

Threats of Agricultural Bioterrorism to an Agro Dependent Economy; What Should be Done?

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Abstract

The economy of Pakistan is primarily dependent on its agricultural resources. Due to the lack of research regarding threat analysis of germ warfare in Pakistan, it is imperative for the agriculturists to understand the potential hazards associated with an attack on the cash crops that contributes heavily to the overall Gross Domestic Product (GDP) growth. Alarming terrorist activities such as 9/11 and many innovative terrorist strategies like Improved Explosive Devices (IED) in different countries, especially in Pakistan, has increased the potential of bioterrorism. Hence there is urgent need of security risk analysis and preparedness. State of the art research labs are not important for the effective production of biological weapons but certainly innovative strategies are required to effectively implement and counter a bioterrorist plan. Bioweapon infection to some staple crops such as wheat and maize can induce a significant loss that can take years to diffuse. This paper is concerned with the vulnerability of certain important crops in Pakistan that can be exposed as soft targets to certain bioterrorists and discusses the preemptive measures that should be undertaken immediately to prevent any sort of nefarious act of bioterrorism.

Keywords: Bioterrorism; Pakistan; Biological weapons; Preemptive measures

Introduction

A nation's economic progression and retrogression is the interplay between three important pillars which are agriculture, commerce and industry. Being an agricultural state; the importance of agriculture for Pakistan is several folds higher as compared to the rest. Generally good agricultural practices allow the state to feed its people, provide raw material to the industry and give a broad base to foreign trade and investments. Despite the fact that a major chunk of Pakistan's economy comes from agricultural and livestock resources, meager consideration is given by the government for improving its agricultural setup. Economic growth of Pakistan is directly linked to its agricultural industry. The agricultural sector accounts for 21% GDP growth and also consumes 45% of the country's manpower. About 62% of the population is directly or indirectly dependent on agriculture for their livelihood [1]. Certain biotic and abiotic stresses are known to cause enormous loss in agricultural productivity in some countries and Pakistan is one of them [2].

The performance of livestock, the single largest contributor (53.2%) to overall agriculture, grew by 4.1% in 2009-10, compared to just 3.5% last year [1]. Since Pakistan has an agro-based economy; this fact makes the country vulnerable to even greater negative consequences from agricultural bioterrorism. Empirical data regarding possible agricultural bioterrorism in Pakistan is not yet reported and the present paper is the first one dealing with the risks and threats associated with different cash crops of Pakistan. Internationally, there were programs by states to use toxin-based weapons for destroying the agriculture of other countries [3]. Even at the local level, people used parasitic species to destroy economically important plant species. An example of this is the use of an invasive species like *Cuscuta reflexa* [4].

The Vulnerable Agricultural Sector of Pakistan

Pakistan, known for its agricultural productivity in terms of wheat, maize and sugar cane, has nonetheless taken for granted the blessing of its abundant food supply. A country must not be complacent regarding food security and food safety. However, in the majority of 3rd world countries, and in Pakistan, such issues are given low priority. Recent advances in biotechnology pose a dual-use dilemma. There is a possibility of deliberate contamination, either from non-state actors or from hostile enemies' intent on destroying the main pillars of this country's economy. Hence, to avoid any untoward incidents, agricultural and food security should be given the highest priority. Anti-plant pathogens are of even greater concern: a few are listed in (Table 1). Deliberate contamination by any of them can cause severe economic loss which can have potentially devastating impact on the already drowning economy of Pakistan.

Important Crops of Pakistan

Pakistan has two principal sowing seasons for crops called "KHARIF" (April-June) and "RABI" (October-December). Generally, there are major and minor crops. Wheat, cotton, rice, sugarcane, potato, maize and chickpea are considered major crops while onion and other vegetables are minor crops [2,5]. Production of major crops in the year 2009 and their contribution to the GDP are summarized in (Table 2). In light of the above discussion, we can conclude that the prosperity of Pakistan is dependent on its agricultural resources which, if damaged accidentally or deliberately, may result in devastating circumstances.

Tactics related to sabotage of agriculture and livestock have been used strategically to inflict economic downfall such as in World War I (WW 1) when German soldiers willfully introduced anthrax and glanders into Romanian sheep, French cavalry horses, and Argentinean livestock destined for use by Allied forces [6].

