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AGRICULTURAL RECOVERY RESPONSES IN POST-PANDEMIC SITUATIONS ARISING FROM MAJOR ANIMAL AND PLANT DISEASES

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The authors' views expressed in this publication do not necessarily reflect the views of the United States Agency for International Development or the United States Government.

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CHAPTER ONE: INTRODUCTION – MAJOR FOOD SOURCES AND ASSOCIATED ANIMAL AND PLANT DISEASES

INTRODUCTION

With increasing globalization, the persistence of trans-boundary animal diseases (TADs) and plant diseases in the world poses a serious risk to world animal and plant agriculture and food security and jeopardizes international trade. In recent decades, the world has experienced devastating economic losses to farmers from major outbreaks of TADs, such as

- Foot and Mouth Disease (FMD) epidemic in Great Britain (2001),
- Classical Swine Fever in the Caribbean and Europe (1996–2002),
- Rinderpest (RP) in Africa in the 1980s,
- Peste des Petits Ruminants in northern Kenya, India and Bangladesh,
- Contagious Bovine Pleuropneumonia in Eastern and Southern Africa (late 1990s),
- Rift Valley fever in the Arabian Peninsula (2000).
- Stem Rust (Race Ug99) of wheat in Eastern Africa (1999)
- Brown Stripe Downy Mildew of maize in India during the 1970s
- Brown Spot of rice in India (causing the Bengal famine of 1942)
- Bacterial Wilt of solanaceous crops in Latin America and South East Asia

The challenge of controlling trans-boundary pests and diseases has become greater, and the ability to contain or eliminate such incidents has failed to keep pace. This has occurred in part because of the increasing need to integrate international efforts and consider private sector capacities in the design and establishment of effective protection services. Although the involvement of more stakeholders can lead to more effective and efficient decisions, it also complicates and lengthens the process of implementation. In spite of these trends, national efforts still drive decisions regarding protection against pests and diseases and responsibility rests primarily with national agencies. A combination of the following national and international factors affects countries in their efforts to combat trans-boundary diseases:

- International trade, which has led to: more and faster trade (more host material, more packaging and more opportunities for long-distance "hitchhiking"); trade in fresh horticultural products, floricultural products, live animals and fresh animal products; new travel and trading routes (e.g. from South Africa to Southeast Asia; from Southeast Asia to South and Central America).

- Conflict and civil unrest, which has led to: difficulties in enforcing quarantine in many areas;- military and refugee movements; a breakdown of institutional support for quarantine and loss of input supply;- increased smuggling; inflows of food aid, which may be contaminated; difficulties in obtaining access to border areas because of landmines and other hazards, thus making these areas difficult to survey.
- Concern about the effects of pesticides on the environment and human health.
- The privatization and deregulation of animal and plant health services in some countries.

ASSESSING THE IMPACTS

The impact of animal and plant diseases on agriculture can be assessed in quantitative terms - lost revenues; costs of eradication, decontamination, vaccination[1] and restocking; and the numbers of affected farms, animals and humans. However, the effects are of multi-dimensional character and the societal effects are sometimes overlooked. While export trade losses in a developing country may be small in terms of the dollar amount, the impact upon its pre-epidemic market share is inevitably greater and more persistent. Other impacts on human health and community stability tend to be more visible and last longer in developing countries, particularly at the village level where animals are husbanded primarily for the benefit of the immediate family, often in impoverished circumstances. These economic and social effects can be classified as "direct," "ripple" (impact on the industry's upstream and downstream activities), "spillover" (impact on other sectors), "long-term", or "remote."

DIRECT EFFECTS

The most direct economic impact of animal and plant diseases is loss of production and/or productivity, and ensuing income losses for farmers. Direct losses are the result of the disease itself, or from animal health measures (stamping-out policies).[2] Direct costs are generally well below the indirect costs of diseases and are directly linked to the rapid containment of outbreaks: case studies have shown that early detection and the implementation of appropriate measures in the event of an outbreak are essential to help minimize direct losses as much as possible.

COLLATERAL DAMAGE (RIPPLE EFFECTS)

The agricultural sector plays a significant role in the economic development of many countries. The production of meat and plant-based food items generates income, jobs, and foreign exchange for all

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[1] The lack of vaccines, or the lack of money to afford vaccines, or the logistical problems of trying to use temperature-sensitive vaccine in remote rural African (and South American and Asian) communities also contribute to the overall impact in developing countries. In the example of Northern Ireland, the government immediately moved to a vaccination program, offering it free to poultry owners in quarantine areas and at cost to those who lived in areas not yet affected by the New Castle epidemic. In Zimbabwe, where a 1994-95 epidemic of Newcastle caused the death of as many as one million broilers in a single week and wiped out entire small farmer chicken populations, comprehensive vaccination is a fairly new concept requiring the support of international agencies and donor groups.

[2] The human mortality rate from bird flu in Indonesia is the highest in the world (108 as of May 2008) Avian influenza has become deeply entrenched in Indonesia with 31 out of 33 provinces being infected. The virus is endemic in Java, Sumatra, Bali and southern Sulawesi with sporadic outbreaks reported from other areas. Since the first outbreaks in 2003 avian influenza has spread rapidly across Java into Bali, Kalimantan and Sumatra. In 2006 the virus spread further east infecting Papua and much of Sulawesi.

stakeholders in the agribusiness industries. Consequently, an epidemic or epizootic can affect the industry's upstream (inputs, genetic resources) and downstream activities (slaughterhouses, harvesting, processing, marketing) in terms of jobs, income for the stakeholders in the industry, or market access.

A survey by the Food and Agriculture Organization of the United Nations (FA0) on avian flu revealed that in the most seriously affected regions of Indonesia, 20 percent of permanent workers at industrial or commercial farms lost their jobs.[3] Similarly, an outbreak of contagious bovine pleuropneumonia in Botswana led to the destruction of more than 300,000 animals in the most seriously affected province, and the immediate closure of the export slaughterhouse, which employed 200 persons. Owing to the catalyst role of livestock raising in the rural economy as a whole, the costs of the indirect effects of these measures were later estimated to be seven times higher than the costs caused by direct losses. In Vietnam, 60 percent of the poorest segment of the population, for which poultry farming accounts for six to seven percent of household income, is particularly vulnerable to income losses caused by avian flu.

SPILLOVER EFFECTS

For most rural societies, animal husbandry and horticulture contributes directly and indirectly to food security and to nutrition as a source of quality protein, vitamins and trace elements, and commercially tradable products. Certain diseases could have significant repercussions on food supply and the nutrition of poor communities that do not have readily available substitute products, which could therefore lead to famine (rinderpest for example). In 1977/1978 a major Rift Valley fever epidemic in Egypt resulted in 200,000 human cases and 600 fatalities. Twenty years later, a new epidemic affected over 500,000 persons in East Africa, and 500 persons succumbed to the hemorrhagic form of the disease.

Another category of economic impact is linked to individual strategies to avoid contamination—or to survive possible contamination. The example of the severe acute respiratory syndrome (SARS) clearly shows the sharp drop in demand in the services sector (tourism, public transport, retail trade, hospitality and food services) resulting from the combined efforts of individuals to avoid any close contact. Based on the experience with severe acute respiratory syndrome in South-East Asia, the World Bank thinks that an avian flu pandemic could result in a 2 percent loss of the world's gross domestic product and cost the world economy US$800 billion in the space of one year. The losses are difficult to calculate and would undoubtedly be much more significant in light of the extremely high mortality rates in developing countries which do not have good health care systems.

The impact of animal diseases on the tourism and leisure sectors could also be quite significant. The negative effect of foot and mouth disease in the United Kingdom on these two sectors amounted to US$49 billion because of restrictions on access to rural areas and represented more than half of the total cost of the disease.

LONG-TERM EFFECTS

It is difficult to calculate the cost of the public's loss of confidence in animal industries in their countries, or of an importer country towards the Veterinary Services of the exporter country.

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[3] World Bank conversation with Lead Livestock specialist Dr. Le Gall posted on www.worldbank.org.

The long-term costs of a slow response are rarely taken into account. Economic analyses focus primarily on the effects of the outbreaks and rarely take into account the long term effects of an endemic situation (characterized by less virulent outbreaks which recur for several years). This is the case of classic swine fever in Haiti where recurrent outbreaks reduced the usage rate by 10 percent, which for pig farmers meant a loss of revenue of US$2.7 million per year. With major crisis, long-term impacts would make themselves felt, since the additional costs of financing prevention and control measures would lead to an equivalent reduction in savings and investments.

REMOTE EFFECTS

Assessing the global impact of an animal disease on international markets would warrant a framework of analysis which would connect markets in spatial terms as well as by products.

It must be pointed out that the crises could have a cumulative impact, particularly since they are amplified by the effects of globalization. For example, the analysis of the global impact of the avian flu crisis in Europe is complicated by recent outbreaks of foot and mouth disease in Brazil, the largest global exporter of beef and poultry. It is therefore easy to imagine what the combination of these two events would mean in terms of the upward push of prices of all meats, similar to what occurred in 2004 with North American beef and bovine spongiform encephalopathy (commonly known as Mad-Cow Disease). The European Union, a net importer of beef, especially from Brazil, would see an increase in the price of beef in its internal markets stemming from the embargo imposed on Brazilian beef because of the foot and mouth disease.

REDUCING THE CONSEQUENCES

It is imperative to prepare a comprehensive and sustained program of demand-based research, active surveillance, vaccine trials, vector control and grassroots education that can reduce the losses and lessened the impact of an epidemic. The same could be said for any infectious disease not yet controlled. These are the tools that are used primarily by developed countries. These are the tools needed by developing countries. Currently, for developing countries it can be safely stated that much of the planning requires a long-term approach.

OBJECTIVES OF THE ASRP

The objectives of the ASRP are to provide a framework for the response and recovery options to mitigate the effects of the most harmful animal and plant diseases. As there have been decades of research conducted in this area, a literature research was conducted. The background literature, relevant websites and important reports are listed in Annexes A and B. The relevant website sources are provided to establish web-links to the USAID website and access links to "must- read" manuals and reports. Chapter 2 outlines a framework for recovery options, and chapters 3 and 4 summarize the most important TADS and plant diseases, respectively. The transboundary plant and animal diseases reviewed here include:

> *Those that are of significant economic, trade and/or food security importance for a considerable number of countries; which can easily spread to other countries and reach epidemic proportions; and where control/management, including exclusion, requires cooperation between several countries.*
>
> Definition recommended by FAO EMPRES Expert Consultation, 24-26 July 1996 (www.fao.org/WAICENT/FAOINFO/AGRICULT/AGA/AGAH/EMPRES)

CHAPTER TWO: A FRAMEWORK FOR RESPONSES TO ANIMAL AND PLANT DISEASES

This chapter presents a Framework for responding to plant and animal diseases which USAID staff can use as guidance in developing investment strategies and projects aimed at agricultural sector recovery. The remainder of this section provides an overview of the key elements of the Framework.

Every year millions of people become ill because of food borne and zoonotic diseases caused by bacteria, parasites, viruses and unconventional agents. These diseases impact significantly on human health as well as household and livestock productivity. At the same time, numerous other plant and animal diseases cause famine and/or nutritional deficits which have a major impact on human health and economic well being.

This framework addresses three separate, but often related categories of animal and plant diseases:

- Non-Zoonotic Diseases: Diseases that afflict a specific species or group of animal species but do not have the ability to infect humans.
- Zoonotic Diseases: Diseases that originate in animals but have the capability of infecting, sickening and sometimes killing humans.
- Plant Diseases: Diseases that are linked to a specific crop or sub-group of plants. Plant diseases are not a source of zoonoses.

The Framework of Preferred Responses will provide USAID field staff with a set of possible actions that USAID could take to mitigate or eliminate either the diseases themselves or significantly reduce the impact of these plant and animal diseases on food security and human health.

There are three elements of the framework: prevention, response and recovery.

The Prevention element includes the activities and measures that are taken to avoid or prepare for an outbreak or pandemic. These include training, contingency plans, investments in research and infrastructure. Response consists of the actions that take place during the outbreak or pandemic and include options such as rapid response teams, quarantines and animal culling. The Recovery element demonstrates alternatives and choices to be considered after a catastrophic loss to the agricultural sector. While the three elements appear linear, the process is actually a cycle. The final step of any recovery plan should be to prepare surveillance and prevention steps to avoid another outbreak and develop updated response options. A complete cycle of prevention, response and recovery encompasses a complete recovery plan.

In the analysis below, the Prevention, Response and Recovery elements will be presented for each of the three animal and plant disease categories (non-zoonotic, zoonotic and plant).

THE ROLE OF THE PRIVATE SECTOR

A successful framework for animal and plant disease prevention, response and recovery relies on the participation of the private sector. Implementing prevention strategies against and outbreak of animal and plant diseases is better put into practice by the private sector, in coordination with the public sector. Through producers and stakeholders along the value chain, the private sector has a vested interest in disease prevention and response from an "asset protection" point of view and as a "market protection" perspective. As stakeholders in the private sector have the most to gain or lose, they are taking leadership and responsibility in prevention strategies, in coordination with international organizations and through public-private partnerships.

- Public-private partnerships in the prevention of animal and plant diseases need to:
- Focus on shared interests
- Identify mutual benefits
- Clearly articulate goals, objectives and responsibilities
- Adapt to changing realities and needs
- Can withstand public scrutiny

The ideal role for the private sector is to take the leadership in prevention strategies and collaborate with the public sector and international organizations to coordinate resources, respond quickly to threats and adopt new technologies.

THE ROLE OF INTERNATIONAL ORGANIZATIONS

International Organizations and Animal Diseases

It is important for USAID staff to recognize the role and specialized services that many international organizations provide when developing response actions. The primary task of the public sector and international organizations is to provide information and technical assistance on animal disease, transmission and research. Understanding their function and how they contribute will result in a stronger response plan. The responsibility for preventive and in many cases post-recovery efforts in livestock sectors rests with the private sector and specific agencies that regulate markets and food quality. The new animal health challenges demand more dynamic approaches provided by the private sector to the acquisition and dissemination of knowledge about the diseases, the standards, the regulation and strategies for their effective prevention and progressive control. It is imperative that the management of animal health not merely depend on on-the-farm technical service, but above all, encompasses an international collective responsibility.

The **Food and Agriculture Organization- FAO** (www.fao.org) has established the Emergency Centre for Transboundary Animal Disease (ECTAD) Unit in FAO Headquarters, to coordinate the response at the global level. FAO works closely with the OIE for global support. Crisis Management Centres (CMC) are integrated in centralized and decentralized ECTADs, for rapid and efficient intervention. The Global Early Warning and Response System (GLEWS) provides the CMC headquarters with information related to the rapid identification of new outbreaks. The focal point of the FAO response is the Emergency Centre for Transboundary Animal Diseases (ECTAD). This comprises the Animal Health Service, Animal Production Service and Livestock Policy Branch of the Animal Health and Production Division together with Emergency Operations Service of the Emergency Operations and Rehabilitation Division, under the direction of FAO's Chief Veterinary Officer. Partners include OIE, WHO, regional organizations, national governments, donors and international research centres. The response follows the WHO/FAO/OIE Global Strategy and the overall coordinating mechanism of the Global Framework for the Progressive Control of Transboundary Diseases (FAO/OIE GF-TADs).

The **World Organization for Animal Health- OIE** (www.oie.int) is the intergovernmental organization responsible for improving animal health worldwide. It is recognized as a reference organization by the World Trade Organization (WTO) and has a total of 172 Member Countries and Territories (as of January 2008). One of the OIE's main missions is to ensure the transparency of the world animal health situation. The OIE launched the new World Animal Health Information System in January 2005 and has as function for members to notify cases of the main animal diseases detected in their territories, including zoonoses. The World Animal Health Information System, better known as WAHIS, is an internet-based computer system that processes data on animal diseases and then informs the international community, by means of "alert messages", of relevant epidemiological events in OIE Members. Whenever an important epidemiological event occurs in a Member country, the Member must inform the OIE by sending an Immediate Notification which includes the reason for the notification, the name of the disease, the affected species, the geographical area affected, the control measures applied and any laboratory tests carried out or in progress.

International Organizations and Plant Diseases

Plant disease is an international concern, which does not recognize boundaries. International organizations provide role of securing common and effective action to prevent the introduction and spread of pests and diseases of plants and plant products and to promote measures for their control. Some of the international organizations that participate in the network of plant health include:

The **Consultative Group on International Agricultural Research- CGIAR** (http://www.cgiar.org/) is a strategic alliance of members, partners and international agricultural centers, many of which focus on crop and plant science. The research centers that conduct research on plant diseases include: West Africa Rice Center (WARDA); CIAT - Centro Internacional de Agricultura Tropical; CIFOR - Center for International Forestry Research; CIMMYT - Centro Internacional de Mejoramiento de Maiz y Trigo; CIP - Centro Internacional de la Papa; ICRISAT - International Crops Research Institute for the Semi-Arid Tropics; IFPRI - International Food Policy Research Institute; IITA - International Institute of Tropical Agriculture; and IRRI - International Rice Research Institute.

The **International Society for Plant Pathology- ISPP** (http://www.isppweb.org) promotes the world-wide development of plant pathology and the dissemination of knowledge about plant diseases and plant health management. The ISPP sponsors an International Congress of Plant Pathology, at intervals of 5 years, and other international meetings on plant pathology and related subjects.

The **International Plant Protection Convention- IPPC** (https://www.ippc.int) is an international treaty to secure action to prevent the spread and introduction of pests of plants and plant products, and to promote appropriate measures for their control. It is governed by the Commission on Phytosanitary Measures (CPM) which adopts International Standards for Phytosanitary Measures (ISPMs).

The **Food and Agriculture Organization- FAO** (www.fao.org) established the Emergency Prevention System (EMPRES) in 1994 for Transboundary Animal and Plant Pests and Diseases in order to minimize the risk of plant disease emergencies in developing countries. Initial priority for plant diseases/pest has been given to the dessert locust. The FAO also provides research on crop disease, training, and support to international initiatives on the control of plant diseases.

The **International Union of Biological Sciences- IUBS** (www.iubs.org) is a nongovernmental, nonprofit organization, established in 1919. Objectives are to promote the study of biological sciences; to initiate, facilitate and coordinate research and other scientific activities necessitating international, interdisciplinary cooperation; and to ensure the discussion and dissemination of the results of cooperative research, particularly in connection with IUBS scientific programs.

The **International Seed Testing Association- ISTA** (http://www.seedtest.org) publishes standard procedures in the field of seed testing, with member laboratories in over 70 countries. ISTA produces internationally agreed rules for seed sampling and testing, accrediting laboratories, promoting research, and providing international seed analysis certificates, training and dissemination of knowledge in seed science and technology to facilitate seed trading nationally and internationally.

ANIMAL DISEASES

NON-ZOONOTIC DISEASES

There are literally hundreds of non-zoonotic diseases that affect animals throughout the world. In this paper the focus is on non-zoonotic diseases that affect domesticated animals that represent a significant source of food for humans. Therefore particular attention needs to be paid to diseases affecting cattle, poultry and swine. Rinderpest, for example, is an infectious viral disease affecting cattle, pigs, domestic buffalo, and certain species of wildlife. Newcastle disease is a common, worldwide plague affecting poultry, the fast growing source of meat protein in the world.

While non-zoonotic diseases do not carry the potential for human pandemics, they do pose a serious problem for small and medium sized producers who rely on their livestock for household food and nutritional security as well as a major source of income, as well as large scale producers who rely on healthy livestock for the survival of their business and the people they employ. Urban consumers who rely increasingly on commercially-raised livestock share similar risks along with the larger scale poultry, pig and cattle producers.

Prevention

In contrast to natural disasters, most animal and plant diseases can be prevented or mitigated. Therefore, the framework requires that these options are presented. It is also recognized that prevention, response and recovery is a cyclical process, with prevention the last step in recovery. Once an animal or plant sector has been successfully restored, you must build in prevention techniques and lessons learned during the disaster into the updated prevention element to ensure long-term success of the sector. Many studies have shown that the cost-benefits ratio of prevention vs. response and recovery are far lower. Actions that can strengthen prevention approaches include:

- Provide capacity building and technical assistance to farmers to apply best agricultural practices in animal husbandry such as providing training in HACCP principles. Research has shown that enforcing good animal husbandry practices reduces the spread of infectious diseases.

- By strengthening steps along the overall value chain in animal production, the transmission of zoonotic diseases can be prevented or dramatically reduced. For example, improve private sector engagement and responsibility in diseases prevention; create or improve food safety laws that prevent animal disease transmissions; improve certification programs and regimes that control the movement of livestock production; and improve public information systems to track diseases and share information among stakeholders and responsible parties along the animal production value chain.
- Preventing a disease through vaccines, resistant breeds and other means is a common and logical starting point. This effort should be linked to the support of public and private investment in research facilities, vaccine distribution and other preventative measures. In addition, the training of veterinarians, extension agents, and other in basic disease recognition and response techniques is essential.
- Develop compensation policies and secure the financial means to follow through on compensation promises in the wake of an outbreak; compensation arrangements whereby farmers or others can be paid fair and quick compensation for any animals or other property destroyed as part of a disease control campaign;
- Prepare legislative and administrative frameworks to permit all necessary disease control actions to be implemented without delay. One example is to arrange for epidemic livestock diseases to be included in national disaster plans so that the police, army and other services can be involved as and when necessary;
- The regulatory framework of a country's international trade plays an important role in establishing ideal condition for prevention. For example, for most live animals, an import permit must be obtained in advance; testing, treatment and health certification must be carried out in the country of origin; and often a period of post-import quarantine is required. In the case of products, they may be permitted entry if it is certified that various procedures have been carried out, such as heat treatment which would kill any disease agent.
- Advance preparation of both generic and disease-specific written contingency plans and operating procedures, the testing of such plans and training of staff; the development of capabilities at national, provincial and local veterinary headquarters, including field and laboratory services and the testing by using simulation exercises.
- Pass legislation to ban practices that increase risk of new outbreaks and encourage transboundary dialogue and cooperation among neighboring countries to protect against re-introduction
- Risk analysis is a tool that can also be used to good advantage for animal disease emergency preparedness planning. In this context, it is most readily applied to preparedness planning for exotic diseases (or exotic strains of endemic disease agents) and comprises three components: risk assessment, risk management and risk communication.

Response

While it is impossible to stop an earthquake or a tsunami, it is possible to intervene early in an outbreak of animal or plant disease to reduce the scope of damage and lay the groundwork for response and a successful recovery.

The two fundamental components for effective response to an outbreak of animal disease are early warning, and early reaction to animal health emergencies. A critical success factor in disease control is the speed and accuracy with which key information is captured, analyzed and disseminated. Well-informed decision making is a vital aid in preventing the escalation of a local emergency into an international crisis.

Early warning enables rapid detection of the introduction of, or sudden increase in, the incidence of any disease of livestock which has the potential of developing to epidemic proportions and/or causing serious socio-economic consequences or public health concerns. The success of a country's capability for rapid detection of the introduction or increased incidence of transboundary and potentially epidemic animal diseases depends on:

- Implementation of an emergency disease information system; establish and maintain surveillance systems based in agricultural extension and veterinary services or run by commercial producers and community-based groups. sustained active disease surveillance to supplement passive monitoring, based on close coordination between field and laboratory/epidemiology veterinary services, and use of techniques such as participatory questionnaires, serological surveys and abattoir monitoring to supplement field searching for clinical disease;
- Ensuring that veterinary services are structured in such a way as to facilitate disease reporting and implementation of a nationally coordinated disease control/ eradication campaign without delay during an emergency;
- Determination of the available international agencies involved in epidemic disease control/containment, including FAO/ EMPRES, which could provide early reaction assistance if needed and establishment of regular communication channels with such organizations.
- Ensured arrangements for involvement of the private sector (e.g. livestock farmers' organizations, veterinary practitioners, livestock traders, commercial farming companies, animal product processors and exporters); and
- Enhancement of laboratory diagnostic capabilities for priority diseases within provincial and national veterinary laboratories; development of strong linkages between national laboratories and regional and world reference laboratories, including the routine submission of specimens for specialized antigenic and genetic characterization of disease-causing agents; strengthening of national epidemiological capabilities to support emergency preparedness and disease management strategies and prompt and comprehensive international disease reporting to OIE and neighboring countries.

