition and properties need to be documented with clarity. Therefore, the scope of a national strategic framework should be concerned on two basic aspects: eco-regional (geographic) expansion and species coverage. It should be noted that all parts of a national territory may be affected or be at risk if a bioinvasion takes place; such invasions should therefore be regulated for all ecosystems and biomes. Special attention should necessarily be given for island, oceanic territories or isolated ecosystems that are more vulnerable to such invasions. For practical and legislative purposes, a distinction must be drawn between unintentional (through trade, tourism, and transport in the sectors of agriculture, forestry, fisheries, horticulture) and intentional introductions (in the form of agricultural and food contamination, and unlawful spread of biological and chemical hazards). Unintentional bioinvasion may take time to spread and therefore, the impact would be rather slow and associated risks would appear during a long span, maybe even after generations. The spread of *Parthenium* on Indian soil is an example. On the other hand, intentional bioinvasions are a kind of bioterrorism where a harmful alien species may be introduced with the ill intention to harm the society and disrupt normal life very quickly. Early detection and alert systems are therefore, essentially required to fight potential bioinvasions. The major prerequisites for establishing such systems are:

- behaviour monitoring of intentionally introduced alien species to assess signs and potential of invasiveness.
- detection of the presence of unintentional introductions and their impacts
- taking emergency action and making authorities powerful to take immediate and necessary action.

Finally, mitigation measures that should come into force to combat invasive alien species are:

- short and long term measures for the eradication, containment and control of invasive alien species.
- positive efforts and strategic planning for the restoration of native biodiversity.

5. Bioterrorism in food

Food terrorism has been defined as "an act or threat of deliberate contamination of food for human consumption with chemical, biological or radionuclear agents for the purpose of causing injury or death to civilian population and/or disrupting social, economic or political stability" (WHO, 2002). Here, chemical agents refer to manufactured or natural toxins, biological agents refer to infectious or non-infectious pathogenic organisms including viruses, bacteria, parasites and radionuclear agents are defined as radioactive materials causing harm, injury or death, when present in excess amounts. There are many things in our surroundings that can directly or indirectly damage food and make it unhealthy for consumption. The objectives of intentional food sabotage such as food adulteration using chemical, biological and or radioactive materials, is therefore, to cause widespread health destruction, inducing terror and panic in society to disrupt social order (Steinbruner, 2000).

Food adulteration can have major diverse implications in society. Contamination or sabotage at production units, centralized food processing, and government distribution outlets could affect a wide range of the population, even in diverse regions. Thus, food borne diseases caused by intentional or unintentional contamination can cause a huge human population exposure.

In terms of biosecurity, risk refers to the probability or probability distribution of agricultural contamination. Risks are also associated with the introduction of unidentified non-indigenous microbial species that may result in undesirable agricultural contamination. With the increased trade and easy mobility of commodities from one place to another, the risks of bioinvasion by detrimental species are going to maximize.

Agricultural biosecurity

The vital role played by Indian agriculture in the past, and the national economy and industrial growth supported by it, are largely underappreciated by many people. These roles include the provision of food, maintenance of healthy ecosystems, generation of employment and enhancement of aesthetic qualities in human life. Besides all these characteristics, the "selling point" nowadays being used to reflect the importance of agriculture and to draw the attention of the policy makers, is simply driven by economics. While many of the plants, animals and other commodities including farm inputs, machines and raw materials are being produced at the domestic level, a significant portion also comes from other nations in the form of exports. Considering that almost 70% of the national population depends on agriculture, forestry, fisheries and animal husbandry for its health and livelihood, the need for agricultural biosecurity has never been realized with greater urgency than now, especially with the increases in the quantum of global trade and rapid transportation (Swaminathan, 2006).

So the "great challenge" for domestic agricultural biosecurity and food safety programs is then threefold: to ensure a safe and ecologically sound agriculture production system, to ensure access to a safe, reliable and inexpensive food supply and at the same time, to maintain the profitability of plant and animal produce. However, our collective ability to meet and manage the challenge at present in the country is under constant threat.

Given the monetary importance of the agriculture sector in the country, it is not an overstatement to mention that the economic well-being of the rural community and thus, the whole nation, is susceptible to significant disturbance and disruption due to invasive pests and introduced pathogens. Several additional factors further expose Indian agriculture to the risks posed by the natural and unintentional introduction of toxins, harmful chemicals, pests and pathogens. These multiplying factors include a genetic simplification and monoculture of planted landscapes and animal lines, that make crops and livestock more susceptible to diseases and pests, and the problems of monitoring plant and animal concentration over local, regional and broad geographical areas. Closely related and equally important risks in agricultural biosecurity also arise due to the intentional use of invasive pests and life-threatening microbes and plant pathogens, the acts that can be called agricultural bioterrorism. Biological terrorism (bioterrorism), the deliberate release of living organisms to inflict damage directly or indirectly, to the crops, livestock, agricultural inputs and humans is of particular concern to scientists. However, despite their high profile, professional, and potentially devastating consequences, the acts of bioterrorism in the field of agriculture are relatively rare, unpredictable and thus far small scale events. In contrast, biological invasions in the form of weeds, seeds, planting material, microorganisms and livestock are occurring routinely. This has significant impact on agricultural productivity, food quality, human and animal health, livestock, water resources and the environment. Scientists, the government and the public must therefore work together to implement an integrated approach to agricultural policy that can address bioinvasion, bioterrorism and biosecurity on the same platform in a very comprehensive manner. To achieve these goals, it becomes necessary for the respective governmental bodies to acknowledge and include prevention mechanisms, early detection and rapid response generation as central mission themes in order to manage, minimize or even control the problems.

Planning and execution of the responses towards agricultural biosecurity reflects our preparedness for such events. The response cycle during emergency should be outlined for risk assessment and immediate appropriate action by the researchers and policy makers, based on the intensity of the natural events, technological failures and biological outbreaks involved. The cycle of emergency response generally begins with preparedness – how people plan to deal with the events - and it examines how far we are prepared for the ultimate hard events. Response mechanisms further address what to do during an emergency to combat threats, and at recovery level include cleaning up after the disaster, and efforts to return to normalcy. Next to this is the mitigation phase which finally concludes with the assessment of severity and intensity of the disaster and our reactions to combat it, in order to further generate experience and expertise to strengthen the levels of preparedness, response and recovery to take up the challenges ahead.

Economic aspects of agricultural biosecurity

Economic losses due to bioinvasions are substantial in many parts of the world including India. Twenty five percent of costs to consumers associated with food products are due to invasive weeds, pests and diseases. Invasive species are second only to habitat destruction as a major cause of biodiversity loss.

From the economic perspective, a major consequence of agricultural bioterrorism upon the extent of disruptions is what it can cause in agricultural commodity and related agri-markets either because of the direct events or because of potentially expensive and intrusive preventive actions (Henson and Mazzocchi, 2002). Several market issues can be identified in relation to the agricultural market sabotage caused due to bioterrorism. Damages due to food contamination, in the forms of below standard products, consumer unwillingness and producer surpluses, and increased cost of prevention, control and repair strategies can directly lead to loss in the national economy. In addition, a substential economic loss is related to the prevention versus management dimensions that covers ethical and social values as well.

Estimation of economic damages caused due to intentional or un-intentional agricultural contamination may become a difficult task in the Indian context because of the complex nature of agricultural markets and their socio-economic impacts. Major issues linked to the economic damages may include the identification of the most affected individuals and/or communities (Evans, 2003) and calculation of economic values due to damage caused to those worst affected in reduced commodity sales, and the assessment of the impact time-line. Due to the highly integrated, societal and well-linked nature of the current Indian economy, the consequences of agricultural contamination at any given point along with the supply chain can also be manifested in other potential sectors such as the food and tourism industries.

Mitigation of agricultural terrorism

Response policies to agricultural terrorism may broadly be categorized into prevention, detection and control/repair mechanisms (Elbakidze, 2003). Prevention is perhaps the most desirable policy option in countering agricultural terrorism activities. Many of the preventive policy options are closely related to farm level production activities, such as reducing the use of chemical pesticides, antimicrobial livestock drugs and vaccination, and harmful biological inputs and radioactive materials. Other prevention mechanisms relate to processing and manufacturing processes, storage and transportation facilities, distribution and service facilities and trade inspection at various levels through agricultural authorities. The utmost purpose of the prevention activities is to reduce the possibilities of intentional or un-intentional agricultural and food contamination incidents.

Detection can be viewed as a part of prevention mechanism. It can facilitate the avoidance and elimination of possible points of agricultural terrorism by identifying key contaminants and degree and intensity of contamination. Surveillance and detection systems (chemical methods as well as machines) should be well equipped in order to identify the qualitative as well as quantitative levels of contaminants in the commodities. Tracking is an integral part of the detection system that allows authorities to identify the sources of outbreaks. Following the consequences, subsequent removal of all affected commodities from the market in a timely manner should be assured by the regulatory bodies. Response, control and repair are least desirable and the ultimate indispensible options or response to agricultural sabotage. Control policies are generally based on management practices to minimize the economic damages caused due to agricultural contamination. This entails stopping the further spread of any infectious contamination and therefore, minimizing the risks of the sabotage. Repairing the market sectors after outbreaks implies eliminating the sources of sabotage and restoration and replacement of fresh, contamination-free commodities in the food supply chain and further, rebuilding consumer faith and confidence in the products.

Responding to agro-terrorism: policy standpoints

Cost-benefit estimate based on the prevention and response mechanisms entail design of effective strategies realizing their necessary extent to assess the associated monetary and non-market costs (Khan *et al.*, 2001, Ferguson, *et al.*, 2001). Certain preventive and control activities at agricultural level may include reduced access to chemical and biological materials, enhanced security measures at central production, processing and distribution facilities, in-time screening by the regulatory authorities, updated sanitary standards at production, transportation, storage and retail outlets and the establishment and/or improvement of detection, surveillance and tracing techniques (Elbakidze, 2003).

From an economic standpoint, the choice of strategy needs to account for both the costs of damages brought about through agricultural contamination and the costs of preventing the incidents. Preventive activities, based on long term policies are thought to be economically justified as long as the additional level of prevention mechanisms outweigh benefits coming from additional control or repair mechanisms. At low probabilities of agricultural terrorism, substantial investment in prevention and subsequent surveillance and detection may look less attractive and remunerative than in the case of high probability of agricultural contamination, because the damage arising due to latter may be many times greater than that of the sabotage itself. For example, either prevention or timely detection and destruction of infected animals in the field may reduce the chances of disease spread and thus will decrease the probability of disease outbreak in the nearby regions. It is clearly realized that prevention and response strategies may not affect intentional terrorism and planned agricultural sabotage, but rather may be helpful in reducing the severity of the attack. Therefore, the intentional tasks to sabotage an agricultural market or creating food contamination are independent of prevention mechanisms being adopted, which in turn, may affect the severity of the damage. Vaccinating animals or birds before terroristic attacks or severe disease outbreaks will not affect the probability of the event, but may decrease the number of infected animals/birds, or save a farm or whole farming community from infection. Further, surveillance and detection mechanisms can decrease the cases of events and inability to detect and eliminate the threat in a given time frame. Low levels of surveillance and poor detection systems may cause severe outbreaks at farms and farming communities. High levels of surveillance and detection activities may decrease the probability of a given farm becoming infected.

Impacts and recommendations

Knowledge, techniques, materials and methods with applications to agriculture, biological science and biotechnology, and the life sciences enterprise as a whole, are expanding rapidly, making it feasible to identify and manipulate characteristic features of the living entities in ways never possible earlier. During *in vivo* experiments being carried out on a routine basis in biological laboratories around the world, researchers are using sophisticated tools to manipulate microorganisms in an effort to understand how they cause diseases and to better understand preventive, curative and therapeutic measures against them. Plant biotechnologists are applying similar tools to study crops and economic plants in an effort to improve productivity and to explore their potential use as inexpensive manufacturing platforms for vaccines, antibodies, proteins, nutraceuticals, drugs and other products that help human society to flourish. Similar trend of developmental efforts are under way with animal husbandry. Scientists in many inter-related biological fields and bioinformatics are relying on current advances in the life sciences to identify drugs for the suppression of cancer and other chronic diseases, develop environmental remediation technologies, improve bio-defense capabilities, and create biomaterials and search for renewable energy resources. All these developmental efforts are being made for a hunger-free world, sound biosphere, and betterment of life in the coming era.

Early and specific diagnosis, prior to the onset of typical disease signs and symptoms, should be the aim of research and development efforts. Improved diagnostic tests for human diseases, should be developed through thorough research efforts. Adequate attention, prioritization, and investments must be devoted to this important area. Other potentially useful approaches (e.g., comprehensive monitoring of host-associated molecular biological markers) should be adequately explored in order to create a comprehensive biosecurity system. There is a similar need for early detection and diagnosis of animal and plant diseases. Equally important is the development of broad-spectrum vaccines or biological response modifiers capable of providing protection against diverse classes of disease causing agents. To date, the industrialized world and well-established companies in the pharmaceutical industries are devoting significant financial incentives to develop new vaccines or therapeutic agents to combat biological threats. However, the current market for such products is extremely uncertain and depends ultimately on government procurement decisions. Since in the present world, all governmental and industrial motives are driven by commerce, continued efforts therefore, should be taken to address failure of commercial interests in this area of biological and agricultural science, which is of potential importance to the social and ethical needs.

Continuing threats of bioterrorism by ill minds on this earth, coupled with the global spread of knowledge, information and technical expertise in the field of biotechnology and biological manufacturing processes, has raised serious concerns over how advancing technological progresses stimulate new threats of biological nature and origin. These possess long-term unique and dangerous implications but remain largely unpredictable. Looking into the serious scene worldwide, the World Health Organization has provided essential biosecurity and biosafety guidelines for the international community. In addition, several UN agencies and programs such as the FAO, OIE, UNIDO, UNEP and UNDP, and non-UN bodies including the EU and OECD, have made significant contributions concerning the biosafety and biosecurity issues of modern agriculture, biotechnology practices, microbiological developments, advances in food production and the transfer, handling and use of genetically modified organisms in the environment (WHO, 2004).

Overall, our society has gained enormously from the advancements and developments in the area of life sciences because of the open exchange of knowledge, expertise, data and concepts. Knowledge, in association with its diverse techniques, has addressed biosafety concerns in the biological science and improved biosecurity, health, agriculture and life science-based industries to a great extent. However, there is a need to impose restrictive regulations and constraints on the free flow of information that may adversely be utilized with malevolent intent in the future. The possible aim of ill minds is to create difficulty for whole civilization to protect themselves against potential threats and ultimately to weaken national and human security. By imposing judicious regulations and constraints we can limit the ill effects of scientific advance in favour of continuing progress in the life sciences and its related technologies to improve health, provide secure sources of food and energy, contribute to economic development in both resource-rich and resource-poor parts of the world, and enhance the overall quality of human life (Sprinkle, 2003).

It is an unfortunate reality that almost all meaningful advances in life sciences and its associated technologies pose potential "dual-use" risks. However, a better science is the best protection against potential threats. Looking into the rapid developments that have been made so far, we are looking forward to entering the *Age of Biological Sciences*, paralleling the *Age of Physical Sciences* in the 20th century. Human civilization finds itself now at the forefront of the biological advancements and therefore should be prepared to face the risks and challenges posed by it, or else, should be ready to pay heavily in terms of environmental degradation, ecological imbalances, agricultural and food insecurity, health hazards and threats on lives, and even poisoning the whole earth. Worldwide, the scientific community needs to work for, promote and strengthen 'safe science' concerned with intellectual property rights that could limit to the minimum, the potential of 'dual use' science and information for the adoption of hazardous bioprocesses, and creation of biological warfare and bioterrorism.

Looking at the Indian context, the country needs to develop a comprehensive biosecurity strategy based on education, regulation, ethical and social mobilization. Considering so many unique properties of the nation, such as a huge population dependent upon agriculture for food and livelihood, different eco-regional plant and microbial populations, diverse biodiversity, efficient scientific manpower and many cultural and ethical issues, the need for a foolproof biosecurity system has never been greater than the present, especially in the era of globalization with the increase in trade, tourism and knowledge. To combat dangers at both the scientific and the societal levels, we need to:

- create a database on historical perspectives of pest/disease outbreaks, bioinvasions and their future implications;
- develop ground surveillance on newly detected diseases and pests of plants, livestock and human being;
- predict epidemiological risks of disease/pest outbreaks in different eco-regions;

- control food security issues and detect challenges ahead through 'responsive' and 'preventive' mechanisms;
- develop state-of-the-art models of potential agricultural and food bioterrorism and scientifically investigate the consequences;
- identify the risks of biological warfare through deliberate use of microorganisms and GMOs;
- educate people, especially farmers, about possible threats and preparedness.

A sound system of protection and security against the misuse of the biological sciences is one that anticipates forthcoming threats arising due to the intentional or unintentional misuse, another that seeks to understand the origins of these threats and that strives to manage perfectly the misuse of scientific advancements. It would be tragic if we fail to consider the nature of future biological threats, using the best available technical and skilful expertise, or to make any serious attempt to avert such threats. The anticipatory perspectives and action plan for the nation should be based on the facts that interdiction and prevention of the bad outcomes of science (or the malicious acts) are far more appealing than treatment and remediation. It is sincerely advocated that the science should remain close to nature, to life, to the ecological boundaries and to its own limits that may not be beyond the human insights.

Recommendations for the adoption of a comprehensive agricultural biosecurity system:

- promote policies and practices, that increase free flow and open exchange of knowledge and information in the life science community;
- strengthen and enhance the scientific and technical expertise within and across the biosecurity communities;
- link scientists and NGO activists with the policy processes;
- ensure broader alliance among social and scientific communities, government, corporates and farmers;
- assemble all the stakeholders and communicate efficiently and honestly about the depth and seriousness of the issues;

- widen the picture on agricultural and food biosecurity and include the least privileged;
- promote organic agriculture and natural resource management.

*Cooperation between scientists, the government, institutions, industries and the public is desired to reduce and prevent future bioinvasions

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Preparedness for Ensuring Biosecurity in the Biotechnology Sector

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The FAO defines Biosecurity as "a strategic and integrated approach that accompanies the policy and regulatory frameworks that analyze and manage risks in the sectors of food safety, animal and plant life and health and associated environmental risks".

The introduction and management of invasive alien species and genotypes, Genetically Modified Organism (GMOs) and their products, and also plant and animal pests and diseases, are covered under the various Biosecurity threats. It is important to approach this issue in a pragmatic way since Biosecurity is a holistic concept of direct relevance to the sustainability of agriculture and food security and protection of environment including Biodiversity.

Biosecurity holds enormous significance today, with the idea of global village developing rapidly. Issues such as trans-boundary movement of biologicals, international standards and guidelines as a safeguard for prevention of introduction and spread of pathogen, policy and regulatory framework to address sanitary, phytosanitary and zoosanitary problems all need to be addressed in a holistic manner.

Globally, Biosecurity in the context of agriculture and environment is being thoroughly debated. The FAO has organized a number of discussions on the subject. An international technical consultation in January 2003 had the participation of 38 countries and eight international organizations including the Codex Alimentarius, International Plant Protection Convention (IPCC), Office of International des Epizooites (OIE) and Convention on Biological Diversity (CBD). The consultation concluded that:

i. It is imperative to recognize the importance of Biosecurity as a key element of sustainable development.
ii. There is a potential to synergize and harmonize the national and sub-national regulatory framework that would result from a holistic approach to Biosecurity.
iii. Countries should cooperate to address Biosecurity issues at regional and sub-regional level.
iv. Risk analysis and management framework are important components of Biosecurity.
v. International standards and guidelines should be framed considering their implication and impact on developing countries with economic transition.
vi. Capacity building is one of the biggest challenges for implementation of a Biosecurity programme. There is a critical need to augment the existing facilities and strengthen capacity-building, especially in developing countries.

Many countries have institutionalized the process of Biosecurity implementation: Australia, New Zealand, and Norway are good examples. Biosecurity is a government responsibility, and to ensure effective compliance some essential requirements are:

- A sound national legislation, regulation and policy framework
- A well structured institutional framework
- An effective risk monitoring, evaluating and management system
- A participatory public awareness and dialogue mechanism

International standards and treaties to safeguard biosecurity

A number of international agreements, standards, treaties, organizations and programmes form a loose international framework for Biosecurity. Some of the important agreements are:

i) *An agreement on the application of sanitary and phyto sanitary measures (SPS) of World Trade Organization* entered into force on 1st January 2005, and sets out the basic rules for food safety and animal and plant health standards. The agreement builds on previous GATT rules to restrict the use of unjustified sanitary and phytosanitary measures for motives of trade. These measures are important to protect human, animal and plant life from risks arriving from toxin- or disease-causing organisms, pests and diseases and to prevent their entry, establishment or spread.

ii) *The FAO International Plant Protection Convention (IPCC)*, the revised text approved in 1997, recognizes the necessity for international cooperation in controlling pests of plants and plant products and preventing their international spread and introduction into endangered areas. Taking into account the internationally approved principles governing the protection of plant, human and animal health and environment, it was desired that a framework should be prepared to develop and apply harmonized phytosanitary measures. This convention provides for national plant protection organizations to be set up to deal with certification, regulation and related issues.

iii) *The FAO-Codex Alimentarius Commission* was created in 1963 by FAO and WHO to develop food standards, guidelines and code of practices to protect the health of consumers and ensure fair trade practices in food trade. An *ad hoc* intergovernmental Task Force was established on foods derived from Biotechnology, with the objective of developing standards, guidelines or recommendations for traits introduced into food through biotechnological interventions.

iv) *Under the Convention on Biological Diversity (CBD) 1992*, guidelines on management of invasion of a new species has been developed. The CBD was drawn up reflecting the fact that biological diversity is important for evolution and for maintaining the life-sustaining systems of the biosphere and that increased urbanization is significantly reducing biological diversity. Conservation of biological diversity is therefore a common concern of humankind, and it is imperative to enhance and complement existing international arrangements for conservation of biological diversity and sustainable use of its components. The Cartegena Protocol on Biosafety (2000) under the CBD, deals with the transboundary movement, transit, handling and use of Living Genetically Modified Organisms (LMO's). The protocol offers many tools for promoting biosafety: advanced informed agreements, biosafety clearing house and risk assessment. Individual governments will decide whether or not to import LMO's on the basis of risk assessment undertaken in a scientific manner. Various socio-economic considerations are taken into account.

v) *The International Treaty on Plant Genetic Resources* for food and agriculture was adopted by the FAO in November 2007 which came into force in June 2004. Its main objectives are in harmony with the CBD and aim to establish an effective, transparent multilateral system to facilitate access to plant genetic resources for food and agriculture, and ensure sharing of benefits in a fair and equitable manner.

vi) *Bonn guidelines on Access to Genetic Resources*, and the fair and equitable sharing of benefits arising out of their utilization were adopted by the Conference of Parties under the CBD in their 6th meeting (COP VI). These guidelines are an important tool in assisting each national government in developing an overall access and benefit-sharing strategy as a part of its overall National Biodiversity Strategies and action plan.

vii) *Budapest Treaty on the International Recognition of the Deposit of Microorganisms* for the purpose of patent procedure and regulation adopted in 1977 and amended in September 1980 is an important instrument to regulate the export and import of microorganisms. Any restrictions should apply to microorganisms deposited or destined for deposit, if they are essential in view of additional security or any danger for human health or environment.

There are a number of other legally binding instruments and soft law and policy declarations under the international policy and regulatory framework relevant to biosecurity in food and agriculture including forestry. The important areas are:

- The *Constitution of the European Commission* for the control of foot and mouth disease (1953) and the *Agreement for the Establishment of regional animal production and health commission for Asia and Pacific* (1973) are relevant to the protection of animal life and health;
- *The Biological Weapons and Toxins Convention (1972)* from the point of view of biological warfare and disarmament;
- *The United Nations Convention on the Law of the Sea* and various agreements establishing regional fisheries management organizations such as the *Convention for the establishment of the Lake Victoria Fisheries Organization* (1994) and *Convention on the Conservation of Antarctic Marine Living resources* (1980) and the various regional seas agreements

are relevant to protecting living marine resources from pollution and invasive alien species;

- *The RAMSAR Convention of Wetlands* and the various regional nature conservation agreements such as the *African Convention on the Conservation of Nature and natural resources (*1985) are also relevant in relation to invasive alien species.
- Soft law instruments include
  - Agenda 21 UNCED (1992)
  - The FAO International Code of Conduct on Responsible Fisheries (1995)
  - The international Code of Conduct for Plant Germplasm Collecting and Transfer of germplasm (1993)
  - The FAO Code of conduct for the import and release of exotic biological control agents (1995)
  - The ICES code of practice on the introductions and transfers of Marine Organisms (1994)
  - The IMO guidelines for the Control and Management of Ships' Ballast Water to Minimize the Transfer of Harmful Organisms and Pathogens (1997) and
  - The IUCN Guide to Designing Legal and Institutional Frameworks on Alien Invasive Species

Our preparedness

As a signatory to WHO, it is obligatory for the country to abide by International Agreement and protocols, such as the SPS, IPCC etc. To meet the challenges posed by the new tools of biotechnology, which have a direct or indirect impact on biosecurity, it is imperative that the nation have in place the required infrastructure, policy and legislation and an institutional framework.

Currently we do have in place a sound national legislation and policy framework, and to address the concerned issues and ensure effective implementation, a comprehensive institutional framework has also been put in place.

There is a clear monitoring, evaluation and management structure, which ensures timely completion of targets.

i) Regulation of GMO and Biosafety guidelines as per the cartagena protocol

As a signatory to CBD, India is abiding by the set procedures and guidelines of the Cartagena protocol. Government of India notified various regulations through a government order, notification No. 1037(E) dated 5.12.1989, which was issued by the Ministry of Environment & Forests under the Environment (Protection) Act, 1986. The notification has set the rules for manufacture, use, import, export and storage of hazardous microorganisms/genetically engineered organism or cells. The notification has also set up various levels of committees considering the level of risk involved. These committees are: the Recombinant DNA Advisory Committee (RDAC), Review Committee of Genetic Manipulation (RCGM), Institutional Biosafety Committee (IBSC), Genetic Engineering Approval Committee (GEAC) and State and District level Biotechnology Co-ordination Committees (SBCC & DBCC).

India has made significant progress towards the development of biosafety regulations and an institutionalized framework for their implementation, to ensure an effective evaluation of transgenic plants before they are given clearance for release in the field. Safety guidelines for recombinant DNA research and development in India have been formulated under the Environmental Protection Act, 1986 by the recombinant DNA Advisory Committee set up by the Department of Biotechnology in consultation with experts in this area and representatives from different ministries. These guidelines have been extensively circulated and are now adopted across the country. Regulatory mechanism for the development and evaluation of transgenics as per the recombinant DNA safety guidelines is based on a three–tier system as given below:

a) Institutional Biosafety Committee (IBSC): This is an institutional committee chaired by the Head of the institution or his nominee and has members from different disciplines, the Biosafety Officer and one member nominated by DBT. The committee's functions are:
  - To provide a half yearly report on the ongoing projects to RCGM regarding the observance of the safety guidelines on accidents and risks, and on deviations, if any.
  - To review project proposals falling under the restricted category, and clear those that meets the requirements under the guidelines.

- To tailor the biosafety programme to the level of risk assessment.

b) Review Committee on Genetic Manipulation (RCGM): The RCGM functions under the Department of Biotechnology and has representatives of various ministries and scientists from different disciplines. The committee is headed by an eminent biotechnologist and has the following functions:
   - To establish a procedural guidance manual for the regulatory process with respect to activity involving genetically engineered organisms in research, production and applications related to environmental safety.
   - To review the reports in all approved ongoing research projects in the high risk category and controlled field experiments, to ensure that safeguards are maintained as per guidelines.
   - To recommend the type of containment facility and the special containment conditions to be followed for experimental trials and for certain experiments.

The RCGM has a sub-committee, namely the "Monitoring-cum-Evaluation Committee", to design field experiments and formats for collection and evaluation of scientific data on plants grown under contained conditions as well as in limited field trials. This is an inter-ministerial committee to field evaluate the transgenic crop trails undertaken by the investigators under the approval of RCGM. The committee was also made responsible for monitoring large scale field trials on transgenic crops permitted under GEAC.

c) Genetic Engineering Approval Committee (GEAC): This inter-ministerial committee under the Ministry of Environment and Forests is the competent authority for release of GMOs into the environment. It is chaired by the Additional Secretary, Department of Environment and Forests and has members from different ministries and scientists from different disciplines. The Ministry of Environment and Forests issues authorization to applicants on the basis of approvals accorded by the GEAC. The important functions of the committee are to control:
   - Import, export, transport, manufacture, process, selling of any microorganism or genetically engineered substances or cells including foodstuffs and additives.
   - Discharge of genetically engineered/classified organisms/cells from laboratory, hospitals and related areas into the environment.

- Large scale use of genetically engineered organisms/classified microorganisms in industrial production and applications (Production shall not be commenced without approval.)
- Deliberate release of genetically engineered organisms.
- The approval will be for a period of 4 years.

Import of all GMOs, including propagating material, is through the National containment/quarantine facility for transgenic plants at NBPGR, New Delhi and is governed by the Plant Quarantine Order 2003. The National Facility has been established at New Delhi for testing of transgenic material in the contained conductors prior to their release for trade. The transgenic material permitted by the RCGM for import is processed at this facility for quarantine clearance. Samples of transgenic crops received form various countries are tested and examined for quarantine clearance.

Facilities for testing of toxicity and allerginicity of GM material have been supported at Indian Toxicology Research Centre (IIRC), Lucknow and Shriram Institute, New Delhi. Import /Export of Microorganism is governed under SCOMAT guidelines of Directorate General of Foreign Trade (DGFT). An International Depository Authority (IDA) has been setup as per Budapast Treaty guidelines for deposit of all microorganisms at Institute of Microbial Technology (IMTECH), Chandigarh.

ii) Food safety

It is important to distinguish between foodstuffs that actually contain genetically modified material (e.g., fresh GM tomatoes), foodstuffs in which DNA has been degraded by processing (e.g., tomato paste from GM tomatoes) and foodstuffs that contain the products of genetically modified organisms but not the original gene (e.g., cheese made with enzymes manufactured by GM micro-organisms). Foods that contain ingredients derived from GM plants, such as oils and sugars, will not contain genetic material from those organisms if the product is highly purified and processed before addition to the food. It should be noted, however, that foods produced from GM microorganisms such as vitamins or supplements should be subject to the same quality control measures as those produced by traditional methods. This was recently highlighted in the production of the amino acid tryptophan (used as a dietary supplement) by GM bacteria. Owing to relaxation of quality assurance measures the resulting product contained impurities toxic to humans.

Labeling & Segregation: Labeling of foods containing GM materials, where the new foodstuff is substantially changed (according to specified criteria) from that of its conventional counterpart, is necessary to allow customer choice. Segregation of commodity crops and derivatives through long supply chains on a global scale will cause difficulties of traceability for those manufacturers and retailers who wish to source products which do not contain GMOs or their derivatives. For enforcement purposes, it is essential to recognize a minimum level for adventitious presence of GM material, below which a product can be considered to be free of GM derivatives. Scientifically validated testing methods would have to be developed and agreed in order for such enforcement to be carried out in a reliable, readily repeatable and practical basis.

The Department has had detailed consultations with regard to the regulatory mechanisms for food safety. The Codex-Alimentaris guidelines are being strictly followed and the policy is being formulated. A strong recommendation has been the "comprehensive labeling" of genes, food and food ingredients, which means mandatory labeling of all such food and food ingredients and products derived, that are not equivalent to the corresponding existing food with regard to; composition and/or; nutritional value and/or intended use; and/or method of production adopting genetic engineering or genetically modified process.

For the GM Food Import/export a draft Notification on GM food labeling has been brought out under the PFA Act. Capacities have been built in 5 laboratories for testing of transgenic traits in GM Food:

- Central Food Technology Research Institute (CFTRI), Mysore
- National Institute of Nutrition (NIN), Hyderabad
- Central DNA Finger Printing and Diagnostic (CDFD), Hyderabad
- Indian Toxicology Research Center (ITRC), Lucknow
- National Bureau of Plant Genetic Resources (NBPGR), New Delhi

These centers are now being set up as referral centers under the PFA Act. A Joint Working Group of the DBT and the Ministry of Health and Family Welfare has been constituted to monitor the GM Food.

iii) Access to genetic resources

India is a Party to the Convention on Biological Diversity (1992). Recognizing the sovereign rights of states to use their own biological resources, the convention expects the parties to facilitate access to genetic resources by other parties subject to national legislation and on mutually agreed upon terms (Article 3 and 15 of CBD). Article 8(j) of the convention on biological diversity recognizes the contributions of local and indigenous communities to the conservation and sustainable utilization of biological resources through traditional knowledge, practices and innovations and provides for equitable sharing with such people, of benefits arising from the utilization of their knowledge, practices and innovations.

Biodiversity is a multi-disciplinary subject involving diverse activities and actions. The stakeholders in biological diversity include the Central Government, State Governments, institutions of local self-governmental organizations, industry, etc. One of the major challenges before India lies in adopting an instrument, which helps realize the objectives of equitable sharing of benefits enshrined in the Convention on Biological Diversity.

The Biological Diversity Act 2002 was brought out with the objectives:

- To regulate access to biological resources of the country with the purpose of securing equitable shares in benefits arising out of the use of biological resources; and associated knowledge relating to biological resources;
- To conserve and for the sustainable use of biological diversity.
- To respect and protect the knowledge of local communities related to biodiversity;
- To secure sharing of benefits with local people as conservers of biological resources and holders of knowledge and information relating to the use of biological resources;
- Conservation and development of areas of importance from the standpoint of biological diversity by declaring them as biological diversity heritage sites;
- Protection and rehabilitation of threatened species;
- Involvement of institutions of states government in the broad scheme of the implementation of the Biological Diversity Act through constitution of committees.