Overview of Threats to Pakistan

Access to the Plant Pathogens for Non-state Actors is not difficult

Three mechanisms can be considered as a source of threats of bioterrorism:

Pathogens from the environment

Pathogens can be isolated and enriched from the environment by a group of moderately expert microbiologists. Zoonotic, enteric pathogens (*Vibrio spp*, *Giardia spp*, *Campylobacter spp*, *Salmonella spp*, and *Cryptosporidium*) can be isolated from the fecal remains of animals [7]. *Bacillus anthracis* is an extremely dangerous bio-warfare agent which can be isolated from soil. A recent study suggested that *Bacillus anthracis* was isolated from the soil samples (5-10 cm top) from the burial sites of animal carcasses [8]. *Yersinia pestis*, the notorious agent of plague, can survive for 16 months in soil [9] while another study claims that it can be viable for 1,700 days [10]. This pathogen can also stay alive in river water for 114 days [10]. All these studies indicate that one needs to properly monitor the previously infected areas of a pathogen. Lahore is one of the areas hit by the Dengue virus. In 2011 about 12,000 people were diagnosed with the virus and about 126 died in the first month of the outbreak [11]. The prolonged monsoon season makes the environment quite conducive to Dengue virus growth. The outbreak of Dengue has sparked a debate among the local population with speculation that such incidents may be intentionally caused. Whether an outbreak is intentional or unintentional, government should nevertheless take measures [1] to monitor the Dengue virus and [2] to critically monitor the samples which are used for diagnostics of Dengue. This last action is necessary because the dengue positive blood samples can be used to enrich the virus through simple viral isolation techniques [12].

Pathogens Introduced by State Enemies

Countries that are potential adversaries and possess enough knowledge to manipulate biological weapons are a resource for bioterrorism. Terrorists must either find an outbreak of the disease or otherwise purchase an infected animal/plant and isolate the relevant pathogen from that source. Many countries are suspected of having anti-agricultural pathogens [13] which may be exported to Pakistan either directly or via biological weapons contractors and middlemen. History is full of such examples when one state has used biological weapons against others. A famous, clandestine operation during WW1 was carried out by the Germans in order to kill the horses and cattle of its opponents using *Bacillus anthracis* [14]. The Japanese used the same agent against the Chinese in 1932 and 1945 [15,16]. The world experienced the official launching of a biological weapons program by Iraq: 25 missiles and 200 bombs laden with biological weapons were prepared in Iraq [17]. Ricin-rich letters were sent to Barack Obama. The poisoned-umbrella killing of Georgi Markov represents a rather worst-case scenario. There is every possibility that such tactics might be repeated on Pakistan to terminate the leadership of this country. Pakistan is already playing a vital role in the war against terrorism. The President and Prime Minister has already been the subject of suicidal attacks by terrorists. It's therefore imperative for the government to take steps in order to secure the people of the country by taking biosecurity measures. An incident regarding food security already happened in the police attack at of Raziq Abad Karachi in 2012 in which more than 100 policemen were hospitalized. Police in Karachi

are fighting a fierce battle against drug mafia and non-state actors. The exact details of the event are still not publically known.

Laboratory Security Breaches

Laboratory security breaches also pose a threat to agriculture. Some of the research labs working on plant diseases and isolation of pathogens could be exploited for the nefarious purposes by non-state actors. Although the strains isolated are not as dangerous as those found in nature, all research labs should be strictly regulated to not ship any such infected material across the country. Under the Environmental Protection Act (Section 31), the government of Pakistan already approved the national biosafety rules in 2005. These rules are subjected to the proper reviews from time to time. In addition, there are institutional biosafety committees that are linked with the national biosafety committee and advisory board to bring about strict regulations in accordance with International Standard Operations. So far, there are no documented reports of accidental pathogen release from the laboratories. Moreover, laboratories which manipulate potential hazardous agents to crops and livestock should enforce that only trained staff have access to it, by means of biometric control, such as fingerprint readers and iris readers.