Early reaction means carrying out without delay the disease control activities needed to contain the outbreak and then to eliminate the disease and infection in the shortest possible time and in the most cost-effective way, or at least to return to the status quo and to provide objective, scientific evidence that one of these objectives has been attained. From that point in time, extraordinary measures should be taken to eradicate the disease and to control its movement. For example, road blocks can be set up on highways to limit movement of possibly-contaminated animals or vehicles; stations should be set up to disinfect vehicles that are allowed to move; police should monitor movement of animals and take control measures when necessary; provincial and social service workers or other counselors can assist farm owners with the grief associated with the likely destruction of their animals and livelihood. Necessary steps for an efficient early reaction to diseases include:

- Ensured access to quality-assured vaccines (containing the appropriate antigenic strain(s) for likely disease outbreaks) through a vaccine bank or from other sources and established standard operating procedures for quarantine and culling methods, (disposal: http://www.fao.org/DOCREP/004/Y0660E/Y0660E02.htm) and infrastructure capacity.
- Harmonization of disease control programs and cooperation with neighboring countries to ensure a regional approach.

Recovery

Successful implementation of the recovery strategy will require not just meticulous vaccination campaigns, but also implementation of a plan to step up and strengthen the monitoring and surveillance system and to reinforce public awareness and education about the issue in order to ensure long term sustainability of the measures taken. If the farm economy is diversified or if there are other opportunities to generate income, the impacts can be mitigated. However, if the economy depends on one or some of the vulnerable products, the impacts can be serious, and local food security can be threatened. The economic impact also depends on response strategies adopted by farmers and possible market adjustments. To help these farming communities resume their economic activities as soon as possible, quick impact activities have to be started at once to restock animals, restore land productivity and rebuild livestock shelters and grain. Funds are required for the provision of seeds, animal feed, tools and animal health services. Recovery will be a much slower process in the livestock sector than for crops, due to the investment and longer-term planning requirements for rebuilding herds.

- Recovery can be facilitated by a public communications plan. The plan must address not only the details of the incident but also to address the fear and potential social disruption. Maintaining consumer confidence will be an important factor in preserving the resiliency of the sector.
- Strengthen customs and border control staff to apply sanitary and phytosanitary standards on food imports and exports and rebuild laboratory infrastructure for disease identification and treatment
- Identify ways to use revenue generated by the flow of livestock in normal times to develop the capacity and funding required to cope with emergency livestock market interventions. As crisis is a recurrent reality, and external funding is uncertain, what can be identified that will make market institutions robust to both crisis and normal periods.
- Conduct market demand studies to identify post-outbreak constraints and opportunities in domestic and export markets and identify market partnerships, cooperatives, and other forms of self-organization that are being used in livestock marketing and evaluate their advantages and disadvantages in playing a role in rebuilding the sector. Evaluate the impact they have in producer prices and transaction costs under a crisis situation and evaluate the reason that leads to the survival or demise of such organizations, and what role (if any) can donors play in supporting such organizations to improve producer well-being.
- Activate any disaster recovery fund provided to fairly compensate for the loss of livestock, and other costs of the incident.
- Technical assistance and other support for farms and businesses and build prevention into the recovery operation by investing in biosecurity in new production facilities and hatcheries.
- Continue to support surveillance systems as they are the best protection against a re-introduction of the disease.

The "Haiti Swine Repopulation Project" during the 1980s is an example of a previous animal disease recovery effort. The project was implemented by USAID and the Interamerican Institute for Cooperation in Agriculture (IICA), following an outbreak of African Swine Fever in 1979 that decimated the swine population in Haiti. From 1983 through 1987, USAID produced and distributed improved swine breeding stock to Haitian peasant farmers whose herds were destroyed following the outbreak of the disease.

More details about the lessons learned and the final evaluation of the project can be found on USAID's Development Experience Clearinghouse:

Interim swine repopulation project (ISRP)

http://dec.usaid.gov/index.cfm?p=search.getCitation&CFID=912229&CFTOKEN=54490594&id=s_BB953908-D566-FC5C-D101BD6862FEC193&rec_no=49063

Evaluation of the Haiti interim swine repopulation project

http://dec.usaid.gov/index.cfm?p=search.getCitation&CFID=912229&CFTOKEN=54490594&id=s_BB953908-D566-FC5C-D101BD6862FEC193&rec_no=49065

ZOONOTIC DISEASES

According to a recent Center for Disease Control (CDC) study, 75% of all new infectious diseases in humans come from animals. These zoonotic diseases are among the most lethal - HIV/AIDS, pandemic influenza - and best known diseases –SARS and Mad Cow- in the past century. Margaret Chan, Director General of the World Health Organization (WHO) warned recently that "Infectious diseases are now spreading geographically much faster than any time in history".

The recent outbreaks of Highly Pathogenic Avian Influenza (HPAI) have focused international attention on the potential threat posed by a new strain of bird flu. The rise and continued spread of the H5N1 strain of avian influenza illustrates some of the conditions associated with zoonotic disease development:

- Dense human populations living in close proximity to poultry and livestock;
- Concentrated animal production systems with tens of thousands of animals living in confined spaces;
- Widespread international food trade in live and processed animal products and illegal trade in pets and exotic animals.
- The informal and unregulated trade and marketing of animals. For example, the spread of HPAI in China from the unregulated trade of chickens.

The potential for a human pandemic arising from a new or current zoonotic disease provides the obvious rationale for paying close attention to these types of diseases. The above framework outlined for the Non-Zoonotic Diseases should be applied for the Zoonotic diseases, and will not be repeated in this section. The added elements address the needs to reduce potential human infection. (http://www.vetmed.wisc.edu/pbs/zoonoses/)

Prevention

- Strengthen producer organizations and official veterinary services (OVS) as the first line of defense and prevention in the outbreak of animal diseases.

- Provide training and equipment for rapid detection and diagnosis of disease outbreaks in animals and humans. There is often a disconnect between the health care sector and the veterinarians, which result in unreported cases and delay in understanding the epidemiology

- Design and support public awareness campaigns that target key behaviors that tend to spread the disease. For example, Indonesia launched a comprehensive national campaign to raise public awareness about avian influenza. The campaign used television and radio spots, billboard ads, leaflets and other media to inform Indonesians about effective steps they can take to reduce the risk of contracting the H5N1 virus. This awareness campaign was driven by the belief that the involvement of all Indonesians - especially backyard farmers - is crucial in bringing avian flu under control. It drew on a variety of communication media in an effort to reach as many people as possible with messages designed to sharpen awareness, shape attitudes, and shift behavior.

- Invest in communications programs that alert producers and consumers to the steps they can take to prevent outbreaks or become infected. At the core of efforts to enhance our food and agriculture preparedness and response capabilities will be the establishment of a well coordinated and efficient communication strategy that links all stakeholders and allows for the rapid dissemination of: specific threat alerts from intelligence partners; incident notifications from field staff; industry or others; routine surveillance information from inspections, laboratory analyses and other local and state sources; and other information deemed critical to preventing illness, and death.

- Enhance the monitoring of farms to ensure hygiene and quarantine of products, and to track their circulation; and maintain and reinforce quarantine stations.

- Promote the use of Healthmap (www.healthmap.org), an independent website that consolidates distinct data sources into a comprehensive view of the current global state of infectious diseases and their effect on human and animal health.

- Stay alert to the risks of exotic diseases (or disease agent strains) by keeping a close watch on the international livestock disease situation. Apart from the scientific literature, the most valuable source of information is the International Office of Epizootics, through such publications as its weekly disease reports and the annual World Animal Health, and through consultation of its Handistatus database. Disease intelligence is also available from FAO, for example in the EMPRES transboundary animal diseases bulletin, which is published quarterly and is also available on the Internet at: www.fao.org/waicent/faoinfo/agricult/aga/agah/empres/empres.htm.[4]

- Expansion of a uniform farm animal identification and tracking system, similar to what is already being provided by IdentiGEN (www.identigen.com) in the United States and Ireland. This will provide the process for a timely trace back of all livestock, consumer foods and food products. A traceability system will not only serve as a proper prevention tool, but will also result in building customers confidence in food safety. The massive loss of consumer confidence in the nation's food and agriculture system could have far costlier consequences than the immediate cost of the incident.

- Market force incentives. Market forces could provide incentives for investments in new security equipment and systems. For example, the FAO completed studies in Vietnam and Indonesian where

[4] PROMED, an Internet server and mailing service, provides an extremely useful forum for rapid dissemination of official and unofficial information on animal, plant and human disease occurrences around the world and Animal Health Net is also a useful source of information.

Critical Control Points (perhaps 'Critical Risk Points' derived from the Hazard Analysis Critical Control Point methodology) was applied to the poultry value chain analysis. By identifying the different key stake holders along the value chains and quantify the production level (and nodes for prevention), it allows interventions to be prioritized, targeted, and proportional. These critical points identified along the value chain can be used as indicators of for proper investments for bio-security measures. This can also lay out who will directly benefit from and should pay for the investment. Additional issues that should be considered include insurance, third-party verification of security protocols, and tax credits or other incentives for investments.

- Establish good financial plans. Experience has shown that delay in obtaining finances is one of the major constraints to the rapid response to emergency disease outbreaks. Forward financial planning is an essential component of successful preparedness, prevention and recovery.

It is desirable for funds to be provided from both the government and private sector for emergency programs against diseases, as the private sector has a vested interest in the health and prevention of disease in animals. This would be agreed upon after a review of the nature and proportion of public and private benefits that will be derived from the elimination of the disease. A funding formula may cover payment of a fixed percentage of the cost of the total campaign by each sector or each sector pays for specific components in the campaign. If the private sector is to contribute, it needs to be determined who in that sector benefits (and therefore should share the cost). This may include processing industries and traders as well as farmer organizations.

Response

- The following resource lists required for an effective operation to an zoonotic disease outbreak should be regarded as indicative rather than exhaustive :
    - National animal disease control centre: senior disease control veterinarians and epidemiologists, financial and administrative officers and extra staff for recording and processing epidemiological and other information; transport maps, computers and communication equipment to local headquarters (e.g. facsimile, e-mail); local animal disease control centers: senior disease control veterinarians and epidemiologists,
    - Diagnostic laboratories: trained laboratory staff, standard laboratory equipment plus any specialized equipment for key emergency diseases and diagnostic reagents for antigen and antibody detection;
    - Diagnostic/surveillance: veterinarians and support veterinary auxiliary staff, , maps, communications equipment, leaflets or posters on the disease(s), diagnostic collection kits and transporters, blood collection equipment and animal restraint equipment;
    - Vaccination: vaccination teams, vaccines, central and local refrigeration storage, transport, maps, cold storage transporters, vaccination equipment and animal restraint equipment;
    - slaughter, burial and disinfection: supervising veterinarian, personnel, transport, humane killers, ammunition and other approved means of killing (e.g. carbon monoxide gassing of poultry), protective clothing, animal restraint equipment, front-end loaders and earth-moving equipment, approved disinfectants, soaps and detergents, shovels, scrapers and high-pressure spraying equipment;

    - Quarantine and livestock movement controls: enforcement teams, transport, roadblocks (if necessary), signs and posters.

- Good farmer and public awareness programs for high-threat epidemic zoonotic livestock diseases that involve improving the veterinary/farmer/health provider interface. In many cases these public awareness programs might have behavioral change messages to educate the public on ways of reducing exposure to the disease agents.
- Implementation of comprehensive compensation plans is particularly important in the case of zoonotic diseases. The provisions for compensation to owners for any livestock or property destroyed should be part of the disease eradication campaign. Compensation should be based on the fair market "farm-gate" value of the animals at the time of slaughter (assuming a value that the animal would have had as a healthy one). The same principle should be applied to products and property. The payment of inadequate compensation is not only inherently unfair, but could foster resentment and lack of cooperation and encourages farmers to hide the presence of the disease. The valuation should be carried out by an independent, professional evaluator.

Recovery

In many cases rebuilding a livestock herd is as difficult as eliminating the initial disease. For example, in the case of Highly Pathogenic Avian Influenza (HPAI), the disease has become endemic in several countries raising the prospect that the virus can never be completely eliminated. In these circumstances recovery may involve finding ways to raise livestock while the disease is still active. Rapid recovery will be critical to ensuring the ongoing viability of food and agriculture businesses affected by an incident. Some of the key actions in disease recovery include:

- The restructuring of conditions for slaughter and marketing are equally important. Governments dealing with the occurrence of Highly Pathogenic Avian Influenza (HPAI) face opposition from the formal and informal poultry sector to end slaughters in towns and cities (i.e., wet markets) and prohibitions on the live selling and slaughter in marketplaces. Slaughter should take place only in approved locations, under regulations that ensure the slaughter of healthy and quarantined birds, and include an appropriate waste treatment system. This should be linked with the adoption of incentive policies (such as favorable loans) toward the establishment of some centralized slaughtering units.
- Credit to micro-enterprises has proven to be a powerful tool to increase income levels of households. Assistance to micro-enterprises should be provided to mitigate the downturn of economic effects with households. For example, participating households can switch from keeping just a few chickens and a pig to rearing a wider variety of livestock in substantial numbers. Financial assistance should be linked with technical assistance to improve management practices, regular vaccination and disease control measures.
- Support services play a vital role in ensuring the success of rebuilding the agricultural sector. In order to foster sustainability of the recovery efforts, projects should make certain that the supply of inputs is guaranteed or that alternative sources of supply can be developed.
- Improving the institutional environment between the veterinary and animal extension systems and the public health systems. Human incidents and diagnoses are not often enough linked to zoonotic causes due to poor communications between health care providers and veterinaries.

EXAMPLES OF PUBLIC-PRIVATE PARTNERSHIPS IN RESPONSE TO ANIMAL DISEASES

Safe Supply of Affordable Food Everywhere, Inc. (SSAFE)

SSAFE (www.ssafe-food.net) is a non-profit, Public-Private Partnership (PPP) among global food system companies, international non-governmental organizations (NGOs), intergovernmental organizations, and academia, with the mission to foster the safe and sustainable free trade of animals and animal products throughout the global food supply chain. The role of SSAFE is to:

- Serve as a resource to national governmental agencies and intergovernmental organizations, particularly international standards-setting organizations, such as OIE and CODEX.
- Provide a trusting and respectful environment among the public and private sectors, leading to consensus and policy development consistent with science-based international standards.
- Align stakeholders to achieve and share consensus for critical actions to address threats to the global food supply chain.
- Leverage resources through public-private partnerships to enable timely and effective actions - including communication - to prevent and respond to food-system disruptions.
- Advocate harmonized policies and promote consistent actions to strengthen the food safety systems at the national, regional and global levels.
- Promote development and implementation of science-based, international standards as part of good business practices.

The SSAFE partnership has launched initiatives in Mozambique, Brazil and China.

In Mozambique, the exploratory phase of the project beginning March 2007 aimed at identifying opportunities to strengthen the animal health capacity of Mozambique in a sustainable manner. SSAFE and Cargill funded the project, while the University of Michigan, the University of Minnesota, and Cargill provided technical expertise. The government of Mozambique and TechnoServe staff provided ground support in arranging meetings with national and provincial government agencies and with various stakeholder communities. The second phase of the project, having begun in early 2008, focuses on strengthening and expanding the existing community vaccination (CV) program and the eventual transition from the CV program into a broader "Community Animal Health" (CAH) program initially focused on poultry health will be an intermediate goal of the project.

During the October 2007 "One World-One Health" symposium in Brazil, organized by Wildlife Conservation Society and co-sponsored by SSAFE, a US$250,000 grant by SSAFE member Cargill was announced to stimulate the development of "One Health" research projects that will be focus on the approach to food production that ensures the health of wildlife and livestock as well as promoting human livelihoods. In China, a program is currently being designed by The Wildlife Conservation Society (WCS), a SSAFE Collaborator, who has been invited by the government of China to provide advice on avian influenza surveillance programs.

The Brazilian Beef Processors and Exporters Association (ABIEC) and the National Export Promotion Agency (APEX)

A good example of a public-private partnership in Brazil is the relationship between the Brazilian Beef Processors and Exporters Association (ABIEC) and the National Export Promotion Agency (APEX).

Since 2001, ABIEC initiated an aggressive promotion program approved by the National Export Promotion Agency (APEX) to promote the brand "Brazilian Beef". They emphasize the product as natural (grass-fed beef as opposed to grain-fed beef), environmental, and healthy. ABEIC has an agreement with APEX valued at US$1.6million for market promotion, 50% of which are APEX funds. Meanwhile, Brazil still suffers with periodic outbreaks of foot and mouth disease. Through coordination between ABIEC and APEX, the industry has been able to expand production, suppress disease outbreak and increase beef exports by 140% from 2001 to 2005.

The National Poultry Improvement Plan (NPIP)

The National Poultry Improvement Plan (NPIP) is a voluntary program administered cooperatively by the USDA, state, federal and the poultry industry to coordinate the public and private sector efforts aimed at eliminating certain diseases from poultry breeding flocks and hatcheries. Since the program's inception in 1935, the NPIP has added provisions and changed programs to meet the needs of the poultry industry. Over 95% of the U.S. breeding and hatchery industry participates in the NPIP program. The provisions of the Plan, developed jointly by industry members and state and federal officials, establish testing standards and protocols used to monitor and control diseases spread through the reproduction process and poultry products for interstate and international shipment.

The objective of the NPIP is to provide a cooperative Industry-State-Federal program through which new technology can be effectively applied to the improvement of poultry and poultry products throughout the country. The NPIP is divided in five subparts: (1) Egg Type- Chickens; (2) Meat-Type Chickens; (3) Turkeys; (4) Waterfowl, Exhibition, Game, Backyard Flocks (WEGBY); and (5) Ostrich.

EXAMPLE OF A PUBLIC SECTOR INITIATIVE IN RESPONSE TO ANIMAL DISEASES

The Animal Health/Emerging Animal Diseases (AHEAD) project

The Federation of American Scientists' Animal Health/Emerging Animal Diseases (AHEAD) project (WWW.FAS.ORG/AHEAD/INDEX.HTML) is managing a major program in sub-Saharan Africa to detect and document the extent of infectious diseases shared by farm and wild animals and to supply treatment, prevention and control services to remote communities that have previously been neglected by other programs, both national and international. The program, AHEAD International Lookout for Infectious Animal Disease (ILIAD), has at the core the need for a permanent and sustainable regional program of in situ surveillance designed to detect, monitor, treat, prevent and control infectious diseases with the goals of increasing livestock production in remote farming communities, protecting the health of wild species, building indigenous physical and professional resources, and introducing communications and epidemiology information technologies. Diseases shared by wild, farmed and captive/bred animals, and by animals and humans, suppress food production, frustrate species preservation efforts and greatly affect public health. Detection, prevention and control of these diseases is an essential element in expanding trade, improving nutrition, exploiting ecotourism and ensuring food security.

To accomplish these goals ILIAD operates an electronically linked network of outpost lab/clinic units located in communities on the perimeters of game reserves and national wildlife parks and national borders not served consistently by governmental veterinary programs. Full coverage of communities lying between outpost locations is accomplished by a kind of "extension service", whereby specially trained veterinary technicians travel weekly by motorbike to the villages lying within a 30-50 kilometer radius of their assigned posts. These technicians utilize the global positioning system to register exact locations of disease and mortality, record data in an epidemiology software program designed specifically for use in developing countries (15), provide immunization and treatment services on a cost-recovery basis, and take blood and fecal samples from animals owned by the community residents and from wild animals outside game reserves.

PLANT DISEASES

The preferred response framework for plant diseases should be a "blueprint" for the outbreak of any plant disease, within which disease-specific plans would operate. As there are thousands of plant diseases, it is more efficient to create a general framework, with selected disease-specific plans operating within the framework. Many of the actions that should be taken during the prevention, response and recovery elements are the same that should be taken for any plant disease, such as training, identifying chemical control agents, and quarantine. A disease specific plan would address the details - what type of training is required, what are the chemical agents that can control the disease and what are the specifications and requirements of quarantine for the specific disease.

Many preventive, response and recovery operations are common between plant diseases and can provide a model for multiple disease specific plans. For example, the U.S. Department of Agriculture has developed a recovery plan for wheat rusts (stem, leaf, and stripe rust); this could be adapted quickly for new rust diseases of corn and soybean with very similar mitigation strategies.

PREVENTION

Prevention is the best recovery option when dealing with most plant diseases- making sure it doesn't happen is the obvious first choice. Many diseases cannot be effectively controlled once symptoms develop or become severe. Preventing a disease through resistant varieties and other means is a common and logical starting point. Any disease mitigation strategy must be coordinated with local, regional and national regulatory authorities and should include coordination with international organizations to prevent or contain transboundary outbreaks.

Actions that can strengthen prevention approaches include:

- Support basic and applied research at national and international research centers. For example, develop or screen new chemical and biological control products; explore new technologies (i.e. nanotechnology); develop new methods for disinfestation, disposal and diagnostics.
- Establish or rebuild laboratory infrastructure for disease identification and treatment.
- Train extension agents in basic disease recognition and response techniques
- Provide for extensive surveys of nursery and retail stock of plants and seeds
- Create or improve expert listings of Subject Matter Experts.
- Formalize lines of authority. It is critical to designate which government agency or entity has the authority to declare a plant disease emergency, which agency or entity will assume lead authority and clearly define the roles and responsibilities of all participants in a strategic plan for a catastrophic plant disease recovery.

- Strengthen public policies on plant variety protection and the introduction of updated disease resistant varieties
- Identify and register chemical controls. Prior approved labels play a vital role in the availability of fungicides, herbicides, etc. and will ensure that some supplies are made rapidly available in a response to an outbreak
- Support public and private investment in research facilities, seed and tissue culture development and other preventative measures.

There are four general control strategies that should be considered when preparing for a disease-specific plan for prevention:

1. **Chemical Control**- What are the chemical agents (fungicides, herbicides, etc.) that can mitigate the outbreak of a specific plant disease? Are they approved for use in the specific country? Are the stockpile reserves sufficient or obtainable from nearby markets?
2. **Biological Control**- Involves the use of organisms other than humans to reduce or prevent infection by a pathogen. What are the biological controls for the particular plant disease and do they naturally within the specific environment or would they need to be purposefully applied where they can act directly or indirectly on the pathogen? Some biological controls produce antibiotics that kill or reduce the number of closely related pathogens; some are parasites on pathogens; and others simply compete with pathogens for available food.
3. **Cultural Control**- Early (and accurate) plant disease detection and the reporting of pathogens for quarantine is imperative. What are the crop rotation practices? What are the irrigation techniques being used and can they contribute to the spread of a plant disease outbreak?
4. **Germplasm/Seed Control**- Are healthy, updated and disease resistant cultivars being used as plant seed? Is the seed coming form an approved "certified" seed program? What are the options available in a country for bio-engineered seed (legally approved or pending)?

RESPONSE

Once a disease outbreak occurs, even a minor one, the capacity to respond in a timely and effective manner will determine, to a great degree, the extent of damage to a staple food crop or economically important export food crops, as well as the economic well being of affected populations.

Prevention includes actions that deter an outbreak, but many preventive measures are not activated until a response in required. Outbreak responses can be prepared in many ways:

- Establish and maintain surveillance systems based in agricultural extension or operated by commercial producers and community-based groups.
- Provide training and equipment for rapid detection and diagnosis of disease outbreaks.
- Design and support public awareness campaigns that target key behaviors that tend to spread the disease.
- Invest in rapid response teams that would be responsible for confirmation surveys that determining the traceability and possible expansion of the disease.

