State of Indian Agriculture

National Academy of Agricultural Sciences
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4. Agricultural Biosecurity

Biosecurity is a strategic and integrated approach that encompasses a policy and a regulatory framework to analyze and manage risks associated with food safety, plant and animal health and environment. It includes biosafety, a term used to describe policies and procedures adopted to ensure environmentally safe application of modern biotechnology including products derived from the use of recombinant DNA technology. The shift towards intensive agriculture, trade liberalization and losses caused to agriculture and environment by animal and plant pests have all contributed to increased significance of biosecurity (Rai, 2007; Swaminathan, 2008).

4.1 Losses Caused by Endemic Pests and Diseases

4.1.1 Plant Pests and Diseases

Plant pests and diseases are the major contributors to biotic stresses that limit realization of yield potential of crop-plants. The annual losses of crop produce in India are estimated at 25% (NAAS, 2008) (Table 4.1). This indicates importance and need for strengthening of the existing biosecurity system more so with the advances in agriculture, and changes in agricultural practices, in climatic conditions, and in indigenous pests, evolving into more virulent forms over the years. The diseases continue to spread over large areas. Therefore the recent potential threat from the deadly Ug99 rust isolate on wheat cannot be overlooked.

Groundnut bud necrosis virus (GBNV), which is understood to be moving from groundnut to other legumes and solanaceous crops, causing soybean bud blight, mungbean/ urdbean leaf curl, tomato bud blight and potato stem necrosis, bunchy top of banana, and Tobacco streak virus (TSV) in sunflower and other crops, are emerging as serious problems (Jain *et al.*, 2007).

In recent years, India faced losses of over Rs 11,800 million due to late blight of potato caused by *Phytophthora infestans;* affecting potato field over 1.4 million hectares. In addition to domestic consumption, exports were affected by the disease (http://www.sathguru.com/absp2/potato.php). Development of transgenic potato is expected to reduce combined direct losses.

Several chronic diseases including diseases of unknown etiology such as mango malformation, parawilt of cotton and others which are also of serious concern resulting from the change in cropping systems/climatic patterns, due to evolution of superior races or resurgence capabilities. Examples of such diseases include foliar blight and Karnal bunt in wheat, sheath blight in rice/maize, bract

mosaic in banana, downy mildew of maize, soybean mosaic, citrus dieback and *Phytophthora* diseases, root knot in vegetables, rice/wheat, coconut (root) wilt, crown rot of oil palms and brown blast disease of rubber.

Threat from Ug99 Rust Isolate on Wheat

A potential threat by the fungal pathogen looms large on our nearly 50 million wheat farmers. If introduced, farmers in Gangetic plains are likely to lose over 7 million tonnes of wheat and wheat products annually. First reported in Uganda in 1999, Ug99 had subsequently spread to Kenya (1999); Ethiopia (2003); Yemen and Sudan (2003); and Iran (2008). The arrival in Iran means that it is a matter of time when spores of Ug99 could fly over to Pakistan, which then will serve as a gateway to Punjab (India), from where it could hit other wheat-producing areas of India (Singh *et al.*, 2004).

Table 4.1. Losses Caused by Pests and Diseases in India

Pest/ disease	Losses in India (in billion rupees)	Reference/ source
Late blight of potato (*Phytophthora infestans*)	11.8	http://www.sathguru.com/absp2/potato.php
Bunchy top of banana Whitefly (*Bemesia tabaci* biotype "B")	0.04	Khetarpal and Gupta (2008a) CAB International (2007)
Cotton bollworm (*Helicoverpa armigera*)	0.25	Fakrudin *et al.* (2003)
Congress grass/ Carrot weed (*Parthenium hysterophorus*)	16	http://www.nrcws.nic.in
Foot and mouth (FMD) disease	100	NDMA (2008a)
Peste des Petits in ruminants	4	NDMA (2008a)
Avian influenza (H5N1) (due to culling of millions of chicken)	290	Rao (2006)
White spot syndrome virus (WSSV)	2-3	Vijayan (2007)
Epizootic ulcerative syndrome (EUS)	2.1	Gopal Rao *et al.* (1992)

Bemisia tabaci biotype "B", another polyphagous pest, with as many as 600 different host (CAB International, 2007) plant species, reported from India in 1999, is an efficient vector for Tomato leaf curl virus, and is suspected to have been introduced with imports of horticultural crops. Biotype "B" is vector of

over 60 plant viruses and losses to the tune of Rs 25,000 million of winter vegetable crops through both feeding and virus transmission are reported (CAB International, 2007). Its ability to feed on many different host plants enables whitefly-transmitted viruses to infect new plant species. Another major insect pest causing serious losses is cotton bollworm *Helicoverpa armigera*, a polyphagous pest, with a host range of 181 plant species, including cotton, pigeonpea, chickpea, maize, sunflower and several vegetable crops, and is estimated to cause economic losses up to about Rs 250 million in India (Fakrudin *et al.*, 2003). Pyrilla in sugarcane is an example that continues to grow and inflict serious crop losses.

Also, from time-to-time, there have been serious outbreaks of insect-pests like gram pod borer *Helicoverpa armigera*, tobacco caterpillar *Spodoptera litura*, sorghum stem borer *Chilo partellus*, rice stem borer *Scirpophaga incertulus*, diamond back moth *Plutella xylostella*, brown planthopper *Nilaparvata lugens*, onion thrips *Thrips tabaci*, army worm *Mythimna separata*, cutworms *Agrotis* spp., rice green leaf hopper *Nephotettix* spp., white grubs *Holotrichia consanguinea*, root grubs *Anomala dorsalis*, fruit flies *Bactrocera cucurbitae* and *B. dorsalis*, termites *Odontotermes* spp. and occasionally red spidermite *Tetranychus telarius*. In 1998, there were serious outbreaks of *Helicoverpa armigera* on cotton, in Guntur district of Andhra Pradesh, and it was followed by resurgence of whiteflies in cotton leading to social problems, including suicide by several farmers.

Golden nematode of potato *(Globodera rostochiensis)*, one of the worst diseases of potato in the world, was first reported from some areas of Nilgiri hills in the sixties. A domestic quarantine was later promulgated to prevent nematode spread from localized areas from the Nilgiris to other potato-growing tracts.

Parthenium in the country has come to the fore as a weed of major economic importance; based mainly on its rapid spread since the past two decades. Its impact is multi-faceted, affecting crop production, animal husbandry, human health and biodiversity, and its overall economic impact is difficult to quantify. *P. hysterophorus* has now invaded around 7-8 million hectares of non-cropped area throughout the country, and cost (Table 4.1) to control weeds in non-cropped areas is estimated at Rs 16 billion (www.nrcws.nic.in). Besides *Parthenium*, *Phalaris minor* is another very competitive and serious weed in wheat, introduced from Mexico to India in 1961 through contaminated foodgrains (wheat) import, and is known to infest almost all crops grown in winter. Wheat, chickpea, pea and lentil are major hosts for this weed. Yield losses vary depending on crop, climate and management practices. The losses are maximum in crops of short stature, chickpea, lentil, peas, and 30 – 100% yield losses were recorded in wheat (Anonymous, 2006).