Economic Losses to Agriculture and Livestock

Disrupting the food economy of a country is more attractive to bioterrorists because of the associated, secondary effects on humanity [18]. Massive economic losses are reported over the years by the mere quantity of a pathogen (or quantities of pathogens). Since 1912, there have been 12, documented cases involving either the use of pathogenic agents to infect livestock or contaminate food [19]. Natural, agricultural outbreaks can have severe consequences. For example, an outbreak of avian influenza resulted in the loss of \$86 million in Pennsylvania in 1983 [20]. The Foot and Mouth Disease Virus (FMDV) outbreak affected the Taiwan pork industry which resulted in the loss of \$7 billion [21]. The direct cattle death/sacrifice resulting from the mad cow disease outbreak in England caused a \$4.2 billion deficit [13]. Farmers happily slaughtered pigs as a preventive measure against the Classical Swine Fever (CSF) outbreak in England. Moreover, the export of pig-related products was suspended which resulted in an economic outcry [22]. In the light of these aforesaid examples, it is imperative for the government to take immediate steps for the protection of wildlife, agriculture and biodiversity. In a worst-case scenario of a bioterrorist event that would harm biodiversity, a complete species would be swept from the region leading to a marked, environmental imbalance. In a case where a particular species has a slow extinction rate, the ecosystem may re-balance itself over a certain period of time. But if a species goes extinct more quickly i.e. because of a deadly infection, a vacuum in the ecosystem will develop which will ultimately affect other inhabitants of the environment and disturb biodiversity. Genetically engineered, invasive, alien species present additional problems [23]. A highly integrated and scientific approach is required to both inform and mobilize government enough to take the necessary steps to combat agriculture-based bioterrorism. Pakistan has devised certain strategies to address all these potential sources of threat. For example, a list of suspected pathogens that are not allowed in import-exports has been created. In addition, the Strategic Export Control Division (SECDIV) was created on 14th September 2004 by the National Assembly. SECDIV is responsible for ensuring the safety and security of goods, materials, equipment's etc. The formation of SECDIV enables Pakistan to safeguard its national security but also

conform to its international obligations [24]. In addition, scientists have developed a voluntary code of conduct to ensure laboratory security and reduce the chances of misuse of biological resources. However, more planning is required to cope with biological weapons.

Use of Biological Weapons by Criminals

Biological weapons may be used by people for theological or ideological reasons but there is every possibility that such deadly biological weapons may also be used by criminals [25]. Hypothetically, criminals may blackmail an industry owner by threatening his industry with a biological weapon. Similarly, biological weapons might be used to gain a competitive edge by one industry over another. In another scenario, the drug mafia may intentionally contaminate “popular” as well as “common” drugs to take revenge on the government because of its anti-mafia actions [13]

Increased Risk of Bioterrorism via GM Crops

Genetic manipulation allows novel traits to be introduced into micro-organisms, animals and crops to improve poultry, livestock, and fish productivity and to increase the resistance of stocks to disease [26]. Plants can be genetically modified to improve nutritional quality, taste, appearance, drought tolerance, disease and insect resistance. Thus, GM crops are often considered as the solution to yield deficits. However, the potential of such technologies is controversial. There is significant uncertainty about the impact of genetic modification on environmental and human health, and questions about whether or not these products will provide a sustainable solution to food problems [27-30]. The risks and benefits associated with GM technologies are difficult to quantify [31]. The risks associated with GM crops are explained in three broad categories [32]:

- Interpretation of the science and specifically whether GMOs are inherently safe or inherently dangerous from a human and environmental perspective;
- Economic analysis and in particular how to evaluate the cost-and-benefits associated with GMOs;
- Socio-cultural impacts and biosafety implications around issues of food production and security, livelihoods, and human health;
- Possibility of irreversible modification in the environment using GMOs is a question still to be answered.

Impact of Threats on the Fragile Economy of Pakistan

Food Supply Chain

As a result of the lack of awareness among people and the absence of a properly functional, food regulatory authority, there are enormous possibilities for an outbreak (intentional or accidental) targeting food supplies. Considering the real threat of bioterrorism, the government should develop several different ways to secure the supply chains of food from pathogens. Deliberate contamination of raw or processed food can be another choice to create mayhem and cause massive casualties. Of late, numerous cases of food supply chain contamination have been reported, having severe implications. Contamination of milk with *S.Thypimurium* in the US (1985) resulted in 170,000 infections [33]. In 1999, consumption of contaminated beef with prions resulted in the deaths of 120 people along with economic damage of an estimated \$87 billion dollars. [34]. Contamination of salad bars with *S.Thypimurium* in the USA resulted in 751 infections