- Establish protocol for the destruction of infected and perimeter trees, vines or fields.
- Develop compensation policies and secure the financial means to follow through on compensation promises in the wake of an outbreak.

The response phase begins when the lead agency (established in the strategic plan for a catastrophic plant disease recovery) formally declares that based on an initial analysis, an emergency exists or has the potential to exist.

Once an outbreak of a plant disease happens, some of the response actions that should be taken include:

1. **Confirmation of Diagnosis**- Some plant diseases are hard to detect or are misdiagnosed; an initial diagnosis should be reconfirmed in the very early stages of a response to ensure the proper actions are taken and mitigate any opportunities for legal action.
2. **Surveys Conducted to Identify Restricted Areas and Control Areas**- Survey teams should conduct trace backs to identify where a plant disease may have originated and then trace forwards to determine where the plant disease may have spread. The survey team should discover:

   a) Movement of plant materials, products or other materials that could facilitate the spread of the plant disease;

   b) Identify equipment shared between individuals and properties; and

   c) Identify individuals that may have moved from affected areas to unaffected locations.
3. **Execution of Control/Quarantine Procedures**- Based on the findings of the survey team, quarantine zones should be designated and enforced based on previously determined quarantine procedures.
4. **Activation of a Communication Strategy**- A well executed communication strategy will help control a plant disease outbreak and conversely, a poorly executed plan could exacerbate an epidemic. During the response to an outbreak, a predetermined communication plan should provide the following measures:

   a) Activate formal lines of emergency communication between government agencies;

   b) Advise property owners/agencies of the decision to contain the disease;

   c) Prepare and deliver briefings for the government;

   d) Prepare and deliver media briefs for the public.
5. **Decision on Eradication or Alternative Action**- The lead agency and participating panel of agency representatives will need to decide on one of three actions:

   a) Attempt a complete eradication campaign,

   b) Continue with the containment program, or

   c) Take no further action.

   This decision should be based on a cost/benefit analysis, reviewing updated reports on the containment or spread of the disease, a review of the impact on international trade, obligations and treaties, and considering the recommendations of subject matter experts.

6. **Implementation of the Chemical Control Strategies**- The chemical control should have been determined during the prevention stage. During the confirmation of the plant disease, an inventory of approved, appropriate chemicals as a response should be taken. The lead agency should determine the quantity of a chemical product that will be required and arrange for priority importation if insufficient amounts are located within the country. If the use of chemicals is authorized, they will be applied following the determination made the lead agency and panel of representatives.

7. **Evaluation of Progress**- A continuous loop of information should be maintained during the outbreak response. If key performance indicators are not being achieved, a new response decision should be developed. A key part of the evaluation to the response is if it is cost beneficial or technically feasible to continue with an eradication effort.

8. **Downsizing of Response**- As the response to an outbreak draws down, it will require fewer resources. There must be a systematic plan for the demobilization of operations just as there was a mobilization plan for the response. The lead agency should coordinate the downsizing operations and begin the transition to the next agreed upon action of the strategic recovery plan.

RECOVERY

The transition from response to recovery or a return to prevention will be determined once an emergency situation is over. Either the outbreak has been eliminated or a catastrophe is in progress because containment has failed, or a determination has been made that the eradication procedure is not considered cost effective (and therefore some other control strategy should be considered).

In many cases, recovery does not mean a return to the status quo. A return to previous levels of operation before a catastrophic loss may not be possible or even desirable. For example, crop production practices might have improved or new varieties of crop may require drastically different levels of resources. Market conditions may have changed where the introduction of a different crop may prove more economically advantageous and/or new environmental issues and standards may provide opportunities or restrictions. Recovery should be flexible and consider several factors- economic, social and environmental.

There are three layers to recovery:

1. No Recovery- This is a difficult determination to make, but sometimes recovery of a crop from a catastrophic loss is simply not practical due to economic feasibility.

2. Management- Recovery provides an opportunity to adopt better management and good agricultural practices that will lead to improved production, efficiency and resistance to future catastrophic outbreaks.

3. Levels of Recovery- Local (Individual), Regional and National Recovery. These operate at distinct tempos and may not develop at all three levels.

Single-season recovery is generally not achievable and should not be anticipated. The systematic recovery of a crop from devastating losses will depend on:

- The particular crop/pathogen combination.

- Supply, logistics and legal introduction of replacement seeds.

- Availability of disease resistant varieties- breeding takes time and disease resistant varieties may not be available.
- Resistant crop varieties may not be the best option for recovery.

Some of the key actions in disease recovery include:

- Build prevention into the recovery operation by investing in biosecurity in new production facilities or enforcing plant variety protection standards.
- Tailor financing to the specific characteristics of the crop being re-introduced. Slow growing plants such as coconuts require longer term financing than rehabilitation an annual crop such as tomatoes.
- Continue to support surveillance systems as they are the best protection against a re-introduction of the disease.
- Pass legislation to ban practices that increase risk of new outbreaks and promote the introduction of biologically engineered varieties that carry disease resistant characteristics.
- Encourage transboundary dialogue and cooperation between quarantine officials in neighboring countries to protect against re-introduction.
- Conduct market demand studies to identify post-outbreak constraints and opportunities in domestic and export markets.
- Strengthen customs and border control staff to apply internationally recognized sanitary and phytosanitary standards on food imports and exports.

The Cassava Mosaic disease pandemic in East Africa during the late 1990s is an example of a plant disease recovery effort. From 1997 to 2004, USAID and the International Institute for Tropical Agriculture (IITA) implemented the Cassava Mosaic Disease Program for Eastern Africa with the goal to boost production of cassava in Uganda, Kenya and Tanzania. The goal was to enhance both short and longer term food security through the implementation of an emergency program to multiply and disseminate mosaic resistant cassava varieties.

More details about the lessons learned and final evaluation of the project can be found online at:

An Evaluation of USAID/OFDA Efforts against Cassava Mosaic Disease, 1997-2004
http://pdf.usaid.gov/pdf_docs/PDACF021.pdf

Cassava Mosaic Disease Pandemic in East Africa
http://www.tropicalwhiteflyipmproject.cgiar.org/docs/ofdareport05.pdf

National Plant Recovery Plans

Both the United States and Australia have established national emergency response plans for plant disease recovery. In the United States, the USDA and the APS collaborated on a series of workshops in 2006 and 2007 to identify significant plant diseases for the design of the "National Plant Disease Recovery System." In Australia, PLANTPLAN was updated in 2008 and provides a set of nationally consistent guidelines covering management and response procedures for emergency plant pest incursions affecting the Australian plant industries.

United States- National Plant Disease Recovery System (NPDRS) [5]

The specific purpose of the NPDRS is to ensure that the tools, infrastructure, communication networks, and capacity are established and function that would be required to mitigate the impact of high consequence plant disease outbreaks. A copy of the plant disease recovery plans are found online at (http://www.ars.usda.gov/research/docs.htm?docid=14271).

As of June 2008, the NPDRS completed six disease-specific plans that are intended to provide a brief primer on the disease, assess the status of critical recovery components and identify disease management research, extension and education needs. The disease/causal agents completed include:

1. Brown Rot of Potato, Bacterial Wilt of Tomato, and Southern Wilt of Geranium [*Ralstonia solanacearum Race 3 Biovar 2*]
2. Huanglongbing or Citrus Greening [*"Candidatus" Liberibacter africanus, L. asiaticus, and L. americanus*]
3. Leaf Rust, Stem Rust, and Stripe Rust of Wheat [*Puccinia triticina, Puccinia graminis, and Puccinia striiformis, respectively*]
4. Philippine Downy Mildew (PDM) and Brown Stripe Downy Mildew (BSDM) [*Peronosclerospora philippinensis and Sclerophthora rayssiae var. zeae, respectively*]
5. Plum Pox or Sharka [*Plum pox virus*]
6. Potato Wart [*Synchytrium endobioticum*]

The recovery plan is an ongoing activity and as new plans are developed, they will be added to the NPDRS. Recovery plans in the pipeline include: late wilt of corn (maize); red leaf blotch of soybean; and rice bacterial blights.

The recovery documents from the NPDRS are not intended to be stand-alone documents that address all of the varied aspects of plant disease outbreak, response, and recovery. They are intended to operate in a comprehensive and consistent response approach with the additional disease-specific recovery plans in NPDRS.

Australia- The Australian Emergency Plant Pest Response Plan (PLATPLAN)[6]

PLANTPLAN is a technical response plan that describes the Australian approach to responding to Emergency Plant Pest (EPP) incursions. A copy of the emergency plant response plan is found online at (http://www.planthealthaustralia.com.au/our_projects/display_project.asp?ID=189&category=2) Mobilization of PLANTPLAN is triggered by a detection of an EPP. The procedures, roles and responsibilities described in PLANTPLAN are generic for all plant pest emergencies. Unlike the NPDRS in the United States, PLATPLAN does not provide recovery plans for disease-specific plant pathogens,

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[5] U.S Department of Agriculture, Office of Pest Management National Plant Disease Recovery System, http://www.ars.usda.gov/research/docs.htm?docid=14271

[6] Australian Emergency Plant Pest Response Plan: Emergency preparedness and response guidelines for Australia's agricultural industries, 2008 - Version 1, March 2008

but provides a description of the general procedures, management structure and information flow system for the handling of EPP incursions at the national, state/territory and district levels.

The PLANTPLAN describes four phases of response to an emergency plant disease incursion: (1) Investigation, (2) Alert, (3) Operational, and (4) Stand Down. The manual is broken into four main sections (Management and Administrative Arrangements; Control Centers Management; Information Systems Management; and Roles and Responsibilities of Decision-Making Bodies) preceded by an introduction and includes a series of appendices provide detail on various aspects of the plan.

CHAPTER 3: MOST SIGNIFICANT ANIMAL DISEASES AND THEIR POTENTIAL IMPACT

INTRODUCTION

The focus of the animal diseases in this paper is limited to the former group List A established by the World Organization for Animal Health formerly known as the International Office of Epizootics (OIE). List A diseases, most of which could also be regarded as being Transboundary Animal Diseases (TAD) include; foot-and-mouth disease (FMD), rinderpest, peste des petits ruminants (PPR), contagious bovine pleuropneumonia (CBPP), Rift Valley fever (RVF), lumpy skin disease, vesicular stomatitis, swine vesicular disease, bluetongue, sheep and goat pox, African horsesickness, African swine fever, hog cholera (classical swine fever), fowl plague Newcastle disease and Avian Influenza. Where possible, information concerning the causal agent of the disease (genus, family and species) is provided.

TRANSBOUNDARY ANIMAL DISEASES OF LIST A AND IMPACT ON THE AGRICULTURE SECTOR

The introduction of animal diseases occurs in many ways. The most common occurrence is through live diseased animals and contaminated animal products entering a country either as imports or as food waste from international aircraft or ships. Other introductions result from the importation of contaminated biological products (for example vaccines) or germless (semen or ova) products; the entry of infected people (in the case of diseases that are transmittable from humans to animals); the migration of animals and birds; or even from natural spreading by insect vectors or wind currents.

African Horse Sickness *(Orbivirus, Reroviradae)*: African Horse Sickness is an extremely infectious and fatal disease, transmitted by an arthropod-borne virus (African horse sickness virus, AHSV) and it is spread by midges (Culcoides species). There are nine serotypes of the virus. The disease is characterized by fever, vascular leakage, and a high rate of mortality. Mortality can be as high as 95% in some forms of this disease. Asymptomatic or mild infections may occur in zebras, African donkeys, and horses previously infected by another serotype of the virus. Dogs are susceptible to infection if they eat infected meat. Zebras are considered to be the reservoir host. African horse sickness (AHS) is endemic in sub-Saharan central and east Africa. This disease often spreads to southern Africa and occasionally to northern Africa. Outbreaks have been seen in Egypt and other parts of the Middle East, as well as in Spain. The disease has never been recorded in North America.

African Swine Fever *(Asfivirus, Asfarviridae)*: African swine fever is the most lethal transboundary disease affecting pigs. It is also a viral disease (caused by African swine fever virus, ASFV) that has shown a great propensity for sudden and unexpected international spread over great distances. This is often associated with the transportation of virus contaminated pig meat products, including food scraps in waste from ships and aircraft. There are no vaccines against African swine fever. It is endemic over much of eastern and southern Africa, where eradication is not feasible at present because of wildlife cycles of infection between warthogs and other wild pigs and ticks, and now also because of infelicity in uncontrolled village pigs. The only practical disease control measure for commercial piggeries is the denial of access to wild and village pigs through fencing and other sanitary precautions. There is, however, a long-term prospect of controlling African swine fever in endemic areas through the development and breeding of genetically resistant pigs.

Avian Influenza ***(Influenza A, H5N1 highly pathogenic strain)*** : Avian Influenza, or bird flu, is a viral infection caused by a variety of different influenza strains in birds that can range from harmless to 100% fatal. These influenzas are classified as type A and are spread through fecal-oral transmissions. Influenza A viruses can also cause illness in other animals and is the most notable of all deadliest zoonotic disease to humans. The World Heath Organization (WHO) has reported human cases of avian influenza A (H5N1) in Asia, Africa, the Pacific, Europe and the Near East. Indonesia and Vietnam have reported the highest number of H5N1 cases to date. Overall mortality in reported H5N1 cases is approximately 60%. The majority of cases have occurred among children and adults aged less than 40 years old. Mortality was highest in cases aged 10-19 years old. Studies have documented the most significant risk factors for human H5N1 infection to be direct contact with sick or dead poultry or wild birds, or visiting a live poultry market. Most human H5N1 cases have been hospitalized late in their illness with severe respiratory disease. The cumulative number of confirmed human cases of avian influenza is available on the WHO website. The cumulated report for June 2008 shows that the H5N1 totals over 240 laboratory diagnosed deaths spread over 15 countries, with Indonesia leading with 110 (more then any country in the world) .

Bluetongue ***(Orbivirus, Reroviradae)***: Bluetongue virus (BTV) is an insect spread viral disease that affects livestock, especially sheep. The disease can prove fatal and presents with fever, excessive salivation, muscle lameness and depression. Bluetongue is a widespread disease, it has been found in Europe, Africa, the Middle East, Australia, the Americas and Asia. (In 2007, there have been nearly 3,000 cases of bluetongue in Northern Europe - including the Netherlands, Belgium, France and Germany), Bluetongue is transmitted through insect carriers and not contagious. Thus insect control is an important aspect of prevention, although vaccines do exist as well.

Bovine Spongiform Encephalopathy ***(BSE prions)***: Bovine spongiform encephalopathy (BSE), caused by novel infectious agents – prions – was first detected in the United Kingdom in 1986. It has since spread to a number of other European countries, although the majority of cases have been in the United Kingdom. In cattle, it has been transmitted through meat and bone meal in animal feed, and supplements containing infected particles from affected animals (State of Agriculture, 2001). It can spread to humans through the consumption of infected issues. In humans, it causes a fatal neurological disease known as variant Creutzfeldt-Jakob disease.

Classical Swine Fever ***(Pestivirus, Flaviviridae)***: Classical swine fever, or hog cholera, is a generalized viral disease in swine caused by classical swine fever virus (CSFV) that is highly contagious and transmitted through direct contact. The disease is endemic in much of South and Southeast Asia, where it is constraint to the development of the pig industry. In Europe, it caused major outbreaks in the in 1997 and 1999. Recent outbreaks have also occurred in Latin America and the Caribbean. It is largely indistinguishable from African Swine Fever but caused by a different virus. While CSF does not cause food-borne illness in people, economic losses to pork producers are severe.

Contagious Bovine Pleuropneumonia ***(Mycoplasma mycoides mycoides)***: CBPP is often regarded as an insidious, low-mortality disease of cattle, but this assessment is based on experiences in endemic areas. In susceptible cattle populations, the disease can spread surprisingly rapidly and cause high mortality rates. The disease is caused by a bacterial mycoplasma and is spread with the movement of infected animals, including acute cases and chronic carriers. Major CBPP epidemics have been experienced in eastern, southern and western Africa over the last few years. It currently affects 27 countries in Africa at an estimated annual cost of $2 billion.

Foot-and-Mouth Disease ***(Aphthovirus, Picornaviridae)***: Foot-and-mouth disease is a highly contagious viral disease (caused by foot-and-mouth disease virus) which can spread extremely rapidly in cloven-hoofed livestock populations through movement of infected animals and animal products, contaminated objects (for example livestock trucks) and even wind currents. Vaccination is complicated by a multiplicity of antigenic types and subtypes. Substantial progress has been made towards the control and eradication of foot-and mouth disease in several regions, notably Europe and parts of South America and Asia. However, outbreaks occurred in Argentina, Brazil, Greece, Japan and the Republic of Korea in 2000, and in the United Kingdom early in 2001. A serious outbreak in Taiwan Province of China in 1997 forced the slaughter of 3.8 million pigs. Eradication can only be viewed as a long-term objective in parts of Africa because of the existence of wildlife reservoirs for the virus.

Sheep and Goat Pox ***(pox viral complex)***: Sheep and GoatPox (SGP) is a viral, contagious disease that causes pox on goat and sheep. SGP is transmitted through lesions and may remain contagious for 2 to 6 months in wool and up to two years in scabs. Goat and Sheep Pox is endemic in Africa, the Middle East, India and Asia and has an extremely high mortality rate. Mortality is up to 50% in fully susceptible flock and up to 100% in young animals. Presence of disease can limit: trade, export, import of new breeds and development of intensive livestock production.

Lumpy Skin Disease ***(pox virus):*** Lumpy Skin Disease is a pox virus that affects cattle and water buffalo predominately in Africa that can cause mild to severe signs including fever, nodules in the skin, mucous membranes and internal organs, skin edema, lymphadenitis, and sometimes death.. The disease has a very high morbidity rate but a rather low mortality rate. It is often explosive and spreads quickly. Although death from lumpy skin disease is rare and mainly in calves, diseased cattle result in milk and beef loss and often causes female cattle to abort. Economic concerns are decreased milk production, abortion, infertility, weight loss, poor growth, and damaged hides. This loss in production can be detrimental to livelihoods.

Newcastle Disease ***(Avulavirus, Paramyxoviridae)***: Newcastle disease is caused by Newcastle disease virus (NDV) which spreads primarily through bird-to-bird contact among chickens, but it can also spread through contaminated feed, water or clothing. Outbreaks occur in most parts of the world, and there have been two major pandemics over the last century. It is a major constraint to the development of village chicken industries, particularly in Asia and Africa. A large number of wild bird species can harbor Newcastle disease virus and, occasionally, the disease affects large-scale commercial poultry operations in developing countries, despite tight insecurity measures. Mexico experienced a major outbreak in 2000, in which13.6 million birds were destroyed.

Peste des Petits Ruminants ***(Morbillivirus, Paramyxoviridae)***: Peste des petites ruminants is a viral disease which primarily affects sheep and goats. The economic impacts of transboundary spread of this disease has been partly due to the inadequate international availability of an effective vaccine until recently, and also because small ruminants have perhaps not received adequate attention in disease surveillance and quarantine programmers in some regions. The Americas, Europe and Oceania are free from the peste-des-petits ruminants virus.

Rift Valley Fever ***(Phlebovirus, Bunyaviridae)***: Rift Valley fever is a mosquito-borne viral zoonotic disease caused by Rift Valley fever virus.. The first recorded outbreak of the disease, in Egypt in 1977, caused an estimated 200 000 human cases of the disease and approximately 600 deaths, as well as large numbers of deaths and abortions in sheep, cattle and other livestock species. In 1997, 1998 and 2000,outbreaks of the disease in eastern Africa not only caused livestock losses and human deaths but also seriously disrupted the region's valuable livestock export trade to the Near East.

Rinderpest ***(Morbillivirus, Paramyxoviridae)***: Rinderpest, caused by the rinderpest virus (RPV), is one of the most serious cattle diseases known. There are two types of rinderpest. The Americas, Europe and Oceania are free from rinderpest and one of the two types was eradicated from southern Africa during the first half of the twentieth century by the strict enforcement of cattle movement controls, quarantining of infected areas and selective" stamping out" of infected herds as well as vaccination in areas at risk. However, by 1962, rinderpest remained endemic over a large swathe of the pastoral regions of eastern, central and western Africa. Considerable progress has been made towards the eradication of the disease in India; however, it is endemic in Pakistan.

Swine Vesicular Disease(human enterovirus B, Enterovirus): Swine Vesicular Disease (SVD) is a contagious viral disease in pigs that is not fatal. It is caused by a human enterovirus known as swine vesicular disease virus. The disease is transmitted through direct contact, fecal matter and pork products as it is very resistant even to the cooking process, the virus can stay in a recovered animals feces for up to three months. SVD is clinically indistinguishable from foot-and-mouth disease in swine. SVD first occurred in Italy and was subsequently recognized in Hong Kong, England, Scotland, Wales, Japan, Malta, Austria, Belgium, France, the Netherlands, Germany, Poland, Switzerland, Greece, and Spain. Outbreaks in the 1990's were reported in Italy, Spain, and Portugal. Morbidity in SVD is lower, and lesions are less severe, than in foot-and-mouth disease. There is essentially no mortality in SVD.

Vesicular Stomatitis ***(Vesiculovirus, Rhabdoviridae)VSV)***: Vesicular stomatitis virus (VSV) is a viral disease caused by vesicular stomatitis Indiana virus affecting cattle, horses and swine but may also affect sheep, goats, wild animals and humans. Vesicular stomatitis is an important livestock disease in the Americas. Occasional outbreaks of this zoonotic vesicular disease has occurred in limited areas. Vesicular stomatitis closely resembles three foreign animal diseases: foot-and-mouth disease (FMD), swine vesicular disease, and vesicular exanthema of swine. Differentiation of these diseases is important, as a wrong diagnosis could mask the spread of an exotic disease. Prompt diagnosis is also important in containing outbreaks of vesicular stomatitis. VSV transmission has not been determined and quarantine is the most common method of control.

HIV/AIDS: A UNIQUE EXAMPLE OF A ZOONOTIC DISEASE

As HIV/AIDS is inextricably linked with the agriculture sector and presents a distinct set of conditions, we present the following summary that should be considered when reviewing zoonotic diseases.

HIV/AIDS is a zoonotic disease that has become a pandemic affecting millions of households around the world. UNAIDS estimates that there were 33 million people living with HIV in December 2007, and that about 2.5 million people were newly infected during 2007.

While the major impacts are felt across a wide range of areas, there are specific impacts on agricultural production, both for the HIV/AIDS affected households, as well as for commercial agriculture in those countries with the Findings from a wide range of studies indicate that in general:

- The HIV/AIDS epidemic has led to significant reductions in food production in AIDS-affected households;
- HIV/AIDS has caused a decline in the supply of labor for food and livestock production. The decline is caused by the illness and deaths of people living with AIDS and by the time spent by household members in caring for sick relatives;
- HIV/AIDS has caused shifts of production from cash crops to food crops in AIDS-affected households. The change has resulted in lower household incomes and a lack of funds to buy non-food essentials or non-labor inputs necessary to maintain agricultural yields; and
- The HIV/AIDS epidemic is leading to a loss of knowledge about farming methods and a reduction in skilled and experienced labor.

THE IMPACT OF HIV/AIDS ON THE AGRICULTURE SECTOR

HIV/AIDS affects the most productive age groups. Furthermore, HIV-infected urban dwellers often return to their village, and rural households provide most of the care for AIDS patients. FAO has estimated that in the 25 most affected African countries, 7 million agricultural workers have died from AIDS since 1985; 16 million more could die within the next 20years. FAO expects the HIV/AIDS epidemic to exacerbate food insecurity. According to recent FAO and UNAIDS studies, agricultural output of small farmers in some parts of Zimbabwe may have fallen by as much as 50 percent over the past five years, mainly as a result of AIDS.