4.1.2 Livestock and Poultry Diseases

The World Organization for Animal Health (OIE), of which, India is also a member, lists several diseases of terrestrial and aquatic animals and requires exporting countries to adopt suitable control and containment measures in addition to notifying other countries to ensure safe trade of livestock and livestock products. The diseases that are of immense importance from animal husbandry

perspective as well as public health include non-zoonotic diseases, Foot and Mouth Disease (FMD), Peste des Petits Ruminants (PPR), Blue Tongue, Babesiosis, Cysticercosis, Anaplasmosis, Infectious Bovine Rhinotracheitis/Infectious Pustular Vulvo-vaginitis (IBR/IPV), Theileriosis, Contagious Agalactiae (Mycoplasmosis), Enzootic Abortion (Ovine Chlamydiosis), Caprine Arthritis/ Encephalitis (CAE), Maedi-visna, Contagious Caprine Pluropneumonia (CCPP), Equine Influenza, Equine Piroplasmosis, Equine Viral Rhino-pneumonitis, Bovine Viral Diarrhoea (BVD), Bovine immunodeficiency virus infection (BIV), Infectious Hydropericardium (Hydropericardium Syndrome), Inclusion Body Hepatitis, Avian Influenza, Bovine Leucosis, and Classical Swine Fever (CSF). The second category includes diseases with known zoonotic potential such as Anthrax, Brucellosis (*Brucellosis melitensis, B. abortus*), Highly Pathogenic Avian Influenza (HPAI), Japanese Encephalitis, Rabies, Sheep Pox/ Goat Pox and Listeriosis.

FMD affects cattle, pig, sheep, goat, buffalo, camel and a wide variety of other cloven-hoofed domestic and wild animals. The economic catastrophe that FMD may cause is elucidated by the recent outbreaks of FMD in United Kingdom (UK) in 2001 and in 2007, which resulted in significant losses of export and livestock (http://defraweb/animalh/diseases/fmd/pdf/epidreport300907.pdf). In India, the disease is endemic and is caused by Types O, A, and Asia 1, with Type O being predominant. More than 5,000 cases are reported every year. Although morbidity rate is high, the mortality rate due to FMD is low. The economic losses are mainly due to loss in milk production, reduction in working ability of draught animals, and reduction in body weight, leading to reduced meat yield. Direct losses are estimated to be more than Rs 100 billion per year (NDMA, 2008a). In addition, the milk and milk products, meat and hide are not accepted by the countries, which are free from the disease, and thus cause impediment to export.

Peste des petits ruminants (PPR) is highly contagious and acute systemic viral disease of goat and sheep and other small ruminants. India has approximately 200 million small ruminants and the disease is responsible for high mortality in susceptible populations, which may reach up to 50% or even more and annual losses due to PPR are estimated to be around Rs 4 billion in India (NDMA, 2008a).

Infection with avian influenza viruses in domestic poultry causes two main forms of disease that are distinguished by virulence of infecting strain. The "Low pathogenic" form usually causes only mild symptoms and highly pathogenic form (HPAI) causes high mortality in affected flocks and the virus spreads more rapidly through carcasses of poultry. HPAI form may affect multiple internal organs, and mortality rate can reach 90-100% often within 48 hours. Although not common, infection with these viruses has the potential to infect and cause death in human-beings. Of the few avian influenza viruses that have crossed the species barrier to infect humans, the HPAI has the largest number of detected cases of severe disease and death in humans. Because of its importance in health and high mortality among infected domestic chicken, control and eradication of avian influenza must be undertaken immediately.

In India, infection by HPAI was first reported in 2006 from parts of Maharashtra, Gujarat and Madhya Pradesh. The disease was successfully contained, and freedom status from the infection was obtained within four months

from OIE. In 2007 and 2008 fresh outbreaks due to HPAI in domestic poultry were recorded in parts of the country, which were contained swiftly.

This disease has caused considerable losses to poultry industry particularly due to ban on transportation of live and dressed poultry. Secondly, poultry meat consumption decreased drastically due to fear in masses to contract disease. And there was blanket ban on the export of poultry and poultry products (Anonymous, 2007).

Infectious diseases in poultry and livestock cause annual losses of about Rs 50 billion, in addition to losses incurred due to restrictions imposed on exports or movement within the country due to public health hazards, especially in epidemic outbreaks when the losses are colossal (Khetarpal and Gupta, 2007).

4.1.3 Fish Diseases

Shrimp farming and carp farming have been the face of Aquaculture in India. By 1993, fish diseases, especially those of viral etiology have emerged as the major constraint for sustainability and growth of shrimp aquaculture. The total collapse of shrimp farming industry in Taiwan in 1987, China in 1992, and India in 1995 was due to infectious viral diseases, causing losses of billions of rupees in revenue to the industry.

Among infectious diseases of cultured shrimps, certain virus-caused diseases stand out as most significant. The pandemics due to penaeid viruses, white spot syndrome virus (WSSV), taura syndrome virus and yellow head virus (YHV), have costed penaeid shrimp industry billions of dollars. The global loss caused by WSSV in 2000 was estimated to be 200,000 metric tons, valued Rs. 50 billion (Rosenberry, 2001). The losses to shrimp farmers due to WSSV in India are estimated at Rs 2-3 billion annually, since 1994 (Vijayan, 2007). Viral diseases are not considered a significant threat in marine and brackishwater finfishes culture in India (Vijayan *et al.*, 2007; Sanil and Vijayan, 2008).

Other than the epizootic ulcerative syndrome (EUS) and some reports on noda virus, no other OIE- notifiable diseases have been reported from India. The EUS is a pathogenic disease caused by fungus *Aphanomyces invadans* in Asian freshwater and estuarine fishes. It causes skin ulceration leading to death, and affects over 30 commercially important fishes both in freshwater and estuarine habitats. EUS with its high epizootic potential and mortality rate has already appeared in freshwater in many north eastern and some southern states. In India, losses due to EUS have been estimated at Rs. 2,125 million during 1992-95 (Gopal Rao *et al.*, 1992, Lilley *et al.*, 2002).

Throughout the world scarcity of water resources suitable for aquaculture and environmental concerns about wastewater discharges have forced many developed countries to employ "recirculating" technologies - systems that employ an intensive, closed-system approach to fish culture. In such systems, preventing and controlling disease is important as disease organisms may recycle with water and, since there is no dilution of pathogens as in the flow-through systems, resulting rates of infection are going to be far greater (Muir, 1994). And, it is extremely difficult to eradicate a disease, once a pathogen has become established in a recirculation rearing system (Delabbio, 2003).