[35]. Pakistan is among the top, three, milk-producing countries (46,000 liters). This production contributes 11.7% to the GDP. 35-40 million people are directly associated with the dairy industry. Most importantly, 6.5 billion liters of non-processed milk is utilized for drinking purposes [36]. In as much as the dairy industry is one of the chief industries related to economic growth in Pakistan, any deliberate contamination of milk, directly or through feeding cattle contaminated fodder, can have a huge impact on the lives of thousands of people associated with the dairy industry (laborers, consumers and middlemen). The case is no different with poultry and beef. Over the period of 11 years, poultry consumption has risen by 239%, i.e., from 322 million tons (2000) to 767 million tons (2010-11) [37]. In as much as poultry and fish hatcheries are also important contributors to the economy, it is important for the government to look into their bio risk management and bio risk preparedness.

Bioterrorism: An Assessment of Pakistan’s Preparedness

Agriculture and livestock in Pakistan are susceptible to bioterrorist activities due to loopholes in the current, obsolete system of agriculture and livestock management. An attack may or may not happen. However, the development of infrastructure to cope with such scenarios is the need of the hour for sustainable economic growth and quality food production. Flexible infrastructure needs to be developed which will allow for consistent review and improvement of the virtually nonexistent system of crop and livestock protection.

Agro-terrorism and the Response of Industry

Bioterrorism events can affect the agricultural industry directly or indirectly. Plants are usually sown on large areas. Unfortunately, these are very difficult to monitor. Contamination with infectious pathogens can result in contamination of other crops within a few days. When contaminated stocks are found, they are immediately removed and destroyed. To determine whether seemingly uncontaminated stock is in fact contaminated or not, one may need the diagnostic services of a veterinary doctor or agriculturist. These are costly procedures to undertake. One may need to apply different chemo therapeutants to different plants and livestock in order to alleviate the infection. Different, systemic fungicides that are sterol biosynthesis inhibiting (SBI) and demethylation inhibiting (DMI) along with human resources will be required [38]. Similarly, for livestock one may need diagnostic kits, chemical reagents, veterinary doctors, etc., as well as the antibiotics required for treatment. These resources are very costly, especially for underdeveloped countries like Pakistan. In order to ensure their safety, these industries need to follow international standards (ISO 14001), but such efforts need resources which the developing countries may not be willing to provide. In addition, if contaminated, raw materials are knowingly or unknowingly used by an industry, the reputation of the industry will be damaged by being devalued and defamed. On the other hand, government should take action against industries not following ISO 14001 and such industries should be immediately forced to shut down. Restrictions and bans placed on those industries will lead to the loss of export markets. Most importantly, consumer confidence will be lost. Different kinds of financial penalties should be imposed on such industries involved in the act. Similarly, government should place bans on such industries for a particular period.

International Compulsions and Legislative Efforts by Pakistan

In order to keep the biosecurity and biosafety practices in place, Pakistan government has signed several international conventions and treaties and also tried hard to bring strict regulations in their laws pertaining to biosafety and biosecurity. Briefly, Pakistan is among the signatory of "Biological Toxin and Weapon Convention" (BTWC) since 1972. Pakistan has participated actively in the review conferences of BTWC and also urged different non signatories to become the signatory of the convention. Being a nonpermanent member of "United Nation Security Council", Pakistan has a compulsion to "The Resolution 1540" adopted by the Security Council in 2004. The resolution bounds Pakistan to refrain from proliferation of biological, nuclear and chemical weapons. Pakistan is also the member of "World Trade Organization" (WTO); that compels Pakistan under the "Agreement on the Application of Sanitary and Phytosanitary measures" (SPS agreement) not to import/export any contaminant that might be used for nefarious purposes intentionally against plants and animals. Beside the aforementioned treaties, Pakistan is the signatory of "Convention on Biological Diversity" (CBD) since 1992. CBD places Pakistan under the compulsion of "Cartagena Protocol on Biosafety" which is an international agreement about the safe and secure trans boundary movement of the Living Modified Organisms (LMO's). In terms of legislation, the country is committed to bring "Bio friendly Legislations" to protect its agriculture, livestock, people and environment. In 2005, under the section 31 of "Environmental Protection Act 1997" National Biosafety Committee (NBC) and National Biosafety guidelines have been proposed to reduce the chances of pathogen release from departments involved in such research. The "Export Control Act 2004" is a major step forward to regulate the import and exports. In spite of the existing praiseworthy legislation there is a need for a National Biosecurity Act as well. In addition a major problem of the under developed countries are the loose implementation of the laws. Therefore, it's imperative for the government to forcefully implement all the laws and regulations pertaining to biosafety.