Labor shortages are particularly serious in agriculture, since production is seasonal and timing is generally crucial. Areas with less developed labor markets and a higher reliance on household labor are also likely to be relatively worse affected. The shortfall in household labor means that some land remains fallow and the household's output declines. An FAO study of several farming areas has shown decreasing yields per area owing to: a decline in soil fertility; an increase in pests and diseases; changes and delays in cropping practices; and less use from the standpoint of commercial agriculture, the countries with the highest prevalence rates are facing more serious issues. The implications can vary between industries dependent on out-grower schemes and those with internal management. All levels of staff are being infected (managers, skilled workers, full time laborers, and seasonal workers), with resulting costs to the companies from lost productivity, termination and treatment costs. In some countries, shortages of labor are increasing costs during peak periods (such as harvest) while also putting the full harvest at risk.

HIV/AIDS is a larger national problem but there are direct activities that can be taken to mitigate the impact by agribusinesses. This prevention planning involves:

- Awareness building of the issue at the business/company level;
- Introduction of prevention programs at the business/company level; and

- Introduction of treatment programs.

Many commercial farms in most affected countries are already feeling the cost of the pandemic, so they are amenable to taking action, but often do not know what action to take. Examples of concrete programs that are addressing the prevention issues include the USAID Market Access Trade and Enabling Policies (MATEP) project in Zambia (which is focusing on developing “awareness educators” who deliver HIV/AIDS prevention messages to their co-workers) and the USAID Southern African Trade Hub which supported the establishment of clusters of businesses to cost-effectively develop workplace programs and to access HIV/AIDS service providers to deliver anti-retroviral therapy (ART).

CHAPTER FOUR: MOST SIGNIFICANT PLANT DISEASES AND THEIR POTENTIAL IMPACT

INTRODUCTION

There are many existing lists of high-threat plant pathogens worldwide, including ones prepared by the U.S. Department of Agriculture (USDA), the Australia Group, the American Phytopathological Society (APS) and the ad hoc group of the Biological Weapons Convention. However, unlike the 15 List A animal diseases recognized by the International Office of Epizootics (OIE), there currently does not exist a single internationally accepted list of the world's "highest priority" plant diseases.

For the purpose of this paper, a threat assessment model adopted by the USDA (based on a quantitative criteria pathogen rating system) was selected as a guide for the selection of the most significant plant diseases affecting staple crops and important food export crops. The model was selected due to the advanced development of the USDA's National Plant Disease Recovery System (NPDRS), a model (for threats to U.S. crops) that can be applied worldwide to determine which plant diseases pose the highest economic threat and which warrant the development of national response and recovery plans. Therefore, this chapter draws upon the findings and principles of the NPDRS and applies the methodology internationally. In addition to guidance provided by the NPDRS, we arrived at our selection of high priority plant diseases through consultations with numerous Subject Matter Experts (SMEs). Most of these SMEs came from the Office of International Programs of the American Phytopathological Society, and from plant pathologists and breeders located in the CGIAR (Consultative Group for International Agricultural Research) centers.

SELECTED SIGNIFICANT PLANT DISEASES FOR STAPLE FOOD CROPS AND EXPORT FOOD CROPS

There are thousands of plant diseases worldwide, many with a valid argument for inclusion in a theoretical "Top 10" list of most important plant diseases. However, such a definitive list is subjective, would depend on regional geography and would always be subject to intense debate by international plant pathologists. Another approach of interest to donors would be to identify the top four to six plant diseases of the most important staple food crops and economically important export food crops. This would provide a review of plant diseases through the filter of specific commodities known to be of extreme importance to food security in developing countries, resulting in disease/crop combinations that are highly important to a particular staple food crop but may not merit a position on an overall "top ten" plant disease list. The inclusion of export crops is important since many USAID projects support these crops as they are vital to improving farmer income and livelihood.

Thus, this paper presents both approaches:

1. The top ten plant diseases and/or disease complexes which may pose the most economic threat to the poor in USAID countries, and

2. A list of the top four to six plant diseases that affect the most widely consumed international staple food crops- Maize, Wheat, Potato, Sweet Potato/Yam, Rice, Cassava, Beans, Sorghum, and Millet- and those which affect a select sample of economically important export food crops (bananas, mangoes, tomatoes, and pineapple).

TEN OF THE MOST IMPORTANT PLANT DISEASE THREATS TO FOOD SECURITY IN DEVELOPING COUNTRIES

We have not attempted to numerically rank these disease/crop interactions in order of importance. Rather, as a pool, these selections represent ten of the most extremely important plant disease threats to food security in developing countries based on consultations with various SMEs (subject matter experts) referenced at the end of this chapter. Some diseases are very specific to a particular crop, such as Wheat Stem Rust (race Ug99), while other plant diseases can affect more than one crop, as is the case with bacterial wilt or the Gemini viruses, both of which can attack many vegetable crops.

1. Downy Mildews of Maize and other Grass Crops
   - Maize Philippine Downy Mildew (*Peronosclerospora philippinensis*)
   - Maize Brown Stripe Downy Mildew (*Sclerophthora rayssiae*)
   - Sorghum Downy Mildew (*Scleropthora macrospora*)
2. Wheat Rusts
   - Stem Rust (*Puccinia graminis*, Race Ug99)
   - Leaf Rust (*Puccinia recondita*)
   - Stripe Rust (*Puccinia striiformis*)
3. Rice Blast (*Pyricularia grisea*)
4. Rice Tungro Virus
5. Ear Rot of Maize (*Fusarium verticillioides*, *Aspergillus flavus*)
6. Bacterial Wilt of solanaceous Crops [tomato, pepper, chili, potato, eggplant] (*Ralstonia solanacearum*)
7. Cassava Mosaic Virus
8. White Fly-Transmitted Gemini Viruses of Diverse Vegetable Crops
9. Potato Late Blight (*Phytopthora infestans*)
10. Fusarium Wilt of Banana (*Fusarium oxysporum* f. sp. *cubense*)

TOP PLANT DISEASES AFFECTING SPECIFIC STAPLE AND EXPORT FOCUSED FOOD CROPS

The plant diseases described below are categorized by crop, listing the five to six most significant pathogens currently affecting that specific commodity. Designating a single plant disease as the worldwide most significant pathogen for a particular commodity is strongly resisted by Subject Matter Experts (SMEs), who have noted in interviews that geography dictates which plant disease poses the highest threat in a particular region. The top "multiple listings" for each of the commodities reflects the general consensus of SMEs, while not providing a numerical ranking. Descriptions for the following diseases were drawn from the reference sites provided in Annex B.

Maize

1. **Philippine Downy Mildew *(Peronosclerospora philippinensis)* and Brown Stripe Downy Mildew *(Sclerophthora rayssiae)***: Philippine Downy Mildew of Maize (PDM), caused by the oomycete *Peronosclerospora philippinensis* and Brown Stripe Downy Mildew (BSDM) caused by *Sclerophthora rayssiae* var. *zeae* are destructive diseases of corn in tropical Asia. These are two of several downy mildew diseases that occur in China, India, Indonesia, Nepal, Pakistan, and Thailand. Corn is the common host for both species. The source of primary PDM infection in corn comes from spores produced by nearby infected hosts such as sugarcane or susceptible grass species. PDM is most commonly spread by wind and rain. Production of spores requires night temperatures ranging from 70 to 79ºF accompanied by free moisture. Wind dispersal of the downy mildew pathogens results in localized spread among fields in a given geographical region. Though the pathogen has been detected systemically in seed, it has been clearly demonstrated that once the seed or grain is dried down below 14% it will not produce an infected plant. In the case of BSDM, the source of primary infection is from soil borne over-wintering spores which germinate in saturated wet soil producing both conidia and swimming zoospores which infect the young plants. Optimum temperature range for infection is 68 to 77ºF.

2. **Ear Rot *(Fusarium verticillioides, Aspergillus flavus)***: Ear rot is likely the most common pathogen of maize ears throughout the world. In contrast to damage from *Giberella zeae*, that from *F. moniliforme* occurs mainly on individual kernels or on limited areas of the ear. Infected kernels develop a cottony growth or may develop white streaks on the pericarp and germinate on the cob. Ears infested by earworms are usually infected with *F. moniliforme*. The fungus produces mycotoxins known as fumonisins, which are harmful to several animal species.

3. **Gray Leaf Spot *(Cercospora zeae maydis)***: Gray leaf spot (GLS) is a serious foliar disease of maize in many temperate and tropical highland regions of the world. GLS is caused by fungal species in the genus Cercospora. The disease is considered the most important foliar disease of maize in the USA and is considered one of the principal constraints to maize production in the mid-altitude maize growing regions of sub-Saharan Africa. GLS is also emerging as a major constraint to maize production in China. Yield losses in excess of 70% have been caused by GLS.

4. **Northern Corn Leaf Blight *(Excerohilum turcicum)***: Northern leaf blight has traditionally been one of the most damaging corn leaf diseases. Use of resistant hybrids has limited yield losses from this disease in commercial corn; however, significant losses continue to occur in seed corn production when highly susceptible inbred lines are planted. The disease appears as long, elliptical greyish-green or tan streaks on the foliage. Lesions most often begin on the lower leaves. As the disease develops, individual lesions may join, forming large blighted areas. In some cases the entire leaves may become

blighted.. Losses due to northern leaf blight are most severe when the leaves above the ear are infected at or slightly after pollination.

5. **Southern Corn Leaf Blight *(Bipolaris maydis)***: This disease has many synonyms associated with both its common name and the scientific name of the causal organism. The imperfect stage of the fungus exists in two distinct races; Race O (old race) and Race T (virulent on corn containing Texas male sterile cytoplasm, Tm-sc). Both races produce phytotoxins. The phytotoxin produced by Race O is nonspecific to cytoplasm types and is produced in small amounts. Race T produces a phytotoxin that specifically affects corn containing Tm-sc. Common hosts of the fungus are corn, sorghum and teosinte. The fungus overwinters on crop debris, primarily on the soil surface, as mycelium, conidiospores and chlamydospores. Conidiospores are windblown or splashed by water to fresh plant tissue in the spring. The spores germinate on the leaf surface and infect the host directly and through stomata. Disease development is favored by warm (20-30ºC) moist weather and the presence of free moisture on the host tissue surface. The fungus is very prolific; able to complete an entire life cycle in 60-72 hours under favorable weather conditions. This disease alone was able to wipe out 15-20% of the U.S. crop during 1970 (losses in excess of U.S. 1 billion), but is now under reasonable control as breeders have moved away from utilization of lines containing the highly susceptible Texas male sterile cytoplasm.

Wheat

1. ***Rust***

   a. **Stem Rust *(Puccinia graminis,* Race Ug99*)***- In a Uganda wheat nursery in 1999, susceptible type stem rust pustules (collection designated Ug99) were found on wheat lines known to have the stem rust resistance gene Sr31, a gene for which no virulence had been reported previously anywhere in the world. Similar virulence was observed in 2001 in Kenya and 2003 in Ethiopia. Race typing (race TTKS based on Pgt system of nomenclature, see Phytopathology 78:526-533) and DNA confirmed the presence in Kenya in 2005. Stem rust of wheat occurs wherever wheat is grown. It is most important where dews are frequent during and after heading, and where temperatures are generally warm (18-30º C). Yield losses can often be severe (50 to 70%) over a large area and some individual fields can be totally destroyed. Damage is greatest when the disease becomes severe before the grain is completely formed. In areas favorable for disease development, susceptible cultivars cannot be grown. Grain is shriveled due to the damage to the vascular tissue, resulting in less nutrient being transported to the grain. Severe disease can cause straw breakage, resulting in a loss of spikes with combine harvesting. Spore bearing structures called uredinia generally appear as oval lesions on leaf sheaths, true stem, and spike. Uredinia can appear on the leaves if other diseases have not killed them. Uredinia are brick red in color and can be seen to rupture the host epidermis, on the leaves uredinia generally penetrate to sporulate on both surfaces. Spores from these structures are carried by wind and water over long distances to infect new fields.

   b. **Leaf Rust *(Puccinia recondita)***- Leaf rust causes very small orange pustules that erupt through the leaf surface. In some cases, pustules are surrounded by a narrow yellow or white halo. The pustules contain masses of powdery orange spores of the rust fungus. Spores may spill out of pustules and form a grainy orange dust on the leaf surface around the pustule. When rust severity is high, field scouts may notice the orange dust on hands and clothing. As leaves age, pustules begin to produce dark black spores instead of orange spores. These black pustules look like tar spots and are most easily seen on the lower leaf surface and leaf sheaths. Although leaf rust may initiate tiny orange spots on culms and heads, it does not form large, open pustules on these organs. This helps distinguish leaf rust from stem rust. Stem rust is uncommon and usually only occurs late in the season because it requires warm temperatures. Leaf rust pustules occur randomly across the leaf; this distinguishes leaf rust from stripe rust, which has narrow yellow stripes of pustules. As with stem rust, leaf rust spores as carried long distances by wind and rain.

c. ***Stripe Rust (Puccinia striiformis)***- The small yellowish uredinia appear in linear rows on the leaf. A single infection can result in a stripe the length of the leaf. Uredinia also can occur in the spike. Stunting of plants is common with severe early infections. Generally, stripe rust can be found throughout wheat production areas at high elevations and in the northern and southern areas of temperate regions. Losses of 40 percent can be common with some fields totally destroyed. It is a major disease of fall seeded wheat in regions with cool nights or of spring wheat planted adjacent to infected fall seeded wheat. Severe losses result when spikes are infected. As with the other rusts, stripe rust spores can travel very long distances in the atmosphere in order to start new infections in distant wheat fields

2. **Head Blight or "Scab"** ***(Fusarium spp.)***: Infected florets (especially the outer glumes) become slightly darkened and oily in appearance. Conidiospores are produced in sporodochia, which gives the spike a bright pinkish color. Infected kernels may be permeated with mycelia and the surface of the florets totally covered by white, matted mycelia. Several species of *Fusarium* can attack the spikes of many small grain cereals (wheat, oats, barley, triticale) and infection is favored by warm and humid weather during and after heading. Temperatures between 10 and 28ºC are required for infection. Once primary infection has occurred, the disease can spread from floret to floret by mycelial growth through the spike structure. Severe levels of infection can cause yield losses of more than 50% and significant reductions in grain quality. Kernels from diseased spikes are often shriveled. Harvested grain containing more than 5% infected kernels can contain enough mycotoxins to be harmful to humans and animals.

3. **Leaf Blotch** ***(Septoria tritici)***: Speckled leaf blotch symptoms first appear in the fall. The initial symptoms are small yellow spots on the leaves. These spots expand and later turn light tan. Lesions are irregularly shaped and range from elliptical to very long and narrow. Lesions contain very small round black speckles that appear like grains of black pepper. The black speckles are fungal fruiting bodies. The black fruiting bodies can usually be seen without the aid of a magnifying glass. The disease begins on the lower leaves and gradually progresses up to the flag leaf. Leaf sheaths are also susceptible to attack. In wet years, the speckled leaf blotch fungus can move to the heads and cause glume blotch symptoms. Brown lesions appear randomly on the glumes and awns. These lesions bleach to light tan and often contain the typical black speckles that are the fruiting bodies of *Septoria tritici*. The fungal fruiting bodies are often seen embedded in the lesions on the awns. The glume blotch phase appears to cause significant yield loss, but this is difficult to measure.

4. **Spot Blotch** ***(Cochliobolus sativus)***: Spot blotch, in combination with Tan Spot and Septoria and Stagonospora leaf blotches, causes serious damage to the carbohydrate producing green leaf tissues. Greatest yield losses occur when the flag leaf and the leaf below the flag leaf become

infected before head emergence. If these leaves are killed before the soft dough stage, the grain will be low in weight. When infected, untreated seed is planted, seedling emergence may be diminished by seedling blight and an increased sensitivity to winter injury.

5. **Powdery Mildew *(Blumeria graminis)***: Powdery mildew, caused by *Blumeria graminis* f. sp. *tritici*, is widely distributed throughout the world, particularly in humid regions. The disease results in reduced kernel size and test weight, and ultimately lower yield. The earlier in the spring mildew begins to develop on the plant, the greater the yield loss. Greatest yield losses occur when the flag leaf becomes severely diseased during heading. Powdery mildew is characterized by a powdery white to gray fungal growth on leaves, stems and heads. The fluffy white pustules are first detected on the lowest leaves of plants 30-50 days after planting. As the plant matures, the white powdery growth changes to a grey-brown color. The leaf tissue on the opposite side of the leaf from the white mold growth becomes yellow, later turning tan or brown. Small, black fruiting bodies (cleistothecia) develop on leaves at 70-90 days after planting. Cleistothecia are recognized as distinct round, black dots within older, grey colonies of powdery mildew. Cleistothecia contain spores (ascospores) that serve to infect neighboring wheat fields.

Potato

1. **Late Blight *(Phytopthora infestans)***: Potato late blight is considered to be the most serious potato disease worldwide. It occurs almost everywhere potatoes are grown. In developing countries alone, yield loss due to late blight is estimated to add up to US$ 2.75 billion each year. In addition, much money is spent on fungicides. Late blight is caused by the fungus *Phytophthora infestans*. Spores transported in the wind or infected tubers carried to new planting areas can cause infestation. Late blight first appears as a few grayish specks on the plant's leaves, and then a cottony film appears. Under certain climatic conditions (high humidity and cool temperatures), the disease can easily lead to the destruction of a whole field of potatoes. The disease also affects tubers, and can make the crop unfit for storage. The disease can be controlled using resistant varieties, combined with cultural practices and a few select fungicides. However, many developing country farmers do not have the sufficient knowledge to manage the disease well. On top of that, the level of resistance in current potato cultivars is only intermediate, and access to resistant varieties by farmers is often limited. Moreover, the use of fungicides tends to be intensive and is often far too costly for resource-poor farmers.

2. **Bacterial Wilt *(Ralstonia solanacearum)***: Bacterial wilt or brown rot, caused by *Ralstonia [Pseudomonas] solanacearum*, limits potato production worldwide in Asia, Africa, and Central and South America, where it causes severe crop losses in tropical, subtropical, and warm temperate regions. The disease may also occur in cooler climates such as relatively high elevations in the tropics or higher latitudes. The bacterium affects more than 30 plant families, including crops and wild species. Race 3 (biovar 2A) strains of *R. solanacearum*, which affect mainly potato but occasionally tomato and other solanaceous crops and weeds, are most common in higher elevations of the tropics (up to 3400 masl). At lower elevations, race 1 strains are most prevalent and affect a wide range of crops and weeds. Crops highly susceptible to race 1 (biovars 1, 3 or 4) of R. solanacearum are potato, tobacco, tomato, eggplant, chili, bell pepper, and groundnut. The Race 3 biovar 2 strain is not yet present in the U.S., and since most of the U.S. potato industry grows varieties which are highly susceptible, USDA plant quarantine officials

have categorized this disease as a "select agent" and has a national recovery plan in place in case of introduction.

3. **Viruses (PLRV, PVX and PVY)**: Potato diseases caused by viruses can cause losses in potatoes in the form of decreased yields, misshapen tubers, and internal discoloration. Since viruses build up quickly in potato stocks, seed production schemes have been developed in order to keep viruses at low levels in seed potatoes. Viruses can be spread by fungi, insects, nematodes and leaf hoppers, and mechanically by contact between plants, plant sap or humans. There are at least three strains of Potato Virus Y (PVYn, PVYc and PVYo). The common strain (PVYo) is prevalent in Maine and the United States. PVY is one of the two most important viruses infecting potatoes in Maine and elsewhere. Severe yield losses—up to 100 percent—are possible from this pathogen. The virus is borne on an aphid stylet and can be transmitted as quickly as in a few seconds. When aphids pick up the virus, they will not keep the virus for their entire life. However, aphids can re-acquire the virus on their stylet numerous times. The virus can also be spread mechanically by human activity. PVY can interact with other viruses, most notably PVX. PVY causes mosaic in potatoes. The symptoms of PVY vary depending upon the strain of the virus and the variety of potato. Some potato varieties have a hypersensititive reaction to PVY. This results in rapid death of the infected area and a small dead area surrounding the infection. Some potato varieties are more sensitive to the PVY viruses and exhibit easily visible symptoms such as a mild mottling. The leaves may become distorted and brittle, often exhibiting a wrinkled and rough appearance. In addition to potatoes, tomatoes and nightshade, plants in the Leguminosae and Chenopodiaceae groups are hosts to PVY.

4. **Early Blight *(Alternaria solani)***: Early blight is a disease of potato caused by the fungus *Alternaria solani*. It is found wherever potatoes are grown. The disease primarily affects leaves and stems, but under favorable weather conditions, and if left uncontrolled, can result in considerable defoliation and enhance the chance for tuber infection. Small lesions coalesce into large lesions, resulting in premature defoliation and considerable reduction in yield. The disease can even be more severe on tomatoes, and can occur on other solanaceous crops and weeds. Resistant varieties combined with foliar fungicides offer the best control.

5. **Verticillium Wilts *(Verticillium dahliae* and *V. albo-atrum)***: Verticillium wilt of tomatoes and potatoes can be caused by two different soil-borne fungi, *Verticillium albo-atrum* or *Verticillium dahliae.* These fungi have a very broad host range, infecting up to 200 species of plants. In addition to tomatoes and potatoes, these fungi can infect cucumber, eggplant, pepper, rhubarb, watermelon, artichoke, beet, broad bean, strawberries, raspberries, and a number of weedy plants. Wilting is the most characteristic symptom of infection by Verticillium spp. Symptoms usually appear on the lower leaves in mid-August when infected plants wilt during the warmest part of the day, and then recover at night. Leaf edges and areas between the veins turn yellow and then brown. In addition, infected plants often have a characteristic V-shaped lesion at the edge of the leaf occurring in a fan pattern. These foliar lesions can enlarge, resulting in complete browning and death of the leaves. Verticillium wilt can be detected by looking for the presence of vascular streaking in stems near the ground. When cut longitudinally, Verticillium-infected stems show a light tan discoloration of the vascular tissue. These symptoms are similar to those caused by another fungus, Fusarium, but vascular streaking caused by Fusarium is generally darker and progresses further up the stem than streaking caused by Verticillium. Infected potato tubers may

also show similar vascular discoloration occurring in rings, especially near the stem end. Although often discolored, the tubers are safe to eat.

Sweet Potato/Yam

1. **Sweet Potato Virus Disease (SPVD)**: Sweet potato virus disease (SPVD) is one of the most damaging diseases of sweet potato and results from dual infections of sweet potato feathery mottle virus (SPFMV), vectored by aphids, and sweet potato chlorotic stunt virus (SPCSV), vectored by whiteflies. SPVD is one of the more devastating diseases that affect sweet potato causing severe reduction in yields but apparently having no effect on the quality of the potato tuber. The disease is characterized by symptoms including vein clearing or mosaic, stunting, leaf reduction and deformation.

2. **Sweet Potato Feathery Mottle Virus (SPFMV)**: Sweetpotato feathery mottle virus (SPFMV; family Potyviridae, genus Potyvirus) commonly infects sweetpotatoes (Ipomoea batatus) in Africa and elsewhere in the world. It is transmitted by aphids in the non-persistent manner. In most East African sweetpotato cultivars, SPFMV causes no symptoms on the foliage. However, dual infection with the unrelated whitefly-borne virus, sweetpotato chlorotic stunt virus (SPCSV; family Closterovirdae, genus Crinivirus) cause the severe symptoms known as sweetpotato virus disease (SPVD). This is the main disease of the crop, characterised by small distorted leaves which are often narrow (strap-like) and crinkled with a chlorotic mosaic and /or vein-clearing and stunting of plants. SPVD-affected plants commonly produce less than half the tuberous root yield of symptomless ones.