The practice of mixing of species and introduction of exotic species could be one of the reasons for emergence of new viruses in India (Karunasagar *et al.*, 2008). The efforts of Indian shrimp farmers to introduce *Litopenaeus vannamei* stock, and their subsequent experimental introduction to Indian state of Andhra Pradesh to prevent spread of pathogens such as WSSV and Monodon baculovirus (MBV), and other exotic pathogens, brought focus on the need for strengthening biosecurity for fisheries in India.

Besides, there are seven OIE listed molluscan diseases (OIE, 2006) not yet reported from India, although their presence in Indian waters cannot be ruled out.

4.2 Biosecurity in Relation to Trade and Exchange

The global trade in agricultural commodities and the transboundary movement of plants and animals have led to situations warranting legislative measures to regulate trade/exchange. Quarantine is a government endeavour enforced through legislative measures to regulate introduction of plant, animal, fish and their products, packaging material, soil, to prevent inadvertent introduction of pests (including insects, nematodes, pathogenic fungi, bacteria, viruses, phytoplasmas, mycoplasmas, weeds) harmful to agriculture of a country/ state/region, and if introduced, preventing their establishment and further spread.

4.3 Historical Cases of Transboundary Movement of Plant Pests

The historical Irish famine of 1845 caused by 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 thirties; bunchy top of banana introduced from Sri Lanka in 1943; the dreaded Golden nematode infesting potatoes introduced in the sixties from 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 crop production and economy of a region/ country (Khetarpal *et al.*, 2001; Khetarpal, 2004; Gupta *et al.*, 2005).

A critical appraisal of transboundary movement of seeds and seed health certification under WTO regime was made by Khetarpal (2004). Plants/planting materials are either imported as bulk material for sowing/planting or consumption and as small samples of trial and germplasm for research work. The bulk imports for sowing/planting carry maximum risk as thorough examination and treatment becomes difficult and planting area is too large. Quarantine examination is often restricted to smaller sub-samples derived from bulk material, and based on the results of these samples the whole consignment is rejected/detained, treated by fumigation or otherwise and/or released. The

Pests and Diseases of Potential Quarantine Significance to India

Plant pests and diseases

Moko wilt of banana- *Burkholderia solanacearun race 2;* 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. *Ftabacina,* Tropical rust of maize – *Physopella zeae;* Viruses of European honey bee *(Apis melliphera); Barley stripe mosaic virus;* Coconut cadang cadang viroid; Palm lethal yellowing *(Phytoplasma);* Pine wood nematode – *Bursaphelenchus xylophilus;* Red ring nematode of coconut - *Rhadinaphelenchus cocophilus;* Mediterranean fruit fly – *Ceratitis capitata;* Cotton boll weevil – *Anthonomus grandis; and Xanthomonas campestris* pv *malvacearum* – Race 18 of Africa:

Livestock and poultry diseases

Rinderpest; Vesicular Stomatitis; African Swine Fever; Transmissible Gastro-enteritis; Anthrax; Brucellosis; West Nile Fever; Tuberculosis; Japanese Encephalitis; Avian Influenza (Bird-flu); Rabies; Newcastle Disease; Chicken Infectious Anaemia; and Salmonellosis.

Fishery pests/ diseases

Koi herpes virus; Furunculosis caused by Aeromonas salmonicida; Spring Viraemia caused by Spring viraemia carp virus in carp; Infectious pancreatic necrosis caused by Infectious pancreatic necrosis virus in fin fishes; Viral Haemorrhagic Septicaemia caused by Viral Haemorrhagic Septicaemia Virus in fin fishes; Infectious Hepatopancreatic and Haematopoietic Necrosis Virus in shrimps: Taura syndrome virus affecting farmed shrimps; Bonamiosis in bivalve molluscs; Marteiliosis in bivalve molluscs; Perkinsosis in bivalve molluscs; Haplosporidiosis in bivalve molluscs

(Sources: Khetarpal and Gupta (2007), NDMA (2008a) and Vijayan (2007).

bulk consignments meant for consumption pose lesser hazards. However, certain small samples meant for research purposes are of immense quarantine importance. These samples usually consist of germplasm materials or wild relatives or landraces of a crop, and are thus more likely to carry diverse biotypes/ races/ strains of the pest. In the case of true seed, internal infections pose greater risks than do the surface-borne contaminations. However, imports of vegetative propagules present a much higher risk than even the true seeds. To combat threat posed by viruses in tissue-culture raised material, the Directorate of Plant Protection Quarantine and Storage (DPPQS) has recognized three laboratories for testing and certification for viruses – Advanced Centre for Plant Virology, IARI, New Delhi; Institute for Himalayan Bioresource and Technology, Palampur, and the Indian Institute of Horticultural Research, Bengaluru.

Import of animals likewise always carries a risk of introduction of new pests and diseases into the country causing serious animal health problems. Once such pathogens are introduced, they can affect susceptible animal population and can spread at a faster rate. Due to the absence of diagnostic tools, such pathogens cannot be diagnosed. Due to lack of vaccines or effective drugs or host resistance against such pathogens, even prevention and control is a difficult task. Hence, there is a need to take extra precaution in import of livestock and livestock products. Similarly, in poultry, import and export policies for eggs and egg products, meat and meat by products, grandparent flocks and vaccines should be stringent keeping in view the global scenario for diseases like Avian Influenza, Newcastle Disease, Chicken Infectious Anaemia and Salmonellosis.

Among the most recognized transboundary animal diseases (TAD), which can potentially inflict enormous losses to livestock in a short time, five already exist in the country - FMD, PPR, Newcastle Disease, hog cholera and bluetongue. Except for bluetongue, official control programmes for others are already in place to minimize losses.

The remaining TADs, Vesicular Stomatitis, African Swine Fever, Transmissible Gastro-enteritis continue to be a threat to Indian livestock. Due to lack of adequate diagnostic facilities at the grass-root level, many infections may go undiagnosed in livestock that may play an important role in production losses due to mass mortality and quick spread. The potential threat to livestock population is the zoonotic dimension of several animal diseases, anthrax, brucellosis, West Nile Fever, tuberculosis, Japanese Encephalitis, avian influenza and rabies.

Furunculosis caused by *Aeromonas salmonicida* is the oldest of the known fish pandemics, believed to have moved from the United States to Europe through rainbow trout (*Oncorhynchus mykiss*). Crayfish plague caused by fungus *Aphanomyces astacus* was introduced to Europe from the US. Epizootic ulcerative syndrome (EUS) epidemic caused by *Aphanomyces invadans* has spread to whole Asia, Australia and beyond. It has caused considerable losses to many wild and farmed species in the Philippines, Indonesia, Thailand, Burma, Bangladesh and India, and even US. All these diseases have successfully invaded the new ecosystems, where vulnerable host species already exist.