Current Approaches for Dealing with Bio warfare and Recommendations for a Secure Pakistan

Technical Capacity-Building

The economy of Pakistan is dominated by its agricultural resources and livestock industries like dairy farming, fisheries, hatcheries and poultry. To the best of our knowledge until now, there is no documented case of a deliberate act of pathogen release. Considering a hypothetical scenario of infectious pathogen release, whether deliberate or non-deliberate, and assessment of the current level of technological capacity in Pakistan with economic constraints; the authors presents certain suggestions that can be used to fill the loopholes in the current system of monitoring of agriculture and livestock

Phytopathological and Zoo pathological Departments

Departments and societies that will ensure the creation of policies and legislation for the protection of agriculture and livestock should be developed under the command of the Ministry for Agriculture and Livestock and involve eminent scientists, technocrats, politicians, security and threat analysts. These departments will also be able to

establish an electronic, disease-reporting system and geographical information system to track the origins and locations of newly-emerged, pathogenic strains. These departments will also cooperate with other organizations such as Pakistan Biosafety Association, Pakistan Botanical Society, Pakistan Academy of Sciences, PASTIC and others to initiate funding for areas of mutual interest.

General Public Awareness and Advanced Training

Some of the diseases related to plants can be handled by local farmers but such individuals usually fail to deal with the exotic diseases. Therefore, veterinarians and agriculturists need specialized training to cope with any pathogen foreign to them [39]. Seminars and workshops should also be conducted in crop/livestock management and protection; contagious crop diseases; prevention against bioterrorism, and responding to agro-terrorism in order to raise awareness among young scientists and the general public. Such seminars, workshops and surveys have been conducted regularly to increase awareness about biosafety, biosecurity and dual-use education. Recently a workshop regarding biosafety and dual-use education was conducted at the Department of Biotechnology, Quaid e Azam University. In addition, surveys have been conducted with young scientists as well as teaching professionals about biosafety, biosecurity and dual-use education as a part of a project by Department of Biotechnology, Quaid e Azam University, Sandia National Laboratories and Landau Network-Centro Volta. Since Police and Rangers control the internal security in the country; it is imperative to train them regarding bioterrorism.

Diagnostic Labs

Pakistan greatly needs properly distributed plant and veterinary clinics. To date, most diagnostics are performed in research institutes. There is a great need of corporate and federal investment to increase the capabilities of these labs in terms of detection of the biological weapons intended to inflict economic chaos. The infrastructure of these labs should support cooperative extension. That is, they should be electronically connected to the rest of the disease-control laboratories at national and international levels. As a result of the long-standing desire by the people of Pakistan for provincial autonomy, the 18th Amendment bill (8th April, 2010) was passed by the National Assembly [40]. Based on the 18th Amendment, provinces are allowed to autonomously control various departments of state, including health and agriculture. The centralized Council of Common Interests (CCI), established by the 18th Amendment, is responsible for coordination on various state matters including agriculture and health.

Since reorganization in 2010 (Post devolution), agricultural affairs are performed by relatively new teams of people who lack the experience and expertise to handle critical situations such as bioterrorism events. Because the system is relatively new, the system itself is also vulnerable to bioterrorism.

Environmental Assessment Technology

Farm fields and crops are indeed very difficult to monitor because of their large areas. One may not be able to check every plant and animal. Unfortunately, most bioweapons are used as aerosols which are odorless, colorless, and tasteless, making it difficult to know whether they're present in the air [41]. A professional surveillance system at borders will be very helpful in order to track down any pathogen smuggled across the border. An efficient reporting system as well as consultancy desks for the health-care issues of people involved

in herding and agriculture can bring fundamental improvements. Such consultancies are already provided in the Netherlands [42]. Our technology of immediate pathogen detection in the environment is primitive. There is a great need to entice the funding agencies to develop automated, remote, sensing capabilities. Of late, partial success has been achieved in the development of those technologies that can detect pathogens in the environment. The TWOBIAAS (two stage rapid biological surveillance and alarm system) Biological Surveillance when commercialized can be an effective tool to detect airborne pathogens while monitoring larger areas. [43]