Under this Act a National Biodiversity Authority (NBA) has been set up to be responsible for all matters relating to conservation of biodiversity, sustainable use of its components and equitable sharing of benefits arising out of the utilization of biological resources.

iv) Crop security

To ensure that all material produced through tissue culture and propagated on a large scale is free from pests and pathogen, a National Certification System for Tissue Culture raised plants has been developed. All mother cultures and Tissue Culture raised material are tested for freedom from viruses and pathogen and a genetic fidelity test is done to ascertain truth to type. An Accreditation unit has been set-up for Accrediting Test Laboratories and certifying the tissue culture production facilities. The Accreditation Test Labs are responsible for certifying the plant material based on standardized test procedures and protocols. Two referral centers have also been set up for the purpose, and are responsible for preparing standards guidelines, maintaining all antisera and diagnostic kits for all viruses and providing necessary training. This certification is for domestic material and also for import /export of tissue culture material as per existing legislation under Plant Quarantine Order 2003.

v) Other repositories

In addition to the above available infrastructure, there are other major repositories established for various collections. The main objective of setting up and strengthening these repositories is to promote conservation/preservation of living organisms including microbes both useful and harmful in agriculture, animal husbandry and boundaries. Some major repositories include:

- The National Facility for Marine Cyanobacteria (NFMC) at Bharathidasan University, Tiruchinapalli has surveyed the Little Andamans and added sixty new strains to its germplasm collection.
- The Tissue Culture and Cryopreservation Repository at NBPGR, New Delhi has a total of 1107 accessions of various priority crops with more than 100 accessions of orthodox seed species and difficult to store species in cryobank.
- The Repository of Medicinal and Aromatic Plants, CIMAP, Lucknow maintains 303 pure compounds and 461 plant extracts from more than 80 medicinal and aromatic plant species to serve as reference material.
- The Drosophila Repository and Research Facility, Devi Ahilya University, Indore has developed an experimental kit for demonstrating the principles of genetics in schools and colleges.
- National Centre for Conservation and Utilization of Blue Green Algae (BGA), IARI, New Delhi holds more than 800 strains of blue green algae.

Public awareness

A proper public awareness is very important with respect to the benefit and risks associated with GM technology. Several factors can play an important role in public acceptance of genetically modified crops. Scientific demonstration of biosafety of transgenic crops and review of Govt. Agencies are extremely important in gaining public acceptance. Public acceptance is also greatly determined by the kind of information provided by the media to the general public. Misinformed public debates on key issues related to crop biotechnology can result in erosion of public confidence and cause mistrust of the technology and its developers. Therefore, clear and understandable consumer information is a very important part of the public acceptance process. Media, research organizations and scientific institutions concerned with crop improvement must also take responsibility for bringing awareness in public about the application of genetic engineering in agriculture with potential benefits as well as constraints.

The Department of Biotechnology has been organizing a number of Roving Seminars across the country. In addition some of the important NGOs and Research Institutes like the MSSRF, Chennai and the TERI, New Delhi have also organized Policy Discussion Forms, Stakeholders Dialogue and Media Debates to spread awareness to the public in general. A concerted effort is being made to conduct and promote research activities for the benefit of the public in consultation with them.

In addition to this there are concerted efforts ongoing to have public dialogues with stakeholders on issues related to Bio-security. A separate biosafety website has been launched and a DBT newsletter constantly covers details of major activities supported and ongoing in universities and research Institutes which contribute to Biosecurity in Agriculture, Health and Environment.

Conclusion

With the expanding frontier of Biotechnology, issues of Biosecurity and Biosafety are of paramount importance. Intellectual property rights, crop security, biodiversity and access to genetic resources, potential bioeconomic damage to the agriculture and livestock diversity and bioindustrial infrastructure are specific issues of concern. It is imperative that these issues be addressed globally and it is the responsibility of policy makers and scientists to adopt and promote policies which facilitate the process. With a concerted effort in this direction, it is possible to ward off all threats faced in the area of food safety, human, plant and animal health and environment security, and ensure an effective Biosecurity system.

Setting up a National Agenda towards Biosecurity

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Biosecurity is a strategic and integrated approach encompassing the policy and regulatory frameworks that analyze and manage risks, mainly in the sectors of food safety, animal, and plant life and health, including associated environmental risks.

Two factors assume paramount importance in this field. One is enhanced productivity, and the other is profitability. These factors have been receiving increasing interest internationally as regulatory and export certification systems have been challenged by:

a. The volume of products being traded internationally;

b. their number, the growing nature of the content and origin of the products, and their wide variety;

c. the increasing need for coordination between national bodies which enforce sanitary, phyto-sanitary and zoo-sanitary measures.

Need for national biosecurity measures

Increased travel is also creating more avenues for the spread of pests, diseases and other hazards that are moving faster and farther than ever before. Improved coordination is therefore being sought among national bodies responsible for enforcing sanitary, phytosanitary and zoosanitary measures for better protection of human, animal and plant life and health, without creating avoidable technical barriers to trade.

Global convergence towards biosecurity

There is growing global recognition that biosecurity will profit from a more integrated approach. Synergy and cooperation among institutions responsible for implementing and the rationalisation of infrastructures, where appropriate, is now recognized as valuable and beneficial. Models have appeared in a number of countries to rationalize regulatory functions among sectors in the quest for improved effectiveness and efficiency. For example, New Zealand has had a Biosecurity Act since 1993 and a Biosecurity Minister and Council since 1999.

The Australian Federal Government, as well as the state and territory governments, industry and other key stakeholders, have been reviewing the *Australian Biosecurity System* (ABS) aiming at further improvements and integration.

International arrangements

Several initiatives are under way, set in motion by the United Nations Organization and other international organizations and institutions to actively promote biosecurity.

The World Trade Organization agreement on the Application of Sanitary and Phyto-sanitary Measures (SPS Agreement) regulates SPS measures in relation to international trade. The *Codex Alimentarius Commission* (Codex), the *International Plant Protection Convention (IPPC) and the Office International des Epizooties* (OIE) provide international standards for food safety, plant health, and animal health, respectively. A further relevant instrument is the *Cartagena Protocol of the Convention on Biological Diversity* (CBD) which applies to the transboundary movement, transit, handling and use of Living Genetically Modified Organisms (LMOs). Guidelines on the management of invasive alien species have been developed under the CBD.

The Food and Agriculture Organisation of the United Nations (FAO), recognizing the growing importance of biosecurity, has made this area one of its sixteen Priority Areas for Inter-disciplinary Action (PAIAs) which aims at "promoting, developing and reinforcing (biosecurity) policy and regulatory frameworks for food, agriculture, fisheries and forestry".

Policy and regulatory framework

The development of a consistent national framework of policy and processes within which to approach national biosecurity issues is of major importance. The strengthening of policy and regulatory frameworks for biosecurity in food and agriculture needs to be accorded the highest priority. Such a framework will provide:

1. Optimization of scarce human and financial resources;

2. improving the cohesiveness of advice on all aspects of biosecurity, including biosafety;

3. recognition of the special importance of biosafety to food and agriculture, as well as the special impact of food and agriculture on biosafety. The development of appropriate standards, guidelines, and other recommendations for food safety and the protection of plant, animal and aquatic life and health, based on risk assessment and taking into account relevant aspects of biosafety, including environmental health, need urgent attention.

Initiatives required

The major conclusion is that we urgently need a *National Biosecurity System* with the following principal goals:

a To enhance national and local level capacities in initiating proactive measures in the areas of monitoring, early warning, education, research, and international cooperation, and to introduce an integrated biosecurity package comprising regulatory measures, education, and social mobilization;

b To organize a coordinated National Biosecurity Programme on a hub and spokes model with effective home and regional quarantine facilities.

The three-tier structure of a National Council, National Centre and National Network, proposed by the National Commission on Farmers, is essential to handle the issue adequately and efficiently.

The proposed National Council will comprise all the Departments and Ministries of the Government of India as well as International and State Government agencies, private sector organizations, as a pooling and sharing platform for experiences. The National Centre will serve as a database and also as a watchdog agency to generate proactive reactions to emerging situations. This Centre needs to function as an environment-scanning mechanism, looking around all the time for possible threats and opportunities, comparing and collating signals, adding value and ensuring that those who have to deal with them receive the information in a user-friendly manner. The Farmers Commission has also recommended a national network called the National Agricultural Bio-security Network, to facilitate partnerships in scientific and technological expertise and to identify those in urgent need of help.

Other areas which require urgent attention are the following

1. Review of all existing acts relating to biosecurity to identify and fill gaps in the existing regulatory framework;
2. Measures to promote education to prevent unconscious and ill-informed introductions of invasive alien species. There is need for launching a Biosecurity Literacy Movement in the country;
3. Social Mobilization: Agricultural biosecurity should be of concern to everybody, and not merely to only a few government departments or academic institutions.

Conclusion

Post-1990 with the onset of the era of liberalization, privatization and globalization, new and hitherto unknown factors and international obligations are shaping the imperatives of a new regime of governance within and amongst many countries, including ours. Thus the environment is changing rapidly and many unfamiliar concerns have been appearing on the horizon. Therefore, the challenge is to stay abreast of events. Most of the agencies in our system are probably in need of a one-time catch-up exercise, because so many things have happened in the last ten or fifteen years, and many of our systems have lost the ability to keep pace. They have first to become relevant and contemporary, and then to keep pace with the changes in the environment.

Agroterrorism: Biosecurity threats and preparedness

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Agroterrorism or agriterrorism is a subset of bioterrorism, since the potential of terrorist attacks against agricultural targets are increasingly recognized as threat, world wide. Agroterrorism refers to the deliberate introduction of a plant or animal disease with the aim of generating fear, causing economic losses and weakening the stability of a country. A disease introduced deliberately may be indistinguishable from one that arises naturally. Hence the criminals or agroterrorists behind such acts can cause serious economic damage and easily escape. Past experiences from agroterrorist attack gives some indication of the level of damage to expect from such an attack. This paper addresses this broad topic, and gives an overview of anti-agriculture biological weapons, common plant or animal pathogens and their potential threat to agriculture and society. It also gives an account of how India, a developing country, is vulnerable to agroterrorism.

Agroterrorists could release damaging insects, viruses, bacteria, fungi or other microbes aimed mainly at wiping out crops or farm animals. They also could attempt to poison processed foods. Although the consequences of an agroterrorism attack are substantial, relatively little attention has been focused on the threat worldwide. Unfortunately, the agricultural and food industries, the most important industries in the world, are the most vulnerable to disruption. It is also an easy way to cause huge damage, compared to other terrorist attacks, and the capabilities that terrorists would need for such an attack are not considerable (RAND, 2003). However, agroterrorism has largely been ignored in terrorist threat assessments. Disease-causing microbes such as foot-and-mouth disease are readily available in countries where they naturally infect crops or livestock. These common diseases present in one country can easily be "weaponized", which may be as simple as just simply walking onto a farm with contaminated shoes. Above all, such an attack might be confused with a natural outbreak of disease, making it difficult even to detect (Woods, 2003). There are several past examples of natural disease outbreaks among plants and animals that demonstrate the destructive potential of an agroterrorist attack. These examples show that the financial impact of an outbreak includes not only the cost of the lost agricultural products, but also the cost of disrupted trade.

Biosecurity threats from Important animal diseases

The economic cost of recovering from serious disease outbreaks is much higher than the disposal cost of the infected animals. The action taken after an attack needs to be quick and effectively control the spread of disease, and animals that might have been exposed must also be destroyed. Sometimes it becomes quite impossible to identify the infected and the uninfected. In such cases all the animals have to be destroyed. This may also include all of the animals within a geographic radius, as well as those that have been exposed through common transportation routes. However, many times the cost of slaughtering and disposing of this increased number of animals is only a fraction of the total cost of disease eradication.

These are a number of examples of disease outbreak from different parts of the world. An outbreak of Foot and Mouth Disease (FMD) in Italy in 1993 cost $11.5 million to eradicate, but the market disruption was more than ten times this amount, about $120 million (Kohnen, 2000). FMD is particularly expensive to eradicate because of its high level of virulence, and it triggers immediate export restrictions. The Canadian outbreak of FMD between 1951 and 1953 is another example. Though this was not a major outbreak, about 2,000 animals had to be destroyed, at a cost of about $2 million. Trade restrictions then decreased the value of Canadian livestock by $650 million, and the total economic impact due to international embargoes was about $2 billion (Vannieuwenhoven, 2000). In 1996, FMD broke out among swine in Taiwan. This outbreak resulted in the destruction of nearly 4 million hogs, and the long-term losses to swine-related industries are projected to reach $7 billion (Wilson and Tuszynski, 1997).

Another animal disease, highly pathogenic in nature, is the avian influenza (HPAI) that struck Pennsylvania in 1983. About 17 million chickens had to be

Agroterrorism: Biosecurity threats and preparedness

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Another animal disease, highly pathogenic in nature, is the avian influenza (HPAI) that struck Pennsylvania in 1983. About 17 million chickens had to be disposed of, and the cost of disease eradication reached $86 million (Wuethrich, 1995). The price of poultry increased as a result, which cost consumers another $548 million. The incident cost an additional $7 million in lost wages (Kohnen, 2000).

Avian influenza

The H5N1 strain of Avian influenza virus is one of the recent flu viruses with a high potential to cause a pandemic outbreak of flu, due to its high lethality in birds and humans. Researchers have found that the human population has no natural immunity to this strain, since it is genetically different from the other 3 strains like H1N1, H1N2, and H3N2. WHO estimates suggest that bird disease and death from H5N1 have occurred throughout Asia. In addition they also estimated that in places with close interactions between people and poultry, H5N1 has resulted in 114 human cases of flu and 59 deaths from late Dec. 2003 to Sept. 19, 2005 in Asia. As a result of avian influenza, millions of farm birds have been killed throughout Asia in an attempt to control the spread of the virus.

When it comes to bioterrorism, influenza has not yet been used as a biological weapon. However, it can be used to cause economic damage to a country and can cause serious damage similar to a natural outbreak. Naturally occurring flu pandemics include the 1918' flu, which caused 20-50 million deaths worldwide and 675,000 in the U.S. The 1957 flu resulted in 70,000 U.S. deaths, and the 1968 flu caused 34,000. Even with widely accessible vaccines, seasonal flu results in an average of 36,000 deaths per year in the U.S. There is concern that laboratory samples of previous pandemic strains could be acquired by bioterrorists.

It is also important now to look at our preparedness to face any such challenges in case of a natural or intentional outbreak. Antiviral drugs like Tamiflu and Relenza inhibit the production of neuraminidase in infected cells, preventing viral escape and reducing severity of illness. Many countries are stockpiling Tamiflu from Roche Laboratories, to prepare for a pandemic flu. The U.S. stockpile contains enough Tamiflu to treat only 2.3 million adults and 100,000 children. Two other companies are currently developing vaccines, which are currently being tested in clinical trials, but their efficacy against H5N1 in humans is unknown. The following countries have reported H5N1 in wild birds or poultry: Afghanistan, Albania, Austria, Azerbaijan, Bosnia and Herzegovina, Bulgaria, Burkina Faso, Cambodia, Cameroon, China, Côte d'Ivoire, Croatia, Czech Republic, Denmark, Djibouti, Egypt, France, Georgia, Germany, Greece, Hong Kong, Hungary, Kazakhstan, India, Indonesia, Iraq, Iran, Israel, Italy, Jordan, Malaysia, Mongolia, Myanmar, Niger, Nigeria, Palestine, Pakistan, Poland, Romania, Russia, Serbia and Montenegro, Slovakia, Slovenia, Spain, Sudan, Sweden, Switzerland, Thailand, Turkey, Ukraine, United Kingdom and Vietnam (Chotpitayasunondh *et al.*, 2005)[1].

H5N1 Avian influenza in India

In India the outbreak of H5N1 Avian influenza was first diagnosed in February 2006. It resulted in widespread debate on our preparedness and capability in the area of biosecurity. India's poultry industry contributes Rs. 35,000 crores to the GNP and provides employment to over 3 million people. This is the only segment of Indian agriculture economy which has been growing consistently, at about 17% per annum. Unfortunately, this segment faced the worst ever crisis in its history, and a situation of total breakdown and collapse, due to this outbreak. A study by a renowned US economist reveals that, in competitiveness, India ranks no.1 in the world in this industry; USA was placed at No.4, China at No. 15. As of now, India ranks No. 2 in the cost of chicken production and will soon become world's cheapest source. If the present rate of growth is sustained, in the next five years poultry could have become the second largest industry in India, next only to the automobile industry. India's poultry industry has been painstakingly built based on indigenous research over three decades. However, it was destroyed by outbreak of H5N1 Avian Influenza strain and the country was forced to depend on import of eggs and chicken.

African horse sickness

African horse sickness (AHS) is a sub-clinical disease known to be highly fatal, endemic, viscerotropic (affecting the internal organs of thorax and abdomen). It is an insect-borne viral disease of horses and mules and donkeys. Its causative agent is an orbivirus measuring 68-70nm in diameter, which is present in the blood and organs such as spleen, lung, and lymph nodes. Traces are also found in serum, tissue fluids, excretions and secretions (Erasmus, 1972)[2].

As of now, nine distinct serotypes of AHS virus have been isolated. Taking into consideration the high mortality rate of horses and mules, these species should be regarded as indicator hosts. The dog is highly susceptible to experimental infection (Theiler, 1906), but play no role in transmission of the disease. AHS is endemic in tropical regions of central Africa and spreads towards Southern Africa. However it has also been reported to occur outside Africa. The most significant outbreaks were in the Middle East during 1959-1963 and in Spain during 1966 and 1987-1990 (Lubroth, 1988).

The AHS virus is transmitted by midges of *Culicoides* species (Du Toit, 1944). The most significant vector, *Culicoides imicola*, and other species like *C.variipennis*, are common in many parts of the United States. These are also considered as potential vector (Boorman *et al.*, 1975). These insects are most active just after sunset and around sunrise. In horse populations, the fatality percentage ranges between 70 and 90, in mules about 50, and in European and Asian donkeys it is about 10 percent.

The AHS virus has several qualities that can be used to cause economic damage to a country. The disease severity is very high, and the mortality rate among many Equidae species is considerably more. The arthropod vector can easily transmit the disease, and the economy related to horse industry is affected. Above all, till now there is a lack of effective treatment. However, the failure of AHS virus to persist in alien regions, and its narrow host range, lasting immunity, and low zoonotic potential render the virus less than ideal for widespread consequences[3].

African swine fever

African swine fever (ASF) is yet another contagious, febrile, systemic, tick-borne viral disease of pigs. The virus is commonly found in blood and other secretions of the body. Initially, domestic and wild pigs were thought to be its only hosts (De Tray, 1957; Steyn, 1932), but in 1963, Spanish workers isolated the virus from the soft tick *Ornithodoros erraticus* (Sanchez-Botzia, 1963). Later it was proved that the virus replicates in the soft tick, and transmission occurs in this way. ASF virus is the only DNA virus that can be considered an arbovirus, since its infection in ticks can cause infection in pigs. African swine fever is present in most African countries and on the island of Sardinia.

This disease is a threat, and the characteristics, that make it a biological weapon are also tremendous. These include the infected animals high morbidity and mortality rates, and the fact that this disease is highly communicable both by direct and indirect means. Effective treatments are also not available for infected animals, and there are no vaccines available for prevention[4].

Contagious bovine pleuropneumonia

Contagious bovine pleuropneumonia (CBPP) is an extremely infectious, acute, sub-acute, or chronic disease of cattle. It affects mainly the lungs and occasionally the joints (Brown, 1998). CBPP is caused by *Mycoplasma mycoides*. It is observed that the small colony type is infectious to cattle, whereas the large colony type is pathogenic to sheep and goat but not to cattle. CBPP is a disease dominant in genus Bos; both bovine and Zebu cattle are naturally infected. European breeds are more susceptible than indigenous African breeds (Provost *et al.*, 1987). Although it is been proved that susceptibility is observed among domestic buffalo, the disease is difficult to produce experimentally in this species (Provost, 1988).

CBPP is endemic in many parts of Africa, Asia and Europe. It is a serious problem in India, China, Spain, Portugal, and Italy, but was completely eradicated from the United States in the nineteenth century. CBPP is transmitted by droplet inhalation from an infected animal; close contact is necessary for the transmission to occur. Outbreaks occur only when the infected animal moves into a naïve herd. It is believed that recovered animals harboring infectious organisms may become active shedders (Windsor and Masiga, 1977). The attack rate is variable: it is not a highly contagious disease. The mortality rate is also variable, and ranges from 10 to 70 percent in various outbreaks. As with many infectious diseases, mortality may depend on other factors such as nutrition, parasitism and general body condition. Due to widespread occurrence of CBPP in many countries, during an intentional outbreak, the mortality rate could be quite high. However, since there is effective therapy and vaccination available for CBPP in most countries it does not pose much risk. Besides, once the disease occurs, immunity can be retained at least for a period of one year.

Rift valley fever

Rift valley fever (RVF) is an acute, febrile, arthropod borne, viral disease of sheep, cattle, and goats (Daubney *et al.*, 1931). It is characterized by high abortion rates, high mortality in neonates, and hepatic necrosis (Easterday, 1965). When it affects humans it is a dengue-like disease accompanied by hemorrhage, meningo encephalitis, retinopathy, and sometimes death (Wood *et al.*, 1990 and Laughlin *et al.*, 1979). Rift valley fever is caused by a RNA virus in the Phlebovirus genus of the family Bunyaviridae (Matthews, 1982). Rift valley fever virus infects many species of animals and humans. Neonatal lambs, kids, calves and puppies are highly susceptible and have a mortality. Humans are highly susceptible to infection by aerosol and mosquito.

Rift valley fever has been found to occur in Africa. The RVF virus is present in dormant eggs of the mosquito *Aedes lineatopinnis* in grassland depressions. When the eggs hatch, infected mosquitoes develop and act as vectors. RVF causes high mortality in young lambs, calves and kids. Mortality in adult sheep is 20 percent and in adult cattle 10 percent. A high percentage of pregnant animals may abort. Rift valley fever is suitable as a biological agent because several genera of mosquitoes can serve as vectors, and therefore the disease could be endemic. RVF infects both humans and livestock and causes tremendous economic damage. The disease is difficult to eradicate if it is introduced into a new area[5].

Sheep and goat pox

Sheep and goat pox is an acute chronic disease of sheep and goats characterized by pox lesions throughout the skin and mucous membranes, a persistent fever and also focal pneumonia with lesions distributed uniformly throughout the lungs. The virus responsible for sheep and goat pox is Capri poxvirus, one of the largest viruses known (Matthews, 1982). Various strains of SGPV cause disease in sheep, goats and some in both (Davies, 1976; Davies and Otema, 1978; Kitching and Taylor, 1985).

The disease is endemic in Africa, the Middle East, the Indian subcontinent, and much of Asia. A goat-pox-like disease was reported in the western United States (Renshaw and Dodd, 1978). Transmission occurs through contact, inhalation of aerosols from infected animals, and contact through skin abrasions. Insects can also serve as vectors. The severity of SGP depends on the strain, age and breed of the affected animals (Davies and Otema, 1981). The mortality rate in adult sheep and goat may go up to 50 percent, and in susceptible lambs, up to 95 percent. Factors such as nutrition, parasitism, and climatic condition also influence its mortality. The high morbidity and high mortality rate, especially in young animals, makes this disease highly potential as a biological weapon. It can also result in high economic loss in terms of productivity, low quality of wool and leather. The disease can easily be transmitted through many routes like aerosol and fomites[6].

Vesicular stomatitis

Vesicular stomatitis (VS) is a viral disease of horses, cattle and pigs. Sheep and goats are occasionally affected. The disease is characterized by fever, vesicles and erosions in the mouth and epithelium on the teats and feet. The causative agent is a bullet shaped RNA vesiculovirus that belongs to the Rhabdoviridae family. Its serotypes are New Jersey and Indiana 1. It causes vesicular lesions in domestic animals and is even known to infect humans. Classical VS occurs only in North and Central America. Serotypes New Jersey and Indiana 1 occur in the United States and Central America and Serotypes New Jersey and Indiana 1, 2, 3 occur in South America. The VS virus has been shown to be transmitted by the sand fly (*Lutzomyia shannoni*) and the black fly (*Simuliidae*). Contact and aerosol may even infect humans.

The VS virus outbreak can cause a huge economic loss. The mortality rate depends on the type of lesion in the animal. Herds experiencing primary oral lesions had an attack rate of 19.8 percent, and mastitis complicates 72% of the cases with teat lesions. Lack of effective treatment and weight loss in affected animals add to the mortality rate. Hence, VSV has a high potential to be used as a bioweapon, as it is linked with substantial direct and indirect economic loss to livestock producers. The vector range is also quite wide, and hence it is spread easily and is difficult to eradicate[7].

Swine vesicular disease

Swine Vesicular Disease (SVD), an acute, contagious viral disease of swine, is caused by an enterovirus. It is characterized by fever and vesicles with subsequent erosions in the mouth and sometimes on the snout, feet and teats. The causative agent enterovirus belongs to the picornavirus family and is closely related to Coxsackie human enterovirus. It is commonly believed that it is transmitted to pigs through their eating of human feces.

Though pigs are the only natural hosts, it has experimentally infected baby mice, and accidental laboratory infection is reported in humans. SVD first occurred in Italy and subsequently in Hong Kong, England, Scotland, Wales, Japan, Austria, Belgium, France, Germany and other countries. Outbreaks were also reported from Spain, Portugal and Italy in 1990. The disease can be introduced into a healthy herd by feeding garbage containing infected meat, by introducing infected animals, or by contact with infected feces.After initial infection, the disease can spread through the contact of susceptible pigs with infected pigs and feces. Hence the threat of its use as a bioweapon is quite high. The outbreak of SVD is reported from many countries but the disease is not severe or fatal. The disease may only cause an economic loss.

Peste des petits ruminants

Peste des petits ruminants (PPR) is an acute or sub acute viral disease prevalent in goats and sheep. It is characterized by fever, conjunctivitis, gastroenteritis, and pneumonia. Goats are more susceptible than sheep. It is caused by a paramyxovirus of the Morbillivirus genus (Appel *et al.*, 1981, Bourdin *et al.*, 1967, Gibbs *et al.*, 1979, Osterhaus 1992). Though PPR is primarily a disease of sheep and goats, white tailed deer is also experimentally susceptible to it. There is a report of its natural occurrence in wild ungulates (Furley, *et al.*, 1987). It is a sub clinical disease in cattle and pigs, but they do not play a role in transmission of the disease.

PPR occurs in most African countries, the Middle East countries like Israel, Iraq, Jordan and it is also seen in the Indian subcontinent (El Hag Ali and Taylor, 1983, Lefevre, 1982). PPR is not very contagious, and transmission happens through close contact, ocular, nasal, oral secretions and feces. Contact infection occurs mainly through inhalation of aerosols produced by sneezing and coughing. Fomites can also be a means of transmission. Young animals are more susceptible and their mortality rate is quite high, but it is lower in adult animals. Poor nutrition, stress of movement, parasitism and bacterial infections increase the mortality rate. PPR could be a biological weapon but it may cause only economic loss. A vaccine lasting for a period of 12 months is available to prevent disease in goats, but it is not effective in the rest of the other host range. There is no effective treatment, but drugs that reduce parasitism and bacterial infections can decrease the mortality rate.

Lumpy skin disease

Lumpy skin disease (LSD) is an acute-to-chronic viral disease of cattle, characterized by nodules on skin that may have inverted conical necrosis with lymphadenitis, and is commonly accompanied by a fever. The organism responsible for it is a Capri poxvirus. The prototype strain of LSD is the Neethling virus (Alexander *et al.*, 1957). There is strong evidence regarding the infection of water buffalo. Experimental infection of some other species is also possible (Davies, 1991). Lumpy skin disease was first described in Northern Rhodesia in the year 1929. Since then the disease is widely spread in most parts of Africa (Davies, 1991). The outbreak was observed in Kuwait during 1986-88 (Anonymous, 1988), Egypt in 1988 (Salem, 1989) and in Israel in 1989 (Shimshony, 1989). Insects play a major role in transmission of the disease (Davies, 1981; Mac Owen, 1959). Contact seems to play a minor role in the spreading of LSD. Morbidity for LSD varies from 3 to 85 percent (Haig, 1957; Mac Owen, 1959; Weiss, 1968). The mortality rate is low and ranges from 1 to 3 percent (Diesel, 1949; Haig, 1957). LSD could be a biological weapon and it may cause only economic loss. The mortality rate is too low, and there is an effective treatment measure. The recovery may take a few months, but complete recovery can be achieved. Vaccination is effective and thus aids in prevention of the disease.

Rinderpest

Rinderpest (RP) is a contagious viral disease of cattle, domestic buffalo, and some species of wildlife. Fever, oral erosions, diarrhea accompanied by lymphoid necrosis characterize the disease. Rinderpest virus (RPV) is a single stranded RNA virus and belongs to the family Paramyxoviridae and the genus Mobillivirus. There is only one serotype of RPV, but the strains widely vary in their virulence, ease of transmission and host affinity. The disease transmission occurs through secretions and excretions, particularly through nasal and ocular discharges and feces. Spreading also occurs by direct and indirect contact with infected animals. There is a wide host range, whose susceptibility to the disease varies. Cattle are highly susceptible, and it is only a sub-clinical disease for sheep and goats of Africa. Usually cloven-footed animals are infected. RP is present widely in the Indian subcontinent, Near East, and sub Saharan Africa. The morbidity rate of Rinderpest is hundred percent and mortality rate ranges from 90 to 100 percent, hence the Rinderpest is definitely of concern as a biological weapon. The disease is highly communicable and contagious, and spreads fast into non-immune herds. Cattle which are not routinely immunized, are highly susceptible to RPV and cause a great loss. Effective immunization is available but the severity of the disease is very high[8].

Classical swine fever

Classical swine fever (CSF) is a highly contagious disease of swine with acute, chronic and persistent presentations (Moennig, 2000, Murphy *et al.*, 1999). It is also known as hog cholera and swine fever. The disease was first reported from North America in 1810 and later in the European continent. The last outbreak of CSF reported from North America was in 1976. The agent responsible for the disease is a single stranded linear Pesti virus belonging to the Flaviviridae family. Only one serotype has been reported so far. The natural hosts of CSF include domestic pig and wild boar type animals. Infection can be induced in some experimental animals (Edwards, 1998).

Transmission can be by several means including direct contact, mechanical fomites, transplacental infection, feeding of improperly handled food and also through biting insects (Dewulf *et al.*, 2000, Kleiboeker, 2002). CSF has been eradicated from most European countries and from Australia, Japan and New Zealand. However, it persists in Asia, Mexico, South and Central America, and some parts of Africa. The disease has a high rate of morbidity and mortality, particularly in places where there is no immunization, but most countries are successful in eradication. There is a possibility of International use of CSF, because the mortality and morbidity rates are quite high. There was a widespread dispersion of the disease (Kleiboeker, 2002). The economic impact would be severe with intentional transmission of the disease. It would affect pork exports and eliminate most pork-based markets, causing huge economic damage[9].

Blue tongue

Blue tongue is a non-contagious, arthropod-borne viral disease of domestic and wild ruminants (Murphy 1999). The virus belongs to the genus *orbi viridae* and the family Reo viridae. Of the 24 serotypes, four are very active, particularly in the United States (Stott, 1998). All ruminants are highly susceptible. Sheep are the most important hosts and they exhibit a clinical disease. A sub-clinical disease can be observed in infected goats, cattle, camels, buffaloes and some wild ruminants.

The disease is transmitted through *Culicoides* midges. The major vector responsible is *C.variipennis sonorensis*, *C.imcola* and *C.brevitari* (Fu *et al.*, 1999). Clinical disease occurs in Africa, the Middle East, the Indian subcontinent, the southern and western United States, China, Mexico, and the Mediterranean basin. Sub clinical disease occurs in Asia, New Guinea, South America, Australia, Brazil and Argentina. In sheep, BT can range from unapparent to severe, depending on the breed, strain of virus, and environmental stress on the animals. Morbidity can reach 100%; mortality varies from 0 to 50 percent. Once infected, animals will recover within a few days, or it may last for two weeks. In cattle, BTV infection is usually sub-clinical. Although morbidity can approach 5 percent, cattle typically recover within a few weeks. However, lameness and unthriftiness may persist for extended period. The morbidity and mortality in goats is minimal, whereas in white tailed deer they can approach 80-90 percent. The morbidity and mortality are high in sheep, goats and cattle.

There is a possibility of using blue tongue as a potential biological weapon, because there is a risk from this to any country with competent vectors. It is difficult to eliminate, or even to control the infection. Affected animals are not easily distinguishable from non-affected ones (USAHA, 2002). Its widespread infection definitely causes a huge economic loss[10].

Foot and mouth disease

Foot-and-mouth disease (FMD) is a highly contagious viral infection of cloven-hoofed domestic animals (cattle, pigs, sheep, goats, and water buffalo) and cloven-hoofed wild animals. Fever and vesicles characterize the disease with subsequent erosions in the mouth, nares, muzzle, feet, or teats. The FMD virus (FMDV) is a member of the genus Aphthovirus in the family Picornaviridae, with seven serotypes. It can survive for long periods in lymph nodes and bone marrow.

FMD is widely distributed throughout the world since World War II. Endemic areas include Asia, Africa, and parts of South America. Most European countries are disease free of it, and have stopped vaccination. North America, Central America, Australia, New Zealand, Japan, and the British Isles are completely free of the disease. It can be introduced or transmitted into a free area by direct or indirect contact with infected animals. It can also occur through spread of aerosol, feeding on contaminated garbage, contact with contaminated objects, artificial insemination and contaminated hormones. The morbidity rate is 100 percent in a susceptible population. Mortality rate is less than 1 percent, but high in young animals. A strain of the virus can be less fatal in some species and severe in others. FMD virus has a wide geographic distribution but has been eradicated from most countries in case of outbreak. It can only cause an economic loss to some extent.

Biosecurity threats from important crop diseases

Throughout history, outbreaks of crop diseases have been associated with famine. The most famous example is late blight of potatoes that swept through Ireland in 1845, ruining the country's staple crop and resulting in the famine of 1845-46. In 1970 leaf blight destroyed about $1 billion worth of corn in the United States (Kohnen, 2000). Brown spot disease of rice contributed to the Bengal famine in India in 1942-43, in which nearly 2 million people died (Rogers *et al.,* 1999). Countries that extensively depend on agriculture for their livelihood are more vulnerable to threats of agroterrorism than other countries.

In recent years, *Fusarium* head blight, which is also called scab of wheat and barley, has affected successive harvests in several parts of the United States, particularly between 1993 and 1998. Abnormally wet weather probably contributed to this disease's spread over 10 million acres, which cost an estimated $1 billion loss in production (Lotterman, 1998).

Even a minor disease outbreak can have severe economic effects, due to export restrictions on agriculture dependent countries. In 1996, a fungus disease called Karnal bunt was discovered in wheat seeds that had been grown in Arizona and shipped to other south-western US states. Subsequently, more than fifty countries—including China, the largest importer of U.S. wheat—adopted phytosanitary trade restrictions against the U.S. These are regulations intended to keep foreign plant diseases or pests outside one's borders in case of any threat (Beattie and Biggerstaff, 1999). By reason of the "highly credible, rapid, and effective control and clean-up of the states concerned", importers such as China accepted a quarantine that included just the affected areas, which allowed international trade of wheat from other regions to continue (Horn and Breeze, 1999). Control and clean-up by the USDA's Animal and Plant Health Inspection

Service (APHIS) cost an estimated $45 million, and the impact on exports was limited to about $250 million, compared to the $6 billion total value of U.S. wheat exports (Kohnen, 2000).

Rice diseases

Rice is probably the world's most commonly used foodstuff. It has been the staple food for over two billion people (Atukorale, 2002). Its cultivation began thousands of years ago. Diseases in rice can be a major threat to the global food supply. Today the major diseases that attack rice are rice blast, rice brown spot, and leaf streak. These diseases cause economic loss, and are a threat to global food security[11].