Water is a continuous medium connecting all parts of planet Earth. In terrestrial situation, discontinuity of land masses generally facilitate control of transboundary pathogens movement, while in aquatic system, continuity of water could allow passage of biota along with micro and macroflora, with potential pathogenic characteristics and related possibility of disease implications. Huge economic losses from aquatic animal diseases have been documented over the last decade, largely due to the lack of proper biosecurity plans/policies. A database of aquatic pathogens in Indian waters and further studies on status of presence/absence of pathogens are needed.

The recent outbreaks of koi herpes virus (KHV) in neighbouring South-East Asian countries is a cause of worry. KHV is a highly contagious viral disease, capable of causing significant morbidity and mortality in common carp, *Cyprinus carpio* (Hedrick *et al.*, 2000). *C. carpio* is raised as a food fish in many countries, and has been selectively bred for ornamental fish industry, where it is known as Koi. The disease may cause 80–100% mortality in affected populations all age

Successful Eradication of Livestock and Poultry Diseases

India has successfully eradicated Rinderpest, another dreaded trans-boundary infection which until recently has been devastating cattle and other ruminants. Although considered exotic till recently, highly pathogenic avian influenza (commonly referred to as bird-flu) invaded country twice, in 2006 and in 2007, and was successfully eradicated. South African Horse Sickness, another dreaded transboundary infection which invaded in the early sixties of the last century was eradicated, a loci of infection still exists in pockets of Africa. After having stopped vaccinations from 1994, the Indian livestock is vulnerable to the disease, should the virus re-enter the country. The consequences would be no lesser than those perceived from small pox in humans today.

groups. Outbreaks of KHV have been confirmed in the United States, Europe and Asia. There is no known treatment for KHV, and the virus is believed to remain in infected fish for life; thus exposed or recovered fish should be considered as potential virus carriers.

The unauthorized introductions pose a serious threat to aquatic systems. Besides competing with the native species for food and other requirements, they bring with them a variety of pathogens (sub-clinical infections/carriers), which may pose serious threats to native populations. International movement of frozen shrimp products from eastern to western hemisphere for trade and aquaculture has resulted in transfer of WSSV from Asia to Americas, and Taura syndrome virus from Americas to Asia (Lightner, 2005). Introduction of exotic/ dangerous organisms/pathogens through shipping activities (ballast water) also pose a serious risk. In recent years, appropriate biosecurity management could have prevented many of the serious losses experienced in aquaculture. As large number of ornamental fishes, especially Koi are being imported to India, there is a potential high risk of KHV entering country. Besides the threats posed by aquatic organisms in ballast water cannot be neglected.

The agricultural economy is also vulnerable to threat from exotic pests/diseases that have the potential to be used as bioweapons (Khetarpal and Gupta, 2007, 2008a). Besides, a large number of destructive indigenous pests of plants, animals and fisheries are endowed with strains/isolates/biotypes, which also have a potential for use as bioweapons. The issue has been recently reviewed (NDMA, 2008a and Raghunath, 2008). The Core Group of Biological Disasters of the National Disaster Management Authority has recently come out with guidelines for the management of such potential disasters. 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. Lack of genetic diversity in certain cases limits natural defense to diseases and biological agents that are intentionally introduced into an environment.

Ballast Water related Threats

Ballast water is fresh or saltwater held in the ballast tanks and cargo holds of ships to provide stability and manoeuvrability during a voyage. When ships take on ballast water, it is common for organisms to be sucked up into the ballast tank. Some of these organisms can survive in ballast tanks for more than 90 days without food or light (Cullins, 1997). This water is finally discharged in the oceans and if the organism survives the journey and if various biological and physical parameters are correct, then there is a chance that the organism will survive in the new environment. This environment favours introductions of non-indigenous organisms—including jellyfish, crabs, clams, fish, snails, and water fleas—transported to new locations by ships. It has been estimated that in the nineties, ballast water may have transported over 3,000 species of animals and plants a day around the world (NRC, 1995), and there is an evidence that the number of ballast-mediated introductions are growing steadily. India is, however, yet to initiate the ballast-water testing programme.

4.4 National Regulatory Mechanism

4.4.1 Plants

In plants and products thereof, the Government of India had legislated the Destructive Insects and Pests (DIP) Act in 1914, which is amended from time-to-time and has provision for domestic quarantine to restrict the movement of certain planting material from one state to another. The Plants, Fruits and Seeds (Regulation of Import into India) Order, 1984 (PFS Order) issued under this Act 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 functioning of quarantine. This Order has now been superceded by the Plant Quarantine (Regulation for Import into India) Order 2003, which came into force as there was an urgent need to fill-in the gaps in existing PFS Order for cases including import of germplasm, genetically modified organisms (GMOs), transgenic plant materials and biocontrol agents, and to fulfill India's legal obligations under the international agreements. This Order incorporates the additional/special declarations for freedom of import of commodities from quarantine and invasive alien species (IAS), on the basis of standardized pest risk analysis (PRA), particularly for seed/ planting materials. The other salient features of the Order include prohibition on import of commodities contaminated with weed/alien species and restriction on import of packaging material of plant origin unless treated. So far, twelve amendments of the Plant Quarantine (PQ) Order 2003 have been notified.

Issues relating to invasive alien species, microorganisms and GMOs are covered under the provisions of Environment Protection Act (EPA) 1986. The Environment Protection Rules cover activities involving manufacture, use, import, export, storage and research on hazardous natural microorganisms, all genetically

engineered organisms including microorganisms, plants and animals. However, it does not clearly state modality for restriction and prohibition of their potential threats to environment (Rana *et al.*, 2004; Khetarpal and Gupta, 2006; Khetarpal *et al.*, 2008).

Infrastructure. The Directorate of Plant Protection Quarantine and Storage (DPPQS) of Ministry of Agriculture is the apex body for implementation of plant quarantine regulations. Currently it has a national network of 35 plant quarantine stations at different airports (11), seaports (11) and land frontiers (13). The PQ Order 2003 puts all imported consignments in two categories (a) bulk consignments for consumption and sowing/ planting, and (b) samples of germplasm in small quantities for research purposes. Both kinds are subjected to different modes of processing in quarantine facilities (Khetarpal, 2004). The Plant Quarantine Stations under the DPPQS undertake quarantine processing and clearance of consignments of the first category (http://www.pla ntquaranti neindia.org). National Bureau of Plant Genetic Resources (NBPGR) undertakes quarantine processing of the second category, which includes all plant germplasm and transgenic planting material under exchange for which it has well-equipped laboratories, greenhouse complex. A Containment Level-4 facility has also been established for processing transgenics (Khetarpal *et al.*, 2001, 2004, 2006). The NBPGR also has a well-equipped quarantine station at Hyderabad, which deals mainly with export samples of the International Crop Research Institute for Semi-arid Tropics (Chakravarty *et al.*, 2005).