Material Transport and Quarantine Procedures

Effective and strict quarantine procedures need to be adopted at airports and sea ports. Any contaminated stock (which may be an infected plant, herd or livestock) must be isolated from the rest immediately after being initially identified. Any movement or shipment of a crop (GM and Non-GM) or animals should be thoroughly monitored only the stock cleared from quarantine should be allowed to be transported further. Suspect, contaminated stock should be destroyed as a first priority. Increased border security and secrecy can also be put into effect. Advanced transport systems (ATS) for livestock and agriculture should be introduced. ATS is characterized by using microchips on vehicles. The microchips contain stored information about the material of transport. The usage of ATS will reduce the chances of any possible transport of malicious material from place to place but ATS will need to be further refined in order to track pathogens. The quarantine laws should be reviewed periodically with the help of plant and animal pathologists.

Operational Bio risk Analysis

Basically, risk analysis can be divided into risk assessment, risk management, and risk communication [44] as follows:

- Risk assessment represents the understanding of the hazards and dangers and its possible consequences;
- Risk management is the systematic analysis of the policies regarding risk assessment; and
- Risk communication is the effective exchange of experience and opinions between assessors and managers of risk [45].

The Department of Agriculture and Livestock should systematically inculcate risk management procedures that include:

- Identifying hazards;
- Taking risk-controlling measures; and
- Critically evaluating and ensuring implementation of risk control measures.

A regional and national organization plan to cope with different scenarios and to identify the pathways that can be utilized by perpetrators will be effective.

Response to a Bioterrorist Activity

Response to a bioterrorist event can be problematic. An incident can lead to multiple responses from different sectors [39]. For example, for an announced attack by perpetrators, the first response will be from local law and enforcement agencies. But for an unannounced release of a pathogen, the first response will be from health-care personnel [39]. Therefore, response to bioterrorism demands rapid and effective diagnostic capabilities and a multi-

disciplinary approach. There is a great need to vaccinate animals against various infections such as Foot and Mouth Disease (FMD). The vaccines are available and are safe to use. Vaccination will curtail chances of zoonosis. The post bioterrorism event scenario will be complex for a country like Pakistan.

Most likely the first responders to a case of agro- and livestock-terrorism will be the laborers associated with these industries. They include people like agronomists, agriculturists, farmers, poultry keepers, etc. All of them will have first-hand experience with the event. There is a great need to train these individuals about response mechanisms and planning. Short courses or diplomas in the field of risk management should be made mandatory for the people who are involved in health care, veterinary and agricultural industry but also for people in the law and enforcement agencies. In addition, the government should conduct free seminars, trainings, workshops and internet-based communications for disease control.

The role of the National Disaster Management Authority (NDMA) in Pakistan is important: NDMA personnel can be considered the 2nd responders to an event. Under the chairmanship of the Prime Minister, the NDMA is an independent body empowered to make decisions in an emergency situation. The NDMA should therefore come up with rapid, emergency plans for risk control. The reporting system has been improved with establishment of district-level, disaster management authorities which will be functional soon [46]. The complete organizational structure of the NDMA is provided in (Figure 2). If there is a bioterrorist event, the NDMA should make available all the necessary plans and manpower for confining the risk and effecting environmental cleanup. In addition, the NDMA should be provided with sufficient budget in the fiscal year so that it could perform its activities without any unwanted pause. At the same time, government needs to allocate a sufficient biodefense budget to prevent any incident. Government should ensure the commitment of research institutes and labs to the Biological Weapon and Toxin Convention (BWTC). All the pro-active, preventative, preparatory, containment and aftercare measures with the government bodies involved are summarized in (Figure 3).

Future Directions: Towards Good Governance in Pakistan

There are several governance issues (e.g. quarantine, awareness raising, narco-terrorism, etc.) which if properly addressed may reduce chances of mishaps. Hence, the role of the government is to oversee development and capability strengthening in both technical and social quarters and in ethical issues in biotechnology and life sciences. Though Pakistan is pro-active in signing all international related conventions (e.g. BTWC) and has also approved biosafety guidelines, monitoring in all its aspects remains very weak. Hence, there is a need to create laws and regulations, as necessary, making sure to have a healthy balance in the progression of science and regulatory hurdles [47]. Pakistan Higher Education is considered a success story which has not only produced high-quality Ph.D. scholars and scientific publications, but has also established a mechanism to oversee ethical issues in research (Figure 1). Hence this discourse is a step toward acquiring knowledge and understanding of issues regarding technology and technology's effects on society which also encourages activities that help to generate healthy debates among various stakeholders and the public [38].