Rice blast

Pyricularia grisea causes blast disease of rice. This disease can cause a serious loss to susceptible varieties during weather favorable to it. It is called leaf blast, rotten neck, or panicle blast, based on the part affected. Spots or lesions are the common symptoms, and are found on leaves, nodes, panicles and collar of the flag leaves. The spot appears gray with a reddish brown margin. The blast fungus usually attacks the node at the base of the panicle and the branches of the panicle. In addition, it may also attack nodes and joints of the stem.

Rice blast is one of the most damaging diseases of rice, because of its wide distribution and its destructiveness. In India, more than 266,000 tons of rice can be lost in a year, which is about 0.8% of the total yield. In Japan, the disease can infect about 865,000 hectares of rice fields. In the Philippines, many thousand hectares of rice fields suffer more than 50% yield losses. A 10% neck rot causes yield loss up to 6% and 5% increases in chalky kernels. Late planting, frequent rainfall, and warm weather also favour the blast infection. Spores usually develop on the lesion and they are airborne, disseminating the fungus over distance. High nitrogen fertilization should not be practiced in areas with a history of blast. Early planting, avoiding high levels of nitrogen, proper flood management, resistant varieties and fungicides can control the disease. Since this is a common disease and a threat to global food security, any intentional use of this disease will cause mass destruction and huge economic loss by reducing the yield[12].

Rice brown spot

Brown spot is a seed borne disease. Brown spot is a common disease of rice caused by *Bipolaris oryzae (Helminthosporium oryzae)*. The most common symptoms occur on leaves and glumes of maturing plants. Symptoms also appear on young seedlings and panicle branches in older plants. Spots are seen immediately after the seedling emergence and continue till maturity. Smaller spots are dark brown in appearance and larger spots have a reddish brown margin with gray centers. The development of brown spot is an indication of a soil fertility problem. Brown spot disease can be reduced by balanced fertilization, crop rotation, and the usage of high quality planting seed. Foliar fungicides are not very effective. Treating the seeds with fungicides reduce incidence and also the severity of seedling blight[13].

There was a major outbreak of rice brown spot in Bengal in India in 1942. The loss of the crop led to one of the worst known famines that claimed two million lives. In the eastern part of the subcontinent, close to Indo-China, Bengal would have been an important staging area for operations against the Japanese as they approached India during their early successes in World War II. The famine must have diverted resources from military operations, illustrating how biological weapons can have indirect effects[14].

Bacterial leaf streak of rice

Bacterial leaf streak (BLF) is caused by *Xanthomonas oryzae pv oryzicola*. It is a very serious disease worldwide commonly affecting cereals and southern cut grass other than rice. Symptoms are narrow, dark greenish, water soaked streaks on the leaf blades. Lesions form, and enlarge to turn yellow orange to brown. Bacterial exudates, commonly seen on the lesions, are amber colored. During the initial stages of the disease, it is usually confused with leaf blight of rice. It can be distinguished at the later stages of infection by the shape of edges of the lesions. It is straight in leaf streak and wavy in leaf blight. Transmission is usually seed-borne, but can occasionally be through irrigation water. Rain and high humidity favor the development of the disease. It is commonly found in Asia, Africa, and in restricted parts of Australia[15].

Bacterial leaf streak is widely distributed in Taiwan, southern China, Southeast Asian countries, India, and West Africa, but not reported to occur in temperate countries. Losses as high as 32.3% in 1000-grain weight due to it have been reported. At three disease intensities, the estimated yield losses were 8.3%, 13.5%, and 17.1% in the wet season, and 1.5%, 5.9%, and 2.5% during the dry season. The disease can be controlled by proper application of fertilizers and proper planting spacing, the use of resistant varieties, and hot water treated seeds. Practicing field sanitation is important. A good drainage system, especially in seedbeds, can also manage this disease[16].

Diseases of potato

The potato (*Solanum tuberosum*) is a perennial plant of the Solanaceae, or nightshade, family, commonly grown for its starchy tuber. Potatoes are the world's most widely grown tuber crop, and the fourth largest crop in terms of fresh produce (after rice, wheat, and maize), but this ranking is inflated by the high water content of fresh potatoes in comparison to other crops. Potatoes have a high carbohydrate content and include protein, minerals (particularly potassium), and vitamins, including vitamin C. Freshly harvested potatoes contain more vitamin C than stored potatoes. New and fingerling potatoes offer the advantage that they contain lower concentrations of toxic chemicals. Such potatoes are an excellent source of nutrition. Peeled, long-stored potatoes have less nutritional value, although they still have potassium and vitamin C. Potatoes also provide starch, flour, alcohol, dextrin, and livestock fodder. Potatoes (particularly mashed potatoes) are known to have a high glycemic index, a disqualifying factor in many diets[17].

Potato diseases have been a great threat to food security, and hence it is necessary to know about them and their consequences. The potato can also be susceptible to the potential threat of agroterrorism. Potatoes are usually infected by late blight and wart. Both can be a serious danger to it and definitely cause an economic imbalance.

Late blight of potato

Late blight of potato is caused by the fungus *Phytophthora infestans*. It is an extremely destructive disease, and attacks both tubers and foliage during any stage of crop development. The fungus spreads very rapidly through the foliage when the conditions are favorable and is capable of causing complete blighting of foliage within a short time. If no control measures are followed the entire field is destroyed, and even the tubers are infected while they are still in the ground. Symptoms of late blight include small, light to dark green, circular to irregular shaped water soaked spots. They are first seen on the lower surface of leaves and start developing at the edge of leaf tips. The lesions gradually expand into large, dark brown or black lesions and appear greasy. Plants severely affected by this fungus usually have a bad odour resulting from the rapid breakdown of potato leaf tissue.

The first stage in control of the disease is prevention by good field husbandry. Disease-free seed potatoes should be used for planting, and potato waste should be burned or treated with herbicides. Disease-resistant varieties should be used when possible and farmers should keep abreast of news of outbreaks to select varieties and treatment. The pathogen is at its most virulent in areas with cool, damp climates or where the soil has become over-watered or over-irrigated, so good management of soil water content becomes even more important when an outbreak is reported[18].

Phytophthora infestans is another organism that can be used as a paradigm of the social dislocations of which biological weapons are capable. An outbreak of *Phytophthora infestans* swept across Europe in the 1840s, destroying potato crops after the potato had established itself as the primary starch food. *Phytophthora infestans* is native to South and Central America and was unknown in Europe, so it broke out unhindered by human knowledge. The outbreak was most devastating in Ireland, where it caused a famine. It led to the death of 1 million from starvation and forced the migration of 1.5 million poor and landless Irish to the Americas[19].

Potato wart disease

Potato wart disease, caused by the soil fungus *Synchytrium endobioticum*, is a dreadful disease that affects the cultivated potato and a number of other *solanum* species. It poses a serious threat to potato production, because the spore can remain viable in soil for a very long time. This disease was first introduced to Europe from the South America in the aftermath of 1840's potato blight disaster. Symptoms usually appear on tubers and stolons (underground stems) and therefore it is not noticed until the tubers are lifted. True roots are never affected. Sometimes, infected plants produce greenish yellow warty outgrowths at the stem base. On tubers, eyes develop into characteristic warty, cauliflower-like outgrowths or swellings. Tubers become distorted and spongy and some times unrecognizable[20]. The outbreak of potato wart on Prince Edward Island (PEI) in October 2000, and the subsequent U.S. ban on PEI potato imports, had far reaching negative impact on total Canadian fresh potato exports during the disease crisis. Any speculation that Canada's other potato producing provinces would move to fill the void in exporting to the United States has been shown false by recent trade data[21]. Disease control in such complicated situations is fraught with difficulties. To help solve the problem, governments have legislated quarantine measures as a first level of control. Consequently, the disease is now subject around the world, to stringent quarantine regulations which prevent the entry of contaminated material. Chemical controls to eliminate the fungus from contaminated soil have not proved to be feasible[22].

Brown rot of potato (Wilt)

Brown rot is caused by the bacterium *Ralstonia solanacearum*, which prefers a warm temperature for its growth and proliferation. The disease is most prevalent in many parts of Europe such as Belgium, France, Germany, Greece, Hungary, Italy, the Netherlands, Portugal, Slovakia, Spain, and Sweden. There have been five outbreaks in England between 1992 and 2000. The symptoms include wilting of the plant aerial parts and the vascular bundles. These vascular bundles are also found in the tubers, and therefore the disease is noticeable in this region. When the tuber is cut into half, a brown ring can be observed. As the disease develops, the ring rots away completely and pale ooze emerges from the eyes and the tuber heel. The disease is transmitted through seed potatoes and water, and can also spread through contaminated potato waste dumped near places where potatoes are grown. It is very important for all tools and equipment to be thoroughly cleaned and disinfected to prevent carry-over to other ground[23].

In almost all outbreaks associated with contaminated water, woody nightshade (*Solanum dulcamara*) plants with roots growing in contaminated watercourses have been found to be infected, and this has acted as a continuing source of infection in the water[24]. Strict inspection of imported ware and treatment of washing water and eradication of woody nightshade reduce the chance of the disease surviving in watercourses.

Diseases of citrus fruits

Citrus fruits belong to the rue family (Rutaceae), and all citrus fruits are botanically a special type of berry called a hesperidium. The fruit has a leathery peel and a fleshy edible interior. Citrus fruits, grown in warm tropical and subtropical areas, are native to Southern China and South East Asia. The important citrus types are of the genus *Citrus*, and include the orange (*Citrus sinensis*), grapefruit (*Citrus paradisi*), mandarin orange (*Citrus reticulata*), lemon (*Citrus limon*) and lime (*Citrus aurantifolia* and *Citrus latifolia*). Minor citrus species include the citron (*Citrus medica*), the shaddock, or pummelo (*Citrus maxima*), the osbeck *Citrus grandis*), and the sour orange (*Citrus aurantium*). From the smallest tangerine to the largest grapefruit, the citrus is well known for its high content of vitamin C which is essential for strong gums and healthy body tissues and for the prevention of the disease scurvy. Oranges, lemons, grapefruit and tangerines are great tasting, low calorie foods, good sources of carbohydrates and fiber, and are low in sodium, cholesterol and fat. They also contain some vitamin A and vitamin B_1, and some minerals that the body needs.

Insect pests and fungus diseases can attack citrus groves. The grower must spray the trees to prevent disease and pest damage. Pest control methods use a combination of natural beneficial predators, farming practices, and chemical sprays to reduce insect pests. The important diseases caused to citrus fruits are huanglongbing, citrus canker, black spot and citrus variegated chlorosis[25, 26].

Huanglongbing (Citrus greening)

Huanglongbing (HLB) is a serious disease of citrus because it threatens all citrus cultivars and causes a rapid decline of trees. It is a serious disease in a number of countries like Asia, Africa, the Indian subcontinent and the Arabian Peninsula, and is reported recently from Brazil, Australia, the U.S. (Florida but not yet California), and the Mediterranean Basin.

The causal agent of HLB is a phloem-limited bacterium called *Candidatus liberibacter*. The two important species are *Candidatus L. africanus* and *Candidatus L. asiaticus*. The bacterium *Candidatus liberibacter* infects nearly all citrus species. Sweet oranges, mandarins and mandarin hybrids are highly susceptible. Early symptoms include leaf yellowing which appear on a single shoot or branch. Leaves have a mottled or blotchy appearance in the initial stages and as the yellowing spreads the affected trees show twig dieback. Fruits are sparse, small and abnormal in appearance, and fail to color properly. They contain aborted seeds and have poor juice quality. Disease transmission occurs through two species of psyllids, *Trioza erytreae* and *Diaphorina citri*. Both species feed and survive primarily on citrus and citrus relatives. Transmission can also occur through grafting and by the movement of infected budwood and citrus.

Control of HLB is very difficult if the inoculum and vector are widespread and established. The general control strategy has been to eradicate all existing sources of HLB within an area. Biological control of vectors is possible in places, since buildup of vector populations is often compromised when hyper parasites are present. Growers must keep a look out on the condition of trees, particularly a sudden change in vigorously growing trees.

Citrus canker

Citrus canker most likely originated in Southeast Asia and has spread worldwide, primarily to warm, moist, coastal regions. It is found in southern Asia, Japan, the Middle East, some countries of Central and Western Africa, the Pacific, and the Americas. The disease was found twice during the 1900s in Australia's Northern Territory (NT), and each time it was eradicated. (NT's first outbreak in 1912 took 11 years to eradicate, after every citrus tree north of latitude 19° south was destroyed.) Symptoms of the disease appear on fruit, leaves and branches of infected plants, and typically consist of small, round, blister-like formations called lesions. These lesions are usually raised, crater-like and tan to brown in colour, surrounded by an oily, water-soaked margin and a yellow ring or halo. The lesions appear scab-like or corky, and the yellow halo is usually absent on the fruit. On leaves the lesion can be seen on both sides of the leaf. Old lesions sometimes fall out, leaving a scattering of round holes.

The disease affects plants in the *Rutaceae* family, including those from the genera *Citrus, Fortunella* and *Poncirus*. One of the most virulent strains of the disease is found in Asia. It seriously affects grapefruit, lime and trifoliate orange rootstock, but also affects mandarin, tangerine, satsuma and kumquat. The disease is most likely to develop after heavy rains. Wind-driven rain, air currents, insects, birds and human movement can spread the canker pathogen and it spreads through movement of infected plants, seedlings, propagation material, and fruit. Contaminated clothing, tools, harvest and post-harvest equipment are also potential infection sources. In areas where citrus canker is established it is difficult to control, but its incidence has been reduced through the use of protectant copper fungicides. Quarantine and eradication can be effective in preventing the spread of the disease in newly affected areas. This involves the complete destruction of affected trees and with bans on citrus planting in affected areas[27].

Black spot

Citrus is susceptible to a large number of diseases and black spot is one of the most common fungal disease worldwide. It is caused by *Guignardia citricarpa*. Citrus black spot is common in subtropical regions like South America, Africa, Asia, and also in Australia. Lemons, grapefruits, limes and mandarins are highly susceptible. The symptoms are necrotic lesions on the fruit, which make them unsuitable for fresh market. Black spot lesions begin as small orange or red spots with black margins and later enlarge to become necrotic. A green tissue surrounds them. Four types of lesion have been observed to date: hard spots, virulent spots, false melanose spots and freckle spots. The symptoms are highly favoured by high temperature, high light intensity and stress.

Infection of citrus black spot is favored by warm conditions. *Conidia* plays an important role in transmission of the disease, and the primary source of infection can be ascospores produced on dead leaves on the ground. In countries where the disease is endemic, fungicides can be used for control. Protective treatment can be achieved with copper or strobilurin fungicides. Removal of dead leaves can also be preventive.

Citrus variegated chlorosis

Citrus variegated chlorosis (CVC) is caused by the xylem inhabiting bacterium *Xylella fastidiosa*. CVC primarily affects sweet oranges in Florida. All cultivars of sweet oranges are susceptible, but the severity of the disease varies. Lemons, limes, mandarins, kumquats, trifoliate orange and grapefruit show fewer symptoms. Symptoms include severe leaf chlorosis between veins that initially resemble nutritional deficiencies. Leaves on the affected trees frequently have brown gummy lesions on the lower side and yellow areas on the upper surface. Trees show reduced vigor and growth. Abnormal flowering is also observed along with abnormal fruit set. Affected fruits are usually small and high in acids. Hence they become unsuitable for the juice and fresh market. Symptoms appear on only one limb initially, but spread to the whole tree in severe cases.

The transmission of the disease is through graft and also vectored by *Xylella* (sharpshooters). Tree to tree spread also occurs. At least 11 species of sharpshooters are known till now. There is no effective approach to cure CVC. But it is important to keep it out of a place and quickly detect any infections that may occur. Control of sharpshooters is also very difficult. It is important to avoid bringing propagation materials from CVC infected areas[28,29].

Apple proliferation phytoplasma

Apples are delicious, easy to transport, low in calories and a natural mouth freshener. Apple is a source of both soluble and insoluble fiber. Soluble fiber helps to prevent cholesterol build up, thus reducing heart diseases. The insoluble fiber provides bulk in the intestinal tract, holding water to clean and move food quickly. The skin of the apple contains vitamin C. The apple is thus very nutritious but 'apple proliferation' is a serious threat in some countries. Apple proliferation phytoplasma is a common disease in the EPPO region that includes Austria, Bulgaria, Czech republic, France, Germany, Greece, Hungary, Italy, Moldova, Poland, Romania, Slovakia, Slovenia, Spain, Switzerland, UK (eradicated), Ukraine, and Yugoslavia. It is found but not established in Denmark and the Netherlands. It is still not confirmed from India or Africa. It is caused by the most severe phytoplasmas.

The symptoms of apple proliferation phytoplasma are severe and vary. The affected trees lack vigour, shoots are thin and the bark gets fluted lengthwise and has a reddish-brown color. A diseased tree may die but if the infection is less severe, it may recover. The leaves are irregularly serrated and smaller. In many cases, chlorosis can be seen, with reddening. Early defoliation occurs, petioles appear short, flowers are sometimes delayed, fruits are reduced in size, and flavor becomes poor both in sugar and acidity. Fruit appears flattened and seed cavities are smaller (Blumer and Bovey, 1957). The possibility of transmission with infected plant material is high because of symptomless infections. Phytoplasmas are present in infected trees, scion (detached shoot) and root stock. Natural spread cannot happen because of the uncertainty of vectors. The economic impact is very high because it is the most important disease of apples that affects most of the cultivars. Precautions must be taken that plants of apple for planting should be free from any phytoplasma infection during the previous season. Resistant varieties must be used if available[30,31].

Tomato yellow leaf curl

The tomato, an important vegetable, in the genus Lycopersicon, is a member of Solanaceae, nightshade family. It was first domesticated in Mexico. The tomato is a herbaceous perennial plant. Most varieties have red fruit, due to the red carotenoid lycopene. Tomatoes prefer warm weather. The tomato is high in vitamin C, and one medium-sized tomato provides about half of the required daily allowance for adults. Tomatoes are also a significant source of vitamin A and are a good source of protein, most of which is in the seeds. Tomato juice contains 19 amino acids, mainly glutamic acid.

The tomato has a therapeutic value and nutritional value. It is highly prone to infections and is a serious threat. Bacteria, viruses, and fungi severely infect the tomato plant. Tomato yellow leaf curl is one of the main viral diseases of the tomato. Tomato yellow leaf curl virus (TYLCV) is the generic name given to a complex of viruses that infect tomato, their main host. It is present in most Mediterranean countries and sub-Saharan Africa, Asia, Japan, Australia, Central America, Mexico and is reported recently from USA, Florida and Georgia.

During the early stage of infection tomato plants are severely stunted, with reduced leaflets and abnormal shaped leaves. Leaves cup downwards and undergo chlorosis and finally deform. Leaf margins roll upwards and curl between veins. When infections are severe, fruit does not form and flowers drop. Transmission of the virus is not known to be seed-borne, but may happen through the vector tobacco whitefly, *Bemicia tabaci*. It attacks a wide range of ornamental and vegetable crops. TYCLV causes serious loss, and it is the main limiting factor on the tomato in most parts of the world[32]. Chemical control of the vector *Bemicia tabaci* is difficult because it creates residues on the crop. Research is being conducted on methods of biological control but it will be a long and difficult task to find a suitable natural enemy[33].

Use of agricultural bioweapons

There has been a large amount of research that has been devoted to anticrop and antianimal agents. During World War I the Germans clandestinely inoculated horses and mules, en route to Europe from the United States, Argentina, and Morocco, by swabbing the animals' muzzles with the infectious agents for anthrax and glanders (Stockholm International Peace Research Institute (SIPRI), 1971). Though these pathogens carried risks to humans as well as to the animals, no instances of human illness were recorded (Geissler and Moon, 1999). This was part of Germany's larger biological sabotage program in which they attempted to infect draft, cavalry, and military livestock between 1915 and 1918 in Romania, Spain, Norway, Argentina, and the U.S (Kohnen, 2000). Japan is supposed to have used animal and plant pathogens, including rinderpest and anthrax, against Russia and Mongolia in 1940 (SIPRI, 1973). These were some of the actual use of biological weapon during World War II, despite the extensive research effort in several countries at that time (Geissler and Moon, 1999).

There were several accusations about use of biological weapon by different countries. The potato beetle was a serious natural concern in Western Europe during World War II. Britain accused Germany of intentionally dropping small cardboard bombs filled with Colorado beetles onto potato fields in southern England, including the Isle of Wight, in 1943 (SIPRI, 1973). On the other hand Germany itself was worried about the possibility of an enemy introducing the beetles into its fields. In 1944 there were reports of potato beetle outbreaks in northern Bavaria and Thuringia, and the Germans were quick to describe these (along with earlier outbreaks) as enemy activity. Neither Britain nor the U.S., however, considered using potato beetles for biological weapon purposes during World War II (Geissler and Moon, 1999). Allegations of biological weapon use continued during the Cold War. For example, Cuba has accused the U.S. of attacking the Cuban people, animals, and crops with biological agents twelve times during the period 1964-97. A recent report offers explanations for each episode, and concludes that each probably occurred naturally or was the result of human activity such as trade or travel (Zilinskas, 1999).

Despite the various accusations, "biological weapons use by states since World War II [agricultural or otherwise] appears to be confined to a handful of state-directed assassinations employing biological agents and toxins." (Falkenrath *et al.*, 1998). One of the well known agroterrorist attacks were documented in 1952, this event occurred when the Mau Mau, a nationalist liberation movement originating with the Kikuyu tribe, used a plant toxin (African bush milk) to poison thirty-three steers at a Kenyan mission station, located in areas reserved for the tribe. This was supposed to be part of a larger sabotage campaign against the British colonists and their livestock all over Kenya (Carus, 2000).

Similarly in the early 1980s, a group of Tamil militants threatened to spread foreign plant diseases among rubber and tea plantations in Sri Lanka, intending to cripple the Sinhalese-dominated government (Carus, 2000). It is not clear which Tamil group initiated the threat, and it is possible that the perpetrator was actually a state actor. (Until the evidence is confirmed, however, the incident will remain classified as having been perpetrated by a non-state actor.) These are only a few well-documented instances of actual or threatened biological weapon use against agriculture by non-state actors during the 20th century (Kohnen, 2000).

In 1978, the Arab Revolutionary Council used mercury to poison Israeli oranges to sabotage the Israeli economy; as a result of this contamination, Israeli orange exports were reduced by 40% and at least 12 people were injured from eating contaminated oranges. In this case, despite the injuries, the primary target of the attack was the Israeli economy. A more serious case was uncovered in May 2000 when inspectors from the Israeli Agricultural Development Authority discovered that Palestinians had been using counterfeit stamps on expired and salmonella-ridden eggs that were then sold throughout Israel. Although they had been operating the scheme for eighteen months, it is unclear how many contaminated eggs were sold or how many people were sickened as a result. In September 1999, two Israelis died of salmonella as a result of eating contaminated eggs (Pate and Cameron, 2001). In October 1997, settlers from Gosh Etzion sprayed a chemical on grapevines in two Palestinian villages south of Bethlehem. The settlers allegedly destroyed hundreds of vines and up to 17,000 metric tons of grapes (Pate and Cameron, 2001).

A number of countries have conducted bioweapons research on anti-livestock or anti-crop pathogens. Countries with documented programs are outlined in the table 1.

Consequences of agroterrorism

Agroterrorist attacks can have serious implications for plant, animal and human health. In addition, the results of an agroterrorist attack may also include major economic crises in the agricultural and food industries, loss of confidence in the government, and possibly human casualties. Humans could be at risk in food safety or public health, especially if a chosen disease is transmissible to humans (zoonotic). However, an agroterrorist attack need not cause human

Table 1: Documented Agricultural Bioweapons Programs

Country	*Dates of Program*	*Diseases Studied*
Canada	1940s-1960s	Anthrax, rinderpest
France	1939-1972	Potato beetle, rinderpest
Former Soviet Union	1935-1992 (current status unclear)	African swine fever, anthrax, avian influenza, brown grass mosaic, brucellosis, contagious bovine pleuropneumonia, contagious ecthyma (sheep), foot-and-mouth disease, glanders, maize rust, Newcastle disease, potato virus, psittacosis, rinderpest, rice blast, rye blast, tobacco mosaic, Venezuelan equine encephalitis, vesicular stomatitis, wheat stem rust, wheat and barley mosaic streak viruses
Germany	1915-1917, 1942-1945	Anthrax, foot-and-mouth disease, glanders, potato beetle, wheat fungus
Iraq	1980s-present (current status unclear)	Aflatoxin, anthrax, camelpox, foot-and-mouth disease, wheat stem rust, wheat smut
Japan	1937-1945	Anthrax, glanders
South Africa	1980s-1993	Anthrax
United Kingdom	1937-1960s	Anthrax
United States	1943-1969	Anthrax, brucellosis, Eastern and Western equine encephalitis, foot-and-mouth disease, glanders, late blight of potato, Newcastle disease, psittacosis, rice blast, rice brown spot disease, rinderpest, Venezuelan equine encephalitis, wheat blast fungus, wheat stem rust

Source: Monterey Institute of International Studies, California.

casualties for it to be effective or to cause large-scale economic consequences. An agroterrorism attack could result in reduced production of food, dramatic loss in economy within affected sectors, or export prohibition which remove agricultural products from the global market and destabilize related markets like processors, exporters, shippers, etc. It can also create social instability by creating public panic about the safety of the food supply and by inciting fear (Chalk, 2001; Wheelis, 2002).

Depending on the erosion of consumer confidence and export sales, market prices of the affected commodities may drop. This would affect even producers whose herds or crops were not directly infected, making the event large scale even if the disease itself is contained to a small region. On the other hand, food products that are not contaminated may become popular, and market prices could rise for such products. Such goods may include substitutes for the food that was the target of the attack (e.g., chicken instead of beef). Economic losses from an agroterrorist incident could be large and widespread. The losses would include the value of lost production, the cost of destroying diseased or potentially diseased products, and the cost of containment such as vaccines, drugs, diagnostics, pesticides, and veterinary services. The export markets would be lost as importing countries place restrictions on products to prevent possibilities of the disease spreading. The multiplier effects would ripple through the economy due to decreased sales by agriculturally dependent businesses such as farm input suppliers, food manufacturing, transportation, retail grocery, and food service and also tourism. The government could bear significant costs, including eradication and containment costs, and compensation to producers for destroyed animals (Monke, 2004).

India is one of the most vulnerable countries in the world to threats of agroterrorism. A bioterrorist attack on agricultural targets must be considered as a "high consequence–high probability event". Food and agriculture have close links with human and environmental health. If the security of food or agriculture is threatened, then everybody's life in the biosphere becomes insecure. In India, agricultural biosecurity (covering crops, trees, and farm and aquatic animals) is of even greater importance since it relates to the livelihood security of nearly 70 per cent of the population, and the food, health, and trade security of the nation. The report of the National Commission on Farmers stressed the need for a systematic review of the present infrastructure and institutional framework in agricultural biosecurity, including the World Trade Organisation specifications for sanitary and phytosanitary measures.

India has been striving to become a biosecure nation, but facilities for sanitary and phytosanitary and Zoosanitary measures are inadequate. The Avian Flu menace apart, India's consignments of farm exports are rejected in hundreds every year on grounds of mycotoxin, salmonella, pesticide residues, *etc.* The Indian biosecurity infrastructure needs to be vastly strengthened. In addition, we need to check introduction of invasive alien species into the country and have effective systems to detect, report and mitigate these problems. It is essential to combat agroterrorism by sharing of information among different stakeholders, strengthening laws and increasing public awareness through education. Besides, it is also important to promote research to combat the threats of agroterrorism. Combined efforts are required by the industry, government and academic research institutes to overcome any problems of agroterrorism.

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Additional resources

[1] http://www.fas.org/biosecurity/resource/factsheets/avianflu.htm
[2] http://www.vet.uga.edu/vpp/gray_book/FAD/cbp.htm
[3] http://www.cidrap.umn.edu/cidrap/content/biosecurity/ag-biosec/anim-disease/ahs.html
[4] http://www.cidrap.umn.edu/cidrap/content/biosecurity/ag-biosec/anim-disease/asf.html
[5] http://www.cidrap.umn.edu/cidrap/content/biosecurity/ag-biosec/anim-disease/rvf.html
[6] http://www.cidrap.umn.edu/cidrap/content/biosecurity/ag-biosec/anim-disease/sgp.html
[7] http://www.cidrap.umn.edu/cidrap/content/biosecurity/ag-biosec/anim-disease/vs.html
[8] http://www.cidrap.umn.edu/cidrap/content/biosecurity/ag-biosec/anim-disease/rpest.html
[9] http://www.cidrap.umn.edu/cidrap/content/biosecurity/ag-biosec/anim-disease/csf.html
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[20] http://www.defra.gov.uk/planth/pestnote/pwd.htm
[21] http://www.thunderlake.com/briefings/potato.doc
[22] http://www.uidaho.edu/ag/plantdisease/pwart2.htm
[23] http://www.dgsgardening.btinternet.co.uk/brownrot.htm

24 http://www.defra.gov.uk/planth/pestnote/brownrot.pdf
25 http://www.cfaitc.org/Commodity/pdf/CitrusFruits.pdf
26 http://www.britannica.com/ebi/article-9273679
27 http://www2.dpi.qld.gov.au/health/4249.html
28 http://www.bcc.orst.edu/bpp/Plant_Clinic/Disease_sheets/Citrus%20variegated%20chlorosis.pdf
29 http://edis.ifas.ufl.edu/pdffiles/PP/PP13700.pdf
30 http://www.eppo.org/QUARANTINE/bacteria/Apple_proliferation/PHYP14_ds.pdf
31 http://www.urbanext.uiuc.edu/apples/nutrition.html
32 http://www.defra.gov.uk/planth/pestnote/yellow.htm
33 http://www.eppo.org/QUARANTINE/virus/TYLC_virus/TYLCV0_ds.pdf

Biosecurity in the National Context: Saving land, water and environment

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Indian agriculture has experienced remarkable growth over the past few decades. This growth has been characterized as a green revolution in some quarters. In the decade between 1992-93 and 2003-04, Indian agriculture recorded a high rate of growth. However, this kind of growth has since slowed down to less than 2 per cent. In parallel with fast agricultural growth, the country has also witnessed impressive progress in reducing poverty. But, due to unabated increases in population, intensive use of land and water resources, reduction in bio-diversity and denudation of forested lands, agriculture's performance has weakened since the mid-nineties. This is a great national concern. Of late there is a marked slow-down in agricultural growth rates in the well-endowed green revolution regions, which have traditionally been the 'food-basket' of the country; these are showing signs of production fatigue. This presages serious food security consequences for the country.

The challenges of sustaining food security and agricultural growth in the context of what Professor M.S. Swaminathan, the doyen of India's agriculture, calls the "evergreen revolution" have been highlighted by several recent studies. It has been found that the total factor productivity (TFP) in agriculture is showing significant signs of decline. While the TFP grew by about 2% per annum between 1981 and 1990, this growth rate in the Indo-Gangetic Plains [which primarily follow rice-wheat rotation] declined into negative values during 1990-96. Such studies also bring out that the main factors of the deceleration in TFP growth rate slow-down in productivity gains of agriculture are decline in public investment in the farm sector, coupled with increased degradation of natural resources. In particular the quality of land has diminished, availability of water has reduced and the state of the environment has deteriorated.

Biosecurity and natural/resources preservation

Biosecurity is composed of two words: bio, which means related to living organisms; and security (or *securité*) which denotes "to be free" from danger or threat, to ensure protection, to feel safe and to be free of deterioration. Thus, biosecurity in the Indian national agricultural context means saving land, water and environment, and conserving and enhancing the quality of natural resources. Bio-security is the converse of bio-hazard, which according to Webster's dictionary is defined as risk to human health, to the environment, or to living organisms. Application and adoption of the tenets of biosecurity on a massive scale are essential for our country's sustainable development. .

According to the Food and Agriculture Organization of the United Nations (FAO), biosecurity aims: (1) to protect agricultural systems, (2) to protect human health and consumer confidence in agricultural products, and (3) to protect the environment and promote sustainable production of agricultural commodities.

Implications of biosecurity in the national context

In the past quarter-century, the green revolution witnessed in wheat and rice production coupled with increased production of milk, oilseeds and marine products have all contributed to augmenting the food-basket of the country. But many new research and development challenges are likely to be faced in maintaining biosecurity in our agriculture. These challenges are: food security, implementing ever-green agriculture to ensure nutritional and calorific security for our ever growing population; a strategic and inclusive approach in our agricultural development, which encompasses a complete adherence to regulatory and policy frameworks; and a holistic adoption both in letter and spirit of the concept of food safety norms for all living beings (both human and animal).

Biosecurity can thus be achieved in our country by placing it high on the agricultural agenda. It is important to increase agricultural productivity as a means of achieving rapid production growth, combined with a significant reduction in rural poverty. In addition, the stagnating and decreasing productivity growth in our prime food production regions needs to be reversed. Diversification resilience in our agricultural sectors needs to be achieved by including a market driven and competitive regime in our agricultural development plans. Further, the current unsustainable land-and water-use practices will have to be replaced by innovative land-and water-conserving technologies suited to the various agro-environments of our country. Finally, the adoption of a biosecurity scheme would imply and ensure an economic and ecologically sound access to food for every Indian, while conserving and improving the natural resource base.

Biosecure agriculture towards meeting current concerns

The challenges of implementing biosecure agriculture are many. Some of these are: our agricultural production is stagnant and food production is on a flattening trend. As explained earlier, the total factor productivity is decreasing. This means that additional inputs are required to maintain previous production levels. Water availability has reduced due to decreased storage capacity of reservoirs and lowering of ground water tables. With the passage of time, the decay in the quality and quantum of natural resources of land have occurred because the economic benefits of the green revolution technology based on the adoption of high-yielding crop varieties and high inputs of chemicals (fertilizers and biocides) have continued to be pursued rather vigorously without any regard to their environmental consequences. In addition, a vast proportion of our farmers can ill afford the replacement costs of lost natural resources. Thus the carrying capacity of the land has been exceeded. This has resulted in the demand for more land for cultivation, so the forested and sloping lands have been encroached upon. Thus, all around in the agriculturally important regions, the environmental quality is worsening. A holistic management of natural resources which harmonizes economies and production and at the same time preserves its quality needs to be implemented urgently.

Goals of saving land, water and environment

Over the past half century, our agricultural R and D have followed a science-led growth. This has paid rich dividends. The new agro-techniques have been evolved as a result of synergy of various disciplines belonging to basic, natural, biological and physical sciences. It is now necessary to enhance the farmers' capacity to use and conserve natural resources (agro-biodiversity, land and water) in an efficient and sustainable manner. The farmer's active participation in R and D as a partner must be the cornerstone of new agricultural initiatives, if bio-secure agriculture practices are to be widely adopted.