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/docfiles/appendix-8) and in germplasm and other research materials (Khetarpal *et al.*, 2001, Khetarpal and Gupta, 2006). The interceptions include pests that are not known to occur in India or have races/ biotypes/ strains not known to occur in India or are present on a new host or are from a country from where these were never reported before or are entirely new pest species hitherto unknown to science or are being reported to be present in India but have a wide host range (Table 4.2). Category (1) and (2) comprise exotic pests or variability not yet reported from India and signify the importance of quarantine in preventing their introduction into the country. The third and fourth category of pests are not expected in the sample as per the risk analysis which is literature-based and since no records are available on the pest/host their presence is unexpected and important from quarantine view point. The same is the case with the fifth category of pest, as these are new species hitherto unknown to science. The last category of pests with a wide host range are critical, and could become invasive in suitable environments.

Besides, the NBPGR is also responsible for ensuring that imported transgenic material is free from pests and terminator gene technology as per the PQ Order 2003. More than 8,000 samples of transgenic germplasm have been imported till date, and have been tested prior to release to be free from terminator gene technology. Besides, several interceptions have also been made including downy mildew caused by *Peronospora manschurica* in soybean from USA and *Cryptolestis ferrugieneus* in paddy from Singapore, which are yet not reported from India.

Table 4.2. Categories of Plant Pests Intercepted in Quarantine

Category	Pest intercepted	Host	Source/ country
1.	Not known to occur in India		
1.	*Peronospora manschurica*	Soybean	USA
1.	Cowpea mottle virus	Cowpea	Philippines
1.	*Heterodera schachtii*	Sugarbeet	Denmark
1.	*Anthonomus grandis*	Cotton	USA
2.	Known to occur in India but the race/biotype/strain not known to occur		
1.	*Helminthosporium maydis/race T*	Sorghum	USA
1.	Pea seed-borne mosaic virus	Broadbean	Bulgaria
1.	Burkholderia solanacearum biovar 3	Groundnut	Australia
3.	Intercepted on a host on which it was never reported before		
1.	*Alternaria zinniae*	Tobacoo	Japan
1.	*Pseudomonas syringae* pv *syringae*	*Hibiscus cannabinus*	Bangladesh
1.	*Aphelenchoides besseyi*	*Fraximus americana*	Australia
1.	*Bruchus ervi*	*Acacia brachustachva*	Australia
4.	Intercepted from a country from where it was never reported before		
1.	*Peronospora manschurica*	Soybean	Malaysia
1.	Heterodera zeae	*Vetiveria zizanioides*	Tanzania
1.	*Bruchus ervi*	*Acacia brachustachva*	Australia
5.	A new species hitherto unreported		
1.	*Drechslera pluriseptata*	*Eleusine coracana*	Zambia
1.	*Tylenchorhynchus neoclavicaudatus*	Potato tubers	USA
1.	*Polenchus minutus*	Palm plants	UK
6.	Known to occur in India but possess a wide host range		
1.	*Colletotrichum graminicola*	Sorghum	Nigeria
1.	*Claviceps purpurea*	*Avena sativa*	USA
1.	*Drechslera sorokiniana*	*Carthamus tinctorius*	Italy, USA

Source: After Khetarpal and Gupta (2008a).

4.4.2 Livestock and Poultry

The veterinary services are backed by suitable Central and State legislations. The Government of India legislation on Indian Veterinary Council Act (1984) regulates

veterinary practices in the country. Another federal legislation, i.e., The Livestock Importation (Amendment) Act, 2001 provides modalities of International Animal Health Certification. Entry of any livestock or livestock product is regulated by the Livestock Importation Act, 1898 (amended in 2001). These importations are allowed subject to compliance of health/quarantine requirements specified by the Government of India. The requirements are developed keeping in view the disease status of the exporting country and the species of livestock/type of product to be imported.

The regulation of import and export of livestock and livestock products, control of exotic disease and certification as per OIE regulations is done through the Animal Quarantine and Certification Services (AQ&CS) under the control of Department of Animal Husbandry Dairying and Fisheries (DADF) through Stations located at New Delhi, Mumbai, Kolkata and Chennai. These Stations are equipped to deal with all imports coming into the country. Their functions include testing of imported livestock and livestock products for quarantine purposes, export certification of livestock/livestock products as per the requirements of the importing country and as prescribed in the Terrestrial Animal Health Code of O.I.E. and/ or implementation of various provisions of the Livestock Importation Act, 1898 (as amended in 2001).

Besides these regulatory provisions, diseases like Bovine Viral Diarrohea (BVD) Malignant Catarrh Fever (MCF), Rabbit Hemorrhagic Disease (RHD) and Avian Influenza (AI) were recently diagnosed in imported livestock and poultry at entry point (NDMA, 2008b). Had they not been intercepted and effectively controlled, they could have potentially played havoc with our livestock and poultry.

For prevention and control of infectious diseases within the country, there are adequate legal provisions in all states of India. Each state enforces either its own Animal Disease Control Act and in case the state does not have an Act, the Act of a neighbouring state is enforced. The various State Acts provide that if an animal is believed to be affected with a scheduled disease, the owner should report the fact to the nearest veterinary practitioner. The Acts also provide for isolation of infected animal, disposal of carcass and infected material by burial or burning and disinfections of premises and vehicles, banning cattle fairs or markets and congregation of animals during outbreak. Non-compliance to provisions of the Law is deemed as cognizable offence and punishable with either fine or imprisonment or both. With a view to prevent transmission of disease organism to disease-free areas, the Act provides that animals should be moved to such disease-free areas through prescribed routes only and before entering, animals should be held for observation in a temporarily established quarantine station where, if necessary, they should be vaccinated and marked. The State Acts also provide for regulating entry of livestock and safeguarding disease-free areas and areas from where a particular disease has been eliminated, putting into place regulations as may be necessary to maintain the eradicated or disease-free status against a particular disease.

Operational framework. The National Veterinary Services are the responsibility of the DADF of the Ministry of Agriculture, Government of India. Subjects like Animal Quarantine, which provide health regulatory measures for import/ export

of livestock and livestock products, animal feeds and prevent inter-state transmission of animal diseases and control of diseases of national importance are responsibilities of the Central Government. The Central Government has a special responsibility for safeguarding the country against any new disease threats.

Sub-national veterinary services. The provision of Veterinary Services at field and laboratory falls within the purview of the State Governments. Such services are provided at the state veterinary hospitals and dispensaries and mobile clinics. Immunization against prevalent endemic animal diseases, animal disease reporting, surveillance and controlling disease outbreaks are important functions of the State Veterinary Services.