3. **Root-knot Nematode *(Meloidogyne incognita)***: In many areas of the world, the root-knot nematode (RKN), Meloidogyne incognita, causes significant yield reductions in sweetpotato. This nematode also infests many other cultivated and noncultivated plants. Research has shown many sources of resistance among germplasm accessions, particularly those from China, Peru, and Japan. Therefore, management of this pest is based on the use of resistant cultivars.

4. **White Fly *(Bemisia tabaci)***: Bemisia is primarily a pest of cultivated plants in tropical and warm temperate regions of the world. It is found throughout the southern United States and is widely distributed throughout the Caribbean Islands, Central and South America, and Mexico. It is present throughout much of southern Europe, Africa, India, and has recently moved into Australia. Bemisia can cause economic damage to plants in several ways. In addition to transmitting harmful viruses, heavy infestations of adults and their progeny can cause seedling death, or reduction in vigor and yield of older plants, due simply to sap removal. When adult and immature whiteflies feed, they excrete honeydew, a sticky excretory waste that is composed largely of plant sugars. Sooty mold grows on honeydew-covered plant parts, obscuring the leaf and reducing photosynthesis, and reducing fruit quality grade.

Rice

1. **Rice Blast** (*Magnaporthe grisea* (Hebert) Barr): Rice blast is one of the most important diseases found in rice. It is caused by a fungus and can affect the leaf, stem, nodes and neck of the rice panicle. With blast, leaf lesions are distinctively grey in the center, exhibit dark borders and are diamond-shaped (large in the middle and tapering to ends). Leaf symptoms are similar to Bipolaris leaf spot (also known as brown spot). When blast attacks nodes on the stem, it can be

confused with rat damage (although rats are associated with physical damage). Panicles affected by neck rot can be confused with stemborer damage (except with blast, the panicle is still connected to the stem). In parts of tropical Asia, rice blast can frequently cause yield losses in the range of 50-70%.

2. **Rice Tungro Virus**: Tungro is one of the most damaging and destructive diseases of rice in countries in Southeast Asia. Outbreaks of the disease can affect thousands of hectares in many countries. The virus is transmitted by leaf hoppers and fields infected with the virus at the early crop growth stage could have as high as 100% yield loss.. Tungro virus disease affects all growth stages of the rice plant specifically the vegetative stage. There are three limitations of effective tungro management: 1) the absence of symptoms at early growth stage of the disease development, 2) lack of resistant varieties to the tungro viruses, and 3) vector adaptation on leafhopper resistant varieties. Planting of resistant varieties against tungro virus disease is the most economical means of managing the disease. There are resistant varieties available from the Philippines, Malaysia, Indonesia, India, and Bangladesh.

3. **Brown Spot *(Helminthosporium oryzae)***: The disease is first seen as brownish spots on the leaves and glumes of the plant. The spots enlarge and become grey at the center and brown at the edge. The affected tissues take on a velvety feel as the fungus begins to develop aerial structures that produce the spores by which it spreads. The spores are carried in the rice seed and when it germinates, the burden imposed by the growing fungus on the developing plants is such that the seedlings are weakened and crop yields are drastically reduced. There was a major outbreak of rice brown spot in Bengal in India in 1942, with the loss of the crop leading to a famine that claimed two million lives.

4. **Bacterial Leaf Blight *(Xanthomonas oryzae)***: Bacterial blight is one of the most serious diseases of rice. The disease reduces grain yield to varying levels depending on the stage of the crop, degree of cultivar susceptibility and a great extent to the conduciveness of the environment in which it occurs. It can cause crop yield loss up to 50 per cent. The presence of weeds around rice field, rice stubbles, and ratoons of infected plants, warm temperature (25-30°C), high humidity, rain and deep water, severe winds and over fertilization are factors favorable to the development of this disease. Symptoms of the disease are observed at the tillering stage. The disease increases with plant growth and reaches its peak at the flowering stage.

5. **Bacterial Leaf Streak *(Xanthomonas translucens* f. sp. *oryzicola)***: Bacterial leaf streak first appears as short, water-soaked streaks between the veins, which become longer and translucent and turn to light brown or yellowish brown. Thus, large areas of the leaf may become dry due to numerous streaks. At the late stage the disease is indistinguishable from the bacterial leaf blight.

6. **Hoja Blanca Virus**: Rice hoja blanca is a viral disease that occurs in cyclical outbreaks, reaching epidemic levels which are maintained over several years. It currently affects rice production in Tropical America and the Caribbean. Hoja blanca disease is caused by a planthopper-transmitted virus: the rice hoja blanca virus (RHBV, Tenuivirus), which induces chlorotic stripes, systemic chlorosis and seed sterility in cultivated rice plants. The virus is persistent and propagative in the delphacid insect vector (*Tagosodes orizicolus*, Homoptera: Delphacidae), which in turn is able to transmit the virus transovarially to the progeny.

Cassava

1. **African Cassava Mosaic Virus**: Depending on variety, cassava plants may show mild to severe mosaic, yellowing, distorted leaves, and stunted growth. Disease symptoms may be expressed irregularly throughout the plant, particularly in more resistant varieties commonly grown in Africa. In some varieties, the majority of plants do not show any symptoms, especially in later stages of growth. ACMV is transmitted by vegetative propagation and by the whitefly *Bemisia tabaci*. ACMV isolates have been found in cassava throughout tropical Africa and in its adjacent islands, including Cape Verde, Sao Tome and Principe, Malagasy, and Seychelles. In India and Sri Lanka a similar disease, called Indian cassava mosaic disease, is caused by a related virus known as Indian cassava mosaic virus.

2. **Anthracnose *(Colletotrichum gloeosporioides)***: Cassava anthracnose disease appears as cankers ("sores") on the stems and bases of leaf petioles. Cankers weaken the petioles so that the leaf droops downwards and wilts. The wilted leaves die and fall causing defoliation and shoot tip die-back or complete death of the shoot. Soft parts of the cassava stems become twisted under severe attack by the disease. The disease usually starts at the beginning of the rains and worsens as the wet season progresses. The main sources of the fungus that causes cassava anthracnose disease are cassava plants with the disease. The fungus spreads by wind carried spores from cankers on the stems, or by planting stem cuttings with cankers. The fungus enters cassava plants through wounds and feeding punctures made by the bug *Pseudotheraptus devastans*. Dead cassava stems and leaves with the fungus also serve as sources of the disease if they are not destroyed after root harvest.

3. **Bacterial blight *(Xanthomonas axonopodis)***: Cassava bacterial blight is caused by a bacterium which occurs inside cassava leaves and stems. Initially, damage by cassava bacterial blight appears as water-soaked dead spots (lesions). The lesions occur between leaf veins and are most evident on the lower surfaces of the leaves. The lesions are small, not completely round in shape, and have a few angles at their edges. These angular lesions later join together into larger patches killing the leaf blade as they enlarge. The main sources of the bacterium which causes cassava bacterial blight are cassava plants with the disease. The bacterium enters cassava plants through wounds and scratches on the stems and leaves.

4. **Cassava Common Mosiac Virus**: Cassava mosaic disease is caused by a virus which occurs inside cassava leaves and stems. The leaves of cassava plants with the disease are discolored with patches of normal green color mixed with light green, yellow, and white areas. This discoloration is known as chlorosis. When cassava mosaic attack is severe, the leaves are very small and distorted and the plants are stunted. The disease symptoms are more pronounced on younger plants.

5. **Bacterial Angular Leaf Spot *(Xanthomonas campestris* pv. *dieffenbachiae)***: Disease symptoms begin as small, watersoaked spots on the lower surface of leaves. Spots enlarge and substantial areas of brown, dead tissue surrounded by yellow halos develop on upper leaf surfaces. Pronounced watersoaking continues on the lower leaf surface, sometimes with a cream to light yellow bacterial exudate (sticky ooze) in the center of the water-soaking. Lesions along the margins of leaves are often seen. The main mode of bacterial movement is probably by splashing rain. Disease development is favored by high temperatures in the range of 29-32°C.. Entry into the plant is facilitated by wounding. The relationship between bacterial leaf spot

severity and yield is unknown. Therefore, it is difficult to comment on the potential usefulness of disease control measures. Growers should stay out of fields when plants are wet, as the bacteria is readily transmitted whenever workers, tools, or farm machinery contact infected, sodden plant material. Since planting stock likely is contaminated with the pathogen, the same tissue culture methods that someday may be used for mosaic virus control, may also help reduce bacterial spot.

Beans and Pulses

1. **Rhizoctonia Root Rot and Web Blight** ***(Rhizoctonia solani)***: Rhizoctonia spp. cause a range of disease, some truely soilborne, others attacking aerial parts. These fungi are a diverse group of organisms that are still being studied to determine their relationships. Most seem to be the imperfect stage of Basidiomycetes. These fungi attack a broad range of hosts and are commonly associated with other crop and weed plants. They are found in almost all soils and in most environmental conditions. On bean, germinating seeds and seedlings are attacked by this pathogen. Reddish spots, which can be sunken, expand to kill the plants. Reddish-brown to brown collar rots are common on young plants. These rots inhibit normal growth and cause stunting or plants with poor vigor. Callus formation and thickening of the collar area also occurs. Root rots form at any time. Extensive root rots cause plants to decline and yields are reduced. Pod rots are brown to greenish-brown, mostly circular, and sunken.

2. **Golden Bean Yellow Mosaic Virus** ***(Gemini virus complex)***: The disease is of major importance in Central and South America countries, Caribbean islands, and Nigeria. Brazil, El Salvador, Guatemala and Jamaica are especially affected. The most striking foliage symptom is a bright yellow or golden mosaic. Leaf wrinkling and rolling is also apparent, along with plant distortion and stunting. Infected pods may be malformed, stunted and show mosaic spots, while the seeds therein are discolored, malformed and reduced in size. Individual diseased plants bordered by healthy ones are commonly seen.

3. **Common Bacterial Blight** ***(Xanthomonas phaseoli)***: Characteristic leaf symptoms of common blight consist of irregular areas of brown dry tissues surrounded by a narrow lemon yellow border. These lesions frequently occur at the leaf margins. Pods have sunken circular spots, at first water-soaked, but later dry, with a reddish brown narrow border. The bacteria invade the seeds and remain dormant until germination begins. Even a trace of infected seed when planted can initiate severe infection of entire fields. The bacteria exude in the leaf and pod spots and are spread mainly by splashing and blowing rain. Warm, humid conditions favor development of the disease.

4. **Rust** ***(Uromyces phaseoli typica)***: Rust is a common disease that affects many plants. Bean rust is caused by *Uromyces phaseoli typica*, and it affects common dry and snap, lima, and scarlet runner beans. It is a worldwide disease, and can destroy an entire crop if conditions are favorable early in the season. It is more severe in humid areas, and is favored by moderate temperatures. It can cause defoliation early in the season, which reduces yield. If only the leaves are infected later in the season, there is little yield loss, and the need for a chemical defoliant may be eliminated. Rust can occur on all above-ground parts of the plant, but rust spots are most numerous on the undersides of leaves. Spots begin as tiny, white, slightly raised spots. These will break open to become distinct round reddish brown spots. When touched, reddish brown dust-like spores brush off. The spots are surrounded by yellow rings on some bean varieties. If the leaves are severely

covered, they fall off. In late season, spots may darken as the black over wintering spores are produced.

5. **Angular Leaf Spot** ***(Phaeoisariopsis griseola)***: Symptoms on leaves, stalks, and pods include angular brown or red colored spots with purple edges and grey to brown centers. The leaves may then fall prematurely as the lesions coalesce. The best know controls against the disease include use of healthy, certified seeds; treating seeds using fungicides such as Fernasan D, or spraying the foliage with fungicides such as benomyl.

Sorghum

1. **Downy Mildew** ***(Scleropthora macrospora)***: These diseases are of serious concern to producers in several countries of Asia, Africa, and throughout the Americas. Symptom expression is greatly affected by plant age, pathogen species, and environment. Usually, there is chlorotic striping or partial symptoms in leaves and leaf sheaths, along with dwarfing. Downy mildew becomes conspicuous after development of a downy growth on or under leaf surfaces. This condition is the result of conidia formation, which commonly occurs in the early morning. The diseases are most prevalent in warm, humid regions. Some species causing downy mildew also induce tassel malformations, blocking pollen production and ear formation. Leaves may be narrow, thick, and abnormally erect.

2. **Bacterial Leaf Streak** ***(Xanthomonas holcicola)***: Bacterial leaf streak initially causes narrow, dark-green and water-soaked streaks on the interveins - usually from tillering to booting. As the disease progresses, the streaks become yellowish-gray and translucent with numerous milky to yellow beads of bacterial exudate formed on the surface of the lesions. Later, when the disease becomes severe, the lesions enlarge and coalesce, then eventually turn brown to grayish white causing leaves to die. High temperatures, high humidity and rainy weather favor the development and spread of the disease.

3. **Bacterial Leaf Stripe** ***(Pseudomonas andropogoni)***: Bacterial leaf stripe is widely distributed and destructive on many types of sorghums (grain, forage, and sweet), sudangrass, and broomcorn as well as on several other related grasses. Long, narrow stripes (1/4 inch by 9 inches or more) form on the leaves. These stripes are initially water-soaked, irregular, and bounded by veins. These areas soon dry and turn brick red, dark purplish red, reddish brown, or tan-to-dark brown depending on the sorghum variety. The color is continuous throughout the lesion. Later, the stripes elongate and fuse to form irregular blotches that cover a large part of the leaf surface and extend into the leaf sheath. Stalks and floral structures may show similar but more restricted lesions. Infection occurs primarily through wounds produced by wind or insects and to a lesser extent through stomates. The bacterium is seedborne and survives in plant residue. Leaf stripe first appears about midsummer and continues until plant maturity.

4. **Sorghum Rust** ***(Puccinia purpurea)***: Early symptoms on leaves are small purple red or tan spots. These enlarge to produce elongated raised pustules that break open to release brown, powdery masses of spores. Sorghum rust is more serious in late-sown crops or susceptible hybrids in humid areas. If the disease is serious, leaves are destroyed and pinching of the grain results. The only reasonable control method is to select resistant hybrids suitable for late planting.

Millet

1. **Downy Mildew *(Sclerospthora macrospora)***: Downy mildew resistance is required to maintain stable pearl millet yields in West Africa, and identifying diverse sources of resistance is necessary as new cultivars are developed. Downy mildew is a major pathogen of pearl millet in Asia and Africa. Stability of resistance in pearl millet lines developed at ICRISAT was studied through a collaborative International Pearl Millet Downy Mildew Virulence Nursery (IPMDMVN). The reactions to downy mildew of 11 pearl millet lines at 17 locations in India, Burkina Faso, Mali, Niger, and Nigeria from 1995 to 1999 were recorded. Disease incidence varied significantly among lines, locations, and years.

2. **Ergot *(Claviceps fusiformins)***: Ergot disease of pearl millet has been reported from India, Pakistan, and several countries in Africa. The ergot causing fungus infects the florets and develops in the ovaries, producing initially copious creamy, pink, or red colored sweet sticky liquid called honey dew. The major source of primary inoculum is sclerotia already in soil from the previous crop or added at sowing with the use of contaminated seed. Disease development and spread depends on prevailing weather conditions during flowering and the timely availability of pollen.

3. **Smut *(Tolyposporium penicillariae)***: Smut disease of pearl millet has been reported from Pakistan, India, USA and several countries in Africa. Symptoms include immature, green sori (pustules) larger than the seed develop on panicles during grain fill. A single sorus develops per floret. As grain matures, sori change in color from green to dark brown. Sori are filled with dark teliospores. Infection occurs when sporidia (asexual spores) suspended in rain or dew infiltrate into the boot. Aerial populations of sporidia are greatest when minimum and maximum temperatures range between approximately 21 and 31 oC, and maximum relative humidity is greater than 80%.

4. **Rust *(Puccinia penniseti)***: On pearl millet, small, reddish brown to reddish orange, round to elliptical uredinia develop mainly on foliage. As severity of infection increases, leaf tissue will wilt and become necrotic from the leaf apex to base. In infection sites developing late in the season, uredinia are replaced by telia, which are black, elliptical, and subepidermal.

5. **Bacterial Spot *(Pseudomonas syringue)***: Symptoms include round, oblong, linear, or irregular water-soaked leaf spots expand to form oval to elongate, tan necrotic lesions with a thin, dark-brown margin. Colonies in culture are grayish white in reflected light and slightly greenish fluorescent in transmitted light. The short, cylindrical rods have 1 to 4 polar flagella at one pole. Temperature for growth ranges from 0 to 35 ºC, with optimum temperatures between 25 and 30 ºC. The bacteria are highly resistant to freezing in water.

6. **Zonate Leaf Spot *(Gloeocercospora spp.)***: Contaminated seed or soil-borne sclerotia (dormant resting structures) initiate epidemics during warm, wet weather. Spores (conidia) produced in lesions are disseminated within and between fields by wind and splashing water. The pathogen likely survives in the soil for several years in the absence of a host. Zonate leaf spot symptoms initially appear as water-soaked spots that later develop tan centers with dark brown borders. Lesions enlarge with time, and become somewhat circular in shape and cover half or more of the leaf width. Concentric and alternating dark brown and light tan rings are often apparent, but may be absent from narrow-leafed varieties. During moist weather, small, salmon-colored spore masses are visible lesions when viewed under magnification.

Bananas

1. **Fusarium Wilt or "Panama Disease"** ***(Fusarium oxysporum f. sp. cubense)***: Fusarium wilt is a severe disease of banana plants caused by the fungus *Fusarium oxysporum* f.sp. *cubense* (Foc). This disease kills susceptible banana plants and there is no cure. Fusarium wilt is the preferred name for what was first called Panama disease because it became prominent in that Central American country in the early 1900s. The fungus infects banana plants through the roots and invades the plant's water conducting tissues. Once Foc is introduced into banana gardens, it remains in the soil making it impossible to grow susceptible bananas in the same location for up to several decades. Foc is thought to have originated in Asia, then spread during the 20th century to become a major problem throughout most banana production regions of the world. An important exception is the South Pacific, where Fusarium wilt is a new disease and not yet widespread.

2. **Banana Bunchy Top Virus (BBTV)**: Banana bunchy top virus (BBTV) is a deadly pathogen which affects many geographical areas of the world-wide banana industry. Infected banana plants produce increasingly smaller leaves on shorter petioles giving the plants a bunched appearance. Fruits may be distorted and plants become sterile before the whole mat (rhizome) eventually dies. The international spread of BBTV is primarily through infected planting materials. BBTV is one of the most serious diseases of banana. Once established, it is extremely difficult to eradicate or manage. BBTV is widespread in Southeast Asia, the Philippines, Taiwan, most of the South Pacific islands, and parts of India and Africa. In Hawaii, BBTV was first observed in 1989 and is now widely established and a huge threat to the Hawaiian banana industry.

3. **Black Sigatoka** ***(Mycosphaerella fijiensis)***: Black Sigatoka, which is also known as black leaf streak, causes significant reductions in leaf area, yield losses of 50% or more, and premature ripening, a serious defect in exported fruit. It is more damaging and difficult to control than the related yellow Sigatoka disease, and has a wider host range that includes the plantains, dessert and cooking bananas (ABB types) that are usually not affected by yellow Sigatoka. Black Sigatoka was first recognized in the Sigatoka Valley of Fiji in 1963, but was probably widespread in Southeast Asia and the South Pacific before that time. In the Western Hemisphere, it first appeared in 1972 in Honduras and now occurs on the mainland from central Mexico south to Bolivia and northwestern Brazil, and in the Caribbean basin in Cuba, Jamaica, the Dominican Republic and southern Florida. In Africa, the disease was first recorded in Zambia in 1973 and has since spread throughout the sub-Saharan portions of that continent. In most areas, black Sigatoka has now replaced yellow Sigatoka to become the predominant leaf spot disease of banana.

4. **Yellow Sigatoka** ***(Mycosphaerella musicola)***: Yellow Sigatoka takes its name from the Sigatoka valley in Fiji where the disease was first recognized in 1912. During the next 40 years, the disease spread to all banana growing countries, making it a classic global disease epidemic. At the time it was the most serious leaf disease of bananas. Today Black Sigatoka is the more serious and aggressive disease.

5. **East Africa Bacterial Wilt** ***(Xanthomonas campestris*** **pv.** ***Musacearum)***: The disease, which has been identified as a bacterial wilt, was first reported in Ethiopia, where it caused only minor problems since banana production is small scale and scattered. Xcm wilt was initially identified in the major banana-producing districts of Mukono and Kayunga in 2001, and as of early 2003,

has subsequently spread throughout at least of the major banana producing district in Uganda, and appears to be manifesting itself as a disease threat of potential epiphytotic proportions. Unlike in Ethiopia, in Uganda and other parts of eastern Africa, the spread of the disease is likely to be more rapid and difficult to control. Xcm infection can result in severe losses in banana production and affects banana productivity. It causes early ripening and rotting of fruits even in the absence of apparent external signs of the disease, and wilting and death of banana plants. Ratoon crops arising from infected mats are severely diseased and often wilt even before bunch production..

Tomatoes

1. **Bacterial Wilt** ***(Ralstonia solanacearum)***: Bacterial wilt is a very destructive plant disease that attacks over 450 different species, including many of the most important economic crop plants. Often endemic, the bacterium transmits through the soil, penetrates the plant root system and eventually causes irreversible wilting and death. Although diseased plants can be found scattered in the field, bacterial wilt usually occurs in discrete areas (foci) associated with water accumulation in lower areas. The initial symptom in mature plants under natural conditions is wilting of upper leaves during the hottest part of the day followed by recovery during the evening and early hours of the morning. The wilted leaves maintain their green color and do not fall off as disease progresses. Under conditions favorable to the disease complete wilt occurs. The vascular tissues in the lower stem of wilted plants show a dark brown discoloration. These symptoms are similar to those of some fungal diseases. A cross section of the stem of a plant with bacterial wilt produces a white, milky strand of bacterial cells in clear water. Unlike potato, a few resistant varieties of tomato do exist, and they are the only way to produce a decent crop when the soil is infested with the bacterium.

2. **Early Blight** ***(Alternaria solani)***: The fungus infects stems, leaves and fruit of tomatoes. It may girdle seedlings causing damping-off in the seedbed. On the leaves, brown circular spots are often surrounded by a yellow area. Leaf spots have characteristic dark concentric rings. Leaf spots usually appear on the oldest leaves first and progress up the plant. As the disease progresses, the fungus may infect the stems and fruit. The spots on the fruit look similar to those on the leaves--brown with dark concentric rings. Dark, dusty spores are produced in concentric rings. The spores can be seen if the spot is touched to a light-colored object. Early blight is the most serious foliar disease of tomatoes.

3. **Fusarium Wilt** ***(Fusarium oxysporum f. sp. Lycopersici)***: The two major wilt diseases of tomatoes are Fusarium and Verticillium wilt. Fusarium wilt occurs when air and soil temperatures are high. Diseased plants first develop a yellowing of the oldest leaves (those nearing the ground). Often the yellowing is restricted to one side of the plant or even to leaflets on one side of the petiole. The affected leaves soon wilt and dry up, but they remain attached to the plant. The wilting continues on successively younger foliage and eventually results in the death of the plant. The stem remains firm and green on the outside but exhibits a narrow band of brown discoloration in the vascular tissue. This discoloration can be viewed easily by slicing vertically through the stem near the soil line and looking for a narrow column of browning between the central pith region and the outer portion of the stem.

4. **Whitefly-transmitted Gemini Viruses** ***(WTGV)***: The whitefly-transmitted gemini viruses have become a major group of pathogens of vegetables in the subtropics and tropics of the Western Hemisphere. In addition to tomato, crops such as cucurbits and beans are also affected by these

viruses. Symptoms of gemini virus infection in tomato can resemble those induced by other viruses, especially those in the Potyviridae and Tobamoviridae. Symptoms of Gemini virus infection vary with virus and strain, cultivar, plant age at the time of infection, and environmental conditions. Symptoms can include the following in various combinations: a bright yellow mosaic, chlorotic mottle, chlorotic leaf margins, leaf rolling, leaf distortion, puckering of leaves, reduction in leaf size, stunting of the infected plant, and flower abscission.