Water scarcity is on the increase. Competition for water use apart from agriculture is growing from civic and industry. The biosecure agriculture of the future will have to incorporate practices of efficient and sustainable management of water resources. The focus of development would be ecological-operational landscape scale watershed agricultural catchments that use land and water resources most efficiently. These watersheds would be community managed and would combine equity, economic, gender, poverty, employment and environmental concerns. New institutional systems which incorporate audit for sustainable land, water and environmental quality must be evolved and implemented.

The crop production systems and the quality of food and environment are intimately inter-linked. The indiscriminate use of chemicals reduces the quality of food and raises the incidence of its contamination with heavy metals and biocides, which are injurious to human health. Thus by saving and preserving the quality of land, water and environment in the context of biosecurity, nutritional security would be enhanced on the one hand, and the environmental balance on the other.

Conclusion

In terms of bio-security, the country would be faced with three main challenges. These are: (1) how to sustain a steady 4% growth rate in agriculture so that an 8–10% GDP growth is achieved over the foreseeable future; (2) how to reverse the process of land (and soil) and water resources degradation; and (3) how to stall and minimize the negative impacts of global warming, and how to improve environmental quality in the future.

There are no easy solutions. A policy shift in the agricultural research and development approach is needed. The green-revolution technologies followed a "package of practices" approach. These practices were seed-centered, placed over-dependence on chemicals, and were based on exploitive land uses. The evergreen biosecure agriculture of the future would be based on principles of conservative ecological agriculture and would be natural resources centered. It would be based on the tenets of precision farming and would integrate use of synthetic and natural resources with extensive/intensive use of resource conservation technologies.

The increases in farm productivity envisaged in the future would require emplacement of efficient agriculture, where productivity of each unit of a natural resource together with man-made inputs would be economic, sustainable and environmentally safe. A consortium approach of different institutions and disciplines working together to solve the problems of presently inefficient agriculture by balancing the societal, environmental, production and economic goals of all stake-holders should be followed. The establishment of an Indian Bio-security Institution, is an urgent need for the country. Such an institute would usher in sustainable hunger and disease–free inclusive development in the country in the times ahead.

Emerging Viruses: The Greatest Challenge to Biosecurity- A Historical perspective

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Among the greatest hazards to biosecurity are viruses. From time immemorial they have been annihilating the human race whenever their paths have met. This is more so in the last two centuries, with the rapid expansion of human civilization and modernization. This article describes a few recorded instances of outbreaks which have occurred and the lessons learned from them.

Mathilde Krim – Professor of public health and founder of AIDS medical foundation- "AIDS is giving us a lesson in humility. It teaches us that the relentless evolutionary forces at play in nature continue to create new forms of life - such as new strains of viruses - and that for all mankind's arrogance and destructive powers, we are not yet the masters of the universe, nor even necessarily nature's favored creation".

When antibiotics were discovered we thought that the war against infectious diseases had been won. Years later came a minuscule virus made of a few strands of DNA (HIV), which showed us just how vulnerable we are. Humans get infected simply because they put themselves in the path of viruses. Major dislocation in social structure such as war, disaster, urbanization, over population, economic depression all impose a stress on the ecosystem, and alter the equilibrium between man and microbe. New microbes have always emerged, but became more frequent as man encroached on nature. Human action from forest clearing to genetic recombination can cause viral catastrophes. Viruses are the single biggest threat to man's continued dominance.

In 1989 in Chicago a 43 year old African-American engineer came down with sore throat, fever and chills not responding to treatment. He then developed bloody diarrhea, dehydration and liver damage and died three days later. The patient's history revealed that he had attended his mother's funeral in Nigeria. She had died similarly, as did his father and brothers. This was later diagnosed as Lassa Fever. His own family was not affected and there were no further local episodes since the vector – a soft furred rat – was not around, and the virus did not pass from human to human. The history of Lassa fever began in 1969 with the mysterious death of two missionary nurses and a near fatal illness of a third. The virus isolated from two of these patients was named "Lassa" after the town Lassa in Nigeria where the disease was first recognized. The disease was called "Lassa fever" and in 1989 caused 5000 deaths in Africa (Macher and Wolfe, 2006).

Emerging Viruses exist somewhere till something changes, which could be a mutation which changes its ability to infect, e.g., H5N1, if it mutates, could infect humans; to humans or a temperature/rainfall change which alters the balance between predators and prey. Building roads through forests brings new viruses into contact with humans, and travel can transmit viruses across the globe.

Overstepping geographical boundaries is another major factor. When the Spaniards invaded Mexico some of them carried the smallpox virus, and the native Aztecs, who had no exposure to it, were totally wiped out (McKay, 1992). The yellow fever virus traveled in ships from West Africa, and open water barrels on the ships bred the vector *Aedes aegypti* .The virus broke out in the Caribbean, and went from there to Cuba in the 17th century (Matumoto, 1985). Japanese ships carrying old tyres to the US, with *Aedes albopictus* (Asian Tiger Mosquito), brought dengue fever to Texas (Eads, 1972).

Man made mechanisms of viral conveyance

Globe trotting: by people (e.g. SARS) or by transshipment of animals for research from exotic locations and when animals travel as stowaways (insects or rodents).

Urbanization: rural people with vectors and viruses hit the already impoverished urban dwellers when they migrate to cities.

Global warming: will lead to wider breeding grounds from tropics to colder regions.

Farming practices: Animals with viruses and close living to humans, e.g. pigs and ducks, could result in viruses jumping the species to infect humans.

Water management: like dams and standing pools provide breeding grounds for vectors like mosquitoes which can transmit viruses.

Modern medicine: provides new routes of virus transmission, e.g., transfusion and immune suppression. Immune suppressed patients can transmit virulent organisms.

Modern science: Bizarre viruses and lab outbreaks are a potential danger.

Hanta virus

This virus was in a rodent (the stripped field rat) in Korea. When the UN alliance was fighting in Korea, some Americans died of fever hemorrhage and renal failure. This was first called the Korean hemorrhagic fever, and none knew the cause. Dr Ho Wang Lee (Lee *et al.*, 1978) isolated the virus in the rat from the banks of the Haantan river. Years later several Seoul residents died. The vector at that time was the drain rat. The virus had therefore found a new host, closer to humanity.

Possible sources of Hanta Pulmonary Syndrome Virus and some ways in which the virus can come in contact are:

1) increasing numbers of host rodents in human dwellings;
2) Occupying or cleaning previously vacant cabins or other dwellings that are actively infested with rodents; Cleaning barns and other outbuildings; Disturbing excreta or rodent nests around the home or workplace;
3) Residing in or visiting areas where substantial increases have occurred in numbers of host rodents or numbers of hantavirus-infected host rodents;
4) Handling mice without gloves;
5) Keeping captive wild rodents as pets or research subjects;
6) Handling equipment or machinery that has been in storage;
7) Disturbing excreta in rodent-infested areas while hiking or camping;
8) Sleeping on the ground; and hand plowing or planting

Suburbanization

Residents of the town of old Lyme-Connecticut 1970 developed joint pains and fever. They were living in houses in a forest region, and had deer in their backyards. Humans came in contact with ticks which harbored the organism, first thought as a virus but later identified as a spirochaete, *Borrelia burgdorferi*- The disease is known as LYMES disease (Kaslow *et al.*, 1981). Similar episodes of viral encephalitis transmitted by mosquitoes in tree holes in the forest have occurred when human populations have ventured into the forests.

Building roads through forests

In 1950 the Belem-Brasilia highway brought humans into the Amazon jungles. Robert Shoppe isolated a new virus in the blood of workers who were laying the roads. In 1968 one of the workers died of fever headache confusion and hair loss, and the Guaroa virus emerged (Whitman and Shope, 1962).

Warming effect

In St. Louis, an encephalitis outbreak was due to warming. The *Culex* mosquitoes matured before their dragon fly predators, which were not available to eat them. The mosquitoes were therefore available to carry the virus that caused St Louis encephalitis (Reeves *et al.*, 1994).

Agricultural whims

Argentinean hemorrhagic fever: After World War II the grasses of the Pampas were cleared for farming. Several predator snakes died, and rodents carrying Junin virus multiplied. This caused an outbreak of fever dehydration hemorrhage. The virus outbreak occurred when farming activity was high (Weiss, 1989).

Where farming brings species together

A Virus from Animal A enters Animal B which has another virus. In the resultant exchange of genetic material, a third virus is born, which may be deadly. For instance ducks carry influenza virus, with duck to duck transmission occuring through water. Pigs carry another strain of the same virus. When duck virus enters the pig, a new strain may emerge, to which the population is not immune. This regularly happens in China.

Humans mixing viruses

The use of immunosuppressive drugs in (e.g.) Transplant, Chemotherapy, treatment of Auto immune diseases, etc., makes individuals more likely to have more than one virus strain at a time. There is, however, no evidence so far of such an event of a hybrid forming in humans. A donor may give a kidney containing an innocuous Cytomegalovirus. The recipient is on immuno suppressants, and the innocuous virus could develop virulence.

Biological product

Contaminated human growth hormone extracted from cadaver pituitaries transmitted Creutzfeld-Jakob Disease (CJD), which cause brain neuronal degeneration. Non disposable silver brain electrodes have also transmitted CJD (Powell-Jackson *et al.*, 1985).

In Marburg West Germany 1967, 25 people developed fever, rash, blood vomiting and diarrhea, and seven died. All were working in a lab that makes polio vaccine using African green monkey kidney cells. This was also seen in Frankfurt and Belgrade production units. The kidneys came from Uganda. The animal handlers did not have the disease since only the kidneys were infective. All cell cultures were destroyed, and the outbreak stopped. Even close contacts got the infection. A harmless virus in an African monkey can be a pathogen for humans when used in the lab. An Australian hitchhiker in Rhodesia in 1976 and a Swedish tourist in Kenya 1990 also died of Marburg Virus (Martini and Siegert, 1971).

In 1989, two shipments of monkeys from the Philippines to Virginia had the deadly Ebola Virus. Viruses adapt fast, and even if a human is not the natural host they can enter and adapt. A lab outbreak could become an epidemic (Geisbert and Jahrling, 1990). A small pox lab outbreak occurred in London in 1973; a technician and three contacts died (World Health Organization, 1978).

The four corners outbreak

Arizona, New Mexico, Utah and Colarado abut the Navajo reserve forest. In the spring of 1993 a 21-yr-old healthy man developed flu like symptoms, had difficulty in breathing, and died in 24 hrs. His fiancé had died a week earlier. In one month, ten more young people died. Tribals observed the Pinion trees were blooming the entire year, due to prolonged rains. Rodents flourished on the fruit, and they carried the Hanta virus, which spread by inhalation of urine-soaked dust or leaves (Hjelle and Glass, 2000).

Norwalk Virus outbreaks occur on cruise ships. Between Jan 1 to Dec 2 of 2002, twenty one outbreaks happened on seventeen ships. The virus is highly infective even if there are less than ten virus particles. It causes acute diarrhoea with vomiting, and spreads through contaminated food and water and also through inanimate objects (fomites). Even immigration and customs officials and luggage handlers can be affected (Cramer *et al.*, 2002).

The potential for breaches in biosecurity is immense. Modern travel and life styles are fraught with danger and require constant surveillance, or would bring disaster of unimaginable dimensions. They could even be tools of bioterrorism. Systematic and internationally harmonized surveillance protocols should be in place and strictly obeyed. "Maybe we are not the most favored but we are still the most creative creatures. The challenge facing us in this century will be to apply what we have learned about the basic blueprint of viral emergence to anticipate the next new plague, and do our best to defang it before it devours us. This will require some humility but will also require a healthy respect for our intellectual prowess and a willingness to develop a united front, a coalition of all our scientific resources, to do silent battle with mankind's tiniest and perhaps most complicated foe" (Henig, 1994).

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Biosecurity and Invasive Species-Management of the exotic weed *Parthenium hysterophorus*

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Biosecurity is a holistic concept of direct relevance to the sustainability of agriculture, food safety, and the protection of the environment, including biodiversity. Invasive species are important in Biosecurity. Biosecurity in agriculture is needed: to protect agricultural production systems, and those dependent on these systems, particularly vulnerable groups exposed to severe health risks. Biosecurity aims to protect the environment and promote sustainable production. However, public awareness of environmental issues and human dependency on biodiversity needs no emphasis. It entails numerous commitments to achieving sustainable development through scientific, social and governmental approaches to guarantee biosecurity.

The United Nations Food and Agriculture Organization defines biosecurity as the management of all biological and environmental risks associated with food and agriculture - ensuring food safety, monitoring the introduction and release of genetically modified organisms and their products, and monitoring the introduction and spread of invasive alien species, alien genotypes, plant pests, animal pests, and diseases. Further, any species, including its seeds, eggs, spores, or other biological material capable of propagating that species, that is not native to that ecosystem; and whose introduction causes or is likely to cause economic or environmental harm or harm to human health is termed as *Invasive and Exotic Species*. The management of invasive alien species into the environment means that a number of issues need to be addressed involving costly regulatory systems. *Parthenium hysterophorus* comes under this category with reference to its invasion of the Indian subcontinent. Probable traits favoring invasiveness in terrestrial plants are: high tolerance of environmental extremes and greater adaptability, high efficiency of water, light and nutrient use, zero or very short dormancy period, high fecundity and high productivity. It is established in some parts of peninsular India that an integrated method could be a better alternative to manage an invasive species such as *Parthenium hysterophorus.*

Impact of *Parthenium* on ecosystems

Increased pressure of both human (400 percent) and livestock (127 percent) populations during the previous century has imposed tremendous pressure on natural resources. Consequently, the demand for food, fruits, fibre, and fodder has increased tremendously. The scope for expansion of land for agricultural production or for any other productive purposes has diminished, since the use of land area for such activities has already crossed the limit. Development and up- grading of the currently available wasteland is the only option available. But the exotic wasteland weed *Parthenium*, which is half a century old to India, is invading and devaluing waste and unused lands all over the country. Currently, an area of 38.61 million hectares is feared already invaded by this weed, and another nine times that area is vulnerable for colonization by it. Some success in combating its growth is visible in southern states of India through an integrated approach. This paper intends to provide overall information (ecology, distribution, menace and management) about the dreaded weed *Parthenium* along with effective methods to suppress its growth.

Parthenium has several built-in properties and efficient behavioral mechanisms, which enables this plant to overcome many ecological adversities and to survive. In the absence of human effort, the plant may be able to survive for a much longer period than hitherto recorded in other species. The weed, apart from its invasive growth in wastelands, finds access to any type of land, like roadsides, railway tracks, vacant sites, graveyards, back yards, factory premises, cultivated land, etc. In intensively cultivated lands, it is eliminated in the weeding process. Its occurrence in grasslands reduces forage production up to 90 per cent (Vartak, 1968). Field and laboratory studies have indicated that germination, growth, flowering, grain and seed yields of agricultural crops are adversely affected by the invasion of this weed (Lakshmi Rajan, 1973; Kanchan, 1975).

It is seen growing sparsely in high altitudes like Kollimalai, Nilgiri and Annamalai Hills in Tamil Nadu; Bhagamandala, Biligiri Rangana Thittu and Baba Budangiri hills in Karnataka; and Kulu Valley in Himachal Pradesh. It is seen growing wild neither in hilly regions, nor in high rainfall areas like the coastal belts of Karnataka, Orissa, Goa and Kerala, but is found growing in the east coast of Tamil Nadu and Andhra Pradesh. Thus, *Parthenium* can adapt to a variety of agro-ecological situations with its own adaptive and protective means to resist various environmental stresses. The area prone to invasion by this weed has been recorded as under:

Unused and wastelands-vulnerable for *Parthenium* invasion

Out of the geographical area of 328726 thousand hectares, land is used in different ways (Table 1):

Table 1: Total Area and Land Use Classification during 2001

Heading	*Area (Thousand Ha.)*
Geographical Area	328726
Reporting area for Land Utilization Statistics	304917
Forests	68854
Not Available for Cultivation	
Area put to Non-agriculture uses (Buildings, Roads, Railways, Rivers, Canals, Nallahs etc.)	22527
Barren & Uncultivable Land (Mountains, Deserts etc.)	19031
Net Area Sown	142021
Current Fallows	12364
Fallow Lands other than Current Fallows	9757
Cultivable Wasteland	13879
Land under Misc. tree crops & groves not incl. In net Area Sown	3572
Total	41572
Permanent Pastures and Other Grazing Lands	10912

Source: Rajya Sabha Unstarred Question No. 2557, dated 12.12 2001

The above statistics reveal the following:

		(Area in Ha)
Areas put to non-agricultural use: at 10 % unoccupied and left open	–	2253000
Current fallow land	–	12364000
Fallow lands other than current fallows	–	9757000
Cultivable waste	–	13879000
Land under Misc. tree crops not included in net sown-at 10 % as left open	–	357200
Total		38610200

Thus, it is seen that a vast proportion of the land is vulnerable to invasion by this weed. Considering a modest estimate of a mere 10% of this area to be invaded by this weed, an area of approximately 38.61 million hectares (9652.5 million acres) is affected and this is quite significant. In some places the infestation is as high as 100% and in many it is more than 50%. Barring a few, like forests, western coastal belts and intensively managed land, all other areas are prone to its invasion. Hence, the problem is serious and must be tackled with priority at both state and national levels.

Ecology and distribution

Parthenium (*Parthenium hysterophorus* L), popularly known as congress weed, star weed, carrot weed, white top and feverfew, believed to have entered India accidentally in the mid fifties, is one of the most feared weed species (Rao, 1956). It grows to a height of 1.5 m, flowers profusely throughout the year since it is insensitive to photoperiod and thermal regimes, and has unique adaptability to a wide range of agro-climatic and soil types. A native of Mexico, the West Indies, tropical South and North America, this weed was first described in India in Pune (Rao, 1956) but it has spread and naturalized in almost all the states. It is found in varying dimensions on waste lands, along road sides, railway tracks, cultivated fields, residential areas, industrial areas and other fallow lands, as well as abandoned fields, thereby attaining the status of number one amongst the terrestrial weeds in India.

Parthenium has prolific seed bearing capacity, producing 624 million spores and 1500 to 20,000 seeds per plant per year, depending upon growth, habitat and longevity. Its high fecundity, efficient seed dispersal mechanisms due to two persistent disc florets which act as floats, enable its quick and unchecked/ uninterrupted spread. Its adverse allelopathic effects on many species enable its quick spread and establishment (Krishnamurthy *et al.*, 1977).

Adverse effects of *Parthenium* both on human beings and animal health have been well documented. It is known to cause asthma, bronchitis, and dermatitis and hay fever in man and livestock. Chemical analysis has indicated that all the plant parts including trichomes and pollen contain toxins called sesquiterpene lactones. The major components of toxin are *'parthenin'* and other phenolics such as caffeic acid, vanillic acid, anisic acid, chlorogenic acid, parahydroxy benzoic acid and P-anisic acid, lethal to human beings and animals.

Seasonal impact on the intensity of *Parthenium*

Parthenium seeds can germinate, grow and colonize during any part of the year, with just one or two showers. When the regular rainy season starts late or first showers, it grows very fast because of its innate drought resistance, thereby suppressing drought sensitive species. This explains why *Parthenium* growth is more rampant in some years than in others. In drought years, the plants remain in the "rosette" form and rejuvenate after rains commence.

Survey of plant biodiversity

A survey of common waste land weed species carried out in Karnataka state revealed that ten species have definite relation with the spread of *Parthenium* (Table 2). In each region, there are predominant botanical agents resisting its entry, as also some associate species (comparatively less dominant) probably with relatively low allelopathic influence. *Cassia sericea* is predominant in the three high rainfall districts of transition belt; *Cassia tora* in two arid districts and *Cassia occidentalis* in two heavy rainfall districts. *Tephrosia purpurea* is observed as an associate species with other dominant species at least in ten low rainfall districts. *Amaranthus spinosus* is predominant in the Bangalore urban area and *Croton bonplandianum* in Mysore district. Mamatha and Mahadevappa (1988 and 1992) have reported that *Cassia sericea, Cassia tora, T. purpurea, A. spinosus* and *Cassia bonplandianum* resisted *Parthenium* invasion in many states in India as observed during the eighties and nineties.

Table 2: Interference among wasteland species and their impact on *Parthenium* suppression

Sl. No.	*Species*	*Extent of Parthenium suppression**
1.	*Amaranthus spinosus* L.	High
2.	*Croton bonplandianum* Baill	High
3.	*Cassia occidentalis* L.	High
4.	*Cassia tora* L.	High
5.	*Cassia sericea* SW.	Very high
6.	*Cassia auriculata* L.	Moderate
7.	*Hyptis suaveolens* Poit.	Moderate
8.	*Ipomoea carnea* Jacq.	Very high
9.	*Mirabilis jalapa*	Very high

Sl. No.	Species	Extent of Parthenium suppression*
10.	*Sida spinosa* L.	Moderate
11.	*Tephrosia purpurea* Pers.	Very high

*Moderate : 26-50%
High : 51-75%
Very High : 76-100%

Note: All the above species are known to suppress *Parthenium* through allelochemicals, except *Ipomoea carnea*, which is a physical suppresser.

Spread in India

As stated earlier, it was first noticed in Pune (Maharashtra) during 1955 on the garbage described by Rao (1956). But, in a short period, it invaded all over Pune (Maheshwari 1966; Santapau, 1967). The 1958-59 floods in Pune helped in wide initial dispersal (Roberts, 1967). In a matter of a few years, it spread to other parts of the country through vehicular traffic, trains, cargo, packaging material, and other natural dispersal agencies (Table 3). It was observed by the author that *Parthenium* was absent in Coastal Karnataka, Coastal Orissa, Jammu and Kashmir, Pondicherry, and Northern parts of Haryana, and was sparsely growing in the peripheral regions of forests in hilly districts of Karnataka. Based on survey reports and also enquiries received by the author, the order in which this weed most looks serious is in Uttar Pradesh, West Bengal, Karnataka, Maharashtra, Tamil Nadu, Andhra Pradesh, Madhya Pradesh, Gujarat and Bihar. It is not seen in the West coast, high elevations and interior forests in any state.

Table 3: Spread of *Parthenium* in India

State	*Areas*	*References*
Andhra Pradesh	- Hyderabad, Krishna, Godavari, Chittoor and Nagarjun Sagar areas. - Tirupati hills and Khadala - Amaravati, Nalla Malais Karnool, Mahaboobnagar, Thimmapur, Waltair, Vijayawada and Mossa river	Krishnamurthy *et al.*, 1977 Santapau, 1967 Mahadevappa, 1996

State	*Areas*	*References*
Bihar	- Mothihari, Narkatiarganj, Balmikinagar - Gangetic plains of Bihar	Maheshwari and Pandey, 1973 Suresh Chandra, 1973
Gujarat	- Ahmedabad, Anand and Baroda	Mahadevappa, 1996
Haryana	- Rohtak, Hissar and Faridabad Eastern parts of Haryana	Mahadevappa *et al.*, 1990
Himachal Pradesh	- Kulu and Manali	Valid and Naithani, 1970
Jammu & Kashmir	- Throughout the State	Prabhakar, 1988 (Personal communication)
Karnataka	- Dharwad - Bangalore, Mysore, Arsikere, Belur, Bhadravati and Shimoga - Kodagu, South Canara and North Canara - Bijapur, Belagaum, Gulbarga, Bidar, Chitradurga, Shimoga, Hassan, Mandya and Tumkur	Madadevappa *et al.*, 1990 Jayachandran, 1971 Mahadevappa, 1996 Newspaper publications
Kerala Madhya Pradesh	- Palghat, Quilon, Kottayam and Kasargod - All over the State except in hills	Mahadevappa, 1996 Tiwari and Bisen, 1984
Maharashtra	- Mumbai city (Juhu area) - Forest nurseries - Joshi Estate	Tiwari and Bisen, 1984 Chandras, 1970 Mahadevappa, 1996
Orissa	- Not much, only in the peripheral parts	Mahadevappa, 1996
Punjab	- Many parts of Punjab	Mahadevappa, 1996

State	*Areas*	*References*
Pondichery	- Scattered distribution throughout the State	Mahadevappa, 1996
Rajasthan	- Udaipur	Mahadevappa, 1996
Tamil Nadu	- Kotagiri of Nilgiri hills - Aliyar submergence area, Coimbatore - Katpadia, Jalarpet, Madurai, Salem, Tanjore	Bidhas Ray, 1975 Mahadevappa, 1996
Uttar Pradesh	- Pantnagar, Rae Bareli, Jhansi - Haridwar	Ellis and Swaminathan, 1969 Mahadevappa, 1996
West Bengal	- Calcutta, Bank and Basin of Rivers	Krishnamurthy *et al.*, 1977

Spread in other countries

Though it is native to Mexico, West Indies, tropical South and North America, its spread is not only restricted to these countries but also has been reported from other parts of the world in addition to India (Table 4).

Table 4: Global spread of *Parthenium*

Country	*Provinces*	*References*
USA	- Florida, Texas, North of Massachusetts, Pennsylvania, Ohio, Michigan, Illinois, Missouri, Kansas - Minnesota - Louisiana - Canton, Baltimore, Maryland, New Port and Virginia	Castex *et al.*, 1940 Arny, 1987 Fernold, 1970 Mackoff and Dahl, 1951 Ogden, 1957 Arny, 1987
Mexico	- Throughout the country	Arny, 1987
Argentina	- Large areas, province of Cordoba	Castex *et al.*, 1940
Trinidad	- Large areas- major problem	Krishnamurthy *et al.*, 1976
Guyana	- Large areas- major problem	Krishnamurthy *et al.*, 1976

Country	*Provinces*	*References*
Jamaica	- Large areas- major problem	Krishnamurthy *et al.*, 1976
Australia	- Queensland, Central Highlands and North Clermont, New South Wales	Dale, 1980
South Africa	- Large areas	Maheshwari, 1966 Vaid and Naithani, 1970 Maheshwari and Pandey (1973)
Mauritius	- Large areas	"
Rodriguez	- Large areas	"
Seychelles	- Large areas	"
Bourbon	- Large areas	"
North Vietnam	- Large areas	"
Bangladesh	- Not in alarming proportion	Mahadevappa, 1996

Menace

Ever since *Parthenium* started invading newer areas and growing in high population, its numerous ill effects on human and livestock health, native flora and agricultural productivity are being reported frequently.

Effect of *Parthenium* on human beings

With the first report from Texas, USA, contact dermatitis due to this weed has long been recognized (French, 1930; Khan and Grothaus, 1936). Shelmire (1939 and 1940) observed the attainment of acuteness of the disease due to this weed inflicting more than 50 per cent of the contact dermatitis in southern parts of the USA. Further, clinical confirmation was obtained through positive patch test with the leaf of *Parthenium* on four patients at Louisiana (Ogden, 1957). In Pune, it was detected as an etiological factor in causing eczematoid dermatitis in 29 cases due to its pollen. Lonkar and Jog (1972) observed dermatitis of the exposed skin surfaces in adult males engaged in agricultural work during 1965, attributing it to occupational exposure to *Parthenium*. It has been observed that the chances of becoming sensitized to the weed are high, when a person comes in contact with the weed for a period ranging from 3 to 12 months (Subba Rao *et al.*, 1976). Ranade (1975 and 1976) developed a vaccine for desensitizing people suffering from the disease, treating more than 400 cases with 20 daily injections with effects lasting for more than 6 months. The author has personal knowledge of 55 individuals suffering from *Parthenium* allergy in Bangalore City. A lady aged forty years was drawing out watery substance from her bulged skin to the tune of one liter per day during the peak season of *Parthenium* growth (Fig 1). In another case, a man aged 47 years suffered from eruptions (Fig. 2a to c) disfiguring his face. He had to sell his house in an extension area due to heavy infestation of *Parthenium*, and went back to his old residence down town. The leaves of *Parthenium*, which have a close resemblance to those of Davana (*Artemisia pallens* Wall), are mixed with it and sold. When ladies wear this, it causes irritation on the neck and cheek (personal knowledge of the author). The details of the disorders and symptoms produced thereof are presented in Table 5.

Table 5: Effect of *Parthenium* of human health and livestock

Disorder	*Reaction*	*Reference*
1. Contact dermatitis	Seasonal eruption of the exposed skin surface	French, 1930 Khan and Grothaus, 1936 Shelmire, 1939 and 1940
2. Eczema	Chronic lichenified eczema of the exposed skin surfaces	Ogden, 1957 Smith and Hughes, 1938
3. Eczematoid dermatitis	Skin eruptions and itching	Ranande, 1975 and 1976
4. Eczematoid dermatitis	Skin eruptions and itching	Suresh Chandra, 1973
5. Dermatitis	Skin eruptions and itching	Lonkar *et al.*, 1974
6. Allergic reactions	Cracks all over the sole	Sundara Rajulu and Gowri, 1976
7. Allergic papules	Sore throat, bubbles in the mouth	Krishnamurthy *et al.*, 1975 Subba Rao *et al.*, 1976
8. Fatigueness	General weakness, skin eruptions	Mahadevappa, 1996
9. Severe dermatitis	Loss of scalp and body hair, ridging on nails	Krishnamurthy *et al.*, 1977

Disorder	*Reaction*	*Reference*
10. Fever in cows	Inflamed udder and rashes	Krishnamurthy *et al.*, 1977
11. Hypersensitivity in rabbit	Restlessness, natural falling of hairs from the dorsal region of the neck and back, small boils and oozing of blood	Sundara Rajulu and Gowri 1976
12. Ulcerations in buffaloes, horses, donkeys, sheep and goats	Acute and chronic toxicity, ulcers both in the mouth and digestive tract, esophagus and abnormal folds, necrosis of kidney and liver	Subba Rao *et al.*, 1976


Figure 1: Allergic reaction on the arm

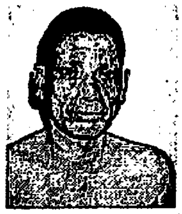


Figure 2a: allergic reaction on the face


Figure 2b: Allergic reaction on the back


Figure 2c: Allergic reaction on the back (enlarged)

Management of Parthenium allergy

The literature reveals that *Parthenium* allergy could be managed by applying ayurvedic principles with specific medicaments. Selected weeds need to be studied individually as medicinal plants for their pharmacological action at both clinical and non clinical levels, and should not be eradicated totally. What is new is the advent of powerful techniques in chemistry, biology and physics which enable the quick isolation, purification and characterization of compounds and their evaluation against specific species based on cell mechanisms. While this approach holds great promise for the discovery of NCEs (new chemical entities) that may become useful drugs, it totally ignores the ayurvedic basis for prescribing the herbal preparations in the first place (Valiathan, 2003). Perhaps it would be rewarding to look for physicochemical fingerprints that many distinguish the antidosha groups of plants from each other and from plants that have few antidosha effects. The finger prints could be developed on the basis of antioxidants, antineoplastics, and immunomodulatory properties. In this reverse approach may lay the key to the biochemical understanding of the perturbation of doshaas and the new kind of therapeutics.

Effect of *Parthenium* on livestock

Though cattle do not normally eat *Parthenium*, its ill effects are observed on them as they walk or graze through patches of this weed. Such cows had inflamed udder and subsequently suffered from fever and rashes (Krishnamurthy *et al.*, 1977). Sundara Rajulu and Gowri (1976) studied a young rabbit by letting it move in a *Parthenium* field. The rabbit exhibited hypersensitivity from the eighth day onwards, followed by hair fall, eruption of small boils on 12th day, blood ooze on 13th day and mortality on the 17th day. Feeding the weed to buffaloes and bull calves caused acute and chronic forms of toxicity and ulcerations were caused both in the mouth and digestive tracts (Subba Rao *et al.*, 1976). They further reported that "labeled parthenin" was found to be excreted in the milk when administered to lactating guinea pigs, rabbits and cows.

Management of *Parthenium*

Ever since *Parthenium* became a menace in different parts of the country, several methods such as manual, chemical and biological are being recommended to suppress its growth. However, no single method has worked satisfactorily. Thus, the integrated approach recommended recently seems to be promising. The merits and demerits of each method are discussed below.

Manual

In small areas, isolated pockets (such as flower beds, lawns, kitchen garden) and in intensively cultivated agricultural fields, hand weeding can be effective and is preferred. The plants are not to be cut or broken but should be uprooted before flowering and burnt or composted. Only persons who are not sensitive to *Parthenium* allergy are to be engaged, after wearing hand gloves and nose covered to uproot the plants. The manual method also finds a place in the integrated approach, in order to achieve quick results. When biocontrol methods are adopted, there will always be a certain proportion of plants left unchecked, which is typical of any biocontrol method. Physical removal of such remnants will supplement the biocontrol efforts in checking the growth of *Parthenium*. But the manual method is neither economical nor practicable for control in areas of heavy infestation. Relief expected from this method when singularly adopted is only temporary and needs to be repeated as and when the weed appears.

Chemical

Several selective herbicides, soap water and salt water have been tried in experimental plots and subsequently under actual *Parthenium* infested field conditions. Chemical suppression is temporary, and the plants regenerate after remaining dormant for a few days. The remnants as well as the newly deposited seeds germinate with slight soil moisture. Since *Parthenium* is more a wasteland weed, there will be hardly anybody to invest in chemical control for merely temporary relief. Further, repeated applications either of common salt, soap water or any herbicide will affect other, beneficial plants and the soil condition, besides polluting the environment due to cumulative residual effects. Chemical methods should be resorted to only in emergencies, for temporary control.