There is an inbuilt disease surveillance system in the country. At administrative level, each State comprises several districts; each District is divided into Tehsils/ Talukas, that are divided further into villages. A village is the smallest administrative unit at the grassroot level. Government Veterinary Services Units have well-knit infrastructure. Broadly, state headquarters and large district towns have Veterinary Polyclinics; each district headquarters has a Veterinary Hospital and each Tehsil headquarters has a Veterinary Dispensary. Veterinary Assistant Surgeons/ Veterinary Officers, who are Veterinary graduates, head such institutions. At the village level, veterinary services are provided by the Veterinary Aid Centres headed by Veterinary Field Assistants who are non-graduate para-veterinary personnel. Each Centre caters to the needs of 5-10 villages. Veterinary Assistants have one to two years training after matriculation in state-run Government Veterinary Training Schools. They impart clinical aid to farmers, and carry out livestock preventive vaccination against prevalent infectious diseases. Under provisions of State Disease Control Acts, livestock owner or any other government or private personnel functioning in the area having knowledge about onset of an infectious disease in the livestock is supposed to inform the Veterinary Aid Centre. This Centre, the first Disease Information Unit at the grassroot level, communicates disease outbreak information to Veterinary Dispensary/ Hospital, which passes on the information to the District Veterinary Officer, and the information further flows to the Director Veterinary Services. The State Director sends a monthly report to Govt of India. Reporting of disease as per the OIE list of diseases is presently an important function of this disease surveillance system.

There are 250 Disease Investigation Laboratories (DILs) in India for providing Disease Diagnostics Service. Many states have disease investigation laboratories at the district level. Each state has a state level laboratory, which is well-equipped and has specialists in animal health disciplines.

Beside DILs, there is one Central and five Regional Disease Diagnostics Laboratories (RDDLs), funded by the DADF of the Ministry of Agriculture. Each State Agriculture University/ Veterinary College also has disease diagnostic facilities. At the national level, the Indian Veterinary Research Institute (IVRI), especially its Centre for Animal Disease Research and Diagnostics (CADRAD) at Izatnagar (Bareilly) and the Disease Diagnostic Laboratory of the National Dairy Development Board (NDDB) at Anand, Gujarat, provides highly specialized and disease diagnostic services. To monitor ingress of exotic diseases a state-of-the-art laboratory exists under the Indian Council of Agricultural Research as a High

Security Animal Disease Laboratory (HSADL) at Bhopal with Biosafety Level-4 standards. To summarize, all state-level laboratories, Regional Diagnostic Laboratories, laboratories of the ICAR/ NDDB, and the HSADL are capable of diagnosing animal diseases.

4.4.3 Fisheries

In most countries, there is no clear distinction between terrestrial and aquatic animal health legislation. In cases where specific regulations for aquaculture exist, their enforcement is applied mostly as an emergency measure to deal with a specific problem, and not as the result of an established programme for surveillance and monitoring of the health status of cultured organisms. Several countries have specific legislation to regulate import and export of live-aquatic organisms and their products for use in aquaculture, for human consumption, or other purposes. Generally, these laws and regulations are in conformity with the rules of the OIE and Agreement on Application of Sanitary and Phytosanitary (SPS) Measures of the WTO (Kalaimani and Ponniah, 2007).

At the central level, the Indian Fisheries Act (1897), which is a century-old, is still in existence. The legal mechanism for control of legally and illegally introduced aquatic organisms and enforcement of the quarantine has to be made stringent. Provisions should be made for regulating movement of native aquatic organisms within India in the wake of disease outbreaks.

Draft legislation on "Live Aquatic Organisms' Importation Act 2006" has been proposed (Lakra *et al.*, 2006). These are based on the existing international agreements and codes of practices for trans-boundary movement of aquatic animals, the recommendations made in various consultations on invasiveness, disease diagnostics, risk analysis, emergency preparedness, capacity-building etc., and existing legal provisions adopted by different countries. An Act is inevitable to strictly implement provisions needed for safeguarding existing conservation and management of aquatic animal diseases and biodiversity in Indian fisheries (Kalaimani and Ponniah, 2007, Ayyappan *et al.*, 2008).

4.5 Biosafety Issues

The development of transgenic crops and their subsequent release to the environment have raised concerns among the public at large regarding their effect on safety, health and the environment. The possible risks are that transgenic phenotypes with altered fitness could change in abundance in the ecosystem, with unwanted effects on other species and on ecosystem integrity or that the ecosystems are affected indirectly by the transgenic plants. Besides, the transboundary movement of transgenics also pose a risk of introduction of exotic pests and diseases into new areas. The Cartagena Protocol on Biosafety of the Convention on Biological Diversity is a legally binding agreement to ensure adequate levels of protection for safe transboundary movement, transit, handling

and use of LMOs resulting from modern biotechnology that may have adverse effects on human health and conservation and sustainable use of biological diversity.

For effective compliance with the requirements of the Cartagena Protocol and to address biosafety issues, the Recombinant DNA Safety Guidelines issued by the Department of Biotechnology (DBT) of the Ministry of Science and Technology cover research in genetically engineered organisms, genetic transformation of green plants, rDNA technology in vaccine development, and on large-scale production and their deliberate/ accidental release into the environment. The Guidelines prescribe specific safety procedures for rDNA research, production, and release to environment. The Guidelines suggest compliance through voluntary as well as regulatory approach.

Besides, the rules for the safe use and release of GMOs have been notified under the EPA. The DBT reviews, permits and monitors the experiments utilizing GMOs and recombinant DNA products, while the Ministry of Environment and Forests (MoEF) implements their large-scale commercial use through its Genetic Engineering Approval Committee (GEAC). The biosafety guidelines prepared by the DBT in 1990, which have subsequently been revised, require that every organization involved in the work on GM plants needs to set-up its Institutional Biosafety Committee (IBSC) for interaction with the Government. Various Committees have been formed by the DBT with well-defined objectives for implementing biosafety guidelines. The Review Committee for Genetic Manipulation (RCGM), a national committee under the DBT, reviews ongoing R&D projects on GMOs, undertakes field visits of experimental sites and issues clearance for import/ export of GMOs for research and training. RCGM has also constituted a Monitoring-cum-Evaluation Committee to monitor 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 monitoring of experiments at their respective field sites (Khetarpal and Pandey, 2001, Gupta *et al.*, 2007). The plant biosafety issues and status of regulatory mechanism and preparedness with special reference to Asia-Pacific countries including India has been recently reviewed (Gupta *et al.*, 2008).

In fact, Bt cotton was the first transgenic crop released commercially in India following several years of biosafety testing to address all issues pertaining to its safety including the following.