5. **Tomato Mosaic Virus *(ToMV)***: The virus is seed-borne. Infested tomato seeds can be the source of infection and the means by which the virus can be disseminated over large distances. Only a few seedlings need to be infected for the virus to spread rapidly. The virus can be spread by horticultural workers on contaminated hands, clothing, and tools during routine horticultural operations such as transplanting, tying, pruning, grafting, pollinating, cultivating, spraying, watering, and picking. The presence of virus in the guttation fluid of tomato plants facilitates spread by workers during horticultural operations. Symptoms can be found during any growth stage and all plant parts are affected. Generally, infected plants have a light or dark green mottling or mosaic with distortion of younger leaves, and stunting to varying degrees. Severely affected leaves may have a "fernlike" appearance and may show raised dark green areas. Fruit set may be severely reduced in affected plants. Symptoms are influenced by environmental conditions such as daylength, temperature, and light intensity as well as by variety, plant age at infection, and virulence of tomato mosaic virus (ToMV) strain. On susceptible cultivars, symptoms may range from severe to none.

Mangoes

1. **Mango Malformation *(Fusarium mangiferae, F. sterilihyphosum)***: Mango malformation disease (MMD) occurs in Asia, Africa, and the Americas and was first reported in India in 1891. MMD is a fungal disease of mangoes caused by several species of Fusarium, some yet to be described. Mango is the only known host of the disease. The disease spreads on a tree very slowly, but if left unchecked, can severely reduce yields. The main method of spreading MMD to new areas is through infected vegetative planting material. There is no evidence that the disease can spread on fruit or the seeds, or that it affects human health. It is usually associated with the bud mite, Aceria mangiferae but the mites have been shown to spread the disease within a tree and not between trees. MMD has been found in most mango growing countries of the world.

2. **Bacterial Canker or " Bacterial Black Spot" *(Xanthomonas axonopodis pv. mangiferaeindicae sensu novo.)***: Bacterial black spot was first recorded in 1981 in the Darwin area of Australia. Since then it has appeared in most areas in Asia where mangoes are grown. It can attack leaves, twigs and fruit. Generally, bacterial black spot does not cause severe losses in Australia but under certain conditions in other countries, it can. There is a definite seasonal variation in disease severity. This agrees with reports from Queensland where the disease is most severe in southern areas but losses can occur in the north when unseasonal wet conditions occur during fruit development. Leaf spots are black and raised. They tend to be angular in shape because they are confined by the larger veins. Twig and stem lesions are black and cracked and can be an important means of survival for the black spot bacterium. Black scabby spots are formed on fruit, often with star shaped cracks within them. The spots have water-soaked margins. Presence of the disease sharply reduces market value of the fruit.

3. **Anthracnose *(Colletotrichum gloeosporioides)***: Anthracnose disease attacks all plant parts at any growth stage. The symptoms are most visible on leaves and ripe fruits. At first, anthracnose generally appears on leaves as small and irregular yellow, brown, dark-brown, or black spots. The spots can expand and merge to cover the whole affected area. The color of the infected part darkens as it ages. The disease can also produce cankers on petioles and on stems that causes severe defoliation and rotting of fruits and roots. With mangoes, on the green fruit, tiny brown spots develop that will only enlarge after harvest. The spots enlarge on a ripening fruit and found anywhere on the peel in tear-shaped patterns. Eventually, the whole fruit rots and fungal fruiting bodies are formed on the rotten surfaces.

4. **Powdery Mildew *(Oidium mangiferae Berthet)***: Powdery mildew is one of the most serious diseases of mango affecting almost all the varieties, it occurs up to latitude of 40 degrees North and South of the equator. It may persist for longer period at an elevation of 600-1200 meters, in many African countries, south of the Sahara, the middle East, Southern Asia and America, from the Southern United States to Peru and Brazil. Mango powdery mildew is an easily recognizable problem; the symptoms are very apparent and are diagnostic. However, it is not easily controlled with cultural practices alone. If susceptible mango cultivars are grown in mildew-prone areas, growers should expect the disease to recur yearly or seasonally. To achieve good yields, such growers must act during flowering, before it is too late to prevent the loss of the current season's crop.

5. **Stem End Rot *(Botryosphaeria spp.)***: The species of Botryosphaeria fungus are among the most serious pathogens that affect mango trees and fruit. Several species occur on mangoes, and these are identified mainly on the morphology of the anamorphs. Stem-end rot is usually a post-harvest disease of mango fruit. It can be important, especially when anthracnose, the most important post-harvest problem on fruit, is well controlled. In general, the stem-ends of affected fruit appear dark brown and watersoaked, and the affected areas may extend internally well into the fruit.

Pineapples

1. **Black Rot *(Ceratocystis paradoxa)***: Fruit rot (black rot), which arises as a result of entry of the fungus via the cut made through the stalk during harvesting, is the most significant post-harvesting disease, producing soft rot inside the fruit. For this reason, the cuts must be treated with a fungicide no more than 6 hours after harvesting. A delay of some days between harvest and utilization of the ripe fruits leads to the development of black-rot or soft-rot. The fungus makes its entry through wounds caused during picking and packing. Infestation starts at the stalk-end of the fruit, resulting in small, circular, water-soaked spots that are very soft. Gradually, the fruit rots and emits a foul smell. The disease can be controlled by dipping of fruits for 5 minutes in Thiabendazole (100 ppm) or Benomyl (3000 ppm). Avoiding injury to the fruit during harvest and transit prevents disease occurrence.

2. **Heart Rot *(Phytopthora parasitica)***: The disease causes complete rotting of the central portion of the stem. The top leaves turn brown and basal portion of leaves shows sign of rotting with foul odor. Poor physical condition of the soil and inadequate drainage are responsible for spread of the disease. Good soil drainage and use of healthy planting material at helps in minimizing the spread of the disease.

3. **Butt Rot *(Thielaviopsis paradoxa)***: Symptoms start at the stem and advance through most of the flesh with the only external symptom being slight skin darkening due to water soaking of the skin over rotted portions of the flesh. As the flesh softens, the skin above readily breaks under slight pressure. The diseases can be controlled by careful handling of the fruit to minimize mechanical injuries. Prompt cooling and maintenance of optimum temperature and relative humidity throughout postharvest handling operations keeps the disease from spreading. Application of fungicides, such as Thiabendazole (TBZ) is recommended.

4. **Heart and Rot Root *(Phytophthora cinnamomi, nicotianae)***: Top rot and root rot are caused by the soil fungi *Phytophthora cinnamomi* and *P. nicotianae* var. *parasitica* which are most prevalent in prolonged wet weather in autumn and winter. Improved drainage helps reduce the risk and monthly spraying with fungicide gives good control. *P. cinnamomi* may also cause rot in green fruit on ratoons. These diseases are largely prevented by the use of paper or plastic mulch on raised beds.

5. **Fruitlet Core Rot *(Fusarium guttiforme)***: Fruitlet core rot (FCR), black spot, fruitlet brown rot, and eye rot are terms that have been used to describe brown to black diseased centers of individual pineapple fruitlets. Leathery pocket (LP) and interfruitlet corking (IFC) are additional symptoms that develop as FCR continues to develop. F. guttiforme causes a light to dark brown discolouration of septa that may extend down the entire fruitlet core. White to pinkish mycelium and sporulation of the pathogen occurs in locules. This is a relatively new disease which requires more research, but it is seen to be spreading rapidly throughout the tropics.

6. **Fusariosis of Pineapple**: Fusariosis is the most serious fruit disease in Brazil where major losses occur on ‘PJrola’, ‘Jupi’, and ‘Smooth Cayenne’ varieties. Fruit losses may reach 80% under severe disease conditions. The disease was first observed in Argentina in 1954. It was first reported in southern Brazil in 1964, and within 10 years was recognized throughout the country. Fusariosis is now also known in Paraguay and Uruguay, and was recently introduced to Bolivia via infected slips from Brazil. Fusariosis has not been reported outside South America. Fusariosis affects virtually all parts of the pineapple plant, but is most conspicuous and damaging on fruit. Initial symptoms are an off color of fruitlets and exudation of gum, which can be confused with exudation caused by feeding of the pineapple fruit caterpillar, *Thecla basilides*. Fruitlets become sunken, light to dark-brown and covered with light pink to greyish mycelium and sporulation of the causal fungus. Individual fruitlets or large areas of the fruit surface may be affected, and damage can range from superficial to extending to the fruitlet core.

ANNEX A: WEBSITES AND ARTICLES BY ANIMAL DISEASE

The focus of the animal diseases in this paper will be limited to the former group list A established by the World Health Organization formerly known as the International Office of Epizootics (OIE). List A diseases[7], most of which could also be regarded as being Transboundary Animal Diseases (TAD) include; foot-and-mouth disease (FMD), rinderpest, peste des petits ruminants (PPR), contagious bovine pleuropneumonia (CBPP), Rift Valley fever (RVF), lumpy skin disease, vesicular stomatitis, swine vesicular disease, bluetongue, sheep and goat pox, African horse sickness, African swine fever, hog cholera (classical swine fever), fowl plague Newcastle disease and Avian Influenza.

GENERAL INFORMATION ON INFECTIOUS ANIMAL DISEASES

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- Disease Factsheets: http://www.cfsph.iastate.edu/DiseaseInfo/factsheets.htm
- Links on Infectious Diseases http://www.fas.org/ahead/promed/promdwww.html
- Merck Manual 2005, 9th ed. / editor: Cynthia M. Kahn.
  Published: Whitehouse Station, N.J.; [Great Britain] : Merck & Co., 2005. Description xxxix, 2712 p.; 21 cm.
  http://www.merckvetmanual.com/mvm/index.jsp?cfile=htm/bc/toc_203700.htm
- Controlling Infectious Disease: http://www.cdc.gov/ncidod/EID/vol3no1/plotkin.htm
- FAO:www.fao.org
- WHO: www.who.org
- World Organization for Animal Health: www.oie.intDisease Factsheets:
  http://www.cfsph.iastate.edu/DiseaseInfo/factsheets.htm
- Links on Infectious Diseases http://www.fas.org/ahead/promed/promdwww.html
- Carcass Disposal Issues in Recent Disasters, Accepted Methods, and Suggested Plan to Mitigate Future Events Dee B. Ellis D.V.M.
  Texas State University-San Marcos, Political Science Department, Public Administration
  http://ecommons.txstate.edu/cgi/viewcontent.cgi?article=1068&context=arp
- Transboundary Animal Diseases
  ftp://ftp.fao.org/docrep/fao/meeting/010/ag273e/ag273e.pdf
- "The Economics of Animal Disease: Synopsis of Conference Presentations and Discussion" By James Pritchett, Dawn Thilmany and Kami Rosenstiel (2003)
  http://dare.agsci.colostate.edu/csuagecon/extension/docs/livestockdisease/apr03-09.pdf

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[7] The OIE established a more comprehensive list of diseases, rectified in 2008 (see http://www.oie.int/eng/maladies/en_classification2008.htm).

AFRICAN HORSE SICKNESS

African Horse Sickness is an extremely infectious and fatal disease that mainly affects horses, donkeys and mules. African Horse Sickness is primarily found in sub-Saharan Africa but has spread to Morocco and the Middle East. The disease is spread through insects and thus is prominent in areas whose climate allows for the proliferation of insects.

WEBSITES

- http://www.defra.gov.uk/animalh/diseases/notifiable/africanhorse/index.htm
- http://www.oie.int/eng/maladies/fiches/A_A110.HTM
- http://www.cfsph.iastate.edu/Factsheets/pdfs/african_horse_sickness.pdf
- http://www.cidrap.umn.edu/cidrap/content/biosecurity/ag-biosec/anim-disease/ahs.html#_African_Horse_Sickness

RELEVANT ARTICLES

- Mellor PS, Hamblin, Christopher, "African Horse Sickness" Vet. Res. 35 (2004) 445–466, Institute for Animal Health, Department of Arbovirology, Pirbright Laboratory, Ash Rd., Pirbright, Woking, Surrey, GU24 0NF, United Kingdom http://www.vetres.org/index.php?option=article&access=standard&Itemid=129&url=/articles/vetres/pdf/2004/04/V4013.pdf
-
- Mellor PS, "African Horse Sickness: transmission and epidemiology" Institute for Animal Health, Pirbright Laboratory, Woking, Surrey, U.K., Veterinary Research 1993 (24), 199-212 http://vetres-archive.tours.inra.fr/file/Vet.Res._0928-4249_1993_24_2_ART0009.pdf
-
- Sinclair, M., "The epidemiology of an African horse sickness outbreak in the Western Cape Province of South Africa" MSc thesis, 2006. University of Pretoria http://upetd.up.ac.za/thesis/available/etd-05042007-141143/unrestricted/00dissertation.pdf

AFRICAN SWINE FEVER

African swine fever is a highly contagious viral disease in pigs that spreads rapidly by direct and indirect contact. African swine fever is endemic in Africa but outbreaks have also occurred in South America, the Caribbean and Europe. The fever is the result of an infection caused by a virus whose isolates vary in virulence.

WEBSITES

- http://www.asfnetwork.org/
- http://www.oie.int/eng/maladies/fiches/a_A120.HTM
- http://epix.hazard.net/topics/animal/asf.htm
- http://www.cidrap.umn.edu/cidrap/content/biosecurity/ag-biosec/anim-disease/asf.html
- http://www.fao.org/docrep/004/X8060E/X8060E00.HTM

BLUETONGUE

Bluetongue is an insect spread viral disease that affects livestock, especially sheep. The disease can prove fatal and presents with fever, excessive salivation, muscle lameness and depression. Bluetongue is a widespread disease, it has been found in Europe, Africa, the Middle East, Australia, the Americas and Asia. Bluetongue is transmitted through insect carriers and not contagious thus insect control is an important aspect of prevention, although vaccines do exist as well.

WEBSITES

- http://www.cfsph.iastate.edu/Factsheets/pdfs/bluetongue.pdf
- http://www.oie.int/eng/maladies/fiches/a_A090.htm
- http://www.aphis.usda.gov/animal_health/animal_diseases/bluetongue/
- http://www.defra.gov.uk/animalh/diseases/notifiable/bluetongue/index.htm

RELEVANT ARTICLES

- MacLachlan , N. James, "Impact of bluetongue virus infection on the international movement and trade of ruminants." Journal of the American Veterinary Medical Association May 1, 2006, Vol. 228, No. 9, Pages 1346-1349
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- Bethan V. Purse, Philip S. Mellor, et al, "Opinion: Climate change and the recent emergence of bluetongue in Europe." Nature Reviews Microbiology 3, 171-181 (February 2005) http://www.nature.com/nrmicro/journal/v3/n2/abs/nrmicro1090.html
-
- Simmons A, "Bluetongue vaccination in England." The Veterinary Record 2008 May 10;162(19):632.

CLASSICAL SWINE FEVER (HOG CHOLERA)

Hog Cholera is a viral disease in swine that is highly contagious and transmitted through direct contact. It is largely indistinguishable from African Swine Fever but caused by a different virus. Hog Cholera was eradicated in the US but is still endemic in Asia, South America, Europe and Africa. Hog Cholera is currently controlled by rapid detection, culling and emergency vaccinations.

WEBSITES

- http://www.aphis.usda.gov/publications/animal_health/content/printable_version/fs_ahcsf.pdf
- http://www.classicalswinefever.org/
- http://www.vet.uga.edu/vpp/gray_book02/fad/hoc.php
- http://www.oie.int/eng/maladies/fiches/A_A130.HTM

RELEVANT ARTICLE

- Irene Greiser-Wilkea and Volker Moenniga, "Vaccination against classical swine fever virus: limitations and new strategies." Animal Health Research Reviews (2004), 5:223-226 Cambridge University Press http://journals.cambridge.org/action/displayAbstract?fromPage=online&aid=775512

BOVINE SPONGIFORM ENCEPHALOPATHY

Bovine spongiform encephalopathy (BSE) or "mad cow disease" is a progressive neurological disorder of cattle that results from infection by an unconventional and extraordinary transmissible agent. BSE is one of several known animal transmissible spongiform encephalopathies including transmissible mink encephalopathy, scrapie, chronic wasting disease of mule deer, and elk, and feline spongiform encephalopathy. The disease name refers to the fact that at the end of the disease, the brain is full of holes like a sponge. The disease may develop in a relatively short time or, as is more usual, will take decades to develop. Scrapie may be the most well known of the spongiform encephalopathies. It occurs in sheep and goats. In general, as in cattle, diseased animals lose coordination of their legs and body movements and eventually cannot stand. The name "scrapie" refers to the fact that the animals can become irritable and develop an intense itch. There are also human conditions that are similar to the animal diseases. In most cases the human diseases are not due to transmissible agents. They can be genetic diseases that run in families, a mutation that happens sporadically in individuals and probably animals as well, or they may be transmitted by ingestion of the infectious agent (e.g. kuru of the Fore people was caused by ritualized cannibalism). There is still some controversy regarding the nature of the transmissible agent that causes these fatal conditions, but the most accepted theory is that the agent is a modified form of a normal cell surface component known as a prion (proteinaceous infectious articles and (pronounced preeon) protein) (PrP). This modified version of PrP is disease causing, and is both less soluble and more resistant to enzyme degradation then the normal protein.

WEBSITES

- http://www.aphis.usda.gov/publications/animal_health/content/printable_version/fs_ahcsf.pdf
- http://www.nal.usda.gov/awic/pubs/oldbib/srb91-05.htm
- http://www.fda.gov/oc/opacom/hottopics/bse.html
- http://www.cdc.gov/ncidod/dvrd/bse/
- http://www.aphis.usda.gov/newsroom/hot_issues/bse/index.shtml
- http://www.bseinfo.org/

RELEVANT ARTICLES

Prusiner, S.B. Prion biology and diseases fatal conformations of proteins during a journey from heresy to orthodoxy. In Prions and Brain Diseases in Animals and Humans. Edited by D.R.O. Morrison. Plenum Press, NY 1998, p. 135-139. 30 refs. ISBN 0-306-45825-X. Part of the NATO ASI series. Series A, Life Sciences: v. 295. It is the proceeding of a NATO Advanced Research workshop on Prions and Brain Diseases in Animals and Humans, held August 19-23, 1996, in Erice, Italy.

The Merck Veterinary Manual 8th Edition. eds. S.E. Aiello and A. Mays. Published by Merck & Co., Inc. of Whitehouse Station, NJ. and in cooperation with Merial Limited. Printed by National Publishing Inc. of Philadelphia, PA 1998, p. 897. ISBN: 0-911910-29-8

Center for Disease Control, National Center for Infectious Diseases. Questions and Answers Regarding Bovine Spongiform Encephalopathy (BSE) and Creutzfeldt-Jakob Disease. Bovine Spongiform Encephalopathy and Creutzfeldt-Jakob Disease. April, 2001 http://www.cdc.gov/ncidod/dvrd/vcjd/qa.htm

Special Reference Brief, Bovine Spongiform Encephalopathy by Janice C. Swanson, December 1990, Animal Welfare Information Center.

CONTAGIOUS BOVINE PLEUROPNEUMONIA (CBPP)

Contagious Bovine Pleuropneumonia is a slow spreading, contagious bacterial disease found in cattle, water buffalo and zebras but not camels or wild bovids. Incidents of the disease are mainly in Africa and Asia but have also appeared in Europe, India and China. CBPP is spread amongst cattle in close quarters and an exposed animal is considered infectious for at least six months.

WEBSITES

- http://www.oie.int/eng/maladies/fiches/a_a060.htm
- http://www.aphis.usda.gov/lpa/pubs/fsheet_faq_notice/fs_ahpleuropneumonia.html
- http://www.cfsph.iastate.edu/Factsheets/pdfs/contagious_bovine_pleuropneumonia.pdf
- http://www.merckvetmanual.com/mvm/index.jsp?cfile=htm/bc/121219.htm

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N.E. Tambi (1), W.O. Maina (1) & C. Ndi, "An estimation of the economic impact of contagious bovine pleuropneumonia in Africa" Rev. sci. tech. Off. int. Epiz., 2006, 25 (3), 999-1012 http://oie.int/eng/publicat/RT/2503/pdf-br-REVIEW25-3/11-tambi999-1012.pdf

Thiaucourt, F., Aboubakar, Y., Wesonga, H., Manso-Silva, L., Blanchard, A., "Contagious bovine pleuropneumonia vaccines and control strategies: recent data." Developments in Biologicals 2004;119:99-111. http://www.ncbi.nlm.nih.gov/pubmed/15742622

Thiaucourt, F., Dedieu, L., Maillard, J.C., Bonnet, P., Lesnoff, M., Laval, G., Provost, A., "Contagious bovine pleuropneumonia vaccines, historic highlights, present situation and hopes." Developments in Biologicals, 2003;114:147-60. http://www.ncbi.nlm.nih.gov/pubmed/14677685

FOOT AND MOUTH DISEASE (FMD)

Foot and Mouth Disease is a highly transmissible disease that affects cloven hoofed animals worldwide. It can also affect sheep, goats, deer, and other cloven-hoofed animals. FMD has been found in Africa, South America, Asia and parts of Europe. As a precaution against the unchecked spread of FMD, animals and animal byproducts from known infected areas are often prohibited from crossing borders.

WEBSITES

- http://datcp.state.wi.us/ah/agriculture/animals/disease/bse/bse_foot.jsp
- http://news.bbc.co.uk/2/hi/in_depth/uk/2001/foot_and_mouth/default.stm
- http://www.cdc.gov/ncidod/dvrd/revb/enterovirus/hfhf.htm
- http://www.defra.gov.uk/footandmouth/about/index.htm

RELEVANT ARTICLES

M. J. Keeling, M. E. J. Woolhouse, R. M. May, G. Davies and B. T. Grenfell, "Modelling vaccination strategies against foot-and-mouth disease." *Nature* **421**, 136-142 (9 January 2003) http://www.nature.com/nature/journal/v421/n6919/abs/nature01343.html

Marvin J. Grubman and Barry Baxt, "Foot-and-Mouth Disease." Clin Microbiol Rev. 2004 April; 17(2): 465–493. http://www.pubmedcentral.nih.gov/articlerender.fcgi?artid=387408

GOAT AND SHEEP POX (SGP)

Goat and Sheep Pox is a viral, contagious disease that causes pox on goat and sheep. SGP is transmitted through lesions and may remain contagious for 2 to 6 months in wool and up to two years in scabs. Goat and Sheep Pox is endemic in Africa, the Middle East, India and Asia and has an extremely high mortality rate.

WEBSITES

- http://www.oie.int/eng/maladies/fiches/a_A100.HTM
- http://www.cfsph.iastate.edu/Factsheets/pdfs/sheep_and_goat_pox.pdf
- http://www.cidrap.umn.edu/cidrap/content/biosecurity/ag-biosec/anim-disease/sgp.html

RELEVANT ARTICLES

V. Bhanuprakasha, B.K. Indranib, 1, , M. Hosamania and R.K. Singha, "The current status of sheep pox disease" Comparative Immunology, Microbiology and Infectious Diseases, Volume 29, Issue 1, January 2006, Pages 27-60
http://www.sciencedirect.com/science?_ob=ArticleURL&_udi=B6T5H-4J616H2-1&_user=6779879&_rdoc=1&_fmt=&_orig=search&_sort=d&view=c&_acct=C000052423&_version=1&_urlVersion=0&_userid=6779879&md5=63982773eebb8590d00fa518489d9b77

T.V.S. Rao and S.K. Bandyopadhyay, A comprehensive review of goat pox and sheep pox and their diagnosis, Animal Health Research Reviews (2000), 1:127-136 Cambridge University Press
http://journals.cambridge.org/action/displayAbstract?fromPage=online&aid=721908

HOG CHOLERA (CLASSICAL SWINE FEVER)

Hog Cholera is a viral disease in swine that is highly contagious and transmitted through direct contact. It is largely indistinguishable from African Swine Fever but caused by a different virus. Hog Cholera was eradicated in the US but is still endemic in Asia, South America, Europe and Africa. Hog Cholera is currently controlled by rapid detection, culling and emergency vaccinations.