Biological

Parthenium control through biological agents is not as simple as in other successful cases due to inherent adaptive features of this weed. There are plant and insect enemies also that can contain its growth. Use of pathogens offers a great scope for its management.

a. Use of botanical agents

Two approaches in using botanical agents (BAs) are:

i) Maintenance of naturally occurring biodiversity and

ii) Planting/promoting the growth of selected plant species in target areas

A botanical survey in relation to *Parthenium* control in India has revealed an interesting factor that the *Parthenium* infestation is more in places where the natural flora has been disturbed. Further, research at the University of Agricultural Sciences, Bangalore confirmed that some botanical agents could exert allelopathic impact and hinder germination and growth of *Parthenium* both in the greenhouse and in its natural habitat. Promoting growth of BAs in abandoned and non-agricultural lands and in *Parthenium* infested orchards would be rewarding, and should be preferred for the following reason. The BAs have in their system allelopathic compounds suppressing germination and growth of only *Parthenium* and not other waste land plants or agricultural crops. Once established in an area, they keep on checking *Parthenium* emergence and growth in subsequent years. There is a need to identify the allelo-chemicals present in these plants, which suppress *Parthenium* growth.

b. Use of insects

There are a good number of insect and non-insect pests controlling weeds through biocontrol approach. Control of *Opuntia* through the introduction of the cochineal insect from Australia is a successful and classical instance in India. Field releases of *Zygogramma bicolorata* beetles in Sultanpalya in Bangalore during June, 1984 resulted in large-scale defoliation of the weed in most parts of Bangalore City. By 1991, it has spread on its own and through releases by voluntary organizations and Research Institutes to far off places causing very significant damage to *Parthenium* populations by fast defoliation. This Mexican beetle is effective only during monsoon season, and hibernates with the onset of winter. Thus, the beetle does not control *Parthenium* in other seasons. As the insect perpetuates on its own, it is advisable for humans to help the spread of the beetle to neighboring areas non infested by it. Voluntary organizations can take up this task continuously to check the growth and spread of *Parthenium*.

c. Use of pathogens

The use of mycoherbicides can supplement biocontrol methods. Various fungal pathogens have been identified from the Neotropics, which can be used as biocontrol agents. The potential species are, rust causing fungi namely *Puccinia abrupta* var. *partheniicola* and *P. melampodii*, and the white smut causing fungus *Entyloma compositarum*. Some success has been achieved by the use of these organisms in Australia. Such efforts are also needed in India and other countries. The leaf hopper (*Orosinus albicinctus)* which transmitted phyllody (phytoplasma) disease in *Parthenium* is widespread in India. Infected plants fail to set seed. This may be another way of reducing *Parthenium* population. Therefore this method needs to be verified on a large scale in uncultivated areas, which are far away from agricultural fields, before recommending for commercial use. The biocontrol method can work only in cases where the host organism has a limited adaptability. Since *Parthenium* is a versatile plant with a very wide adaptability, no one or two agents can control it. Using pathogens as biocontrol agents indicates that management of this weed through pathogens cannot be as simple as in some other successful cases because of high regeneration capacity, large seed production ability, germination ability throughout the year and extreme adaptability of this weed in wide range of ecosystems.

Further, as already referred to, *Parthenium* has been a threat to cultivation of crop plants and also causes health hazards to mankind and to the natural ecosystem as a whole. Management of this noxious weed by pests and diseases infecting other crop plants is not feasible, as it acts as collateral host for these pathogens during off-season. Fortunately, there are a few pathogens in nature found to infect *Parthenium* specifically and their commercial exploitation as potential biocontrol agents would help in reducing its further spread.

The above review highlights the scope of the use of fungal and bacterial pathogens for the management of *Parthenium*. Most of the microorganisms named, although have shown significant potential against this weed, are yet to be investigated thoroughly for their development as herbicides.

Integrated *Parthenium* weed management (IPWM)

The adaptive research carried out jointly by the University of Agricultural Sciences, Bangalore and Programme for *Parthenium* Elimination (PROPEL), Bangalore, in and around Bangalore City for five years commencing from 1986, involving large areas and employing different control methods individually and in combination has clearly demonstrated that only an integrated approach now termed "Integrated *Parthenium* Weed Management (IPWM)" can be effective in suppressing this weed. If a concerted effort is made adopting IPWM, the results will be visible in the second year and, by the third year the *Parthenium* population will come down to a negligible level.

The newly designed IPWM strategy includes the following six steps: (i) Maintenance of natural biodiversity; (ii) In places where cleaning and exposing soil is unavoidable, planting of botanical agents at the start of rainy season and promoting their growth to insulate such opened up soils against invasion by *Parthenium*. (iii) *Parthenium* plants which may grow along with BAs are to be removed in the first one or two years, so that BAs establish well and perpetuate on their own; (iv) Release of Mexican beetle during monsoon season; and (v) In the case of gardens, flower beds, lawns and intensively cultivated agricultural fields, manual removal only has to be taken up; (vi) In situations where the above methods cannot be adopted, it can be temporarily suppressed through herbicide application. The last two methods (manual removal and herbicide application) can also be integrated initially with biological methods in order to achieve desired results faster.

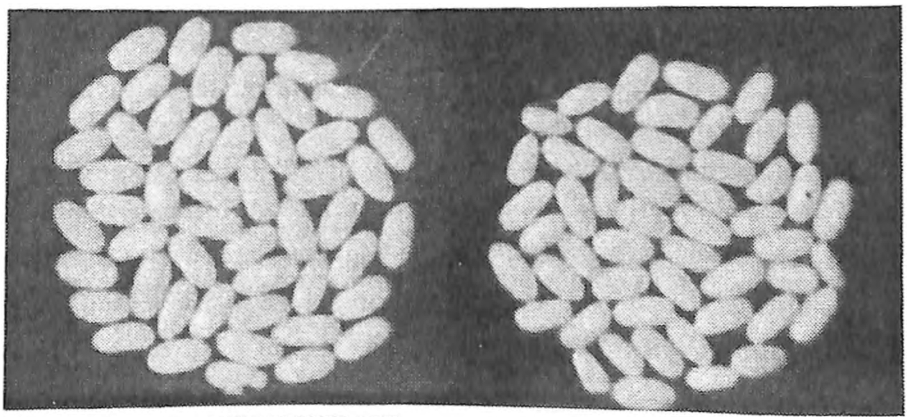
The effort should be like that of a community management programme, by arranging campaigns involving government departments, private organizations, youth clubs, self help groups and NGOs. Awareness programmes and demonstrations on integrated management practices will help to manage the weed very successfully and effectively. Family members should involve themselves in managing the weed in their respective fields, in and around their houses as well as on roadsides, adopting the IPWM detailed above. This will reduce the crop losses and health risks of the human beings and cattle and other animals. Intensive campaigns through awareness programmes, trainings, demonstrations, leaflets, folders, etc., with continued long range support of the mass media are useful.

Uses of *Parthenium*

Parthenium has also been registered as a beneficial plant, both in India and abroad. If a plant finds extensive use for different purposes, this is a way of reducing its prevalence in wasteland, and contributes indirectly to suppression. Its medicinal use in the West Indies such as a folk remedy against various afflictions, ulcerated sores, certain skin diseases, facial neuralgia, fever and anemia has been documented (Arny, 1897). Dry flowers are used as tonic for digestion, cleaning the blood, abortive, vermifuge, emenagogue and as insecticide in parts of Europe. A positive test of extract of *Parthenium* plant with Wagner and Dithmar reagent is reported. They indicated that the medicinal properties, if any, must be due to substances other than alkaloids. Its root decoction is being used by Kosti Indians as a curative for dysentery and some kinds of fever; as insecticide and for curing skin diseases like psoriasis. Studies at the Cancer Research Institute, Mumbai, indicated that parthenin, the principal ingredient, possesses anticancer properties. When such a property is confirmed, its profitable exploitation by pharmaceutical industry to produce the Anti-cancer drug could be explored. All such vague suggestions have been criticized both in and outside India. As felt at present, its harmful effects both from medical as well as animal health and agricultural production point of view are researchable and need consideration.

Parthenium plants have been commonly used as packing material for various fruits. *Parthenium* leaves are also seen bundled (or adulterated) with Coriander leaves and sold in the vegetable market. It has also been reported that the solid matter of *Parthenium* being fibrous, it is possible to convert it into natural fiber reinforced polymer (NFRP) composites, which can be manufactured and converted to end products like helmets, molded tableware, molded chairs, floorings, doors, etc. Pollen grains of *Parthenium* also possess antifungal activity, producing an inhibitory effect on downy mildew, *Sclerospora graminicola.* The grown up plants are used as centering material in the construction of buildings and bridges in several parts in southern India. Further, studies carried out at the Indian Institute of Science, Bangalore, during the mid-eighties have indicated a possibility that *Parthenium* plants can be ensilaged after mixing them in a certain proportion with conventionally used feeds (Narasimhan, 1987, personal communication). The fibrous nature of the *Parthenium* stem is a point that needs the attention of industrial researchers to explore, if this weed has potential in manufacturing paper or such other materials.

In Europe *P. argentatum,* a sister species of *Parthenium*, is reported to have potential economic value and is being used for manufacturing of tyres for aeroplanes. Some people out of ignorance or otherwise are using *Parthenium* flowers for preparation of bouquets, flower vases, etc. The weed is also used as firewood, as green manure in rice fields. The slight antibacterial and absence of anti-leukemic activity of parthenin has already been noticed. A few scientists have put forth the argument that the fantastic growth of *Parthenium* keeps the carbon dioxide in the atmosphere at optimum level. It is difficult to believe that *Parthenium* alone can keep CO_2 at optimum level. But in years of drought, when most plant species fail to grow, *Parthenium's* drought tolerance can let it grow and bring down CO_2 level to some extent. Patil *et al.*, (1997) reported that a 20 per cent leaf water extract of *Parthenium* when sprinkled on mulberry leaves improved both the qualitative and quantitative traits like larval weight, fineness of silkworm thread, cocoon weight (Plate 1). Beneficial effects of aqueous extract of *Parthenium* on mulberry silkworm cocoons attributed the improvement to the similarity of steroids present in the *Parthenium* plant. Hiremath and Ahn (1997) reported that *Parthenium* extract in methanol had insecticidal properties on brown plant hopper of paddy. Nagaraja *et al.*, (1997) observed stimulating effect of *Parthenium* leaf extract on soybean and chickpea. The effect of control of *eupatorium* weed by *Parthenium* leachate application was reported by Patil *et al.*, (1997); Chetty *et al.*, (1997). In sorghum, *Parthenium* extract spray was found to reduce shoot fly incidence by 17 per cent (Bhuti and Hiremath 1997). In red gram, the pod and grain damage was reduced by treatment with *Parthenium* (Das *et al.*, 1997). *Parthenium* along with cow dung could be used in the production of biogas, although the yield was lower than when water hyacinth was used in biogas plants (Sreenivasa and Majjigudda, 1997). Thimmaiah and Bhatnagar (1997) developed modified substrata involving chopped *Parthenium* leaves (50g) + (100g) and cow dung manure, (300g) for successful vermitechnology. Son (1995) experimented on the decomposition pattern and nutrient enhancement of *Parthenium* and found that decomposed *Parthenium* recorded higher phosphorus content while decomposed sugarcane trash recorded higher potassium content. The highest percentage of reduction (41.45%) in phenol content was observed with *Parthenium* even though the phenol content was higher in *Parthenium* at the end of composting.



Parthenium 20% AQUIOUS EXTRACT　　　　CONTROL

Plate 1: Effect of *Parthenium* extract on silk worm cocoon development

Field experiment with rice indicated significant contribution of organic manures on the build up of the available nutrients. The weed population in the rice field was influenced by the incorporation of organic wastes like composted coir pith and *Parthenium*. In a residual crop of soybean, composted *Parthenium* application recorded higher grain yield over inorganic and other organic wastes. Sreenivasa and Majjigudda (1997) studied the possibility of utilizing weeds including *Parthenium*, *Cassia* and water hyacinth in various combinations with cattle dung for biogas generation to find that *Cassia* and *Parthenium* in combination with cattle dung at 25:75 (w/w) resulted in 156 and 137 liters of biogas production per kg dry matter, respectively. A higher proportion of *Parthenium* in the mixture was found to be deleterious, result in reducing biogas formation as well as methane content. Kohli *et al.*, (1997) reported that the plant extract of *Parthenium* controlled the weed *Ageratum conyzoides*. Parthenin adversely affects the metabolic make-up of *A. conyzoides* and can be tried to check its seed germination and growth. Similar study made by Chetti *et al.*, (1997) using *Parthenium* extract to control *eupatorium* revealed significant differences over all biophysical and biochemical constituents. Ensilagation by packing chaff-cut weed in trenches along with small quantities of salt and allowing fermentation for 2 to 3 months detoxified the contact allergen/toxin parthenin and the result was highly palatable to livestock. The animals did not show any ill effects even after feeding with the silage for 3 months. This however needs verification through large scale experiments on various animals at different ages.

Future strategies

1. Biological control measures to solve the problem of *Parthenium* spread.
2. Educating people and ensuring their participation for uprooting and burning the plants before they flower and set seeds.
3. Further understanding vulnerable stages in its life history by studying its ecology and biology to arrest its spread.
4. Control through exploiting its beneficial attributes.
5. Farming systems and crop sequences that minimize its impact and regulate its population.
6. Plant association which can suppress it such as *Cassia sericea, Stylosanthus* spp. and other botanical (Competitive weeds) agents identified for specific agro climatic situations.

Conclusion

Invasive species influence health food and biosecurity directly or indirectly. To obviate their entry and spread to a new geographical region is the key point. Their management needs significant technological intervention for knowledge and the economic empowerment of scientists, academicians, administrators, policy makers and public to initiate appropriate development and welfare programmes for livelihood and social security. The future lies in our own hands.

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Initiatives of FAO towards Ensuring Biosecurity

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Biosecurity is now a key concern of the FAO, as it is in several countries and many international fora. It has assumed tremendous importance of late because of the significant surge in imports and exports between countries, the emergence of new and difficult species being discovered in our system, its complexity and the difficulty in ensuring protection from these uncertain risks and threats, and its significant inter-sectoral implications. We have seen how Mad Cow Disease affected the West and how the SARS virus and Avian Flu have caused serious global ripples with their threat to humans and severe socio-economic implications. We need a large investment in research and development, and surveillance and diagnostics management. These have critical impact on our environment, on food, livelihood and nutrition security, and also on our own security – the very survival of humankind itself. In this paper an attempt is made to flag some of the key issues which have to be looked into, in order to put together a comprehensive integrated biosecurity policy framework in this country.

The legislative, regulatory and structural mechanisms required for the purpose of a National Integrated Biosecurity Act have to be harmonized internally with several other sectoral regulations and laws related to this aspect, which exist today in various forms. As this involves the coordination of several departments, agencies and state apparatus, we have to resolve whether to have several acts or one comprehensive act to cover all areas under one umbrella. Again, when we talk about this we may have the choice of introducing a brand new act or of adapting an existing act from nations like New Zealand, or Australia, which have a more effective and organized legislative mechanism in place. The proposed act should further analyse and incorporate the key areas to harmonize or comply with various international requirements and obligations or arrangements.

Further, there is the crucial question of making the policy framework proactive vis-à-vis a reactive one. In India, we only try to act after something has happened already – we and our society, our bureaucracy being basically reactive in its approach – which may very often result in gross adhocism, firefighting or virtually knee-jerk responses. We have to think seriously about managing the crisis through contingency planning as well as strategic planning wherever necessary. We have to think about how we communicate the associated risks to the public, to allay undue fears – while putting in perspective a balanced public perception of the accompanying threats. We have to think about our emergency action plan, how we build a dynamic, real time survey and surveillance apparatus, and plan mitigation strategies across sectoral specificities.

A good deal of effort should be put into capacity building, expertise development and creation of facilities for diagnostics for a whole range of activities. Many technologies have come up of late, and a whole lot of procedures and methodologies have evolved. Therefore many policy initiatives are required to arrange for training, and procuring tools and equipment. We need to build a great degree of coordination and cooperation to synergize the efforts being made by several actors or agencies. The March 2006 meeting with the National Farmers Commission, talked about how networking has to be made more effective and widespread. There are several inter-sectoral or cross-disciplinary perspectives to be brought to the fore. This has to be at the national, regional and local levels: in the areas of technology transfer; in exchanging information and knowledge as well as in training and capacity building. This is very important as the task seems huge. Just take the training aspect, for example. There are many areas to be looked into such as: who are the people to be trained, across states and disciplines, the identification of trainers, development of training materials for various levels, quality aspects, choice of technology, tools and equipment for diagnostics, management, mitigation, and a lot of information access, generation and dissemination.

Again, there has been a welcome suggestion of creating a National Biosecurity Fund. We have to invest money in developing the large infrastructure needed for this, on establishing research and development (R&D) activities, in training and manpower development; in various strategic areas of cooperation and in networking to equip us to handle those tasks competently. We have a huge porous border, both coastal and terrestrial. We have a series of biosecurity related trans-boundary issues with Nepal, Bangladesh, and Pakistan, and similar coastal issues with nations across these boundaries. We surely need enough funds to address all these areas.

Coordination is a great concern that I would like to highlight here. We have already a number of measures in place towards fighting bio-terrorism. Many agencies are doing great work in these areas but are not necessarily informing or sharing with one another what is being done. Much effort is required to synergize interdepartmental, inter-ministerial, and inter-state as well as international cooperation. We have to take much of the work already done by various state and national agencies, as well as draw lessons from various international commissions and global agreements.

The FAO has been active in this for a couple of years now. It has a dedicated biosecurity portal – called the International Portal on Food Safety, Animal and Plant Health – that deals with the issue in detail. FAO considers Biosecurity as "a strategic and integrated approach that encompasses the policy and regulatory frameworks (including instruments and activities) that analyse and manage risks in the sectors of food safety, animal life and health, and plant life and health, including associated environmental risk. Biosecurity covers the introduction of plant pests, animal pests and diseases, and zoonoses, the introduction and release of genetically modified organisms (GMOs) and their products, and the introduction and management of invasive alien species and genotypes". The FAO considers Biosecurity a holistic concept, of direct relevance to the sustainability of agriculture, food safety, and the protection of the environment, including biodiversity.

The FAO supports capacity-building activities for developing countries, including development of capacity-evaluation tools (need assessment at the national level through a tool called the PCE or phyto-sanitary capacity evaluation), and the coordination of sectoral initiatives. It provides critical information and knowledge on all these areas. It has been active in developing and framing international standards and guidelines, and agreements between various nations as partners. The FAO has played a stellar role in IPCC (for plant health), in OIE for the animal health issues, biosecurity in forestry specially to handle emerging issues such as alien invasive species and CODEX guidelines with WHO regarding the food safety issues (including GMO foods) and their standards, parameters, and testing methods. These are contentious issues between countries. The FAO has also sponsored some training programmes and organized various technical activities, conferences, etc., to discuss related issues and develop national capacities in this regard. I understand that FAO also does outsourcing with a couple of capable agencies and consultants around the world to provide these services in a very reliable and effective manner.

The FAO very much encourages and supports such activities. Through the quarantine projects in India, it has assisted the setting up of six modern quarantine facilities at different ports of entry. They provide fundamental state-of-the-art technology to assess the quality of incoming materials, and resolve the problems associated with entry both of livestock and plants. FAO has also helped in developing national capacities in manning and operating these facilities in tune with international standards, and in keeping with WTO/SPS sanitary requirements. FAO has also organized a host of expert consultations on these. All these are available for anyone wishing to take advantage of them. In brief, the FAO has been active in all these areas and is very keen to encourage a viable regulatory mechanism on biosecurity in India, and assures all necessary assistance in this regard.

At the local level, FAO India manages a knowledge-management community–called Solution exchange (www.solutionexchange-un.net.in)–which is a mechanism of sharing development experience between practitioners. I am very happy to state that the National Agricultural Innovation Project (NAIP) as well as the National Horticultural Mission (NHM), and many other government organizations are using this free knowledge service to improve their effectiveness and outreach. This endeavour has been acclaimed as a unique knowledge-sharing mechanism. I invite biosecurity experts to join this platform to exchange knowledge on various aspects of biosecurity. Perhaps we have arrived at a point in human civilization, where the collective conscience and intelligence of people can be instrumental in making things better for all of us.

Biohazards in Agricultural and Food Commodities and Their Control by Radiation Technology

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Biohazards are living organisms, or toxic substances produced by them, that can cause illness or disease or adverse effects in humans, animals or plants. In today's context many biological agents find use in workplace, and some of them could be hazardous. The route of transmission of a biohazard could either be indirect, through contamination of agricultural and food commodities and insect vectors, or direct, through physical contact with an infected individual or injury by needles and sharp objects.

Sub-viral particles and viruses

Sub-viral particles include viroids and prions. Viroids are circular single stranded RNA molecules, with no protein-coding genes. They cause diseases like cadang-cadang of coconut (246 nucleotides) and citrus exocortis disease (375 nucleotides). Prions are entirely-protein molecules that are known to be etiological agents of diseases like scrapie, bovine spongiform encephalopathy, Creutzfeldt Jakob's disease and Kuru.

Viruses can be broadly divided into RNA viruses, which may be either single stranded or double stranded, and single stranded or double stranded DNA viruses. There are also mixed RNA-DNA viruses, for example retroviruses. Viruses are further categorized as non-enveloped DNA viruses, for example ssDNA parvovirus, papovavirus, dsDNA, adenoviruses, iridoviruses, or enveloped DNA viruses, for example dsDNA, hepadna virus, dsDNA pox virus, dsDNA herpes virus. RNA viruses are classified as (+) strand or (–) strand viruses. These may be again non-enveloped, for example ssRNA picorna virus and dsRNA reovirus, or enveloped, for example ssRNA togavirus, rhabdo, paramyxo and retro (using reverse transcriptase).

The common viral diseases include the common cold, caused by rhinoviruses that are ssRNA (picornaviruses) with more than 100 serotypes, influenza, caused by enveloped RNA orthomyxoviruses, measles, caused by a paramyxovirus, mumps caused by a paramyxovirus, rubella (German measles) caused by togaviruses, chickenpox and shingles and herpes caused by herpes viruses, AIDS, caused by HIV, and rabies caused by ssRNA rhabdoviruses.

Some viruses are also involved in human cancers. These include adult T cell leukemia, caused by HTL V1 RNA viruses, Burkett's lymphoma caused by Epstein Barr virus, a herpes DNA virus, neopharyngeal carcinoma caused by another herpes DNA virus, hepatocellular carcinoma caused by hepadna hepatitis B virus, and many skin and cervical cancers, caused by papilloma viruses of the DNA papovavirus family.

Common food borne diseases caused by viruses include hepatitis A with an incubation period of 15-30 days. It leads to fever, weakness, nausea, and jaundice. This virus spreads through fecal contamination via water, soil or food handlers. The other viruses that cause food-borne illness include the small round shaped (SRS) virus or Norwalk agent, with incubation period 1-2 days. The disease is characterized by nausea, vomiting diarrhea, pain, headache, and fever. Some of the rotaviruses are also involved in food-borne illnesses, characterized by diarrhea in infants and young children with an incubation of 1-3 days.

Rickettsia

Rickettsia are the microtatobiotes between viruses and bacteria. Some of the well-known diseases caused by rickettsia are typhus fever, caused by *Rickettsia prowazekii*, Rocky Mountain spotted fever, caused by *Rickettsia rickettsii*, and Q fever caused by *Coxiella burnetti*. It is also the organism targeted in milk pasteurization.

Bacteria

The most common disease outbreaks result from attack by bacterial infectious agents. These include upper respiratory tract infections caused by *Staphylococcus aureus*, lower respiratory tract infections caused by *Bordetella pertussis* and *Streptococcus pneumoniae*. Infections of the oral cavity are caused by *Neisseria meningitides*, *Haemophilus influenzae* and *Streptococcus pyogenes*, and that of pharynx caused by *Corynebacterium diphtheriae*. Other common bacterial diseases include suppuration by staphylococcus, gonorrhea by *Neisseria gonorrhea*, typhoid by *Salmonella typhi*, tuberculosis by *Mycobacterium tuberculosis*, cholera by *Vibrio cholerae*, tetanus by *Clostridium tetani*, diarrhea by *Escherichia coli*, meningitis by *Neisseria meningitides*, gas gangrene by *Clostridium perfringens*, plague by *Yersinia pestis*, syphilis by *Treponema pallidum* and anthrax, caused by *Bacillus anthracis.* The last organism caused a post 9/11 scare in US, being transmissible through postal mail. As a result, all mail to the Capitol Hill is today irradiated in an electron beam facility prior to distribution.

Food-borne diseases can be classified as food-borne infections or food poisoning. The former requires either the presence or formation of a sufficient number of live cells, whereas the latter is caused by pre-formed toxins with or without the presence of live cells. Food borne infections are caused by organisms like *Salmonella typhi,* Enterotoxic *E. coli,* Enterohaemorrhagic *E. coli, Shigella dysentariae, Campylobacter jejuni, Vibrio cholerae, Salmonella paratyphi, Vibrio parahemolyticus, Aeromonas hydrophila, Listeria monocytogenes, Helicobacter pylori.* Food poisoning is caused by the toxins produced by bacteria like *Staphylococcus aureus, Clostridium botulinum and Clostridium perfringens.*

There are several medical complications associated with bacterial infections. These include Broncho-pneumonia, cholecystitis, caused by *Aeromonas hydrophila* infections; meningitis, spondylitis, pericarditis, and aortitis, caused as a result of infection by *Brucella abortus*, hemolytic urolytic syndrome and erythema as a result of infection by enterohemorrhagic *E.coli*, Salmonella and Shigella.

Fungi

Fungi cause several diseases, collectively called mycosis. Superficial mycosis like ring worm, athlete's foot, and jock itch are caused by fungi like *Microsporum favus*, *Trichophyton,* and *Epidermophyton.* Subcutaneous mycosis is caused by fungi like *Sporotrichosis*, *Sporothrix schenckii,* and *Chromoblastomycosis.* Several fungi are involved in systemic mycosis, for example cryptococcosis caused by *Cryptococcus neoformans,* coccidioidomycosis caused by *Coccidioides immitis,* candidiasis caused by *Candida albicans.* A number of fungi produce mycotoxins, secondary metabolites that cause several diseases known as mycotoxicoses. Aflatoxin, a well known mutagenic, hepatocarcinogenic, and teratogenic mycotoxin, is produced by *A. flavus and A. parasiticus*. Trichothecines, skin irritant and ematic mycotoxins, are produced by *F. sporotrichoides, F. culmorum*, and *T. Roseum*. Ochratoxins, produced by *A. ochraceous* are known to be nephrotoxic. Fumonisins, produced by *F. moniliforme*, are found to be involved in oesophageal cancers. Citrinin, produced by *P. citrinum* and *P. viridicatum*, cause nephrotoxicity. Patulin, a toxin produced by *P. patulum* and *P. urticae*, is known to be involved in certain sarcomas. Zrearalenone, a toxin produced by *F. roseum* and *F. nivale*, is known to possess oestrogenic activity. *Ergot*, the cause of ergotism, is produced by the fungi of *Claviceps sp.*

Protozoa and parasites

A number of protozoa cause serious human diseases. These include amoebic dysentery characterized by diarrhea, fever, chills, and liver abscess. Cryptosporidiosis is characterized by diarrhea, fever, nausea, vomiting. Giardiasis is characterized by diarrhea and green stools. These diseases are caused by consumption of raw or mishandled food, and contaminated water. Toxoplasmosis, characterized by mononucleosis and death, is caused by the consumption of raw under-cooked meat.

Aniskiasis characterized by abdominal pain, cramps, nausea, and vomiting. Ascariasis is known to cause bowel problems in children. Trichinosis is characterized by muscle pain, fever and sometimes even death. Taeniasis is also known to cause digestive problems. Most of these diseases are caused by the consumption of raw or undercooked foods, especially meat.

Vector-borne diseases

Some of the disease agents are spread through insect vectors. The best-known vector borne disease is malaria, whose parasite is carried by mosquito. Another is epidemic typhus, caused by *Rickettsia prowazeki*, carried by infected louse and human lice. Similarly, diseases like lime disease, Rocky mountain spotted fever and plague, caused by *Borelia burgdorferi, R. rickettsii, and Yersinia pestis* respectively, are carried by infected ticks, fleas and rodents.

Common source epidemics

Agents that have a common source and a reservoir cause many human diseases. This needs to be kept in mind while devising control strategies for biohazards.

For example, anthrax (caused by *Bacillus anthracis*) comes from the meat of infected cattle, swine or goats. *Shigella dysenteriae*, the cause of bacillary dysentery in humans, comes from fecal contamination of food and water, and can spread through carriers like human handlers of food. Soil is the source of *Clostridium botulinum* contamination of food, and meat serves a good substrate for its multiplication.

Host-to-host epidemics

Certain diseases spread host-to-host in epidemic proportions. These include for example diphtheria, caused by *C. diphtheriae*, spread from human cases that act as carriers. Hantavirus, a cause of pulmonary syndrome, is spread by the inhalation of rodent fecal material. Menigococcal meningitis, caused by *Neisseria meningitides*, spreads through human carriers. Tuberculosis, caused by *Mycobacterium tuberculosis*, is spread through human sputum or by consumption of non-pasteurized milk of infected dairy cattle. Many of the viral diseases, for example influenza, measles, mumps, small pox, and chicken pox, are caused by contact with infected carriers.

Quarantine biohazards

Quarantine biosecurity is becoming an important issue in international trade. Agricultural commodities are normally contaminated with exotic insect pests, parasites and plant pathogens, and sometimes seeds of noxious weeds. International regulations require neutralization of these biohazards before dispatch of the export consignment.

Food Bio-terrorism

Following the events of September 11, 2001, on May 18, 2002, the fifty-fifth World Health Assembly of the UN adopted a resolution (WHA 55.16) expressing serious concern about threats against civilian populations by deliberate use of food as a vehicle for transmission of hazardous biological, chemical and radionuclear agents. The resolution provided for strengthening national food safety surveillance, and control systems to deal with emergencies of food terrorism. Responding to the national need, the US congress enacted 'The Public Health Security and Bioterrorism Preparedness and Response Act of 2002' (The Bioterrorism Act). The act empowers USFDA to take necessary steps to protect the public from a threatened or actual terrorist attack on the US food supply, and other food related emergencies. Consequently, exercising powers vested under the act, the USFDA has initiated (i) registration of food supplying facilities, domestic and foreign, including manufacturers or processors, packers, and storage or holding facilities, and (ii) prior notice of shipments of imported foods.

Neutralization of biohazards

Some of the conventional methods used to achieve neutralization of biohazards include thermal treatment by conventional heating, and by using infrared, microwave, and radiofrequency radiation. However, heating agricultural produce compromises its quality, in terms of freshness and nutritive value. Cold methods, such as fumigants like methyl bromide, ethylene dibromide or ethylene oxide, are being increasingly discouraged and phased out because of the harmful residues these fumigants leave on the commodity, also their reactivity with ozone, an environmentally important concern. Other non-thermal chemical methods suffer from many disadvantages related to their use under commercial conditions.

Radiation for quarantine treatment of agricultural commodities

One of the major problems of international trade in agricultural commodities is the presence of exotic insects and pests. This invites quarantine restrictions and hinders the movement of produce from one country to another, and sometimes also from one state to another within a country. Therefore, in order to be competitive in the international market, effective quarantine treatment of food and agricultural produce is necessary.

Treatment with ionizing radiation is a very promising and effective alternative technology currently available for food and agricultural commodities to overcome quarantine restrictions in international trade. It has several advantages over conventional methods. The cold nature of the treatment makes it very suitable for application to fresh agricultural produce. It is also more effective, because of the high penetrating power of ionizing radiations. It is an environmentally friendly technology, and safe to workers. A number of radiation processing plants for treatment of healthcare products already exist in India. Facilities for treatment of food and agricultural commodities are coming up and will be available soon.

Sources of ionizing radiations

The sources of ionizing radiation can be classified into two broad categories: radioisotopes, and machines. In accordance with international regulations such as Codex General Standards for Food Irradiation, the ionizing radiation permitted for irradiating foods is limited to:

a) Gamma rays from radioisotope cobalt-60 or cesium-137
b) X-rays generated from a machine operated at or below an energy level of 7.5 MeV.
c) Electrons generated from a machine operated at or below energy level of 10 MeV.

Radioisotope sources

It is general practice to use cobalt-60, however, cesium-137 can also be used. While cobalt-60 is produced in nuclear power reactors by bombardment of cobalt-59 with neutrons, cesium-137 is a fission product and has to be extracted from the spent fuel of a nuclear reactor through reprocessing. Cobalt-60 is the preferred choice, but cesium-137 has advantages in building portable or modular irradiators. The energy of radiation emitted by a radioisotope is fixed, but variable energies can be obtained from machine sources. Radioisotopes also provide much lower dose rates than machine sources.

With a half-life of 5.27 years, an annual replenishment of 12.3% is needed to maintain the source strength. For use as a radiation source, cobalt-60 pellets are encapsulated in stainless steel and further pellets or slugs, loaded in stainless tubes to form a pencil. Several such pencils are then mounted on a rack to make the final source of radiation in a radiation processing facility. Goods to be irradiated are conveyed to the irradiation chamber through a labyrinth, which prevents radiation from reaching the work area and operator room. When the facility is not in operation, cobalt-60 is stored in the source rack under water at a depth of about 6 meters. The water column absorbs the radiation, and acts as a shield to prevent radiation in the cell area when the source is idle. During the processing of a commodity, the source rack is brought up to the irradiation position after activation of all safety devices. The irradiation chamber is shielded with concrete walls, usually about 1.5-1.8 meters thick. The goods in aluminium carriers or tote boxes are mechanically positioned around the source rack, and turned around their own axis so that the contents are irradiated from both the sides.

The absorbed dose is determined by the dwell time of the carrier or tote box in the irradiation position. The dwell time can be preset after taking into consideration the dose rate, which in turn depends upon the source strength.

Machine sources

Machine sources used in food irradiation include various types of electron accelerator. The electron beam emerging from the accelerator can be either used directly or converted into X-rays. Both DC (Direct Current) accelerators and microwave or radio-frequency linear accelerators (LINAC) are used. In both types, electrons are accelerated close to the speed of light in an evacuated tube. Electrons emitted from an electron source are pushed from the negative end of the tube and are attracted by the positive end. The higher the potential difference, higher the speed they attain. A scanning magnet at the end of the accelerator tube deflects the mono-energetic electron beam onto the material being irradiated. In a LINAC, pulses of electrons produced at the thermionic cathode are accelerated in an evacuated tube by driving radio-frequency electromagnetic fields along it. The LINAC electrons are mono-energetic, but the beam is pulsed. As the electron beam can be directed at the product, the efficiency of electron accelerators is about 20% higher than that of gamma sources.

Because of its lower depth of penetration (5 mm/MeV in water), an electron beam cannot be used for irradiation of thick chunks of food or bulk packages. This difficulty can be overcome by converting electrons into X-rays, by fitting a water-cooled converter plate to the scanner. The electrons strike the metal plate and their energy is converted into X-rays, with an efficiency that depends on the material of the converter plate and the energy of the striking electrons. The X-rays are as penetrating as gamma rays.

The choice of an irradiator

A number of aspects are considered during the choice of an irradiator. These include:

- The type of commodity
- Whether loose bulk or packages
- Throughput required

- Thickness and shape of the product
- The size and shape of the container
- The packaging density of the product
- Techno-economic feasibility
- Socio-political implications

Process control

During irradiation processing the aim is to expose the material to at least the minimum required dose that governs the effectiveness of the process. Correct measurement of dose and dose distribution in the product ensures that the radiation treatment is both technically and legally correct. Application of an experimentally established dose for the purpose of radiation processing of a specific food is important both technologically and economically. Dose and dose distribution are determined by product and source parameters. Product parameters are primarily the density of the commodity and packages. The source parameters vary with the facility or the type of radiation being used.

Mechanism of action of ionizing radiation

Ionizing radiation brings about the desired effects by different mechanisms in different foods, depending upon the dose of radiation. It does so by causing changes in bio-molecules, primarily DNA, either by direct deposition of energy or indirectly through production of radiolytic product of water that interacts with the bio-molecules. The extent of the effect depends on the radiation energy absorbed, increasing linearly with the dose in the range normally employed in food irradiation. Water is an abundant component of food. Therefore, interaction of water with radiation plays a major role in irradiation. The radiolytic products of water, such as hydroxyl radicals, hydrated electrons, hydrogen atoms, and peroxides, are highly reactive and highly involved in the effects of irradiation. The effects of the interaction of radiolytic products of water with bio-molecules are also called indirect effects.