Conclusion

Pakistan is among those countries which are largely dependent on their agricultural resources for sustainable and progressive economic growth [39,40]. Due to the 9/11 incident, Pakistan's security and vulnerability have become of paramount importance inasmuch as Pakistan served as a front-line ally in the war on terrorism. Pakistan strongly supports global cooperation toward the war on terrorism, making itself a strong adversary of terrorists in Afghanistan. Pakistan is the subject of viable threat from terrorist organizations for being a front-line state in the ongoing war. There is a strong possibility that such terrorist organizations may practice germ warfare tactics against Pakistan. In a scenario like that, agricultural security should not be taken for granted. To the best of our knowledge this manuscript is the first of its kind to address the agricultural security of Pakistan.

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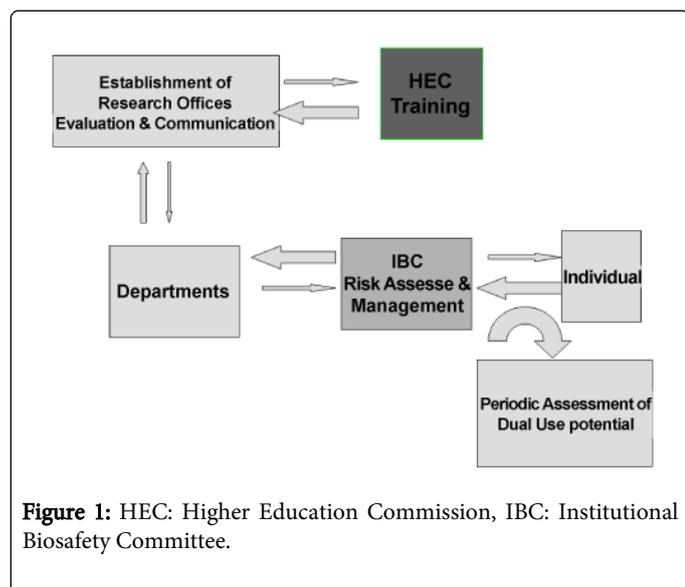


Figure 1: HEC: Higher Education Commission, IBC: Institutional Biosafety Committee.

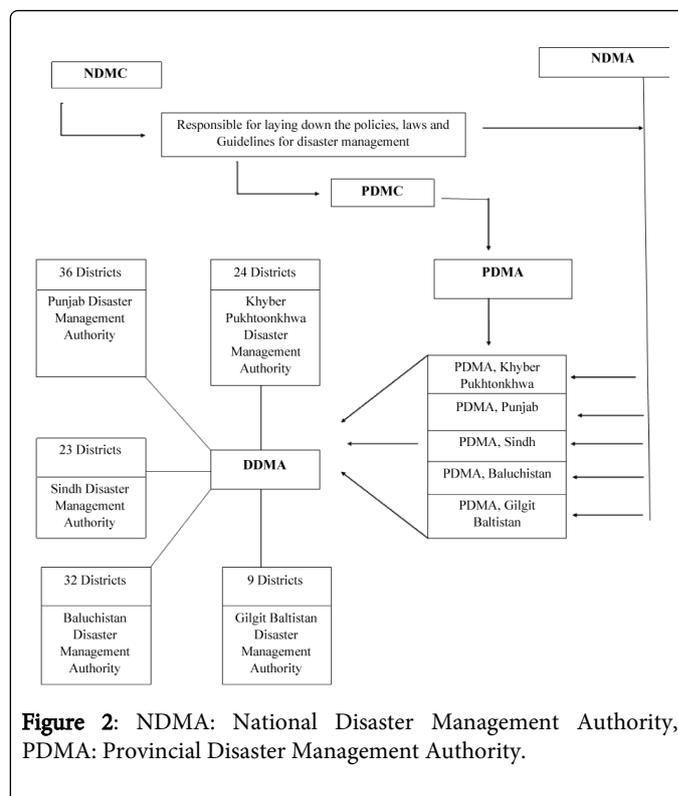


Figure 2: NDMA: National Disaster Management Authority, PDMA: Provincial Disaster Management Authority.