WEBSITES

- http://www.aphis.usda.gov/publications/animal_health/content/printable_version/fs_ahcsf.pdf
- http://www.classicalswinefever.org/
- http://www.vet.uga.edu/vpp/gray_book02/fad/hoc.php
- http://www.oie.int/eng/maladies/fiches/A_A130.HTM

RELEVANT ARTICLE

- Irene Greiser-Wilkea and Volker Moenniga, "Vaccination against classical swine fever virus: limitations and new strategies." Animal Health Research Reviews (2004), 5:223-226 Cambridge University Press
http://journals.cambridge.org/action/displayAbstract?fromPage=online&aid=775512

LUMPY SKIN DISEASE

Lumpy Skin Disease is a pox virus that affects cattle and water buffalo predominately in Africa. The disease has a very high morbidity rate but a rather low mortality rate. It is often explosive and spreads quickly. Although death from lumpy skin disease is rare and mainly in calves, diseased cattle result in milk and beef loss and often causes female cattle to abort. This loss in production can be detrimental to livelihoods.

WEBSITES

- http://www.cfsph.iastate.edu/Factsheets/pdfs/lumpy_skin_disease.pdf
- http://www.oie.int/eng/maladies/fiches/a_a070.htm
- http://www.vet.uga.edu/VPP/gray_book02/fad/lsd.php
- http://www.defra.gov.uk/animalh/diseases/notifiable/lumpy/index.htm

RELEVANT ARTICLES

- I Yeruham, O Nir, Y Braverman, M Davidson, H Grinstein, M Haymovitch, and O Zamir, "Spread of Lumpy Skin Disease in Israeli Dairy Herds." The Veterinary Record, Vol 137, Issue 4, 91-93 http://veterinaryrecord.bvapublications.com/cgi/content/abstract/137/4/91
- Prozesky L, Barnard BJ., "A study of the pathology of lumpy skin disease in cattle." Onderstepoort J Vet Res. 1982 Sep; 49(3): 167-75 http://www.ncbi.nlm.nih.gov/pubmed/7177597
- P Hunter, D Wallace, "Lumpy skin disease in southern Africa: a review of the disease and aspects of control." Journal of the South African Veterinary Association, 2001

NEWCASTLE DISEASE

Newcastle disease is a highly contagious viral disease that can affect all species of birds. Newcastle disease was discovered in 1926 and continues to exist in most of the world, although it has been eradicated in some European nations. Newcastle disease is spread through the bodily discharges of infected birds to healthy birds and spreads rapidly in confinement. (Note: Exotic Newcastle disease refers to strains that are exotic to the United States.)

WEBSITES

- http://www.aphis.usda.gov/publications/animal_health/content/printable_version/ada_ahend.pdf
- http://www.cidrap.umn.edu/cidrap/content/biosecurity/ag-biosec/anim-disease/exnewcastle.html
- http://www.oie.int/eng/maladies/fiches/a_A160.htm
- http://www.defra.gov.uk/animalh/diseases/notifiable/newcastle/index.htm

RELEVANT ARTICLE

- Alders, R.G. (Robyn G.); Spradbrow, P. B. "Controlling Newcastle disease in village chickens: A field manual." ACIAR monograph series ; no. 82. Canberra: Australian Centre for International Agricultural Research, 2001. 112 p.: ill. ISBN: 1863203079
-

PESTE DES PETITS RUMINANTS (PPR)

Peste des Petits Ruminants is a viral disease primarily of goats and sheep that is closely related to Rinderpest Disease. PPR has been found in Africa, the Middle East, Asia and India. Transmission is from direct contact and is most prevalent during cold and dry seasons or rainy seasons. There is no specific treatment for PPR but the rinderpest vaccine is often utilized as are antibiotics.

WEBSITES

- http://www.cfsph.iastate.edu/Factsheets/pdfs/peste_des_petits_ruminants.pdf
- http://www.fao.org/DOCREP/003/X1703E/X1703E00.htm
- http://www.oie.int/eng/maladies/fiches/a_A050.HTM
- http://www.cidrapsummit.net/cidrap/content/biosecurity/ag-biosec/anim-disease/ppr.html

RELEVANT ARTICLES

- M. S. Shailaa, David Shamakia, Morag A. Forsytha, Adama Diallob, Lynnette Goatleya, R. P. Kitchinga and Thomas Barretta, "Geographic distribution and epidemiology of peste des petits ruminants viruses." Virus Research, Volume 43, Issue 2, August 1996, Pages 149-153 http://www.sciencedirect.com/science?_ob=ArticleURL&_udi=B6T32-497C7D0-N&_user=6779879&_rdoc=1&_fmt=&_orig=search&_sort=d&view=c&_acct=C000052423&_version=1&_urlVersion=0&_userid=6779879&md5=685dfb962fa81e9882f41c9318c7d158

- T. T. Bazarghani, S. Charkhkar, J. Doroudi, E. Bani Hassan , "Review on Peste des Petits Ruminants (PPR) with Special Reference to PPR in Iran." Journal of Veterinary Medicine Series B Volume 53 Issue s1 Page 17-18, December 2006 http://www.blackwell-synergy.com/doi/abs/10.1111/j.1439-0450.2006.01014.x?prevSearch=%28%28title%3A%28Review+on+Peste+des+Petits+Ruminants+%28PPR%29+with+Special+Reference+to+PPR+in+Iran%29%29%29

- A. Diallo, C. Minet, C. Le Goff, G. Berhe, E. Albina, G. Libeau and T. Barrett, "The threat of peste des petits ruminants: progress in vaccine development for disease control." **Vaccine,** Volume 25, Issue 30, 26 July 2007, Pages 5591-5597 http://www.sciencedirect.com/science?_ob=ArticleURL&_udi=B6TD4-4N4S3YP-2&_user=6779879&_rdoc=1&_fmt=&_orig=search&_sort=d&view=c&_acct=C000052423&_version=1&_urlVersion=0&_userid=6779879&md5=e9391487370e7c732af2012b5113ebeb

RIFT VALLEY FEVER

Rift Valley Fever (RVF) is a viral disease that primarily affects domestic livestock, but can also be passed to humans (however no human-to-human transmission has been documented. RVF is first indicated by a wave of unexplained abortions as nearly 100% of pregnant livestock abort their fetuses.

WEBSITES

- http://www2.dpi.qld.gov.au/health/3957.html
- http://www.cdc.gov/ncidod/dvrd/spb/mnpages/dispages/rvf.htm
- http://www.who.int/mediacentre/factsheets/fs207/en/
- http://www.cidrap.umn.edu/cidrap/content/biosecurity/ag-biosec/anim-disease/rvf.html

RELEVANT ARTICLE

- Arthur RR, el-Sharkawy MS, Cope SE, Botros BA, Oun S, Morrill JC, Shope RE, Hibbs RG, Darwish MA, Imam IZ. "Recurrence of Rift Valley fever in Egypt." The Lancet, 1993 Nov 6; 342 (8880): 1149-50 http://www.ncbi.nlm.nih.gov/pubmed/7901480

- Digoutte JP, Peters CJ. "General aspects of the 1987 Rift Valley fever epidemic in Mauritania." Research in Virology. 1989 Jan-Feb;140(1):27-30. http://www.ncbi.nlm.nih.gov/pubmed/2711042

- Jouan A, Coulibaly I, Adam F, Philippe B, Riou O, Leguenno B, Christie R, Ould Merzoug N, Ksiazek T, Digoutte JP. "Analytical study of a Rift Valley fever epidemic." Research in Virology. 1989 Mar-Apr;140(2):175-86. http://www.ncbi.nlm.nih.gov/pubmed/2787923

RINDERPEST VIRUS (RPV)

The Rinderpest Virus is an infectious viral disease affecting cattle, pigs, domestic buffalo, and certain species of wildlife. There is no treatment for infected animals, and during an outbreak, the mortality rate is nearly 100%. A recent epidemic that affected much of Africa from 1982-1984 is believed to have cost at least $500 million, whereas during an earlier epidemic in the 1890s, 80-90 percent of all cattle in sub-Saharan Africa succumbed to the virus.

WEBSITES

- http://www2.dpi.qld.gov.au/health/3957.html
- http://www.oie.int/eng/info/en_peste.htm
- http://www.cidrap.umn.edu/cidrap/content/biosecurity/ag-biosec/anim-disease/rpest.html
- http://www.oie.int/eng/maladies/fiches/a_A040.htm
- http://www-naweb.iaea.org/nafa/aph/stories/2005-rinderpest-history.html

RELEVANT ARTICLES

- Barrett T, Rossiter PB. "Rinderpest: the disease and its impact on humans and animals." Advances in Virus Research. 1999;53:89-110 http://www.ncbi.nlm.nih.gov/pubmed/10582096

- Normile, Dennis. **"**Rinderpest: Driven to Extinction?" *Science* 21 March 2008: Vol. 319. no. 5870, pp. 1606 – 1609 http://www.sciencemag.org/cgi/content/summary/319/5870/1606

AVIAN INFLUENZA

Avian Influenza, or bird flu, is a viral infection caused by a variety of different influenza strains in birds that can range from harmless to 100% fatal. These influenzas are classified as type A and are spread through fecal-oral transmissions. Influenza A viruses can also cause illness in other animals and even humans. *Highly Pathogenic Avian Influenza (HPAI):* Highly Pathogenic Avian Influenza is an extreme version of the previously discussed Avian Influenza. The current H5N1 strain is endemic in many bird populations, particularly in Southeast Asia and has begun to spread globally after its initial discovery in Asia. HPAI is characterized by the sudden onset of severe disease, rapid contagion, and a mortality rate nearing 100% within 48 hours. H5N1 is also capable of infecting humans, raising concern that it could cause a global pandemic should the virus acquire the capacity for human to human transmission. Illustrative websites include:

WEBSITES

- http://www.nal.usda.gov/awic/aflu/Avian%20Influenza.htm
- http://www.nwhc.usgs.gov/research/avian_influenza/avian_influenza.html
- http://www.cidrap.umn.edu/cidrap/content/influenza/avianflu/biofacts/avflu.html#_Hosts
- http://www.nwhc.usgs.gov/publications/field_manual/chapter_22.pdf
- http://www.who.int/csr/disease/avian_influenza/avianinfluenza_factsheetJan2006/en/index.html

- http://www.fao.org/avianflu/en/index.html
- http://www.who.int/csr/en/
- http://www.oie.int/downld/AVIAN%20INFLUENZA/A_AI-Asia.htm
- http://www.aphis.usda.gov/animal_health/emergency_management/downloads/faq_ahai.pdf

RELEVANT ARTICLES

- Alexander, Dennis J. "A review of avian influenza in different bird species" Avian Virology, VLA Weybridge, Addlestone, Surrey KT15 3NB, UK Veterinary Microbiology, Volume 74, Issues 1-2, 22 May 2000, Pages 3-13 http://www.sciencedirect.com/science?_ob=ArticleURL&_udi=B6TD6-405KDD3-2&_user=10&_rdoc=1&_fmt=&_orig=search&_sort=d&view=c&_acct=C000050221&_version=1&_urlVersion=0&_userid=10&md5=6aa68356f67c6347e338636ad19b71c9

- Hiroshi Kida, Toshihiro Ito, et al. "Potential for transmission of avian influenza viruses to pigs." Society for General Microbiology, J Gen Virol 75 (1994), 2183-2188; http://vir.sgmjournals.org/cgi/content/abstract/75/9/2183

- Taisuke Horimoto and Yoshihiro Kawaoka, "Pandemic Threat Posed by Avian Influenza A Viruses" Clinical Microbiology Reviews, January 2001, p. 129-149, Vol. 14, No. 1 http://cmr.highwire.org/cgi/content/abstract/14/1/129

- Swayne DE, Suarez DL., "Highly pathogenic avian influenza." Rev Sci Tech. 2000 Aug;19(2):463-82

- JSM Peiris, FRC Path , W C Yu, FRCP , et al. "Re-emergence of fatal human influenza A subtype H5N1 disease." The Lancet, Volume 363, Issue 9409, 21 February 2004, Pages 617-619 http://www.sciencedirect.com/science?_ob=ArticleURL&_udi=B6T1B-4BRSK3C-D&_user=10&_rdoc=1&_fmt=&_orig=search&_sort=d&view=c&_acct=C000050221&_version=1&_urlVersion=0&_userid=10&md5=ec8ee48d826a7ec27c8483c6ff5e2116

- Kumnuan Ungchusak, M.D., M.P.H., Prasert Auewarakul, M.D., et al." Probable Person-to-Person Transmission of Avian Influenza A (H5N1)" The New England Journal of Medicine, January 27, 2005. Volume 352:333-340, Number 4 http://content.nejm.org/cgi/content/abstract/352/4/333

SWINE VESICULAR DISEASE

Swine Vesicular Disease is a contagious viral disease in pigs that is not fatal. The disease is transmitted through direct contact, fecal matter and pork products as it is very resistant even to the cooking process, the virus can stay in a recovered animals feces for up to three months. Swine Vesicular Disease is clinically indistinguishable from Foot and Mouth Disease in swine.

WEBSITES

- http://www.oie.int/eng/maladies/fiches/a_a030.htm
- http://www.vet.uga.edu/vpp/gray_book02/fad/svd.php
- http://www.cfsph.iastate.edu/Factsheets/pdfs/swine_vesicular_disease.pdf
- http://www.aphis.usda.gov/lpa/pubs/fsheet_faq_notice/fs_ahswinevd.html

RELEVANT ARTICLE

- Knowles NJ, Wilsden G, Reid SM, Ferris NP, King DP, Paton DJ, Fevereiro M, Brocchi E. "Reappearance of swine vesicular disease virus in Portugal." The Veterinary Record. 2007 Jul 14;161(2):71

VESICULAR STOMATITIS (VSV)

Vesicular Stomatitis is a viral disease affecting cattle, horses and swine but may also affect sheep, goats, wild animals and humans. Vesicular Stomatitis is largely found in the Americas and presents like foot and mouth disease and swine vesicular disease. VSV transmission has not been determined and quarantine is the most common method of control.

WEBSITES

- http://www.oie.int/eng/maladies/en_fiches.htm?e1d7
- http://www.aphis.usda.gov/lpa/pubs/fsheet_faq_notice/fs_ahvs.html
- http://www.cfsph.iastate.edu/Factsheets/pdfs/vesicular_stomatitis.pdf

ANNEX B: WEBSITES AND ARTICLES BY PLANT DISEASE

The focus of the plant diseases for this paper include the top five to six plant diseases that affect the most widely consumed international staple food crops- Maize, Wheat, Potato, Sweat Potato/Yam, Rice, Cassava, Beans, Sorghum, and Millet- and a sample of economically important export food crops, including bananas, mangoes, tomatoes, and pineapple. Full descriptions for each plant diseases are provided in Chapter 4.

MAIZE

A list of common names and diseases (bacterial, fungal, nematodes and parasites, viral and viruslike agents, phytoplasmal and parasitic higher plants) of maize is found on the American Phytopathological Society website: http://www.apsnet.org/online/common/names/corn.asp

RELEVANT MAIZE ARTICLES

"Maize Diseases: A Guide for Field Identification", CIMMYT Maize Program, 4th Edition, http://www.cimmyt.org/english/docs/field_guides/maize/diseases.htm

"The Maize Doctor", CIMMYT (International Maize and Wheat Improvement Center), http://maizedoctor.cimmyt.org

PHILIPPINE DOWNY MILDEW (*PERONOSCLEROSPORA PHILIPPINENSIS*)

Websites

http://www.plantmanagementnetwork.org/proceedings/npdn/2007/posters/05DownyMildew.pdf

http://www.cropscience.org.au/icsc2004/poster/3/4/1/439_georgemlc.htm

http://nt.ars-grin.gov/fungaldatabases/new_allView.cfm?whichone=all&thisName=Peronosclerospora%20philippinensis&organismtype=Fungus&fromAllCount=yes

Relevant Articles

- Yen, T.T.O., and B.M. Prasanna. "Analysis of genetic polymorphism among downy mildew resistant and susceptible maize inbred lines using Simple Sequence Repeat (SSR) markers", Maize Genetics Cooperation Newsletter, Vol. 75., 2001 http://www.agron.missouri.edu/mnl/75/59yen.html
- "Recovery Plan for Philippine Downy Mildew and Brown Stripe Downy Mildew of Corn", Office of Pest Management National Plant Disease Recovery System, USDA, 2006 http://www.ars.usda.gov/SP2UserFiles/Place/00000000/opmp/Corn%20Downy%20Mildew%2009-18-06.pdf

BROWN STRIPE DOWNY MILDEW (*SCLEROPHTHORA RAYSSIAE*)

Websites

- http://www.bcc.orst.edu/bpp/Plant_Clinic/Disease_sheets/Brown%20Stripe%20Downy%20Mildew.pdf
- http://www.plantmanagementnetwork.org/proceedings/npdn/2007/posters/02BrownStripeDowneyMildew.pdf
- http://nt.ars-grin.gov/fungaldatabases/new_allView.cfm?whichone=all&thisName=Sclerophthora%20rayssiae&organismtype=Fungus&fromAllCount=yes

Relevant Articles

- "Recovery Plan for Philippine Downy Mildew and Brown Stripe Downy Mildew of Corn", Office of Pest Management National Plant Disease Recovery System, USDA, 2006 http://www.ars.usda.gov/SP2UserFiles/Place/00000000/opmp/Corn%20Downy%20Mildew%2009-18-06.pdf

EAR ROT (*FUSARIUM VERTICILLIOIDES, ASPERGILLUS FLAVUS*)

Websites

- http://cropdisease.cropsci.uiuc.edu/corn/Fusariumkernelandearrot.html
- http://cropdisease.cropsci.uiuc.edu/corn/Aspergillusearrot.html
- http://www.ars.usda.gov/research/publications/publications.htm?seq_no_115=195534
- http://maizedoctor.cimmyt.org/index.php?option=com_content&task=view&id=213&Itemid=50
- http://nt.ars-grin.gov/fungaldatabases/new_allView.cfm?whichone=all&thisName=Fusarium%20verticillioides&organismtype=Fungus&fromAllCount=yes
- http://nt.ars-grin.gov/fungaldatabases/new_allView.cfm?whichone=all&thisName=Aspergillus%20flavus&organismtype=Fungus&fromAllCount=yes

GRAY LEAF SPOT (*CERCOSPORA ZEAE MAYDIS*)

Websites

- http://cropdisease.cropsci.uiuc.edu/corn/grayleafspot.html
- http://www.ext.vt.edu/pubs/plantdiseasefs/450-612/450-612.html
- http://maizedoctor.cimmyt.org/index.php?option=com_content&task=view&id=237&Itemid=50

NORTHERN CORN LEAF BLIGHT (*EXCEROHILUM TURCICUM*)

Websites

- http://cropdisease.cropsci.uiuc.edu/corn/northerncornleafblight.html
- http://ohioline.osu.edu/ac-fact/0020.html
- http://www.omafra.gov.on.ca/english/crops/pub811/3lfnlb.htm
- http://www.udel.edu/IPM/cca/diseaseslides/sld028.htm

SOUTHERN CORN LEAF BLIGHT (*BIPOLARIS MAYDIS*)

Websites

- http://cropdisease.cropsci.uiuc.edu/corn/southerncornleafblight.html
- http://nu-distance.unl.edu/homer/disease/agron/corn/CoSCLB.html
- http://www.cbwinfo.com/Biological/PlantPath/BM.html
- http://nt.ars-grin.gov/fungaldatabases/new_allView.cfm?whichone=all&thisName=Bipolaris%20maydis&organismtype=Fungus&fromAllCount=yes

WHEAT

A list of common names and diseases (bacterial, fungal, nematodes and parasites, viral and viruslike agents, phytoplasmal and parasitic higher plants) of wheat is found on the American Phytopathological Society website: http://www.apsnet.org/online/common/names/wheat.asp

RELEVANT WHEAT ARTICLES

- "The Wheat Doctor", CIMMYT (International Maize and Wheat Improvement Center), http://wheatdoctor.cimmyt.org
- "Wheat Page- Pests and Diseases", Kansas State University http://www.oznet.ksu.edu/wheatpage/pests%26diseases.htm
- "Diseases of Wheat- Fungal", Government of Alberta, Canada http://www1.agric.gov.ab.ca/$department/deptdocs.nsf/All/prm7802?OpenDocument

RUST

STEM RUST (PUCCINIA GRAMINIS, RACE UG99)

Websites

- http://www.ars.usda.gov/Main/docs.htm?docid=14649
- http://www.globalrust.org/
- http://arsserv0.tamu.edu/research/publications/publications.htm?SEQ_NO_115=217650
- http://nt.ars-grin.gov/fungaldatabases/new_allView.cfm?whichone=all&thisName=Puccinia%20graminis&organismtype=Fungus&fromAllCount=yes

Relevant Articles

- "An Assessment of Race Ug99 in Kenya and Ethiopia and the Potential for Impact in Neighboring Regions and Beyond", Expert Panel on the Stem Rust Outbreak in Eastern Africa, 2005 http://www.cimmyt.org/english/wps/news/2005/aug/pdf/Expert_Panel_Report.pdf
- Hodson, D.P.; Singh, R. P.; and Dixon; J. M." An Initial Assessment of the Potential Impact of Stem Rust (Race Ug99) on Wheat Producing Regions of Africa and Asia Using GIS", International Maize and Wheat Improvement Center (CIMMYT), http://www.cimmyt.org/gis/pdf/UG99postH.pdf

LEAF RUST (PUCCINIA RECONDITA)

Websites

- http://www.globalrust.org/
- http://www.oznet.ksu.edu/path-ext/factSheets/Wheat/Wheat%20Leaf%20Rust.asp
- http://www.nappfast.org/casestudies_files/wheat_rust%20.pdf
- http://nt.ars-grin.gov/fungaldatabases/new_allView.cfm?whichone=all&thisName=Puccinia%20recondita&organismtype=Fungus&fromAllCount=yes

Relevant Articles

- McCallum, B.D. andSeto-Goh, P. "Physiologic specialization of wheat leaf rust (Puccinia triticina) in Canada in 1999", Canadian Journal of Plant Pathology, 24: 205–210 (2002) http://article.pubs.nrc-cnrc.gc.ca/ppv/RPViewDoc?_handler_=HandleInitialGet&journal=tcjpp&volume=24&articleFile=k02-010.pdf

STRIPE RUST (PUCCINIA STRIIFORMIS)

Websites

- http://www.ars.usda.gov/Main/docs.htm?docid=9918
- http://www.globalrust.org/
- http://www1.agric.gov.ab.ca/$department/deptdocs.nsf/all/faq11389

Relevant Articles

- Chen, X. M., Moore, M., Milus, E. A., Long, D. L., Line, R. F., Marshall, D., and Jackson, L. 2002 "Wheat stripe rust epidemics and races of Puccinia striiformis f. sp. tritici in the United States in 2000", Plant Dis. 86:39-46, 2000 http://apsjournals.apsnet.org/doi/pdfplus/10.1094/PDIS.2002.86.1.39
- Blount, A. R., Rizvi, S. A., Barnett, R. D., Chen, X., Schubert, T. S., Dankers, W. H., Momol T. M., and Dixon, W. N. 2005. "First report of stripe rust caused by Puccinia striiformis f. sp. tritici on wheat in Florida", 2005, http://pestalert.ifas.ufl.edu/pstriiformis.pdf