- Environmental safety studies (pollen escape/ out-crossing, aggressiveness/ weediness, effects on non-target organisms, effect of Bt protein on soil microflora)
- Food safety studies (compositional analysis, allergenicity, toxicology, presence of Cry1Ac proteins in Bt cotton seed oil, feeding studies on cows, buffaloes, poultry and fish)
- Risk management studies (refuge strategy designed for Bt susceptible insects by growing of 20% non-Bt crops)
- Baseline susceptibility studies of bollworms populations collected from nine major cotton-growing states of India to Cry1Ac protein
- Multilocation field trials for cost-benefit analysis to prove effectiveness of Bt technology in reducing bollworm infestation, insecticide sprays and increasing yields and net incomes.

The events leading to Bt technology adoption (http://www.envfor.nic.in/divisions/csurv/geac/bgnote.doc), after meeting all the regulatory requirements for their commercial release and its on-farm performance highlights key role played by the DBT, MoEF, ICAR and seed companies like Mahyco and Monsanto to address biosafety issues related to GM crops.

Five years after the release of the first Bt cotton hybrid, in 2007 Bt cotton was grown in 6.2 million hectares by 3.8 million small and resource-poor farmers. Farmers who grew Bt cotton in 2005 also grew it in 2006, and that confirms its superior performance in the fields. Bt cotton increased yield by up to 50%, reduced insecticide sprays by half, with environmental and health implications, and increased income by up to Rs 12,500 or more per hectare. At the national level, increased farmer income from Bt cotton in 2006 was estimated at Rs 42 billion to Rs 8.5 billion, production almost doubled, and India, which used to have one of the lowest cotton yields in the world, is now an exporter of cotton. The story of Bt cotton is remarkable. With political will and farmer support in place, adoption is projected to continue increasing with Bt cotton plantings escalating from the current 66% to 80% or more. Another biotech product Bt eggplant is currently in advanced large-scale field trials, with expectations of approval in the near future (APCoAB, 2006, ISAAA, 2007).

4.6 Challenges and Strategies

- Regular review of all the legislations on plants and animals that are related to biosecurity needs to be done for adapting to the changing global scenario. An Act on Importation of Live Aquatic Organisms needs to be enacted on priority.
- The infrastructure for quarantine of plants, animals and fisheries need to be upgraded in terms of manpower and capabilities to bring it up to the international standards as the increase in imports and the stipulation of WTO-SPS Agreement has brought about additional challenges to be addressed. National standards need to be developed for overcoming Sanitary and Phytosanitary (SPS) related impediments concerning quality and compliance to international standards. Strengthening would be for both prevention of exotic pests and to check interstate spread of indigenous pests and diseases of plants and animal origin. This may be accomplished by effective implementation of domestic quarantine regulations/ certification services against certain important pests and diseases which have been introduced/ detected in the country recently, and which are likely to spread fast to areas free from such pests and diseases (NAAS, 2001). Establishment of quality control laboratories, their accreditation for monitoring microbial and chemical contamination and checking for pollutants, toxicants and adulterants will be needed, and the manpower requirement needs to be met for these specialized technical works.
- Pest risk analysis (PRA) enables quarantine services to technically justify new regulations, phytosanitary guidelines or safeguards, operational procedures, entry status of imported articles and resource allocations (Gupta and Khetarpal, 2004). The DPPQS has taken initiative to undertake PRA as per

the WTO-SPS norms but needs to be supported on the matter as far as expertise is concerned. This would be the most ideal way of warding the exotic diseases by rejecting certain imports with prior knowledge and/ or permitting imports with proper prophylactic treatments. The DADF through its Technical Committee on Animal Health is responsible to access risk analysis and prepare health protocols required as per OIE norms for import of livestock and livestock products. It may be emphasized that risk analysis procedures should provide a basis for biosecurity and not create barriers to trade.

- The risk classification of micro-organisms is outdated and needs to be seriously reviewed and updated, and also a network of containment laboratories of different Biosafety Levels may be established in different parts of the country on priority basis (Pradhan, 2008).
- The country has unorganized, primitive, subsidiary livestock-rearing systems which do not allow science and technology to permeate into them. Crop production systems are better placed than livestock-rearing even in small and marginal holdings, possibly because livestock rearing continues to be a subsidiary appendage to crop production and not a primary occupation with the majority of the farmers. There is a need to strengthen extension and advisory services in livestock sector. Due to awareness among masses to take balanced diet and due to change in food habits with more inclination towards non-vegetarian food, there has been phenomenal growth of poultry farming in India. Poultry sector is now a full-fledged industry. Due to rapid growth in this sector and with more and more poultry farms coming up, the role of biosecurity is much more.
- In a situation wherein stray cattle are allowed to roam freely and stray dogs and pigs abound streets, in cities and towns, biosecurity assurance is a formidable task. Though originating from bats and wolves primarily, the stray dogs continue to be a major threat of rabies in India. Similarly, migratory birds and sea-gulls are implicated in the spread of avian influenza. But, backyard poultry rearing in the backyards without wherewithal of disease control will continue to introduce and perpetuate problems such as avian influenza, which can be effectively put out only through organized means. Also, the potential threat of encephalitis from unhygienic swine rearing in the country cannot be overlooked.
- The major exports of animal origin products include milk powder, ghee, base products for sweets such as *khoa*, meat from poultry and buffaloes, egg powder, skins and hides. Unless production systems are put into healthy operational format, quality may suffer considerably (Balaraman, 2007).
- There is a need to establish vaccine banks and antisera banks for exotic pests and pathogens as well as new/ emerging native pests and diseases and stockpiling of antivirals so that sufficient vaccine stock of diseases like Rinderpest that have been eradicated is available for use in clean areas in the event of disease outbreak.
- Comprehensive plans for immunization of animals for those diseases that are vaccine preventable just like pulse-polio campaigns need to be initiated at the national level. Such an approach, if not eradicate, would surely bring down disease incidence, and over-time help in creating disease-free zones within the country. Such zones can act as export pockets for different countries.

- Seed is the basic unit of agriculture but the status of seed-health testing in the national seed certification programme is pathetic. Only for two crops, certification at seed level exists. For others, it is only based on field inspection (Khetarpal *et al.*, 2005). This is leading to spread of seed-borne diseases specially seed-transmitted viruses of important leguminous, solanaceous and other crops, which are further disseminated by insect vectors.
- The indiscriminate and excessive use of pesticides in intensive agriculture scenario is also leading to development of resistance among pathogens and pests, thus aggravating pest and disease situation, including residual toxicity problems. Spurious pesticides in the market are a major concern contributing to this problem. Continuous intake of low levels of pesticides is also detrimental to immune system of livestock and humans.
- Research needs to be reprioritized based on critical gaps identified to meet requirement for export and import. A few that need immediate consideration are as follows.
  - Survey and surveillance of disease/pests of national and international importance to have endemic pest database. Disease forecasting system particularly for economically important pests and diseases of plants and animals at the national level needs to be developed. Disease hotspots for major endemic pests need to be identified and mapped as has been initiated for a few crop pests like rice blast (Fig. 4.1).
  - Generation of a comprehensive epidemiological data on important pests to fix tolerance limits, to develop PRA as per WTO norms.