Wholesomeness and safety aspects

No other method of food processing has been subjected to such a thorough assessment of safety as radiation processing. The various aspects of wholesomeness and safety of radiation-processed foods have been studied in great detail (WHO, 1994; Diehl, 1997). These include:

- Possibility of induced radioactivity
- Microbiological safety
- Safety of chemical changes
- Nutritional adequacy
- Animal feeding
- Human trials

At the energies of the gamma rays from Cobalt-60 (1.3 MeV) and those recommended for X-rays (5 MeV) and accelerated electrons (10 MeV), no induced radioactivity has been detected. The microbiological aspects of radiation-processed foods have been studied in detail. Not one of these studies has indicated that foods preserved by radiation pose any special problems in relation to microflora. It has been found that there are no unique radiolytic products formed, and free radicals in the system disappear, depending on the nature of the commodity and its post-irradiation storage and treatment. In fact, the chemical differences between radiation-processed foods and non-irradiated foods are too small to be easily detected. Though the rough composition of food remains largely unchanged, some losses in vitamins may be encountered. However, these losses are often minor and can be made up from other sources.

Animal feeding studies have been the most time consuming and expensive feature of wholesomeness testing of irradiated foods. None of the short-or long-term feeding studies, as well as the mutagen testing studies, conducted with several irradiated foods in various species of laboratory animals has shown any adverse effect on the animals. Similarly, no adverse effects were found in human volunteers fed irradiated food (WHO, 1994).

International approval

In 1980 a joint FAO/IAEA/WHO Expert Committee on Food Irradiation (JECFI) reviewed the extensive data on wholesomeness collected up to that time, and concluded that irradiation of any commodity up to an overall dose of 10 kGy presents no toxicological hazards and introduces no special nutritional or microbiological problems. An Expert Group constituted by WHO in 1994 once again reviewed the wholesomeness data available till then and validated the earlier conclusion of JECFI (WHO, 1994). In 1997 a joint FAO/IAEA/ FAO Study Group constituted by WHO affirmed the safety of food irradiated to doses above 10 kGy (WHO, 1999). In view of this recommendation the Codex Committee on Food Standards of The Codex Alimentarius Commission has also revised the Codex General Standard for Irradiated Foods in 2003. It now allows use of doses higher than 10 kGy in case of a technological need.

Global trade in agricultural commodities

Global trade in food, including fresh agricultural produce, is increasing among the countries. With regard to quarantine treatment and trade in food and agro-horticultural produce, the provisions of the following agreements under WTO agreement are of particular relevance:

- Applications of Sanitary and Phytosanitary (SPS) Measures
- Technical Barriers to Trade (TBT)

The Agreements on Sanitary and Phytosanitary (SPS) Practices and Technical Barriers to Trade (TBT) under the World Trade Organization (WTO) have provided a distinct incentive to the adoption of irradiation as an SPS measure in international trade, under the principle of equivalence. Thus, irradiation can be applied to overcome quarantine barriers, and to hygienize products for international trade. These agreements are administered under the standards, guidelines, and recommendations of the international organizations such as the Codex Alimentarius Commission, International Plant Protection Convention, and International Office of Epizootics. Governments that impose regulations stricter than those recommended by these organizations are required to justify their positions to the WTO. This should encourage the application of radiation for improving international trade in agro-horticultural foods among WTO member states.

Irradiation as a quarantine treatment

The most important single pest group of quarantine importance present in fruits and ornamental flowers is the fruit fly. A dose of 75-150 Gy has been found to prevent the emergence of adults from the eggs of the fruit fly. One Gray (Gy) is the unit of absorbed dose equivalent of 1 Joule of energy per kg of material. Radiation is equally effective against other pests including moths, weevils, beetles, and mites. A dose of 300 Gy has been found highly effective in destroying their reproductive capacity. A number of agro-horticultural commodities are amenable to radiation processing. The low doses recommended for quarantine applications do not affect the freshness or organoleptic quality of fresh fruits and vegetables. Dried fruits, herbs, spices and grains, can withstand even higher doses.

The Animal and Plant Health Inspection Service (APHIS) of the USDA issued a Final Rule on 'Irradiation Phytosanitary Treatment for Imported Fruits and Vegetables' in 2003. In the same year Food Standards Australia and New Zealand permitted the use of irradiation as quarantine treatment for the import of tropical fruits. In 2004 International Plant Protection Convention (IPPC) also included irradiation as a quarantine treatment. These regulations have opened up the market for the irradiated commodities.

In India, in 2004, the Ministry of Agriculture & Co-operation amended the plant quarantine regulations to include irradiation as a phytosanitary treatment. This enabled the signing of a framework equivalence work plan agreement between USDA-APHIS and the Ministry of Agriculture & Co-operation, Government of India, for the export of mangoes to the US after radiation processing at a generic dose of 400 Gy.

Technology demonstration

In 1986 a National Monitoring Agency was constituted by the government of India with Secretary for Health as its Chairman to oversee commercial applications of radiation processing technology. In 1991 the Atomic Energy Act was amended to include Atomic Energy (Control of Irradiation of Food) Rules, later amended in 1996. In 1994 the government of India amended the Prevention of Food Adulteration Act Rules to permit radiation processing of onion, potato and spices. This was subsequently amended in 1998 and 2001 to list more commodities. A proposal for generic approval for radiation processing of food and agricultural commodities is currently pending with the Ministry of Health & Family Welfare.

Subsequently, the Department of Atomic Energy (DAE) set up two radiation processing units, to demonstrate the application of the technology on a commercial scale. One unit, Radiation Processing Plant, Vashi, Navi Mumbai, for foods requiring medium and high doses of radiation like spices, dry ingredients and vegetable seasonings, commenced operations in January 2000.

It processes more than 1500 tons of spices and dry ingredients every year. A low dose irradiation facility, KRUSHAK (Krushi Utpadan Sanrakshan Kendra), Lasalgaon, near Nashik, for radiation processing of onion and potato for controlling sprouting, and insect disinfestation of agricultural commodities including mangoes, became operational in 2003. Last year more than 300 tons of agricultural commodities were processed. The facility is being upgraded to process mangoes for export to the US in the 2007 mango season. Large-scale studies involving traders, farmers and NGOs have shown very encouraging results with commodities like onion, potato and garlic.

At BARC the vision is to deploy radiation processing technology on a wider commercial scale so that farmers, traders and exporters can benefit from its advantages. The interest of entrepreneurs, both in the private and co-operative sectors, is increasing, as evident from a large number of MoUs that have been signed by the Board of Radiation and Isotope Technology with prospective entrepreneurs to set up radiation processing units. Many plants are in the advanced stages of construction and commissioning.

FTD, BARC is working in collaboration with many agricultural universities and institutions of ICAR for enhancing the deployment of BARC technologies. Some of the NGOs like Fresh-O-Veg, Indore and the Federation of Farmers Association, Andhra Pradesh, are playing a lead role in improving the lot of the farmers and primary producers of the region by encouraging induction of newer technologies aimed at improving productivity, reducing post-harvest losses, improving food hygiene, and developing international trade. These efforts can help improve sustainability of agriculture and providing support for the much-cherished second green revolution in this country.

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Managing Natural Resources for Biosecurity

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Biosecurity is essential to provide disease free healthy environment to plant, animal and human beings. It may, generally, be understood as a regime ensuring requisite safety measures to stop the inadvertent or ill-designed entry of pollutants, pathogens and weeds paralyzing our biological systems. Its scope, however, is much broader in embracing all other diverse issues of food, nutritional, livelihood and environmental securities. The conservation, amelioration and sustainable management of natural resources, viz., land, water, air, vegetation and climate is, therefore, central to the meaning of bio-security. The future bio-secure agriculture should be no more resource exploitative, but based on principles of safe utilization and conservation agriculture. We still do not have adequate policy and regulatory frameworks to prevent or deal with degradation of natural resources, contaminations of foods, geogenic malnutrition and environmental changes altering characteristics and functions of different ecosystems. It is being felt increasingly, therefore, to have comprehensive review of emerging issues affecting biosecurity and mobilize the required infrastructure and institutional frameworks to deal with them.

India has achieved remarkable growth in food production in the post green revolution period. The green revolution has, however, triggered many second and third generation problems of declining soil health, depleting ground waters, water logging and secondary salinization in major irrigation commands and pollution of soil, water, air and food resources. The degrading natural resource base has lowered total and partial factor productivity, especially for Indo-Gangetic Plain. The 1990s have witnessed a depressed rate of production and productivity of major categories of crops compared to 80s (Anonymous 2004 a). The food grain production and productivity increased at an annual compound growth rate of 2.93 and 3.13 percent in 80s, which declined respectively to

1.91 and 2.11 percent in 90s. Similarly, productivity of pulses and oilseeds decreased from 2.14 and 3.48 percent in 80s to 0.67 and 1.27 percent in the 90s, respectively. The stagnating productivity is reflected in slowdown in agriculture with agricultural trend growth rate falling to about 2 percent during Tenth Plan. The emerging scenario threatening our food, economic, livelihood, and bio-security is a matter of great concern to planners, scientists, environmentalists and farmers alike. Achieving 4 % agricultural growth rate during Eleventh Plan has, therefore, become critical to have 8 % growth in GDP to fulfil the needs of growing economy. We need to adopt appropriate natural resource management strategies for sustained productivity, environmental protection and overall biosecurity.

Rehabilitating degraded lands

Land degradation, eating into the vitals of natural resource base, is a biggest threat to food, environment and bio-security of the country. Many prospering civilizations perished in the past for the simple reason that land care was not accorded the due attention. About 146 million ha of total geographical area is, today, degraded due to soil erosion, Water logging, salinity/alkalinity, soil acidity and some other complex problems (Table 1). The degraded soils with

Table 1: Degraded lands in India (Mha)

Sl. No.	*Type of Degradation*	*Arable land (in Mha)*	*Open forest (<40% Canopy) (in Mha)*
1.	Water erosion (>10 t/ha/yr)	73.27	9.30
2.	Wind erosion (Aeolian)	12.40	–
	Sub total	85.67	9.30
3.	Chemical degradation		
	a) Exclusively salt affected soils	5.44	–
	b) Salt-affected and water eroded soils	1.20	0.10
	c) Exclusively acidic soils (pH< 5.5)	5.09	–
	d) Acidic (pH < 5.5) and water eroded soils	5.72	7.13
	Sub total	17.45	7.23
4.	Physical degradation		
	a) Mining and industrial waste	0.19	–
	b) Water logging & marshy lands (permanent) (water table within 2 mts depth)	0.97	–
	Sub total	1.16	–
	Total	104.28	16.53
	Grand total (Arable land and Open forest)	120.81	

Source: NBSSLUP (2007)

very low productivity do not contribute much to the national GDP. We need to have macro and micro level land-use planning backed up by appropriate decision support systems consistent with the prevailing socio-economic-environmental-market imperatives for sustainable management of our natural resources. The plans must be wedded to the strategies of diversification and integrated farming, seeking all round development of an area. There are immense opportunities to accomplish the task by employing state of art Remote Sensing, Geographic Information System (GIS) and Information Technology based approaches and tools. The Planning Commission, Government of India, envisages rehabilitation of 88 Mha of degraded lands in the next four plan periods; 20Mha in XI Plan.

Eroded lands: Incresed soil erosion taking away productive top soil causes decline in crop productivity, erosion of bio-diversity, flash floods and siltation into rivers and other water bodies (Yadav *et al.*, 1993; Agnihotri *et al.*, 1994; Faroda 1999). About 5.3 billion tonnes of soil got eroded annually at an average rate of 16.33 t ha^{-1} yr^{-1} (Dhruvanarayana and Ram Babu 1983). While 61 % soil moved from one place to another, nearly 29 % was lost permanently to the sea. The remaining 10 % was deposited in multipurpose reservoirs reducing their holding capacity by 1 to 2 % per annum. The eroded soil carried alongwith about 8 million tones of plant nutrients. About one-third of the eroded area was under high to very severe erosion category (Table 2). The areas revealing severe erosion included Siwalik Hills, north-western Himalayan regions, ravines, shifting cultivation regions, Western Coastal Ghats and black cotton soils areas of Peninsular India. The adoption of appropriate soil and water conservation measures is essential for protecting the lands from accelerated soil erosion.

Table 2: Area under different classes of soil erosion by water in India

Soil erosion rate ($Mg\ ha^{-1}\ yr^{-1}$)	*Area (km^2)*	*Soil erosion class*
0-5	801,350	Slight
5-10	1,405,640	Moderate
10-20	805,030	High
20-40	160,050	Very high
40-80	83,300	Severe
> 80	31,895	Very severe

Source: Singh *et al.*, (1992)

Watershed management: The ICAR Institutes and SAUs have developed model participorty watersheds in different regions and demonstrated their usefulness in reducing soil and water losses and improving the socio-economic status of farmers (Table 3). The operational research project, Fakot in Garhwal Himalaya has increased the total food production, cropping intensity and average family income during 20 years of its operation (Dhyani *et al.*, 1997). The area has decreased under wastelands and increased under irrigation and horticultural/ fodder/fuel plantations. The grazing of animals changed to stall feeding and seasonal migration stopped. The project also led to more empowerment of women.

Table 3: Impact of integrated watershed-management practices on run-off (flood moderation) and soil loss

Watershed	*Run-off (% of rainfall)*		*Soil loss (Mg ha^{-1})*	
	Pre-treatment	*Post-treatment*	*Pre-treatment*	*Post-treatment*
Fakot (U.P.)	42.0	14.2	11.9	2.5
GR Hali (Karnataka)	14.0	1.3	3.5	1.0
Behdala (H.P.)	30.0	15.0	12.0	8.0
Joladarasi (Karnataka)	20.0	7.0	12.0	2.3
Una (H.P.)	30.0	20.0	12.0	10.0

Source: Samra and Pratap Narain (1998)

The watershed management in a participatory mode, ensuring transparency and equitable sharing of services and benefits among the different stakeholders of the watershed, is emphasized for sustainable success (Samra, 2003). The stakeholders, therefore, need to be involved in the programme right from the planning process and should be organized into different committees/ samities to look after various conservation works. The kind of goods and services to be created should be in tandem with the needs and aspirations of local inhabitants. A proper coordination is to be ensured between the different departments of agriculture, horticulture, soil conservation, forests, animal husbandry and rural development, NGOs and self help groups. The watershed associations after getting registered under the Societies Act should open joint accounts to have complete transparency. A corpus fund could be created by the watershed societies for upkeep of watershed after the expiry of project period.

A meta analysis of 311 case studies on watershed management programs in India brought out the benefits of watershed management in terms of efficiency, equity and sustainability (Table 4). The mean benefit-cost ratio of programs was quite modest at 2.14. The internal rate of return of 22 percent was comparable with many rural development programs. The programs generated enormous employment opportunities, augmented irrigated area and cropping intensity and conserved soil and water resources. The performance of watersheds was at its best with rainfall ranging between 700-1000 mm. The technologies need to be scaled up for watersheds falling beyond this range for tapping the potential benefits of watershed management.

Table 4: Summary of benefits from the sample watershed studies

Indicator	*Particulars*	*Unit*	*No. of studies*	*Mean*	*t-Value*
Efficiency	B:C ratio	Ratio	128	2.14	21.25
	IRR	Percent	40	22.04	6.54
Equity	Employment	Person Days/ha/yr	39	181.50	6.74
Sustainability	Irrigated area	Percent	97	33.56	11.77
	Cropping intensity	Percent	115	63.51	12.65
	Rate of runoff	Percent	36	-13.00	6.78
	Soil loss	Tons/ha/yr	51	-0.82	39.29

Source: Joshi *et al.*, (2005)

The watershed management merits its adoption on a large scale in rainfed areas supporting 40 % of human and 60 % of livestock population. These areas bypassed by the green revolution in the country still have low productivity and marketable surpluses. The Government of India has established National Rainfed Area Authority to herald agricultural and economic prosperity in these regions by bringing in much needed convergence of resources with different Ministries and Departments and adoption of improved farm technologies. The technological interventions required are water harvesting and ground water recharging for supplemental irrigations, micro-irrigation, adequate and integrated fertilizer use (including secondary and micro-nutrients), introduction of suitable crops of maize, pulses and oilseeds, integrated pest management, organic farming, increased credits, low premium crop insurance and regular trainings to upscale skills and knowledge of farmers.

Salt affected soils: The saline and alkaline soils occupying 8.5 million ha occur extensively in arid, semi-arid and the sub-humid regions of the country. The most affected states are Gujarat, Uttar Pradesh, Rajasthan, West Bengal and Andhra Pradesh. These soils containing excessive amounts of soluble salts affect adversely the growth and yields of many crops. The area under salinity has been increasing at the rate of 3,000 to 4,000 ha per annum. About 5.6 million ha of salt affected soils out of the total of 8.5 million ha, were in the irrigation commands of the country (Singh 1998).

Application of amendments like gypsum and pyrites is essential to reclaim alkali soils. As amount of gypsum would govern the cost of reclamation, it may be applied at the most economic rate. It required to be added @ 25 % of gypsum requirement (GR) for rice and @ 50 % of GR for wheat (Table 5). About 1 million ha of alkali lands have been reclaimed in three states of Punjab, Haryana and Uttar Pradesh. The reclaimed area is contributing nearly 6 million tons of paddy and wheat annually. The leaching of salts with good quality water and disposal of drainage effluent through well laid out horizontal sub-surface drainage system is an important intervention for amelioration of these soils. Although initial cost of laying the drainage system is high (~Rs.30,000- 50,000/ha), the long term benefits would overweigh the initial investments. The sub-surface drainage also increased the yields of sugarcane by 36 % in Godavari delta of Andhra Pradesh (Subba Rao 1999). Nearly 20-25 thousand ha of barren waterlogged saline lands have been reclaimed by this technology. The technology needs to be promoted by central and state governments and international donor agencies. The reclamation of 8.5 million ha of salt affected soils can, therefore, give additional 50-55 million tons of food grains. Some other measures for checking the rise of water table and development of salinity are lining of canal irrigation network, bio-drainage and proper on-farm water management.

Table 5: Crop yields as affected by amount of gypsum applied (t ha^{-1})

Amount of gypsum (t ha^{-1})	*Dhaincha (green manure) (1970)*	*Wheat (1970-71)*	*Rice (1971)*	*Wheat (1971-72)*	*Rice (1972)*	*Pearl millet (1974)*	*Gram (1974-75)*
0.0	0.44	0.00	4.39	1.52	7.18	1.06	0.12
7.5	3.99	1.89	6.21	2.79	7.23	1.33	0.47
15.0	4.35	3.49	6.39	3.45	7.13	1.96	0.69
22.5	4.70	4.16	7.08	3.72	7.17	1.81	0.90
30.0	4.58	3.79	6.66	3.98	7.03	1.91	0.93
CD (5%)	0.51	0.64	0.81	0.70	NS	0.52	0.44

Source: Anonymous (2004b)

Acid soils: About 25 million ha of acid soils in the country have very low productivity of less than 1 t/ha due to deficiencies as well as toxicities of certain nutrients. There is ample scope to raise the productivity of these soils by following liming and balanced fertilizer use. A large number of field experiments in different acid soil regions of the country have proved the usefulness of liming and adequate fertilizer use in increasing yields of a variety of crops (Table 6). The liming at 2-4 q/ha (1/10th of lime requirement) in furrows along with recommended fertilizers was quite effective in realizing higher and economic yields. Liming helped adapt better many acid sensitive crops like cotton, soybean, groundnut, french bean and pigeonpea etc. by lowering exchange acidity and improving quality of soils. Anticipating yield increase of 1 t/ha, liming on 25 million ha could increase foodgrain production by 25 million tonnes/annum. This will also reduce toxicities of iron and aluminium.

Table 6: Crop response to fertilizer and lime in acid soils (Relative yield)

Crop	*Centre*	*Farmers' Practice*	*Recommended NPK*	*NPK+Lime*
Groundnut	Bhubaneswar	100	177	221
	Dapoli	100	139	174
	Ranchi	100	162	179
Pigeonpea	Bhubaneswar	100	153	200
	Ranchi	100	215	253
Cowpea	Dapoli	100	149	185
Greengram	Jorhat	100	128	171
Rapeseed	Jorhat	100	137	158
Pea	Ranchi	100	149	183
Mustard	Umiam (Meghalaya)	100	286	1057
Wheat	Palampur	100	178	200
Maize	Ranchi	100	149	180
	Palampur	100	138	154
	Umiam (Meghalaya)	100	239	314
Average		100	171	259

Source: Sharma & Sarkar (2005)

The cheap liming materials like basic slag and lime sludges are available with Tata Steel Industries and paper mills, respectively besides low grade limestones. The required tie ups should be effected with these companies to have supply of the amendments of desired specifications through fertilizer cooperatives/ companies. The government may consider grant of subsidy on transportation of the materials.

Open degraded forest lands: The physically deteriorated open degraded forest lands are having very low productivity in terms of food, fuelwood, fodder, fiber and energy supplies. These lands need to be managed through alternative institutions, leasing, contracting and social capital investments. There is large scope for bringing large chunks of these wastelands under energy plantations of Jatropha (Bio-diesel) Pongamia, fuel wood and fodder.

Managing soil fertility

The impaired soil health is often cited as one of the reasons for stagnating crop productivity in the country. The inadequate and imbalanced nutrient use coupled with neglect of organic manures has caused deficiencies of secondary and micronutrients in many parts of the country. Our soils are, today, showing falling organic carbon levels and deficiencies of macro, secondary and micronutrients under intensive agriculture. The deficiencies are to the tune of 89, 80, 50, 41, 49, 33, 13, 12, 5 and 3 % of nitrogen, phosphorus, potassium, sulphur, zinc, boron, molybdenum, iron, manganese and copper, respectively. The soils are, generally, not replenished adequately even with the macro nutrients (nitrogen, phosphorus, potassium), let alone secondary (sulphur) and micronutrients, removed by the crops. The imbalanced fertilizer use in terms of NPK is evidenced by their wider consumption ratios of 19.9:5.9:1 and 29.6:8.8:1 against desirable one of 4:2:1 in agriculturally important states of Panjab and Haryana, respectively (Fertilizer Statistics, 2005-06). It has been estimated that our soils are operating on a negative nutrient balance of about 6 MT/annum. The crops remove about 28 MT of NPK per annum. The addition through chemical fertilizers and organic manures is only to the tune of 18 and 4 MT, respectively.

The limiting nutrients, not allowing full expression of other nutrients, lower the overall fertilizer use efficiency and crop productivity. A simple relationship between food grain production and fertilizer consumption at country level for the last four decades has revealed a decline in partial factor productivity of fertilizer (NAAS 2006). The same trend was also evident from the field trials conducted under All India Coordinated Research Project of the Project Directorate of Cropping System Research, Modipuram and All India Coordinated Project on Long Term Fertilizer Use of ICAR. The declining fertilizer use efficiency in food grain production is, however, a matter of great concern. The fertilizers have been the mainstay of food production in India, as about 50 per cent improvement in crop productivity over the last 35 years could be attributed to fertilizer use.

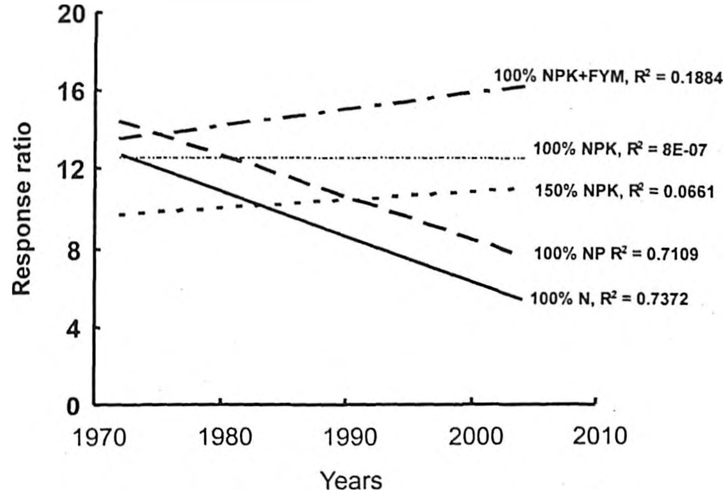

Figure 1: Nutrient response ratios (kg grain/kg nutrient) in cereals (Source : LTFE data, 1972-2003)

The long term studies on fertilizers by ICAR since 1970 further revealed that the application of nitrogen alone caused reduction in response ratio from initial 12.5 to 5 over 30 years period (Figure 1) primarily due to deficiencies of phosphorus and potassium. The response ratio increased with the application of phosphorus along with nitrogen, but its reduction with time was again conspicuous in the absence of potassium application. The ratio got stabilized at a higher level only with the balanced application of NPK. Any further improvement in the response ratio beyond this level could not be effected merely with the addition of higher amounts of chemical fertilizers. The response ratios appreciated with a rising trend only when chemical fertilizers were supplemented with organic manure. The average response ratios of N, NP, NPK and NPK+FYM were 8.1, 10.1, 12.8 and 15.2, respectively (Figure 2). The continued additions of NPK at higher rate without organic manures would induce deficiencies of secondary and micro nutrients, thereby, lowering the response ratios. The deficiencies of sulphur and zinc and drop in the response ratios became evident in crops at some locations when sulphur and zinc were omitted from the fertilization schedule. Likewise, increased mining of soil potassium seems to be a cause of more rampant decline in rice yields compared to wheat in Indo-Gangetic Plain, as revealed by the analysis of data pertaining to rice-wheat cropping system from 24 research stations in IGP (NAAS, 2006).

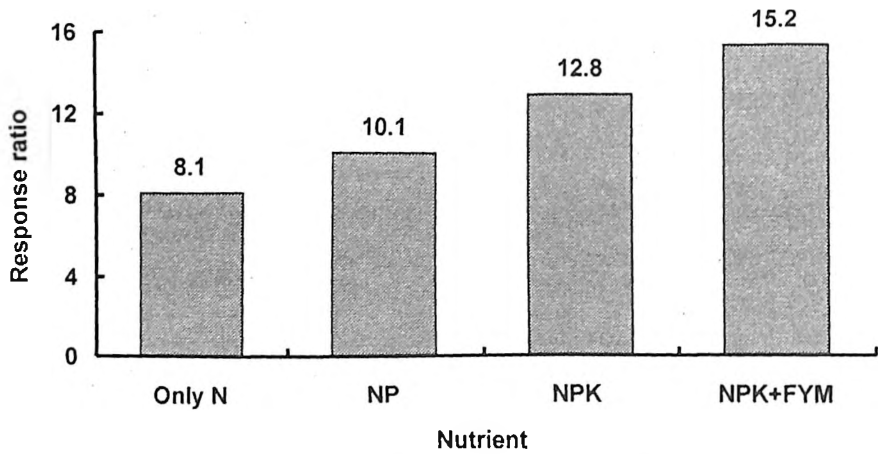

Figure 2: Response ratios (kg grain/kg nutrient) of nutrients (Source: LTFE data, 1972-2003)

Site specific nutrient management: The site specific nutrient management (SSNM) correcting deficiencies of all primary, secondary, micronutrients and imbalances promises higher productivity and profitability. The improved management, on an average, gave annual grain productivity of 13.3 tha^{-1}, of rice-wheat system at 10 locations representing northern states of the country (Table-7). The extra income over the farmers' practice was Rs 20,530 with a benefit: cost ratio of 4.9. The Integrated nutrient management encompassing conjunctive use of chemical fertilizers including secondary and micronutrients, organic manures, composts/vermicomposts, bio fertilizers and green manures should be the most ideal system of nutrient management. The system enhances nutrient-use efficiency, maintains soil health, enhances yields and reduces cost of cultivation.

Table 7: Benefits of Site Specific Nutrient Management in Northern States of India

Location, State	*Grain yield* SSNM plot, Kg/ ha/yr*	*Grain yield FP plot, Kg/ ha/yr*	*Change in yield (SSNM-FP), kg/ ha/yr*	*Nutrients applied under SSNM***	*Nutrients giving profit (BCR>2)*	*Extra investment (SSNM-FP), Rs./ha*	*Extra net returns (SSNM-FP), Rs./ha*	*BCR of improvement (SSNM-FP) system basis*
Sabour Bihar	13,849	8,658	+ 5,191 (60%)	N P K S (4)	N P K S	4,980	33,621	6.8
Palampur Himachal Pradesh	9,896	6,955	+ 2,941 (42%)	N P K S B Zn (6)	N P K S B Zn	3,416	18,576	5.4
R.S.Pura Jammu & Kashmir	13,182	9,718	+ 3,464 (36%)	N P K S Cu Mn Zn (7)	N P K S Cu Mn Zn	7,254	19,771	2.7
Ranchi Jharkhand	10,957	6,202	+ 4,755 (77%)	N P K S B Cu Mn Zn (8)	N P K S B Cu Mn Zn	4,163	30,195	7.3
Ludhiana Punjab	16,828	16,414	+ 414 (3%)	N P K S B Mn Zn (7)	N P K S B Mn Zn	3,130	(-) 4,372	-1.4 (no improvement)
Faizabad Uttar Pradesh	12,385	7,481	+ 4,904 (66%)	N P K S B Mn Zn (7)	N P K S B Mn Zn	6,455	31,414	4.9
Kanpur Uttar Pradesh	14,555	11,605	+ 2,950 (25%)	N P K S (4)	N P K S (K higher rate only)	4,483	17,612	3.6
Modi puram Uttar Pradesh	16,679	11,334	+ 5,345 (47%)	N P K S Cu Mn Zn (7)	N P K S Cu Mn Zn	1,380	36,917	26.8
Varanasi Uttar Pradesh	12,116	10,996	+ 1,120 (10%)	N P K S B Cu Mn Zn (8)	N P K S B Cu Mn Zn	2,890	7,384	2.6
Pantnagar Uttaran chal	12,447	9,974	+ 2,473 (25%)	N P K S B (5)	N P K B	3,115	14,185	4.6
Average	13,289.4	9,933.7	3,355.7 (39%)			4,126.6	20,530.3	6.33

Source: Tiwari *et al.*, (2006) ;

* Rice yield is as rough rice (paddy) + wheat grain yield , BCR = benefit cost ratio (net returns/unit investment in fertilizer).

The response to uniformly applied N was assumed to be positive.

**NPK applied to each crop. Sulphur and micronutrients applied only to rice in the system.

Strengthening soil testing service: For site specific nutrient management, the soil testing service needs to be strengthened in the country. The service, presently, is inadequate in having the capacity to analyze only 7 million soil samples/annum against 115 million farm holdings in the country. A farm holding, therefore, has a fare chance of its testing only after 15 years or so. Obviously, there is an urgent need to open up more soil testing laboratories, at least one each in different districts/blocks of the country for more coverage and enhanced capacity. The National Commission on Farmers has already recommended a countrywide network of 1000 advanced soil testing laboratories, 500 of them to be located in dry farming areas. The laboratories need to be computerized and equipped with the facility for analyses of all nutrients including secondary and micro nutrients. These laboratories should also participate in the preparation of geo-referenced soil fertility maps at district and block levels in partnership with State Agricultural Universities for serving as a guide for better management of soil fertility problems in the country. Some of them should have capabilities of monitoring heavy and toxic metals and other contaminants.

Extending subsidy on P, K S and micronutrients: The withdrawal of subsidy on phosphatic and potassic fertilizers during 1992-93 led to their less consumption and imbalanced fertilizer use in the recent past. The introduction of Concession Scheme subsequently to restore their consumption has, in fact, not met with the desired results. The concessions made by the states under the scheme are quite uncertain unlike the central subsidy on fertilizer urea. The urea still remains the most preferred fertilizer. The subsidy, therefore, has to be extended to phosphate and potassium fertilizers to increase their use. The continuous use of high analysis chemical fertilizers (devoid of sulphur impurities) has made sulphur a limiting nutrient in many soils of the country. Its requirement in the country is about I MT now. For correcting disorder, the super phosphate being manufactured by small scale industry in the country (66 units) and also supplying 11 percent sulphur needs to be brought under subsidy regime for its greater use. The availability of micronutrient fertilizers is still not assured in many areas. There is need to bring them also under subsidy regime to promote their use.

Providing nutrient based fertilizer subsidy: The product based fertilizer subsidy requires to be replaced with nutrient based to have wider basket of fertilizers and balanced fertilization.

Production of fortified and customized fertilizers: The fortification of fertilizers with micronutrients holds great promise and requires to be taken up speedily. A host of customized fertilizers suiting to different soil-crop situations also need to be promoted for precise nutrient applications.

Managing water resources

We have only 4.2 percent of world's fresh water resource to sustain 16 and 17 percent of world's human and animal populations, respectively. The per capita availability of utilizable water in the country has gone below 1000m^3 as compared to international norms of 1700 m^3. The irrigation sector is the largest consumer of fresh water (about 83 %). Its share, however, is going to decline to 75 % in the near future in the wake of growing competition from the industrial and domestic sectors. The future gains in agricultural productivity of the country are, therefore, going to be determined by proper development and utilization of surface and ground water resources. The excess use of canal water has, however, led to occurrence of water logging (Table 8) and secondary salinization in major irrigation commands of the country. The overdraw of ground water, on the other hand, has forced sharp fall in the ground water levels in Central Panjab, Haryana, Western Uttar Pradesh, Rajasthan, Tamilnadu, and West Bengal. The declining ground waters entail mounting over head costs to the farmers in deepening their wells, installing submersible pumps and incurring more power to lift water from increasing depths. The hard hit are the marginal and small farmers whose shallow/dug wells would grow dry as the water table goes deeper with overdraw. For equitable resource use, we should have clearly defined property rights to surface and ground waters. Presently, a land owner is entitled to draw any amount of ground water even if no water is left for others in the area. The overdraw becomes rampant with

Table 8: Trends of water table rise in selected irrigation commands

Irrigation Command	*Rise of water table (m/annum)*
Mahi Right Bank Canal Command (MRBC), Gujarat	0.28
Rajasthan Canal Command (IGNP), Rajasthan	0.29 - 0.88
Western Yamuna & Bhakra Canal Command, Haryana	0.30 - 1.00
Sirhind Canal Command, Punjab	0.10 - 1.00
Sharda Sahayak Canal Command, Uttar Pradesh	0.68
Malprabha Canal Command, Karnataka	0.60 - 1.20
Nagarjuna Sagar Irrigation Project, Andhra Pradesh	0.32
Sriram Sagar Irrigation Project, Andhra Pradesh	0.26

Source: Singh (1998)

access to free or subsidized power to run the tube wells. The inequitable system of sharing water, however, draws very less motivation from rural communities for execution of water storage and ground water recharge measures.