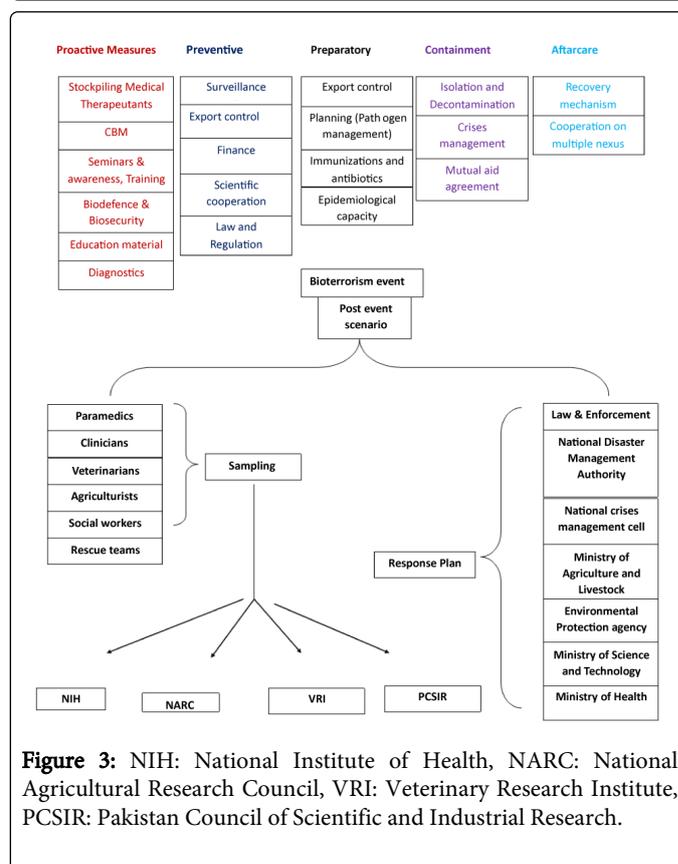


Figure 3: NIH: National Institute of Health, NARC: National Agricultural Research Council, VRI: Veterinary Research Institute, PCSIR: Pakistan Council of Scientific and Industrial Research.

Potential Phytopathogen	Hosts /Disease	Symptoms	Literature cited
<i>Colletotrichum coffeanum</i>	Green Coffee Berry	Dark and sunken spots covering the whole cherry, appear pinkish after spore production	[48,49]
<i>Dothistroma pini</i>	Established pine trees-Needle Blight	Yellow to brown spots on needles, Black fruiting bodies	[49,50]
<i>Erwinia amylovora</i>	Majority of Family of Rosacea (Cydonia, Pyrus, Prunus)	Wilt and Death of flowers, Withering and Death of shoot and twigs	[49,51]
<i>Ralstonia Solanacearum</i>	Tomatoes, Potatoes, solanaceous crops	Wilting, stunting, yellowing etc.	[49,52,5]
<i>Puccinia graminis</i>	365 species of cereals and grasses	Small chlorotic fleck, Pustules, powdery masses of the spores on plant	[49,6]
<i>Fiji disease Virus</i>	Sugarcane	Leaf galls, death of meristematic tissues, stunting	[49,7]
<i>Tilletia indica</i>	Wheat, rye	Reduced number of spikelets, dwarfed, dusty, brown or black spore masses	[49,8]
<i>Xanthomonas albilineans</i>	Sugar cane	Wilting, Necrosis	[49,9]
<i>Xanthomonas compestris</i>	Solanum spp, Nicotians, Capsicum, tomatoes, leguminous plants	Rotting and wrinkling of seeds, Hilum discoloration, lesions etc.	[49,10]
<i>Sclerotinia sclerotiorum</i>	408 plant species, canola, cabbage, apricot etc.	Wilting of leaves, lettuce drop, light color	[49,11]
<i>Peronospora hyoscyami</i>	Tobacco	Localized lesions, yellow spots, light brown necrotic areas	[49,12]

Table 1: Potential anti plant pathology.

Major Crop	Production in 2009	Contribution to GDP (%)
Cotton	12698 bales	1.8
Sugarcane	49373 tons	0.8
Rice	6883 tons	1.4
Wheat	23864 tons	3.1
Ministry of food and agriculture, federal bureau of statistics		

Table 2: Contribution of cash crops (food/nonfood) to overall economy of Pakistan.

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