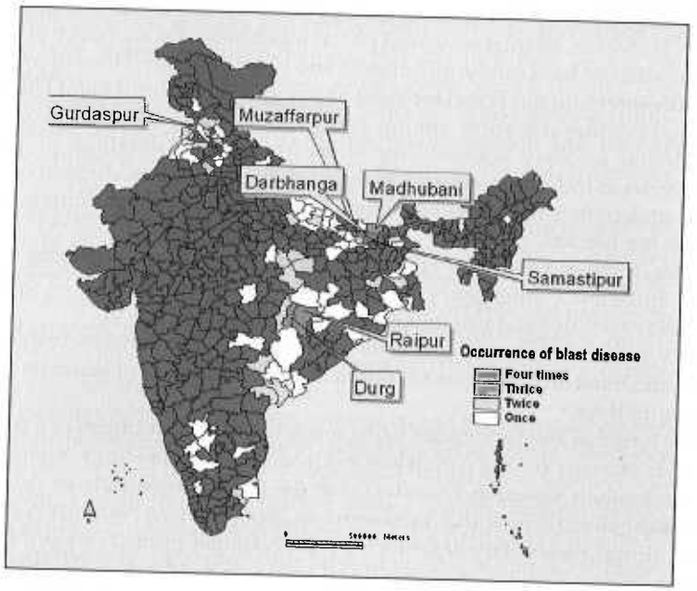

Fig. 4.1 Disease hotspots of rice blast during 1993- 2002
Source: T.P. Trivedi (Personal Communication).

- Study of genetics of resistance to major plant diseases; identify genes for resistance/ durability of resistance in important crops like rice, maize and grain legumes, by pyramiding both conventional and molecular genes for resistance. Also, efforts need to be made to unfold etiology of certain economically important diseases.
- Development of diagnostic protocols using molecular techniques for detection of exotic pests and their variants not easily detectable but otherwise of grave economic concern.
- Development of digitized keys for identification of exotic pests, especially keeping in view the fact that number of conventional taxonomists are gradually declining.
- Evaluation of biosafety risks in import of transgenics and beneficial biocontrol agents.
- Development of diagnostic protocols for seed certification for use by the certification agencies or seed-testing laboratories, as they are immensely important in trade (Khetarpal *et al.*, 2005)
- Development of methods to detect presence of transgenic/GM contamination (deliberate or inadvertent mixing of GM seed with non-GM seed) in unknown sample during quarantine processing.

- There is a need to develop database on biosecurity for policy-makers, administrators and industry groups. A website http://www.plantquarantineindia.org consisting of national database on legislation, quarantine procedures and methodologies, designed by DPPQS for information related to plant quarantine is available. Compilations on potential quarantine pests of various crop groups taken up at the NBPGR (Dev *et al.*, 2005). However, an internet-based portal mechanism for 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) to facilitate communication among countries in these sectors needs to be developed for easy accessibility of information. A database of aquatic pathogens in Indian waters and analyses on the risk of introduction of exotic pests and pathogens affecting aquatic ecosystem along continuous water-bodies are needed.
- Besides, there is a need for HRD for creating rapid response teams to deal with epidemic/ emergency situations, operational aspects of different biosafety facilities and upgradation of skills and proficiency.
- Finally, awareness about biosecurity in the interest of national security among scientific fraternity and general public is to be enhanced to generate respect for regulations.

At the national level efforts are being made for the development of a coherent biosecurity strategy for the country as evidenced by the meetings organized by MS Swaminathan Research Foundation at the National Institute of Advanced Studies, Bangalore (Bengaluru), in November, 2006, and by a National Workshop on Agricultural Biosecurity organized by the National Bureau of Plant Genetic Resources, Indian Council of Agricultural Research in March, 2008. It has been highlighted that there is a need for "convergence of the efforts of all Departments and Ministries" to develop a coherent biosecurity strategy (Khetarpal and Gupta, 2008b). It has also been emphasized that education, regulation, and social mobilization are three pillars to formulate a biosecurity strategy (Swaminathan, 2008). A road map to achieve an integrated agricultural biosecurity system is proposed as follows.

- It is imperative to develop and enforce "Ecologically Sustainable Development Strategies" to meet current needs without compromising ability of the future generations to meet their needs. An integrated plan for maintaining plant, animal including aquatic animal biosecurity and health, where all levels right from border to the farm, including the environment, need to be developed. The most important aspect is the management of disease and pest risks associated with import of plants, animals including aquatic animals, and products. The strategy to be adopted could be broadly categorized into preventive and curative types. The process of import risk analysis and application of vaccinations and quarantine measures are scientific approaches adopted as preventive strategy. While development of survey-surveillance, monitoring programmes, reporting and awareness generation on indigenous/ introduced pests would form a part of curative strategy. Thus, an Integrated National Agricultural Biosecurity System needs to be developed on priority, which may encompass elements of compliance to international norms, international linkages, surveillance, monitoring, quarantine and reporting, awareness, research and development, resources and funding. The implementation machinery for enforcing legislation and research back-up for disease/pest diagnostics and mitigation needs to be addressed on top priority.
- India is too large a country to be considered a single entity in matters relating to biosecurity. Zoning and compartmentalization will help demarcation of healthy production zones and protect their domestic and global commercial activities without apprehensions. For the livestock sector, imports of germplasm and semen of cattle, sheep, goats, swine, poultry parent stock, equine and canine are of primary concern. While strict scrutiny must be exercised as per international norms, familiarization and simplification of procedures will go a long way in encouraging entrepreneurs in their participation.
- The approach adopted for biosecurity needs to take into consideration major climate change events that are most likely to influence behaviour and distribution of plant pests and diseases. Factors like temperature increase are likely to increase over-wintering populations of pests and pathogens, changes to phenology of host may shift pest/ predator/ host dynamics, result in shorter life-cycles and more generations per year and the historical geographic ranges may shift southwards.
- The vicious cycle of low priority, low inputs and poor production performance needs to be broken by bringing in large-scale investments in this sector. There is an urgent need to introduce organized, intensive, commercial systems of farming and of livestock rearing with a sound back-up of linkages for processing, value-addition and marketing. Biorisks can be handled efficiently only to the extent to which our farm-operating systems are organized and monitored.
- The emergency action plan and rapid response team which are critical in case of outbreak of an epidemic need to be established. A network of various

stakeholders such as Ministries of Agriculture, Environment and Forests, Home Affairs, Health and Family Welfare, Defence, Food Processing, and Science and Technology need to work in close collaboration. A co-ordinated effort and synergy is all that is required to have an effective biosecurity system in the country (Swaminathan, 2008; Khetarpal and Gupta, 2008).

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