The water use efficiency of canal irrigation is hardly 40 percent and requires to be enhanced to 60-70 %. Hence, we should have de novo examination of the existing water management practices on the touchstone of sustainable and efficient water management. While we should have adequate policy directives to regulate the use of canal and ground waters, emphasis requires to be laid on proper technology development for rainwater harvesting and its recharge, increased use of poor and waste waters, multiple use of water, participatory irrigation management, improved on-farm management and cost–effective micro-irrigation/fertigation systems.

Adopting Resource Conserving Technologies (RCTs)

The conservation of water, nutrients, energy and time is becoming critical to enhance productivity and profitability and conserve environment (Abrol and Sunita Sangar 2006). Accordingly, the RCTs like Zero tillage, bed planting, ridge and furrow system and laser land leveling offering savings in water (15-20%), nutrients (20-30%), energy (30-60%) planting time (50-65%) and increases in yields (5%) are becoming popular in Indo-Gangetic plain (RWC-CIMMYT 2003). The zero tillage and bed planting already spread to about 2.5 million ha in IGP, are targeted to cover 5 and 3 million ha, respectively in the next five years. The newly developed machines like Happy and Turbo seeders are able to pick up rice residues (which are being burnt presently), shred them and lay as mulch over soil surface. The mulch moderates soil hydro-thermal regime, conserves organic carbon and nutrients and inhibits weed growth. These need to be promoted to cover 11million ha area under wheat in IGP. The intervention would have wheat production increased by 2 million tonnes with an overall saving of Rs 2200-3300 crores. The custom hiring of laser levelers and ridge makers needs to be promoted especially in black soils for soybean, cotton and sorghum production.

Adopting integrated farming systems

The vast synergies available with different farm enterprises have remained largely under-exploited due to crop or commodity driven policies. The farming system approach integrating different components of farming, viz crops, horticulture, livestock and fisheries offers greater opportunities of productivity enhancement, employment, income generation, nutritional security and risk bearing abilities for small land holders. It allows the utilisation of primary and secondary products of one component as basic input for another component. Multiple deployment of inputs based on the principles of recycling also minimises loading of environment with pollutants. A number of farming systems suiting to varied socio-economic-environmental conditions of India could be employed with productivity gains of 3-5 times compared to monocultures.

There are over 12 million ha of waterlogged lands with very low productivity in Orissa, Bihar, Assam, West Bengal and eastern Uttar Pradesh. The adverse soil conditions allow only one anaerobic paddy crop with a very low yield of less than 1 t/ha. Adoption of an integrated farming system involving fruits/ vegetables + fish/prawn - coconut - poultry gave a net return of Rs.70,000/ha/ annum which was much higher compared to monoculture rice (Samra *et al*.,, 2003).

The ICAR Research Complex for NEH Region, Barapani has developed a farming system model for hilly terrains by combining crops (cereals, pulses, oilseeds), horticulture (mango and pineapple), vegetables, livestock (piggery, duckery) and fisheries. The multienterpise system generated annual income of Rs 40,000 which was nearly 5 times more profitable than traditional mono crop of rainfed rice (Samra 2004). This system could be further improved for profitability by inclusion of export generating industrial crops.

Naturally occurring perennial ponds of size 0.1 to 0.5 ha are ideally suited for pig-cum-fish enterprises in eastern region. The ponds required cleaning of aquatic weeds and deepening to required depth. The pigs are raised on crop/ farm byproducts. The washings of the pig shed are recycled into the fish pond. The system yielded a net profit of about Rs.40,000 per annum with minimum environmental loading.

A very promising integrated farming system involving crops, fishery, poultry, piggery, dairy and agro-forestry has been developed for shallow water table lands in Ludhiana, Punjab by an innovative farmer (Gill *et al*.,, 2005). The model provided yield advantage of about 40 % and economic returns of

Rs.75,000 compared to rice-wheat alone. The system generated additional employment of 500 person days/ha/year and is environmentally benign.

Fish culture in paddy fields is carried out with promising results in West Bengal & Orissa. This system allows production of fish and prawns as well as rice from the same field without causing reductions in rice yields. This source of animal protein is important for household nutrition and farm income. The system is suitable for waterlogged areas of the canal commands in Bihar. Fish was grown in the rice fields with central pond type fish refuge covering 10% of the rice field area. The central refuge concept was to facilitate movement of machinery in the field after rice harvest when fish can be kept in the refuge. The keeping of fish in central refuge also stretched the duration of fish growth from 4 months to 6-7 months. Stocking of fish in the rice fields enhanced the overall income by 23-32% as compared to sole rice crop grown in the region.

While the existing knowledge merits its dissemination to the relevant areas, the research efforts need to be directed towards development of more location specific farming system models. The ICAR Institutes, State Agricultural Universities and some reputed NGOs should be called upon to develop such models. The awareness, technological backstopping and trainings should be entrusted with the local KVKs, Line Departments, and ATMAS. The finances could be made available by the Government agencies or by NABARD to meet the initial investment on such enterprises. The ventures have a pay back period of only 2-3 years.

Mitigating contaminations of Soil-Water-Air-Foods

The soil and water in certain areas are getting contaminated with toxic elements from geogenic sources or from sewage water, industrial effluents, urban solid wastes, pesticides and fertilizers etc. The toxic elements enter the food chain becoming a potential health hazard to humans and animals.

Arsenic contamination: Nearly 30 million people in a belt of 34,000 km^2 covering parts of Malda, Murshidabad, Nadia, North and South 24 Parganas and Bardman districts of West Bengal adjoining Bhagirathi river are exposed to chronic arsenic poisoning through intake of contaminated food and water. The people having increased arsenic uptake suffer from arsenical melanosis and hyperkeratosis, skin cancer, enlargement of liver, non-cirrhotic portal fibrosis, and respiratory disorders. In severe cases, gangrene in the limbs and malignant neoplasm are also observed. The arsenic poisoning also causes many abnormalities in animals.

Table 9: Arsenic (mg kg^{-1}) in edible parts of crops grown on arsenic contaminated soils

Crop	*Level of contamination of soil*		
	Low (<0.4 mg kg⁻¹ As)	*Medium (0.4-0.8 mg kg⁻¹ As)*	*High (>0.8 mg kg⁻¹ As)*
Rice (*Kharif*)	0.4-0.5	0.5-1.2	1.6-2.8
Rice *(Boro)*	1.2-1.6	1.9-3.3	4.9
Spinach	3.3	3.0-4.6	4.5-6.2
Fenugreek	-	4.4	4.7
Beet	-	4.3	4.5-5.1
Radish	3.6	4.5-5.1	4.9-6.0
Brinjal	-	-	2.5
Dolichos Bean	-	2.5-3.1	3.4-3.9
Ladies Finger	2.1	2.7	3.8
Tomato	-	2.3-3.3	-
Garden Pea	-	2.4-3.5	3.5
Cauliflower	-	-	5.6
Knolkhol	-	2.5	2.5-3.2
Chilli	-	-	3.0-3.1

Source: Sanyal (2001)

The root cause of the problem is more withdrawal of groundwater for summer paddy, when the groundwater availability in the reservoir is at its minimum, causing oxygenated decomposition of pyritic sediments containing high amounts of arsenic. These sediments upon oxidation release sulphuric acid that solubilizes arsenic. The solution moves down to aquifers polluting the groundwater. As per WHO standards, the arsenic concentrations in ground waters above 0.01 mg L^{-1} are considered to be unsafe. But, the levels are, generally prohibitive in ground waters at shallow depths of < 37.5 m (Sanyal 2001). The surface water (ponds, shallow wells) and groundwater at greater depths (>75 m) generally did not have arsenic at toxic levels. The soils as well as crops of the affected areas have shown build up of arsenic after irrigation with arsenic rich water. The accumulation in crops was more in soils with high contamination (Table 9). The *boro* or summer rice irrigated primarily with underground water contained more arsenic than *kharif* rice. The edible parts of leafy and underground vegetables (spinach, fenugreek, beet and radish etc) contained much higher arsenic as compared to vegetables with fruit as edible part (brinjal, beans, ladies finger, tomato etc). In general, fruit/grain of plants showed less accumulation of arsenic compared to root, stem and leaf. Over 40 % of animals like cattle and goats showed arsenic poisoning symptoms in the areas. Arsenic intake by animals was low through drinking water and more through feed sources.

The problem could be mitigated through substitution of boro rice requiring more groundwater with summer legumes and pulses, reduced irrigation coupled with addition of zinc sulphate, more use of organic and green manures moderating arsenic toxicity in soils and plants (Mukhopadhyay *et al.*, 2002; Ghosh *et al.*, 2004) and phytoremediation employing hyper accumulating plants (brake fern, water hyacinth) and microbial spp (blue green algae) etc.

Selenium toxicity: The selenium toxicity is found in the seleniferous region of Punjab (Hoshiarpur, Jallandhar and Nawanshahar districts). The affected areas have prohibitive levels of selenium in soils and ground waters (Tables 10 & 11). The fodder, cereal and vegetable crops grown on these soils are having selenium contents more than the permissible levels and their consumption is causing chronic selenosis (selenium poisoning) in animals and human beings.

Table 10: Selenium content of soils from toxic (seleniferous) and non-toxic (non-seleniferous) areas

Location	*Content (mg kg^{-1})*	
	Range	*Mean ± SD*
	Surface (0-15 cm)	
Seleniferous areas (24)	0.85-4.52	2.12±1.13
Nonseleniferous areas (10)	0.23-1.08	0.42±0.24
	Sub-surface (15-45 cm)	
Seleniferous areas (24)	0.40-2.19	1.16±0.51
Nonseleniferous areas (10)	0.08-1.15	0.32±0.27

Source: Dhillon and Dhillon (1991)
Figures in parentheses refer to the number of soil samples

Table 11: Selenium content of underground water used for irrigation of crops in the toxic (seleniferous) and non-toxic (non-seleniferous) areas

Location	*Content (µg L^{-1})*	
	Range	*Mean ± SD*
Toxic areas (16)	2.54-69.53	17.43±19.75
Non-toxic areas (51)	0.25-8.63	1.91±1.73

Source: Dhillon and Dhillon (1991)
Figures in parentheses refer to the number of water samples

The animals suffering from selenosis are seen with cracks in the hoofs followed by their gradual detachment, peeling off of horns and loss of hair from the body. The presence of very large amounts of selenium in blood, hair and hoofs confirms selenium poisoning in animals (Table 12). The mortality of animals is high besides occurrence of disorders in their reproductive system in severely affected areas. About 55% humans in the affected areas revealed loss of hair from their body particularly head, malformation of finger as well as toe nails and progressive deterioration in general health. In some of the affected humans, fingernails were totally damaged and blood oozed from the fingertips. The problem of selenium toxicity could be tackled to a large extent with the application of gypsum to the soils. One time application of gypsum @ 0.8 t ha^{-1} to wheat in a wheat-rice sequence significantly reduced accumulation of selenium in grain and straw of wheat and rice for 2 years (Table 13). The other options could be growing of selenium resistant crops

Table 12: Selenium content in blood, hair and hoof of affected and normal animals

Animal body part		*Content (mg g^{-1})*	
		Range	*Mean ± SD*
Blood	Toxic (8)	2.15-5.34	3.83±0.45
	Non-toxic (5)	0.037-0.150	0.060±0.045
Hair	Toxic (15)	12.58-55.17	28.21±14.99
	Non-toxic (5)	0.027-0.110	0.057±0.031
Hoof	Toxic (8)	21.15-39.85	30.38±7.36
	Non-toxic (2)	0.534-0.927	0.731±0.197

Source: Dhillon and Dhillon (1991)
Figures in parentheses refer to the number of soil samples

Table 13: Selenium concentration (mg kg-1) of wheat and rice crops as influenced by gypsum application in a seleniferous (toxic) soil

Gypsum applied (t ha^{-1})	*First Year*				*Second Year*			
	Wheat		*Rice*		*Wheat*		*Rice*	
	Grain	*Straw*	*Grain*	*Straw*	*Grain*	*Straw*	*Grain*	*Straw*
0.0	19.6	16.6	9.9	18.0	12.4	11.1	8.9	16.6
0.2	14.4	15.5	8.5	16.2	11.1	9.9	7.2	15.8
0.4	13.4	12.4	5.9	13.8	7.2	7.7	5.7	12.2
0.8	9.2	8.5	3.7	7.5	5.2	6.0	5.8	10.6
1.6	9.7	9.8	3.7	6.5	5.2	4.9	4.0	7.3
3.2	8.8	9.1	3.8	7.2	4.5	4.8	4.2	6.2
LSD (P=0.05)	1.3	1.5	1.7	2.4	1.6	1.4	1.3	2.8

Source: Dhillon and Dhillon (2000)

and adoption of the less irrigation demanding maize -wheat instead of rice-wheat sequence.

Sewage water/Industrial effluents toxicities: India generates about 18.4 million M^3 of wastewater per day as sewerage and industrial effluents from sugar, paper, pulp, fertilizer, thermal power, drugs, paints, electronic goods and dying industries. About 63 % the waste water gets generated from 299 class I and 345 class II cities of the country. Agro-based and food processing industries such as paper, tannery, fruits pulp, and sugar industries etc. consume large amounts of fresh water and discharge large volumes of effluents. Tannery industry generates about 30 to 40 litres effluents per Kg of skin/hide processed. There are 3000 tanneries in India producing about 80 million pieces of hides and 133 million pieces of skin per annum. There are 295 distillery units with production capacity of 2.7 million m^3 of alcohol per annum. About 8.0 million tones of molasses from sugar mills are utilized to produce about 1.5 million m^3 of alcohol per annum. The production of alcohol results into generation of distillery effluent 15-16 times its volume.

Table 14: Nutrient status (mg kg^{-1}) of the soils from sewage and non-sewage irrigated areas around Kolkata

Seasons	*Depth (cm)*	*Org. matter (g kg^{-1})*	*Available*			*DTPA - extractable*			
			N	*P*	*K*	*Fe*	*Cu*	*Mn*	*Zn*
Monsoon	0 - 15SI	20.3	310.0	85.4	269	86.4	37.1	20.2	254.0
	NS	15.5	94.0	18.2	360	50.4	2.1	20.8	3.4
	15 - 30SI	19.8	326.0	121.0	267	103.0	38.3	10.9	164.0
	NS	14.5	90.0	17.6	340	52.5	2.3	22.8	3.7
Winter	0 - 15SI	37.0	254.0	74.8	182	143.0	34.9	27.9	308.0
	NS	19.1	98.6	19.4	370	56.6	2.4	22.4	3.6
	15 - 30SI	32.0	217.0	74.2	181	104.0	35.9	26.1	322.0
	NS	18.4	100.2	19.2	360	60.4	2.5	23.6	3.8

Source: Mitra, A. and Gupta (1999)
SI=Sewage irrigated; NS=Non sewage irrigated

The waste waters are, generally, used for irrigation on agricultural lands for the cultivation of vegetables, fruits and other food crops. As hardly 20% of waste water is treated in the country (Patnakar 2001), the effluents are, generally, loaded with prohibitive levels of heavy metals and toxic compounds and have higher values of BOD (biological oxygen demand) and COD (chemical oxygen demand) (Khurana *et al.*, 2003). The higher concentrations of chromium, nickel and cyanide in effluents from electroplating area compared to domestic area have been reported in Ludhiana, Punjab (Tiwana *et al.*, 1987). The effluents of a leather industry complex in Jallandhar, Punjab increased markedly the concentrations of Cu, Fe, Mn, Zn, Al, Cr and Ni in sewage water (Brar *et al.*, 2000). The higher contents of lead were found in berseem and maize fodders grown on soils irrigated with sewage water than with normal irrigation water in Panjab (Kansal and Singh, 1983). The lead toxicosis has been reported in buffaloes and cattle fed on green fodder grown on soil contaminated with lead discharged from a factory (Kwat a *et al.*, 1986). Likewise, the carpet industry in Bhadoi, U.P. is also reported to have increased concentrations of chromium in open drains by discharging its effluents (Singh *et al.*, 2001).

The continued use of waste water on agricultural lands increases the contents of xenobiotic substances, heavy metals and pathogenic microbes in soils, waters and foods (Brar *et al.*, 2000). The irrigation with sewage for long led to the build up of heavy metals upto a depth of 0.3 m in soils of Calcutta vegetable belt (Table 14). The accumulations were also significant in soils around Ludhiana, Jallandhar, Amritsar, Sangrur (Table 15) and Hyderabad (Table 16).

The heavy metals contents in vegetables irrigated with sewage water in Calcutta vegetable belt were 2-40 times higher than with normal irrigation waters (Mitra and Gupta 1999). The higher concentrations of toxic elements were reported in cereal, oilseed, coarse grain and vegetable crops raised on soils irrigated

Table 15: Mean DTPA extractable heavy metals in soils (mg kg^{-1}) irrigated with sewage and ground water in cities of Punjab

	Ludhiana		*Jalandhar*		*Amritsar*		*Sangrur*	
	SW	*GW*	*SW*	*GW*	*SW*	*GW*	*SW*	*GW*
Pb	4.21	1.09	3.57	1.37	5.06	0.98	2.76	1.32
Ni	3.58	0.78	0.47	0.20	0.65	0.26	0.40	0.20
Zn	11.9	5.6	3.65	1.25	12.8	3.78	2.10	1.45
Mn	25.4	5.6	7.99	4.92	9.44	6.99	8.34	5.37
Fe	49.2	12.8	12.86	6.12	14.7	13.66	10.88	6.27
Cd	0.30	0.05	0.14	0.08	0.19	0.02	0.12	0.02
Cu	-	-	5.13	1.01	14.2	0.56	1.88	0.94

Source: Khurana *et al.*, (2003)
SW - Irrigation with sewage water GW - Irrigation with ground water

Table 16: DTPA extractable heavy metals (mg kg^{-1}) in sewage polluted soil (0 - 0.30 m) at Hyderabad

Element	*Mean*	*Per cent samples in each category*			
		Low	*Medium*	*High*	*Excessive*
Zinc	39.0	4	-	44	52
Copper	26.9	-	20	16	64
Iron	160.2	-	-	8	92
Manganese	24.5	-	4	80	16
Lead	24.0	-	4	16	80
Chromium	4.3	-	-	84	16
Nickel	2.8	4	16	76	4
Cadmium	0.1	44	48	8	-
Cobalt	6.2	-	-	20	80

Source: Anonymous(2004c) Final Report. ICAR Network Project on Heavy Metals Contamination in Peri-Urban Areas

with sewage water around cities in Punjab (Table 17) and Andhra Pradesh (Table 18). For safe use of waste waters, there should be strict enforcement of safeguards on their use as prescribed by the regulatory authorities. The effluents should be pre-treated to remove/reduce their toxic load. The effluent treatment plant of leather industries at Jallandhar, Punjab lowered significantly the

Table 17: Distribution of heavy metals in various plants in polluted soil and normal soils of Jalandhar

Crop	*Plant part*	*Element (µg g^{-1} dry matter)*					
		Cu	*Fe*	*Mn*	*Zn*	*Ni*	*Cd*
Maize	Root SI	15	392	27.9	68	1.97	0.60
	TWI	10.0	275	21.8	50	1.50	0.36
	Shoot SI	12.6	255	31.3	60	1.67	0.42
	TWI	8.0	216	19.8	46	1.20	0.28
Toria	Root SI	24.0	550	46.5	82	7.0	3.4
	TWI	14.0	340	26.4	54	6.0	1.62
	Shoot SI	15.4	596	40.6	74	6.4	4.0
	TWI	10.0	348	28.1	46	4.4	1.44
Bajra	Root SI	10.5	316	27.7	54	1.40	0.50
	TWI	6.0	128	23.0	42	1.0	0.2832
Shoot	SI 8.0	370	24.5	48	1.68	0.50	
	TWI 5.8	140	24.0	35	1.0	0.32	
Lady-finger	Root SI	14.0	440	38.3	70	2.48	1.0
	TWI	12.0	280	28.0	36	2.0	0.50
	Shoot SI	11.0	348	33.7	52	1.90	1.0
	TWI	8.0	216	26.0	44	1.7	0.50

Source: Khurana *et al.*, (2003)
SI=Sewage Irrigated; TWI=Tube-well Irrigated

Table 18: Heavy metal concentration (mg kg-1 dry matter) in paragrass treated with sewage at Hyderabad

Element	*Mean*	*Per cent samples in each category*		
		Moderate	*High*	*Excessive/ Toxic*
Zinc	71.9	0	39	61
Copper	9.1	8	61	31
Iron	214.6	13	62	18
Manganese	51.4	48	42	9
Lead	17.1	0	4	96
Chromium	4.8	0	65	35
Nickel	4.5	0	91	9
Cadmium	1.6	0	78	22
Cobalt	8.9	0	0	100

Source: Anonymous (2004c) ICAR Network Project on Heavy Metals Contamination in Peri-Urban Areas

concentration of chromium in the effluent from initial 21 ug mL^{-1} to 0.8 ug mL^{-1} (Brar *et al.*, 2002). A number of organizations in Tamilnadu are already using the treated effluents on agricultural lands. The M/s Sheshasayee Paper and Boards Ltd., at Pallipalayam in Tamilnadu has successfully used effluents (40 million litres per day) after pre-treatment for raising sugarcane on about 816 ha. The pre-treated effluent is being used continuously for more than two decades without any adverse effects on soils and crops (Pushpavalli *et al.*, 1999).

The high establishment and operational costs of waste water treatment plants are some of the constraints in their large scale use. Presently, two-third of the waste water generated world over receives no treatment (Marino and Boland, 1999). The cost-effective methods based on biological and soil-aquifer treatment approaches are, therefore, being advocated. The waste waters could also be used safely after their dilution with fresh water to contain the load of toxins within the permissible limits (Minhas and Samra 2004). The use of waste waters in raising non-food agro-forestry plantations (Chhabra 1995), green belts around cities, flowers and upkeep of parks etc could be viable option from ecological and environmental perspectives. Aquaculture based disposal of sewage, providing better livelihood opportunities, also seems to be an attractive proposition for high rainfall areas (Minhas and Samra 2004).

Sewage sludge: The sewage sludge is generated after treatment of effluents.

Although it is a rich source of organic matter and nutrients, it has toxic substances of waste water concentrated in the solid phase. Applying it as such to the agricultural lands is supposed to be risky. The contents of heavy metals in sludge are related to the industrialization profile of a city. The Coimbatore city in Tamilnadu known for large number of manufacturing and metal based industries, produced sludge with very high concentrations of heavy metals compared to sludge from Hyderabad in Andhra Pradesh (Table 19). The direct application of untreated sludge in fields results in the build up of heavy metals beyond permissible limits for its safe use in agriculture (Williams *et al.*, 1980).

Table 19: Heavy metal contents in sewage sludge

Metal	*Hyderabad*	*Coimbatore*
Zn	113.0	2630.0
Pb	256.5	5720.0
Cd	2.48	923.0
Cr	12.7	2740.0
Ni	22.5	3460.0

Source: Chitadeshwari *et al.*, (2002).

Urban solid waste (USW): The rapid urbanization and industrialization are accompanied with generation of large amounts of urban wastes. About 57 million tonnes of urban solid wastes are generated per annum from over 450 class I and class II cities in India. Big metropolitan cities like Delhi, Mumbai, and Kolkata with population size greater than 10 million are generating 4000 to 6000 tons of USW per day. Smaller urban areas like Chennai, Hyderabad and Bangalore are producing about 2000 to 3000 tons of USW per day. The situation is going to be quite alarming in the near future with no let up in urbanization and growing constraint of land availability for landfill sites. About 630 million people would be living in cities in India by 2025, constituting 45 percent of total population. Accordingly, the USW generation from urban areas in India would increase to 107 million tons per annum. In the absence of any proper management system, these wastes become a potential source of pollution of soil, water and air resources. The municipal solid wastes are still disposed of most unhygienically on open low lying areas or landfill sites around cities. These dumping sites are unsightly heaps of garbage that emit foul odours and turn out to be potential breeding grounds for insects, rodents and disease causing pathogens.

The biodegradable component of wastes is, generally, rich source of nutrients and organic carbon. Its conversion into compost is desired to serve the twin objectives of cleaning the environment and augmenting the supplies of organic manure. There should, therefore, be growing interest in development of cost effective and eco-friendly composting technologies both in public and private sectors. The wastes have a potential to provide 8 million tonnes of good quality compost containing 150 thousand tonnes of NPK.

Table 20: Heavy metal content (mg kg^{-1}) of red soils treated with urban solid wastes

Metals	*Normal Soil*	*Waste Treated Soil*
Lead	5.0	170.0
Nickel	2.0	10.0
Cobalt	5.0	7.0
Cadmium	0.4	0.9
Chromium	6.0	47.0

Source: Jeevan Rao and Shantaram (1999)

The value of composts is, however, questioned when these are loaded with toxic elements threatening soil quality and human health. For instance, there has been an appreciable build up of heavy metals in red soils treated with urban wastes for 10 years around Hyderabad (Table 20). Such contaminations could be avoided by segregating the industrial waste containing heavy metals and toxic chemicals from the biodegradable waste. For proper safeguards on use of composts, the regulatory authorities must ensure compliance of quality standards for organic fertilizer (compost) by the manufacturers (Table 21). Effective community participation is essential for handling and management of urban wastes.

Table 21: Proposed quality parameters of compost

Sr. No.	*Parameter*	*Range*
A. Physical Parameters		
1	Moisture content	15-25% w/w
2	Bulk density	0.7-0.9 g/cc
3	Inerts or sand contents	<10%
4	Particle size	>90% passes through 4.0 mm sieve
5	Odor	Absence of foul odor
6	Color	Dark brown to black

Sr. No.	*Parameter*	*Range*
B. Chemical Parameters		
1	Total organic carbon	Minimum 16-20%
2	Total Nitrogen	Minimum 0.8%
3	C:N ratio	<20:1
4	Phosphorus	0.5-0.8%
5	Potassium	1-2%
6	PH	6.5-7.5
7	Conductivity	< 4 dSm^{-1}
C. Biological Parameters		
1	Pathogen	Free from pathogens of plant & animal origin
2	Weeds	Free from weeds
3	CO_2 evolution (Basal respiration)	<15 mg CO_2 - C/100 g TOC/day
D. Heavy Metals		Maximum Permissible value (mg/kg)**
1	Cadmium	5.0
2	Chromium	50.0
3	Copper	150.0
4	Mercury	2.5
5	Nickel	50.0
6	Lead	300.0
7	Zinc	500.0

Source: : Manna *et al.*, (2004)
+All estimations are on dry weight basis.
** Values as notified by Min. of Environment and Forest, India, 2002

Pesticide residues and contaminations: India consumes large quantities of pesticides to protect crops against pests and diseases. About 85-90 percent of applied pesticides do not reach the targeted pests, but disperse through air, soil and water. A large number of these pesticides residues have high immobility in soils and build up to toxic levels with their repeated use. The indiscriminate pesticide use is, today, causing widespread contamination of foods and water (Table 22). The studies by the Indian Council of Medical research, New Delhi and All India Coordinated Research Project on Pesticides Residues of ICAR have revealed that 51 and 60 % of food items were contaminated with pesticides; 20 and 11 % had residues more than the maximum residue limit, respectively (Figure 3). The daily intake of even small quantities of these residues with food could be hazardous in the long run causing carcinogenecity, reduced life span and fertility, increased cholesterol, high infant mortality and many metabolic and genetic disorders.

Table 22: Pesticide residues in food commodities

Commodity	*Samples Analysed*	*Samples Contaminated*	*Samples> MRL**
Fruits	378	183	3
Vegetables	796	485	93
Milk	468	304	71
Spices	92	37	6
Total diet intake(Veg. & Non-veg.)	507	373	65
Water(Surface & Ground)	610	230	-
Feed & Fodder	98	51	4
Honey	8	51	Nil

Source: Agnihotri (1999), *MRL - Maximum Residue Limit

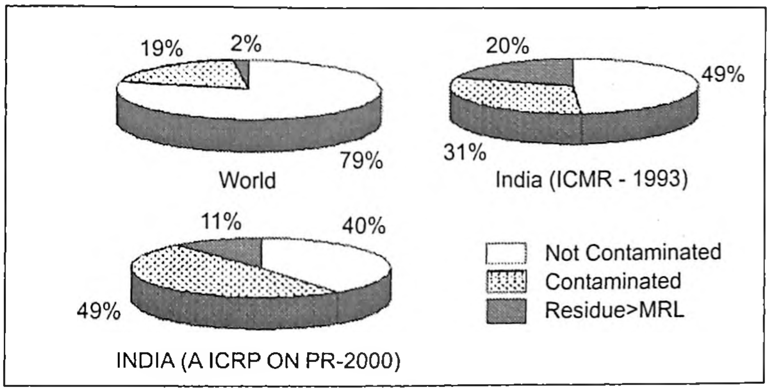

Figure 3: Pesticidal contamination of food commodities (Source: Agnihotri 1999)

The pesticide residues need to be kept within the prescribed limits for both domestic as well as export markets. India is an active World Trade Organization (WTO) member, and could look for large opportunities in export of agricultural commodities. But, the commodities having more residues may not gain entry into world markets by attracting non-tariff barriers.

The pesticides contaminations could be contained by adopting integrated pest management (IPM) approach based on the synergistic use of resistant varieties, appropriate cultural practices, application of bio-pesticides and use of bio-control agents. The IPM envisaging bare minimum use of synthetic pesticides has already been accepted as a National Policy. We need to develop and demonstrate IPM concepts and techniques vigorously with focus on major pesticides consuming crops like cotton, rice, sugarcane, vegetables and fruits.

Bio intensive IPM modules and protocols for mass multiplication and release of bio control agents such as *Trichoderma sp.* should be developed. The most commonly used bio-pesticides include *Bacillus thuringiensis* (Bt), Baculoviruses and Neem. Biocontrol agents, such as *Trichogramma*, are parasites and predators of pests and their eggs. The demonstrations by National Centre for IPM (NIPM) under ICAR have shown success in controlling pests of rice and cotton without the use of chemical pesticides. The adoption of IPM becomes all the more important in some areas where pests have become resistant to most pesticides. For instance, about 70% farmers of Bhiwani district in Haryana reported their inability to control pests of cotton (American, pink and spotted bollworm, white fly and jassid) with pesticides.

Burning of crop residues: Large quantities of combine harvested rice and wheat straw are being burnt in Punjab, Haryana and western Uttar Pradesh. About 12 and 9 million tonnes of rice and wheat straw constituting 81.4 and 48.2 % of the total straw production, respectively are being burnt in Punjab alone. The burning of straw causes air pollution with particulate matter and emissions of carbon dioxide. The emissions of CO_2, a green house gas having global implications, may be around 28.2 million tonnes annually on account of burning. There are also substantial losses of nutrients contained in the straw to the atmosphere. The loss is almost complete of N, 25 % of P, 20 % of K and 5-60% of S. In terms of money, the loss of N alone may run to about Rs. 618 million per annum. Besides financial loss, the burning of residues is a potential health and environmental hazard.

The crop residues being rich sources of organic matter and plant nutrients, should be returned to the soils after converting them to value added manures. The recycling of crop residues would help restore declining crop productivity in Indo-Gangetic plain linked largely with the build-up of organic matter reserves in the soils.

Fertilizer use and ground water pollution: The excessive use of fertilizers for crops like rice, wheat, maize, sugarcane, cotton, grapes and other commercial vegetables in certain areas may affect the quality of soil and water. A lot of concern is being voiced, of late, regarding pollution of ground waters with nitrates due to more use of nitrogenous fertilizers. The problem is thought to be more in areas having light textured soils consuming higher doses of N followed by heavy irrigations. The World Health Organization recommends 10 mg L^{-1} nitrate nitrogen as safe limit in drinking waters. The same limit is also accepted by Indian Council of Medical Research and Bureau of Indian Standards (IS 10050:1991). There are reports of nitrate pollution of ground waters in agriculturally intensive areas of Punjab, Haryana, Gujarat, Maharashtra, Andhra Pradesh and Orissa (Subba Rao 1989). There are 773 nitrate affected villages in Gujarat alone. About 68 % of water samples from 113 villages in Ludhiana district of Punjab were found to have nitrate levels above the permissible limit. The hazard was even greater (84 %) during post monsoon period.

The nitrate nitrogen in waters beyond the permissible levels causes methaemoglobinaemia in infants (Blue-baby syndrome) by affecting the oxygen carrying capacity of the red blood corpuscles. The other health disorders associated with nitrate toxicity include cancers of gastro-intestinal and oral tracts, Alzeimer's disease, hypertrophy of thyroid and many absorptive and secretive malfunctions.

As a safeguard against health related fertilizer use disorders, we should advocate integrated plant nutrient supply system (IPNS) envisaging use of organic manures in conjunction with chemical fertilizers. The system reduces dependence on chemical fertilizers by promoting farm yard manure, composts/ vermicomposts, bio-fertilizers and green manures to maintain soil fertility. The organic manures also enhance nitrogen use efficiency, minimizing chances of nitrate movement into ground waters.

Mitigating impacts of climate change

The spectre of impending climate change and associated ecosystem alterations is looming large on many parts of the world in the wake of increased green house gases (CO_2, CH_4, N_2O, O_3 and CFCs) emissions and global warming (IPCC, 2002). The carbon dioxide gas contributes largely to global warming (40-50 %) followed by methane (20-25%), Chloro-fluoro-carbons (15-20 %) and nitrous oxide (5-10 %). The emissions of CO_2 alone total around 27 billion tones today. The share of countries like United States, China, Russia, Japan and India is 5.9, 4.7, 1.7, 1.3 and 1.1 billion tones, respectively. Rest of the countries contributed less than 1 billion tonnes.

The levels of carbon dioxide, the most important green-house gas, are expected to increase by 30% in the next 50 years. The climatic change could have far reaching repercussions on the sustainability of agriculture and biosecurity by altering agro-meteorological parameters, overall crop-water balance, pest and disease incidence and land use etc. It has been estimated that an increase of 0.5°C in mean temperature in Punjab, Haryana and Uttar Pradesh would have reduced the productivity of wheat crop by 10%. As glaciers melt, sea levels would rise and inundate low-lying resource rich coastal regions and islands. The quick melting and vanishing of Himalayan glaciers, regulating water and hydro-power supplies to adjoining Indo-Gangetic plain, puts a big question mark on the sustainability of agriculture in the northern states of the country. The changed rainfall pattern will enforce change in land use and whole bio-diversity. Naturally, we can afford to release only a limited amount of carbon into the atmosphere to keep the greenhouse warming effect within safer limits. A temperature increase of 1°C is the maximum that could be allowed. This safe limit is bound to be reached in just 40 years if we continued with the present state of affairs.

Agriculture including livestock and other activities contributes 29 % of CO_2 equivalent GHGs (1415 Tg out of 4880 Tg) emissions in India (Garg and Shukla, 2002; Garg *et al.*,, 2003). However, a substantial portion of emitted carbon dioxide from the agricultural systems would be sequestered in agricultural biomass and soil. Accordingly, the net CO_2 emission from agriculturally impacted systems is only 2 % (19.8Tg) of national CO_2 emissions (928 Tg). Therefore, the actual GHGs load from agricultural systems (CO_2 19.8 Tg, CH_4 391 Tg, N_2O 96 Tg) may be only around 10 % of national load. The contribution of Indian agriculture towards GHGs emissions budget is, therefore, not as large as anticipated earlier on certain extrapolations of data generated in USA, Europe and Japan (Ahuja, 1990). As the emissions of CH_4 and N_2O from agricultural activities are over 65 and 90 %, respectively of Indian emissions, we need to adopt improved soil, water and fertilizer management practices that reduce GHGs emissions (Aulakh and Adhya, 2006).

Many countries, especially European Union Members and Japan are showing deep concern on emerging climatic changes and are keen on adoption of viable mitigation measures to reduce green house gas emissions. The Kyoto protocol stipulates that polluter bear the brunt of environmental change. Obviously, the countries like United States and China contributing largely to GHG emissions, should take conscious initiatives in reducing emissions. Although India's share in total emissions is relatively less, it should participate vigorously being a responsible member of international community in collective global efforts in reducing emissions.

The clean development mechanisms have provisions to pay through carbon trading. The companies and countries pumping out large amounts of carbon dioxide could invest in emission reduction schemes in developing countries and economies in transition. India should provide a strong back-up for such international protocols. The large area under waste lands in our country could be gainfully employed for sequestration of green house gases by taking up large scale plantations. The restoration of degraded and desertified soils in India is 10 -14Tg C yr^{-1} (Lal 2004). The plantation programmes could be linked to paper & pulp, plywood, medicines and bio-fuel-based industries. The Indian farmers, therefore, would be benefited greatly by carbon trading projects. It is heartening to note that World Bank Agency, BioCF (Bio Carbon Fund) has already signed carbon credits pact with two Indian firms based at Orissa (J K Paper Limitea, Rayagada) and Andhra Pradesh (Vanitha Empowerment, Development and Advancement Cooperative Society, Hyderabad) (Gargi Parsai 2007). The project in a contract farming mode has been developed jointly by the firms to cover 3500 ha of degraded lands owned by small and marginal farmers in six districts of Orissa and Andhra Pradesh. The J K Paper Ltd will provide farmers the required planting material and know how and enter into buy back contracts with them to purchase harvested timber. The farmers would be benefited both from sale of timber and carbon credits. The additional income from carbon credits is likely to encourage farmers to raise more agro-forestry plantations on degraded lands. There is growing interest in the country to bring about 2.5 million ha of wastelands under bio-fuel plantations of Jatropha (*Jatropha curcas*) and Karanja (*Pongamia pinnata*) to supply 2.6 million tonnes of biodiesel in order to blend 5% petrodiesel with biodiesel.

There is need for more research focus on modeling carbon sequestration potential of different land use /cropping/soil management systems and develop mechanisms and procedures for quantifying accruals of carbon stocks with different mitigation practices (Milne *et al.*, 2006). The added knowledge would facilitate carbon trade negotiations and development of protocols under clean development projects.

Besides carbon sequestration, we need to develop speedily non-carbon sources of energy like hydro-power, nuclear, solar and wind energies and enhance energy use efficiencies in industry, transport, domestic appliances and agriculture. Coal still accounts for nearly half of India's total energy use. A large part of it is used by thermal power plants. Most of the present day generators have thermal efficiency of 35 percent or less. The energy use efficiency could be increased greatly in agriculture by effecting better designs of machinery. To reduce vulnerability to climatic change, we should develop more adapted cultivars, livestock and fish to new agro-meteorological situations.

Mitigating trace element deficiencies and malnutrition

Over 2 billion people worldwide, one-half from south Asia alone, still suffer from protein-energy-trace elements-malnutrition syndrome (United Nations 1992). The dietary inadequacies of Zn, Fe, I, Al, Cu, Mn, Co etc affect both physical and mental health of people. The problem is more serious in young children, women of child bearing age and livestock. The trace element deficiencies could be geogenic in nature depending on mineral and soil composition or induced due to increased mining of nutrients under intensive agriculture. The Zn deficiency has assumed bigger dimension on world scale (Takkar *et al.*, 1989; Robson, 1993) and is second in importance to Fe in human health. A fairly large number of Indian soils have become deficient in micro and secondary nutrients during post green revolution period, affecting soil- plant- animal-human health.

The Zn content of crops grown on Zn deficient soils is generally low than the Zn sufficient soils. The dietary intake of 0.2- 0.3 mg Zn day^{-1} is regarded deficient. Its deficiency causes dwarfism, hypogonadism, anemia, geophagia, anorexia, skin lesions, rough and dry skin, immuno-suppression and loss of taste etc. (Prasad 1976; Hambridge *et al.*, 1987; Ringstad *et al.*, 1990). The Zn deficiency in cattle has been reported in many European countries (Blood and Radostitis 1989). The parakeratosis disease, associated with bone and joint disorders and thickening of skin, has been reported from Punjab and Haryana in animals feeding continuously on forages deficient in Zn (<20mg kg^{-1} dry matter) (Vasudevan 1987). Likewise, wool-shedding syndrome in Corriedale sheep was observed at the Central Sheep Breeding Farm, Hissar due to Zn deficiency (Mandokhot *et al.*, 1987). The Zn deficiency syndrome was also manifested in sheep fed on Zn-deficient rhodes grass and sorghum in Sudan (Mahmoud *et al.*, 1985).

Iron deficiencies are noticed in soils, cereals, forages and fruits despite its being one of the most abundant minerals on earth. The iron malnutrition is, therefore, a problem in many parts of the world (United Nation, 1992), especially in developing countries where poor people depend largely for their food on cereals containing low iron. The iron deficiencies are associated with anemia, fatigue, nervousness, reduced appetite, lower weight gain, sore tongue and memory loss etc. The iron deficiencies have been reported in livestock of north-western Rajasthan (Ghosal *et al.*,1976) and sheep and goats in West Bengal (Sarkar *et al.*., 1992a,b).

The deficiencies of Cu, generally, occur in sandy soils or soils having large content of organic matter (Baker and Senft, 1995). Its deficiency causes defective melanin synthesis leading to leucoderma (vitilogo), osteoporosis, arthritis, infertility and cardiovascular disorders etc. (Davis and Mertz, 1987). The deficiencies of Cu caused depigmentation of hair and skin in buffaloes in India, Pakistan and Indonesia (Randhawa, 1999; Sinha *et al.*, 1976). In South Australia and New zealand, the cows grazing on Cu deficient lands suffered from heart failure Falling Disease.

The cobalt deficiency is widespread in soil-plant-animal chain (Blood and Radostitis, 1989). The cobalt accumulated in plants is converted into B_{12} in ruminants. The low content of Co in soil was linked to its deficiency in the child (Shuttleworth *et al.*, 1961).The child was fed exclusively on milk from the cow who, in turn, grazed fodder grown on Co deficient soil.

The trace element–malnutrition could be mitigated through fortification of foods and medicines with the desired elements or correction of micronutrient deficiencies in soils through addition of fertilizers and manures. The latter approach is desirable as it would sustain crop productivity and food security besides overcoming malnutrition. The emerging micronutrient deficiencies and falling soil health are being ascribed as one of the reasons for the decline in productivity of major crops, especially in the indo-Gangetic plain (NAAS, 2006). We also need develop crop varieties that have higher contents of trace elements in their grains.

Epilogue

Proper management of natural resources is essential to ensure nutritional, food, environmental and bio-security. The indiscriminate use of resources under intensive agriculture is, however, causing widespread land degradation and contamination of soil, water, air and food resources. About 120 million ha are, today, degraded due to increased soil erosion, water logging, salinity/alkalinity, soil acidity and some other factors. The overdraw of ground water are forcing fall in ground water levels, ingress of saline sea water in coasts and higher arsenic concentration in irrigation water in many parts of the country. The inadequate and imbalanced fertilizer use is causing deficiencies of micro and secondary nutrients and impairing the chain of soil-plant-animal-human health. The deteriorating natural resource base is one of the reasons for stagnating crop productivity, especially in the Indo-Gangetic plain, and slowdown in agricultural growth. The persistent micro and secondary nutrient deficiencies in soils and produce are affecting human and animal health by influencing many enzymatic and metabolic functions. The problem of malnutrition may be more conspicuous in children, women and animals in such areas. The more extraction of ground water is aggravating the problems of geogenic arsenic and selenium toxicities in some parts of West Bengal and Punjab, respectively.

The degrading soil and water resources need to be rehabilitated for optimum productivity through appropriate technological interventions like participatory watershed management, site specific integrated nutrient management, integrated water management, participatory irrigation management, addition of amendments, integrated farming systems, resource conserving technologies, micro-irrigation/fertigation and diversification etc.

The unmindful discharge of industrial effluents, sewage waters and urban solid wastes on the agricultural lands is leading to contaminations of soils, vegetation, ground waters and agricultural produce. The foods contaminated with pathogens, heavy metals and other toxic elements are potential health hazards. For safe use of these wastes in agriculture, these need to be pre-treated/ composted and conforming to quality standards laid down by the regulatory authorities. Sanitary and phyto sanitary measures are important in the international food trade.

The impending climatic change due to global warming could have far reaching repercussions on the sustainability of agriculture and biosecurity by altering agro-meteorological parameters, overall crop-water balance, pest and disease incidence and land use etc. While we should take adequate measures to reduce the emissions of green house gases through better soil, water, fertilizer, energy management; the research efforts need to be guided towards having new adaptations of crops, livestock, fish and microbes to changing climatic situations.

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The Role of Biosecurity in Integrated Pest Management

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The global market environment and movement of agricultural products, seeds and planting material have enabled the introduction of insects, mites, pathogens, nematodes, weeds, etc. from one part of the globe to other regions. It has not usually been deliberate to introduce any harmful organism, due to strict system of plant quarantine and phyto-sanitary measures at seaport, airport and surface transport but there are certain natural entry points for movement of undesirable invasive species. Therefore, the surveillance, monitoring, quarantine measures, containments, diagnostics, management of pests in agro-ecosystem and conservation of useful fauna and flora are needed to manage pests by utilising knowledge resources in the changing scene of agriculture and horticulture. Efforts are on for a multi-disciplinary team with the support of various stakeholders, to disseminate the knowledge of integrated pest management so as to conserve the useful fauna and flora and avoid the entry and buildup of harmful species in the multi-crop environment.

This may partly reflect the experience of the research workers and managers, but in large part it is accurate to state that the methodology of systems science has not been applied to pest management in the broad sense of the term. Pest management is a combination of processes; including acquiring information from the agro-ecosystem, decision making and action to manage the pest. A comprehensive application of the systems approach would include developing models for data acquisition (sampling procedures, sampling frequency, and so on) and the grower decision process. Applying design and control techniques to this larger system could result in some very interesting recommendations; for the present, however, the emphasis on modeling agro-ecosystem dynamics is well placed.

Pest forecasting provides opportunity to farmers for preparedness and allows timely action to apply bio-agents and pesticides, which ultimately cut down the cost of production and serve as a tool in precision farming. Pest forecasting through mathematical and computer based models deals with perception of the future activity of biotic agents which adversely affect crop production. Pest forecasting models are essential tools, and a pre-requisite of IPM as the insect population and disease incidence levels are deciding factors in pest management. One of the earliest forecasting works on plant pests was forecasting of late blight of potato (*Phytophthora infestans*) by Dutch rules which considered several climatic factors together such as dew at night (at least 4 hours), minimum temperature at night (less than 10°C), mean cloudiness on following day (more than 0.8) and rainfall in the next 24 hours (minimum of 0.1 mm). In India, one of the earliest works on pest forecasting was started by Dr S Pradhan's biotic theory of locust population explosion. According to him, temperature is one of the most important factors which determines the duration of various stages in the insect life cycle and number of generations. The development of the biograph had been one of the important findings to show the rate of development on different temperature regimes. Later, various other models were developed such as wheat stem rust rules based on climatological parameters. The main requirements for developing pest forecasting models are data on weather parameters, pest population, natural enemies and crop phenology. Ecological considerations are the foundation of pest management programme.

Monitoring of pest

Crop pest surveillance and monitoring are cornerstones in a pest management programme. Monitoring of pest population through surveillance implies a complete vigilance on pest population, natural enemies, cropping system and weather factors. An ideal surveillance team should include entomologists, pathologists, nematologists, agricultural meteorologists, modelers and production scientists for collection of data on various aspects. Monitoring of pest population at regular intervals round the year provides quantitative and qualitative data.

The interrelationship and dependence of plants, pests, natural enemies of pests and weather and their quantification need full understanding. Therefore, a forecasting system for pest is mainly developed by using various mathematical

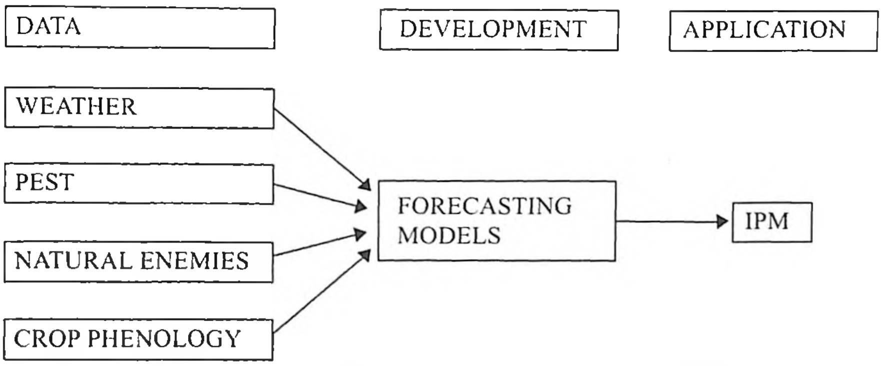

Figure 1: Relationship of components of Pest Forecasting

models based on biotic and abiotic factors. These models may be deterministic, statistical, system simulation, expert system, schematic or geographical. It would be better if such models have the input of indigenous technical knowledge of the farming community to provide location specific models for the use of crop production managers. The location specific models for polyphagus pests need to be fine tuned based on local factors before field application. These prediction models will make the farmers prepare against pests and decide application of bio-agents, pesticides and other approaches in integrated pest management timely.

Monitoring tools

Various monitoring tools *viz.* light traps, pheromone traps, manual count of eggs, larvae, visual estimation of crop damage have been used in India and elsewhere. These also include roving and fixed plot observations in different parts of India.

The monitoring of pests has been found useful in the following ways:

1. Identification of geographical distribution, key mortality factors, peak activity, mode of carry over and off-season survival.
2. Conservation of natural enemies.
3. Precision farming.
4. Remote sensing and geographic information system (GIS).
5. Preparedness of crop protection managers and farmers.
6. Avoidance of excessive use of pesticides.
7. Reduction in cost of production.
8. Environmental protection.

Key pests

The pest forecasting models for key pests need to be developed through collaboration with ICAR institutes, State Agricultural Universities and KVKs. Some of the key pests identified at present for development of forecasting models are:

- *Helicoverpa armigera* (American bollworm/pod borer)
- *Spodoptera litura* (tobacco caterpillar)
- *Nilaparvata lugens* (brown plant hopper)
- *Bemisia tabacci* (Whitefly) and cotton leaf curl virus
- Bacterial leaf blight of rice
- Grey Mildew of cotton

Development of forecasting models

The prerequisite of an economically viable, environmentally sound and easily adoptable pest management programme is precise forewarning of pest occurrence and peak activity period. The following basic information and methods should be followed for development of dynamic pest prediction system:

i) Quantitative seasonal studies

Sampling of population, spatial and geographical distribution of pest abundance, seasonal counts in relation to climate, phenology of the crop and topography needs to be provided for modelling.

ii) Life history and biology of pest

The length of life cycle, number of generations in a year, growth index, life span, survival rate, food, habitat, over seasoning, collateral hosts and intrinsic growth rate in field and simulated laboratory conditions need to be available within the working group. The effects of abiotic factors on development of pests, spread and mode of carry over need to be worked out accurately.

iii) Ecological Studies of pest

Life-table studies of pests are important for better understanding of pest population build-up, natural mortality factor, critical stage, and intrinsic growth rate. The life-table of a pest can be used to find the favourable periods for mating, emergence etc. Besides these, the spatial pattern can also provide clues to find suitable sampling schemes to be used for collecting pest population data. The migration and immigration of pests along with mode of carry-over and spread can be used for forecasting.

iv) Crop Phenology

The different crop growth stages and fertilizer dosages, irrigation and plant spacing influences the phenology of the crop. The population on various phenological stages needs to be studied.

v) Natural enemies

The population of natural enemies present on various time intervals in the crop needs to be worked out precisely for different locations. These natural enemies play important roles in pest suppression. Sometimes the use of pesticides drastically reduces the population of natural enemies, and alters the pest population.

vi) Agro ecosystems

Changes in cropping pattern and diversified crops are emerging as a method of increasing profitability in some parts of the country. The number of crops and wide range of varieties with different maturity groups serve as a suitable niche for build up of *Helicoverpa*. Therefore, information on cropping pattern and crop sequences needs to be included in the modelling. Population on various crop host plants is to be counted regularly.

vii) Surveillance of pests

Crop pest surveillance and monitoring implies complete vigilance on biotic and abiotic factors affecting crop growth.

Monitoring for emergence of soil pests or migrating pests through regular monitoring of population as direct count on crops plants, light traps, pheromone traps, wind traps and soil samples for visual observation of immature stages of pests, indicates the pattern of population build up. Even emergence traps fixed in the soil and crop plants also work as a tool. The population of the pests should also be counted on alternate or collateral hosts at periodic intervals, for their occurrence on major host plants.

viii) Modelling of pest population

Based on the data available, various modelling options are available to model the pest population with the other factors such as weather, natural enemies present, and crop biology. The relationship between the different components is shown in Figure 1. Successful techniques in pest forecasting include statistical, mathematical and simulation models. Statistical techniques such as simple linear regression, multiple regression, non-linear models, and the group method of data handling, stochastic process and time-series analysis are used in pest forecasting. Mathematical models such as simple growth models like logistic, Gompertz etc., are widely used in pest forecasting, particularly to forecast disease development and assess loss. If the model involves the current week pest population data as a dependent variable and previous few weeks weather parameters as independent variables then the model may be used for forecasting purposes.

ix) Data Requirement

1. Reliable, genuine data on pest population for long period at definite time intervals.
2. Weather records of the study sites.
3. Crop phenology.
4. Population of natural enemies.

x) Integration of Research

A working group of plant protection scientists, agricultural meteorologists, crop modeler, statisticians and computer scientists in coordination with production and ecological scientists should be formed for the development of a forewarning system.

Development of pest forewarning models

Some of the pest forewarning models developed at National Centre for Integrated Pest Management (NCIPM) includes aphid and *Helicoverpa* which use 10-20 years historical data collected by AICRP, ICRISAT and SAUs. The linkages and coordination have been found to be effective in developing statistical weather-based prediction models. The sensitivity and validation of these models are tested before they are put into operation under field conditions in the localities from where the data have been collected. These simple working models may be found suitable for field application in agriculture by using computers.

Prediction rule for rice gall midge at Cuttack, Orissa

Rice gall midge, *Orseolia oryzae* is an important pest of rice and can cause considerable loss of yield in rice crop. Cuttack region in Orissa is one of the endemic areas of rice gall midge in India. Data on per cent infestation (Onion leaf/silver shoot) along with weather parameters from meteorological observatory were collected at Central Rice Research Institute (CRRI), Cuttack during kharif seasons, from 1991 to 2000. The analyzed data revealed that gall-midge infestation started from July-August and reached its peak activity in the month of September (except 1998, in which infestation started in mid-September and attained maximum peak at the end of October). The weather criteria for gall midge are given in Table 1.

Table 1: Weather Criteria identified for Gall Midge

Criteria	Condition
Rain (August)	> 400-500 mm
Rain (September)	< 225 mm
Bright Sunshine Hours (August)	3-3.7 hrs
Bright Sunshine Hours (September)	> 5 hrs

However, the peak level of infestation varied from 19 to 48 percent (silver shoot). The weather parameters were hypothesized to be contributed for year-to-year variation in the level of infestation. Four out of 16 weather parameters tested, namely rainfall and bright sunshine hours of August and September were found to be effective in determining the level of infestation. Rainfall in August (400 to 500 mm) and in September (<225 mm) were found to be congenial for infestation, along with bright sunshine hours in August in the range of 3 to 3.7 hours and that in September > 5 hours, for severe infestation in the month of September. (The mean monthly maximum temperature for July, August and September was in the range of 30^{O} to 33^{O} C, while the minimum varied within 23^{O} -26^{O} C. The afternoon relative humidity of >70 % during this period was found to be congenial. However, no significant relationship was established between pest infestation and temperature or relative humidity.) The developed prediction rule predicted the infestation level accurately in 9 out of 10 years between 1991 and 2000.

Prediction rule for yellow stem borer of rice at Sambalpur, Orissa

Yellow Stem Borer, *Scirpophaga incertulas* is the major pest of rice and its distribution is throughout India. It causes considerable loss of yield in the rice crop. Data on male moth population were recorded using synthetic sex pheromone traps along with several weather parameters viz. rainfall, minimum temperature, maximum temperature and relative humidity from meteorological observatory located at Chiplima (Sambalpur) of Orissa during *Kharif* seasons from 1996 to 2001. The analyzed data revealed that infestation of yellow stem borer started from the third week of August, reaching its peak in the first fortnight of October, though the pest remains active upto second week of November, *Kharif* season. However, the base population of previous *rabi* season (*boro* rice) influenced the *Kharif* pest population along with weather parameters. In analyzing the data from 1996 to 2001 to develop criteria for prediction of the base population, rainfall (April), rainfall (July) 200-400 mm and number of weeks with weekly T max < 40° C during April & May was taken into consideration.

The prediction rule developed is as follows:

1. Total points >7 - high population in *Kharif* (August-October). (Increase over base).
2. Total points 5-7 - moderate population (slight decrease from base).
3. Total points < 5 - low population (drastic decrease from previous base)

Among the weather parameters tested, rainfall in April and July, along with weekly mean maximum temperature during April and May, were found to contribute to determining the next *Kharif* pest population. Rainfall in April (any amount), in July (200-400 mm) and the number of weeks with weekly mean maximum temperature below 40°C had positive effect on build up of yellow stem borer population. These weather parameters predict population level: high, moderate and low.

A prediction for rice blast

A model has been developed by the Directorate of Rice Research, Hyderabad for prediction of rice blast in and around Hyderabad. The influence of different weather parameters, maximum and minimum temperatures, morning and evening relative humidity, rainfall, rainy days per week and leaf wetness on the leaf blast severity and neck blast incidence were worked out and equations generated by step-down regression.

The analysis indicated the influence of weather conditions during crop growth on leaf blast severity and neck blast incidence. At the experimental field, DRR, minimum temperature and rainy days / week had shown a profound influence on both leaf and neck phase of the disease, followed by the other weather conditions like leaf wetness, maximum temperature and relative humidity, while the intensity of rainfall had no significance. However, at the farmers' fields, blast development was influenced more by rainfall than other climatic conditions, though temperature, morning relative humidity and rainy days/ week also showed significant influence on the disease development.

In general, the step-down multiple regression analysis shows that the minimum temperature, morning relative humidity, rainy days per week, followed by evening relative humidity, leaf wetness, maximum temperature and rainfall are the significant weather factors for leaf blast development, while both minimum and maximum temperature, rainy days per week followed by the intensity of rainfall and leaf wetness have a significant effect on neck blast incidence.

This clearly indicates that minimum temperature, morning relative humidity and rainy days/week increased the leaf blast severity, while the minimum and maximum temperature and rainy days/week increased the neck infection under natural conditions. These may be selected as contributing factors for prediction of leaf and neck infection in nature.

Regression models for prediction of rice blast have been developed by Himachal Pradesh Krishi Vishwavidhyalaya, Palampur (H.P.) and are being validated in farmers' fields.

Simple rule for *Helicoverpa armigera* forcasting at Deccan plateau

The data collected from ICRISAT, Hyderabad were analysed and a rule of thumb has been found to predict the level of attack during any year using the surplus/deficit rainfall of different months. The rule has accounted for the severity of pod borer attack in different districts of Andhra Pradesh during the winter of 1997-98.

The surplus or deficit of monsoon rainfall (i.e., the excess or low rainfall of June, July, August and September), referred to here as 'A', and 'B' surplus or deficit rainfall during November, of any place in this region may play a crucial role. A and B can be calculated as:

A = (Actual total rainfall during four monsoon months in a year - Long term average rainfall of that period of that place)

B = (Actual total rainfall during November month in a year - Long term average rainfall of that month of that place)

Positive (+) value of A or B indicates surplus rainfall and negative (-) value indicates rainfall deficit.

Prediction models for *Helicoverpa armigera*

The prediction model for *Helicoverpa* in Cotton and Pulse environment and seed potato crop have also been developed and validated for field application.

Remote sensing and GIS in pest forewarning

The use of remote sensing in agriculture was started with the detection of wilt disease in coconut on the Kerala coast. Later, the main emphasis was shifted to crop acreage estimation, crop condition assessment and yield forecasting. Some work has been done on forecasting of locusts *(Schistacirca gregaria)* at the Regional Remote Sensing Service Centre, Jodhpur. The locusts oviposit in the sandy desert where moisture is present in the soil. The satellite detection of moist sand as a breeding ground and the amount of green vegetation as food in the desert give the possible amount of locust population. The migration of locusts is forecast using the wind direction.

Disease forecasting is believed to be possible by remote sensing, as the disease inoculated plants increase reflectance, particularly in the bands of chlorophyll absorption (0.5-0.7 11In) and water absorption (1.45 and 1.95 11In). Research in this direction is scanty. However, disease severity assessment and yield loss estimation use changed reflectance pattern of diseased plants. The greenness vegetation index derived from LANDSAT MSS digital data in the four bands has been successfully used to distinguish between diseased wheat in the Pakistan Punjab and healthy wheat in the Indian Punjab.

GIS is another tool which can be used effectively for mapping geographical distribution of pests, delineating hotspot zones. Superimposition with causative abiotic and biotic factors on visual pest maps can be useful for pest forecasting. District-wise geographical distribution maps of rice and cotton pests have been prepared at NCIPM.

The insect pests mapped were: Leaf folder, Stem borer, Brown plant hopper, White backed plant hopper, Green leafhopper, Gundghi bug, Grass hopper, Rice hispa, army worm; and diseases were: Blast, Brown spot, Sheath blight, Bacterial leaf blight. The revised pest distribution maps for rice crop from 1993–2002 have also been prepared for 13 pests. Figures 2 and 3 show the geographical distribution of hot spots of leaf folder and brown leaf spot, in rice, respectively.

Information technology

The recent advances made in Information Technology particularly in communication and computing will be highly useful in successful implementation of forecasting models. Different stations can be interconnected with one another and can share the data. Users can directly use the pest forecasting models with the help of the Internet, and along with the forecast, proper pest management options can be given to all. Moreover, as the costs come down, Information Technology would form the essential component of any pest forewarning system.

Role of other agencies

The pest forewarning system can be improved by linking it with weather forecasting and field level validation. The NCMRWF (National Centre for Medium Range Weather Forecasting) issues weather forecasts five days in advance and expects shortly to issue them seven days in advance. With the help of these forecasts, farmers are advised in different farm operations like sowing, transplanting, irrigation and harvest. Advice on plant protection measures is very meagre. This agro-advisory service would improve, if it could forecast the time of pest attack, and its Economic threshold Level (ETL), the population density at which it causes economic loss for taking pest management decisions. Spraying should be done according to forecast rainfall and wind information.

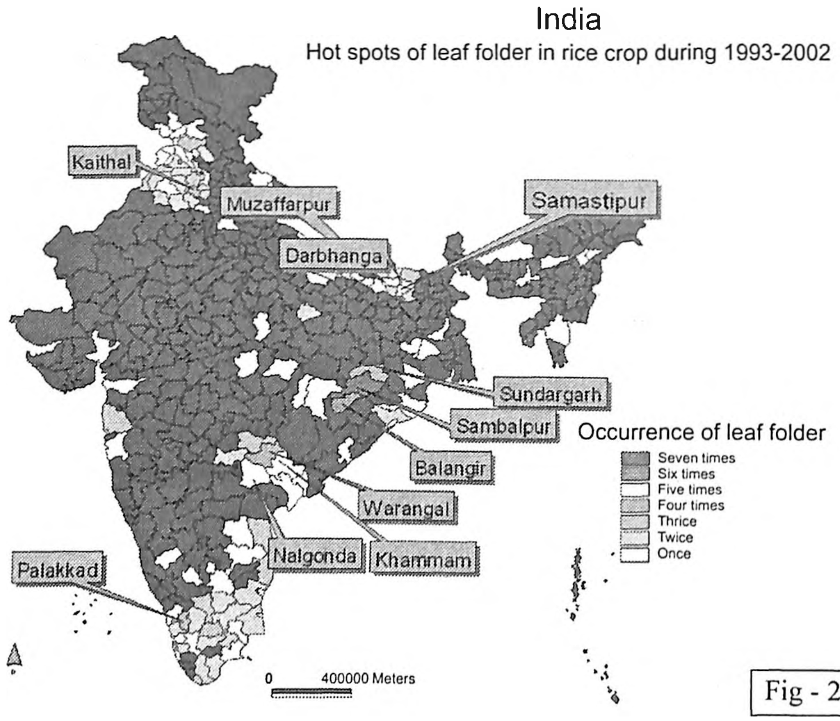

Fig - 2

Integrated pest management

IPM is a systems approach to minimize the losses caused by insect/pests, plant diseases, nematodes, rodents, weeds, etc. on a sustainable basis by promoting eco-friendly pest management strategies and reducing reliance on chemical pesticides. IPM programmes are environment friendly, economically viable and socially acceptable.

"IPM is a pest management system that, in the context of the associated environment and the population dynamics of the pest species, utilizes all suitable techniques and methods in as compatible a manner as possible and maintains pest populations at levels below those causing economic injury."(FAO, 1967)

The National Agricultural Policy (para 24) gives special emphasis to IPM: "Integrated Pest Management and use of biotic agents in order to minimize the indiscriminate and injudicious use of chemical pesticides will be the cardinal principle covering plant protection". It envisages 4% per annum growth rate in the agricultural sector. This growth target is to be achieved against the constraints of land resources, increasing biotic and abiotic stresses, loss of

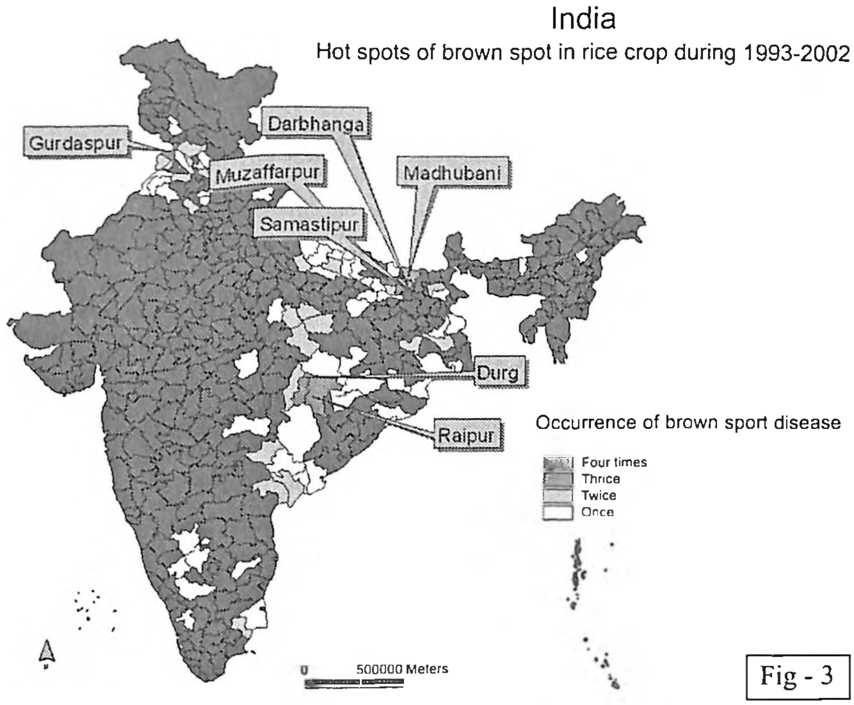

Fig - 3

bio-diversity, climate change and competition in international trade, while addressing the nutrition and quality of food. There is a need to strengthen and understand the agro-ecosystem and associated biotic and abiotic factors, and their inter-relationship and mutual dependence. Among the biotic stresses, and insect pests, plant diseases, nematodes, vertebrate pests and weeds are the major groups causing losses. In India, 15.6% of production is lost to pests, which is estimated as a cost of over Rs. 68,000 crores. The various pest management techniques and decision tools such as, ETL and economic injury level need to be further simplified for wider adoption, especially by marginal farmers. Some pest problems like *Helicoverpa armigera, Spodoptera litura*, Diamond back moth, aphids, jassids, white fly, brown plant hopper, rice stem borer, sheath blight, bacterial leaf blight, root rot and wilts, cotton leaf curl virus, leaf spots of groundnut, leaf blight of cereals, downy mildew, root knot nematodes and weeds are major constraints on various production systems in different agro ecological regions of the country.

Insect pests and diseases are dynamic components of an ecosystem. So far, the individual components of pest management have been evaluated and used for the management of various pests in individual crops. This has been a complex procedure, mainly influenced by chemical pesticides. It has further diluted financial resources, and sometimes increased pest problems due to ecological imbalances. It is thus relevant that simple and farmer friendly IPM modules as a systems approach be validated and promoted in a cropping system mode which is economically viable and socially acceptable. These IPM modules, in a predominant cropping system, must be promoted in a participatory mode with multi- institutional support. The role of industry and volunteer organizations for sustainability and promotion of IPM approaches should be accelerated, so that the visible impact of environment friendly pest management programmes is seen across the country.

Biocontrol agents and biopesticides comprise the core of the IPM strategy. Currently, biopesticides constitute only about 1.5% of the pesticide industry and expected to reach 12-15 % by the end of 2005 mainly through chorus of organic farming amounting to $ 380 million. In order to meet the current demands a National Biocontrol R&D Network programme was started in 1989 and as a result we see around 200 R&D projects already implemented. 410 biopesticides production units are currently in operation in the country.

To put maximum pest endemic area under IPM, bioproduction units should be established that make quality biopesticides available to local farmers. Also, seeds of tolerant and resistant varieties form a foundation of the IPM programme, hence seed replacement should be a core strategy in agricultural production. Organic manures, like vermi-compost to maintain soil health, should be adequately addressed to sustain agricultural productivity. Facilities for pesticide residue assessment of agricultural produce should evolve hand in hand with organic farming, so as to verify the premium IPM produce.

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