HEAD BLIGHT- SCAB (*FUSARIUM SPP.*)

Websites

- http://www1.agric.gov.ab.ca/$department/deptdocs.nsf/all/agdex92
- http://wheatdoctor.cimmyt.org/index.php?option=com_content&task=view&id=109&Itemid=43
- http://64.233.169.104/search?q=cache:8uA5TfsF-1IJ:www.fao.org/DOCREP/006/Y4011E/y4011e0j.htm+http://www.fao.org/DOCREP/006/Y4011E/y4011e0j.htm&hl=en&ct=clnk&cd=1&gl=us
- http://www.uky.edu/Ag/Wheat/wheat_breeding/FHB.htm

LEAF BLOTCH (*SEPTORIA TRITICI*)

Websites

- http://www.oznet.ksu.edu/path-ext/factSheets/Wheat/Wheat%20Speckled%20Leaf%20Blotch.asp
- http://ohioline.osu.edu/ac-fact/0002.html
- http://nt.ars-grin.gov/fungaldatabases/new_allView.cfm?whichone=all&thisName=Septoria%20tritici&organismtype=Fungus&fromAllCount=yes

SPOT BLOTCH (*COCHLIOBOLUS SATIVUS*)

Websites

- http://vasatwiki.icrisat.org/index.php/Cochliobolus_sativus
- http://ohioline.osu.edu/ac-fact/0051.html
- http://www1.agric.gov.ab.ca/$Department/deptdocs.nsf/All/prm2432?OpenDocument#common
- http://nt.ars-grin.gov/fungaldatabases/new_allView.cfm?whichone=all&thisName=Cochliobolus%20sativus&organismtype=Fungus&fromAllCount=yes

Relevant Articles

Ginkel, M. van; McNab, A.; and Krupinsky, J. editors "Septoria and Stagonospora Diseases of Cereals: A Compilation of Global Research" 1999, CIMMYT, http://www.cimmyt.org/Research/Wheat/pdf/Septoria/septoria.pdf

POWDERY MILDEW (*BLUMERIA GRAMINIS*)

Websites

- http://www1.agric.gov.ab.ca/$Department/deptdocs.nsf/All/prm2466?OpenDocument#common
- http://nu-distance.unl.edu/Homer/disease/agron/wheat/WhPowMil.html
- http://ohioline.osu.edu/ac-fact/0010.html
- http://nt.ars-grin.gov/fungaldatabases/new_allView.cfm?whichone=all&thisName=Blumeria%20graminis&organismtype=Fungus&fromAllCount=yes

Relevant Articles

- Vechet, Lumbomír "Reaction of Winter Wheat Cultivars and Breeding Lines to Blumeria graminis f.sp. tritici", Department of Applied Genetics, Division of Genetics and Plant Breeding, Research Institute of Crop Production, Prague-Ruzyně, Czech Republic, Vol. 42, No. 1: 15–20, 2006 http://www.cazv.cz/attachments/PPS_42_15-20.pdf

POTATO

A list of common names and diseases (bacterial, fungal, nematodes and parasites, viral and viruslike agents, phytoplasmal and parasitic higher plants) of potato is found on the American Phytopathological Society website: http://www.apsnet.org/online/common/names/potato.asp

RELEVANT POTATO ARTICLES

- "Major Potato Diseases, Insects, and Nematodes" International Potato Center, 2006 http://www.cipotato.org/publications/pdf/002408.pdf
- Panta, Ana; Ynouye; Cecilia, Espinoza; Catherine and Roca; William "Protocol for virus elimination in potato, sweet potato and other Andean root and tuber crops (ARTCs)" International Potato Center, Peru, 2006 http://research.cip.cgiar.org/confluence/download/attachments/13542/CIP10+Virus+elim+text+P+SP+RTC.pdf?version=1

LATE BLIGHT (*PHYTOPTHORA INFESTANS*)

Websites

- http://gilb.cip.cgiar.org/
- http://www.ipm.ucdavis.edu/PMG/r607101211.html
- http://www.apsnet.org/online/proceedings/lateblite/papers/lb004.htm

Relevant Articles

- Selman, L.; Andrews, N.; Stone, A.; and Mosley, A. "What's Wrong with my Potato Tubers?", Oregon State University Extension Service, 2008 http://extension.oregonstate.edu/catalog/pdf/em/em8948-e.pdf
- "Late blight-resistant potato to help Russian farmers", Innovations Report, July 8, 2002 http://www.innovations-report.de/html/berichte/agrar_forstwissenschaften/bericht-11890.html

BACTERIAL WILT (*RALSTONIA SOLANACEARUM*)

Websites

- http://www.cipotato.org/potato/pests_diseases/bacterial_wilt/
- http://www.massnrc.org/pests/pestFAQsheets/ralstonia.html
- http://www.cipotato.org/potato/pests_diseases/bacterial_wilt/symptoms.asp
- http://www.agf.gov.bc.ca/cropprot/ralstonia.htm
- http://nt.ars-grin.gov/fungaldatabases/new_allView.cfm?whichone=all&thisName=Ralstonia%20solanacearum&organismtype=Fungus&fromAllCount=yes

Relevant Articles

French, E.B. Gutarra, L.; Aley, P.; Elphinstone, J. "Culture Media for Ralstonia solanacearum Isolation, Identification and Maintenance", extracted from Fitopatologia, Vol. 30 (3) 1995. Lima, p. 126-130 http://www.cipotato.org/Training/Materials/Bacterial/Bacterial8.PDF

VIRUSES (PLRV, PVX AND PVY)

Websites

- http://www.ars.usda.gov/research/publications/publications.htm?seq_no_115=167307
- http://www.ag.auburn.edu/aaes/communications/highlights/spring99/potato.html
- http://www.umext.maine.edu/onlinepubs/htmpubs/2492.htm

- http://vegetablemdonline.ppath.cornell.edu/factsheets/Virus_Potato.htm
- http://www.agbioforum.org/v7n12/v7n12a08-kaniewski.htm

Relevant Articles

- Cabrera, Antonio; Chuquillanqui, Carlos C.; Salas, Alberto; Salazar, Luis F.; Roca; William "New sources of resistance to Potato leafroll virus (PLRV) in wild Solanum section Petota germoplasm from CIP genebanck" International Potato Center http://research.cip.cgiar.org/confluence/download/attachments/13239/WP+35.doc?version=1

EARLY BLIGHT (*ALTERNARIA SOLANI*)

Websites

- http://vegetablemdonline.ppath.cornell.edu/factsheets/Potato_EarlyBlt.htm
- http://nu-distance.unl.edu/homer/disease/agron/Potato/PoErBlt.html
- http://saspp.org/content/view/18/11/
- http://www.aces.edu/pubs/docs/A/ANR-1052/ANR-1052.pdf
- http://nt.ars-grin.gov/fungaldatabases/new_allView.cfm?whichone=all&thisName=Alternaria%20solani&organismtype=Fungus&fromAllCount=yes

Relevant Articles

Nadia, G. El-Gamal, F. Abd-El-Kareem , Y.O. Fotouh and Nehal, S. El-Mougy "Induction of Systemic Resistance in Potato Plants Against Late and Early Blight Diseases Using Chemical Inducers under Greenhouse and Field Conditions" Plant Pathology Department, National Research Centre, Giza, Egypt, 2007 http://www.insinet.net/rjabs/2007/73-81.pdf

VERTICILLIUM WILTS (*VERTICILLIUM DAHLIAE AND V. ALBO-ATRUM*)

Websites

- http://www.plant.wageningen-ur.nl/projects/verticillium/Items/PDFfiles/cht1.pdf
- http://www.extension.umn.edu/yardandgarden/ygbriefs/p261vert-tom-pot.html
- http://aas.bf.uni-lj.si/september2006/25jamnik.pdf
- http://utahpests.usu.edu/plantdiseases/htm/vegetable/vascularpotato
- http://nt.ars-grin.gov/fungaldatabases/new_allView.cfm?whichone=all&thisName=Verticillium%20dahliae&organismtype=Fungus&fromAllCount=yes
- http://nt.ars-grin.gov/fungaldatabases/new_allView.cfm?whichone=all&thisName=Verticillium%20albo-atrum&organismtype=Fungus&fromAllCount=yes

SWEET POTATO/YAM

A list of common names and diseases (bacterial, fungal, nematodes and parasites, viral and viruslike agents, phytoplasmal and parasitic higher plants) of sweet potato/yam is found on the American Phytopathological Society website: http://www.apsnet.org/online/common/names/swtpotat.asp

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Websites

- http://www.sciencedirect.com/science?_ob=ArticleURL&_udi=B6T5T-4B2CCM9-1&_user=10&_rdoc=1&_fmt=&_orig=search&_sort=d&view=c&_acct=C000050221&_version=1&_urlVersion=0&_userid=10&md5=024286a10ffaeb7359aae5740ff0ad9c
- http://cat.inist.fr/?aModele=afficheN&cpsidt=2395460
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- Fuentes, Segundo and Roca, William “Extreme genetic resistance to the sweetpotato virus disease (SPVD) discovered in sweetpotato and wild Ipomoea genetic resources” http://research.cip.cgiar.org/confluence/download/attachments/13239/Extreme+genetic+resistance+to+SPVD.doc?version=1

SWEET POTATO FEATHERY MOTTLE VIRUS (*SPFMV*)

Websites

- http://image.fs.uidaho.edu/vide/descr780.htm
- http://www.bspp.org.uk/ndr/july2006/2006-16.asp
- http://apsjournals.apsnet.org/doi/pdf/10.1094/PHYTO.2000.90.9.944
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Milgram, Melissa; Cohen, J.; and Loebenstein, G. “Effects of Sweet Potato Feathery Mottle Virus and Sweet Potato Sunken Vein Virus on Sweet Potato Yields and Rates of Reinfection of Virus-Free Planting Material in Israel” Phytoparasitica 24:3, 1996
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ROOT-KNOT NEMATODE (*MELOIDOGYNE INCOGNITA*)

Websites

- http://www.lucidcentral.com/keys/sweetpotato/key/Sweetpotato%20Diagnotes/media/html/TheProblems/Nematodes/RootKnotNematode/Root-knot.htm

- http://www.cipotato.org/sweetpotato/nematodes/
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ŠIRCA, Saša; UREK; Gregor and KARSSEN, Gerrit "The incidence of the root-knot nematode Meloidogyne incognita and Meloidogyne hapla in Slovenia" 2004 http://aas.bf.uni-lj.si/junij2004/02sirca.pdf

WHITE FLY (*BEMISIA TABACI*)

Websites

- http://creatures.ifas.ufl.edu/veg/leaf/silverleaf_whitefly.htm
- http://whiteflies.ifas.ufl.edu/wfly0002.htm?
- http://www.pk.uni-bonn.de/ppigb/entomol2.htm#4
- http://www.ars.usda.gov/research/publications/Publications.htm?seq_no_115=188022

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RICE

A list of common names and diseases (bacterial, fungal, nematodes and parasites, viral and viruslike agents, phytoplasmal and parasitic higher plants) of rice is found on the American Phytopathological Society website: http://www.apsnet.org/online/common/names/rice.asp and http://www.apsnet.org/online/common/names/wildrice.asp

RICE BLAST (*MAGNAPORTHE GRISEA* (HEBERT) BARR)

Websites

- http://www.planthealthaustralia.com.au/project_documents/uploads/Rice%20blast.pdf
- http://www.padil.gov.au/viewPest.aspx?id=475
- http://ascus.plbr.cornell.edu/blastdb/about.html
- http://www.ars.usda.gov/is/AR/archive/aug04/rice0804.htm
- http://www.knowledgebank.irri.org/RiceDoctor/Fact_Sheets/Diseases/Rice_Blast.htm

RICE TUNGRO VIRUS

Websites

- http://www.knowledgebank.irri.org/RiceDoctor/Fact_Sheets/Diseases/Tungro.htm
- http://www.knowledgebank.irri.org/IPM/diseaseDiagnosis/3.3.1._Tungro_Rice_tungro.htm
- http://www.ncbi.nlm.nih.gov/ICTVdb/ICTVdB/00.065.0.02.001.htm

BROWN SPOT (*HELMINTHOSPORIUM ORYZAE)*

Websites

- http://www.cbwinfo.com/Biological/PlantPath/CM.html
- http://www.knowledgebank.irri.org/RiceDoctor/Fact_Sheets/Diseases/Brown_Spot.htm
- http://www.knowledgebank.irri.org/IPM/diseaseDiagnosis/3.1.3._Brown_Spot_Bipolaris_oryzae.htm
- http://apsjournals.apsnet.org/doi/abs/10.1094/PDIS.1999.83.10.936

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BACTERIAL LEAF BLIGHT (*XANTHOMONAS ORYZAE*)

Websites

- http://www.knowledgebank.irri.org/RiceDoctor/Fact_Sheets/Diseases/Bacterial_Leaf_Blight.htm
- http://www.dawn.com/2007/11/05/ebr5.htm
- http://www.oisat.org/pests/diseases/bacterial/bacterial_leaf_blight.html

BACTERIAL LEAF STREAK (*XANTHOMONAS TRANSLUCENS F. SP. ORYZICOLA*)

Websites

- http://www.invasive.org/browse/subject.cfm?sub=11184
- http://www.knowledgebank.irri.org/IPM/diseaseDiagnosis/3.2.2._Bacterial_Leaf_Streak.htm
- http://nt.ars-grin.gov/fungaldatabases/new_allView.cfm?whichone=all&thisName=Xanthomonas%20oryzae&organismtype=Fungus&fromAllCount=yes
- http://www.science.oregonstate.edu/bpp/Plant_Clinic/Disease_sheets/Bacterial%20leaf%20streak%20of%20rice.pdf

HOJA BLANCA VIRUS

Websites

- http://image.fs.uidaho.edu/vide/descr689.htm
- http://www.dpvweb.net/dpv/showdpv.php?dpvno=299
- http://www.biologia.ucr.ac.cr/rbt/attachments/volumes/vol52-3/40-MU%C3%91OZ-Expression.pdf

CASSAVA

A list of common names and diseases (bacterial, fungal, nematodes and parasites, viral and viruslike agents, phytoplasmal and parasitic higher plants) of cassava is found on the American Phytopathological Society website: http://www.apsnet.org/online/common/names/cassava.asp

AFRICAN CASSAVA MOSAIC VIRUS

Websites

- http://gemini.biosci.arizona.edu/viruses/acmv/index.htm
- http://image.fs.uidaho.edu/vide/descr166.htm
- http://www.ciat.cgiar.org/biotechnology/cbn/sixth_international_meeting/Posters-PDF/PS-4/P_Zhang_Increased.pdf
- http://www.ciat.cgiar.org/asia_cassava/pdf/proceedings_workshop_02/264.pdf
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Websites

- http://www.ciat.cgiar.org/tropical_fruits/pdf/poster_soursop_high_value_crops_2005.pdf
- http://www.sciencedirect.com/science?_ob=ArticleURL&_udi=B6T5T-3X3TJFD-6&_user=10&_rdoc=1&_fmt=&_orig=search&_sort=d&view=c&_acct=C000050221&_version=1&_urlVersion=0&_userid=10&md5=4bbbb4c3d7c14e7c4b16f0ce55294ce3
- http://nt.ars-grin.gov/fungaldatabases/new_allView.cfm?whichone=all&thisName=Colletotrichum%20gloeosporioides&organismtype=Fungus&fromAllCount=yes

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BACTERIAL BLIGHT (*XANTHOMONAS AXONOPODIS*)

Websites

- http://www.ciat.cgiar.org/biotechnology/cbn/sixth_international_meeting/Posters-PDF/PS-4/srestrepo.pdf
- http://www.ciat.cgiar.org/biotechnology/pdf/redbio_chile_07/poster_rxam1_redbio_07jbeltran.pdf
- http://nt.ars-grin.gov/fungaldatabases/new_allView.cfm?whichone=all&thisName=Xanthomonas%20axonopodis&organismtype=Fungus&fromAllCount=yes
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- http://www.ncbi.nlm.nih.gov/ICTVdb/ICTVdB/00.056.0.01.023.htm
- http://www.oisat.org/pests/diseases/viral/mosaic_virus.html
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BACTERIAL ANGULAR LEAF SPOT (XANTHOMONAS CAMPESTRIS PV. DIEFFENBACHIEA)

Websites

- http://edis.ifas.ufl.edu/VH053
- http://orbita.starmedia.com/aldocova/pathos/disyu.htm
- http://musalit.inibap.org/pdf/ET050012_en.pdf

BEANS AND PULSES

RHIZOCTONIA ROOT ROT AND WEB BLIGHT (*RHIZOCTONIA SOLANI*)

Websites

- http://www.extento.hawaii.edu/Kbase/crop/Type/r_solani.htm
- http://www.rbgsyd.nsw.gov.au/science/hot_science_topics/Soilborne_plant_diseases/Vietnam_template3/Rhizoctonia
- http://nt.ars-grin.gov/fungaldatabases/new_allView.cfm?whichone=all&thisName=Rhizoctonia%20solani&organismtype=Fungus&fromAllCount=yes

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- "Bean Diseases", Atlas of Common Bean Production in Africa http://www.ciat.cgiar.org/africa/pdf/atlas_bean_africa/bean_diseases.pdf
- "Integrated Pest and Disease Management In Major Agroecosystems; Bean Pathology", CIAT, 2004 http://www.ciat.cgiar.org/ipm/report_2004/ipm_2004_10.pdf

GOLDEN BEAN YELLOW MOSAIC VIRUS (GEMINI VIRUS COMPLEX)

Websites

- http://studium.ppg.br/sites/virologia/index.php?area=scientificprogram
- http://www.sciencedirect.com/science?_ob=ArticleURL&_udi=B6TBH-4KBF195-2&_user=10&_rdoc=1&_fmt=&_orig=search&_sort=d&view=c&_acct=C000050221&_version=1&_urlVersion=0&_userid=10&md5=f0342e0484baaf8b022e7680eeda7113

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- "Data Sheets on Quarantine Pests: Bean golden mosaic bigeminivirus", Prepared by CABI and EPPO for the EU, http://www.eppo.org/QUARANTINE/virus/Bean_golden_mosaic_virus/BGMV00_ds.pdf

COMMON BACTERIAL BLIGHT (*XANTHOMONAS PHASEOLI*)

Websites

- http://vegetablemdonline.ppath.cornell.edu/factsheets/Beans_BactBlights.htm
- http://www.extension.umn.edu/yardandgarden/diagnostics/beanbactblight.html
- http://www.css.msu.edu/bic/PDF/Common%20Blight.pdf
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- "Integrated Pest and Disease Management In Major Agroecosystems; Bean Pathology", CIAT, 2004 http://www.ciat.cgiar.org/ipm/report_2004/ipm_2004_10.pdf

RUST (*UROMYCES PHASEOLI TYPICA*)

Websites

- http://www.forestryimages.org/browse/detail.cfm?imgnum=1436166
- http://www.css.msu.edu/bic/PDF/Rust.pdf
- http://www.hort.uconn.edu/Ipm/veg/htms/bnrust.htm
- http://www.ca.uky.edu/agc/pubs/ppa/ppa13/ppa13.htm

ANGULAR LEAF SPOT (*PHAEOISARIOPSIS GRISEOLA*)

Websites

- http://www.forestryimages.org/browse/detail.cfm?imgnum=5360386
- http://www.plantmanagementnetwork.org/pub/php/research/2005/snap/
- http://www.css.msu.edu/bic/PDF/Angular%20Leaf%20Spot.pdf
- http://nt.ars-grin.gov/fungaldatabases/new_allView.cfm?whichone=all&thisName=Phaeoisariopsis%20griseola&organismtype=Fungus&fromAllCount=yes

SORGHUM

A list of common names and diseases (bacterial, fungal, nematodes and parasites, viral and viruslike agents, phytoplasmal and parasitic higher plants) of sorghum is found on the American Phytopathological Society website: http://www.apsnet.org/online/common/names/sorghum.asp

DOWNY MILDEW (*SCLEROPHTHORA MACROSPORA*)

Websites

- http://maizedoctor.cimmyt.org/index.php?option=com_content&task=view&id=194&Itemid=29
- http://nt.ars-grin.gov/fungaldatabases/new_allView.cfm?whichone=all&thisName=Sclerophthora%20macrospora&organismtype=Fungus&fromAllCount=yes
- http://www.uaex.edu/Other_Areas/publications/PDF/MP297/6_diseases.pdf

BACTERIAL LEAF STREAK (*XANTHOMONAS HOLCICOLA*)

Websites

- http://web.aces.uiuc.edu/vista/pdf_pubs/315.pdf
- http://www.ipmimages.org/browse/detail.cfm?imgnum=0162030
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BACTERIAL LEAF STRIPE (*PSEUDOMONAS ANDROPOGONI*)

Websites

- http://www.uaex.edu/Other_Areas/publications/PDF/MP297/6_diseases.pdf
- http://plantpathology.tamu.edu/Texlab/Grains/Sorghum/sorghum.html
- http://www.ca.uky.edu/agc/pubs/ppa/ppa10a/ppa10a.pdf
- http://www.aragriculture.org/crops/sorghum/performance_tests/sorghum_update_2006.pdf

SORGHUM RUST (*PUCCINIA PURPUREA*)

Websites

- http://www.dpi.qld.gov.au/cps/rde/dpi/hs.xsl/26_4738_ENA_Print.htm
- http://www.ars.usda.gov/research/publications/publications.htm?SEQ_NO_115=170725
- http://espace.library.uq.edu.au/view/UQ:138869

- http://nt.ars-grin.gov/fungaldatabases/new_allView.cfm?whichone=all&thisName=Puccinia%20purpurea&organismtype=Fungus&fromAllCount=yes

MILLET

A list of common names and diseases (bacterial, fungal, nematodes and parasites, viral and viruslike agents, phytoplasmal and parasitic higher plants) of tomatoes is found on the American Phytopathological Society website: http://www.apsnet.org/online/common/names/pearlm.asp

DOWNY MILDEW (*SCLEROPHTHORA MACROSPORA*)

Websites

- http://www.ars.usda.gov/research/publications/publications.htm?SEQ_NO_115=140160
- http://nt.ars-grin.gov/fungaldatabases/new_allView.cfm?whichone=all&thisName=Sclerophthora%20macrospora&organismtype=Fungus&fromAllCount=yes

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- Thakur, RP; Shetty, HS; and Khairwa, IS "Pearl Millet Downy Mildew Research in India: Progress and Perspectives", SAT eJournal, ICRISAT, August 2006, Volume 2, Issue 1 http://www.icrisat.org/journal/cropimprovement/v2i1/v2i1pearlmillet.pdf
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ERGOT (CLAVICEPS FUSIFORMIS)

Websites

- http://www.icrisat.org/vasat/learning_resources/crops/pm/pm_diseases/html/m3l1/index.html
- http://www.apsnet.org/phyto/SEARCH/1984/Phyto74_201.asp
- http://www.apsnet.org/online/Archive/2007/iw000079.asp
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- http://nt.ars-grin.gov/fungaldatabases/new_allView.cfm?whichone=all&thisName=Claviceps%20fusiformis&organismtype=Fungus&fromAllCount=yes

SMUT (*TOLYPOSPORIUM PENICILLARIAE*)

Websites

- http://www.icrisat.org/vasat/learning_resources/crops/pm/pm_diseases/html/m4l1/index.html
- http://www.ars.usda.gov/Research/docs.htm?docid=8909#Smut
- http://genes.pp.ksu.edu/is/np/pearlmillet/qs.htm?pf=1

- http://chravinderreddy.com/pdfs/Reddy%20et%20al%20APS-2005.pdf
- http://nt.ars-grin.gov/fungaldatabases/new_allView.cfm?whichone=all&thisName=Tolyposporium%20penicillariae&organismtype=Fungus&fromAllCount=yes

RUST (PUCCINIA PENNISETI)

Websites

- http://www.icrisat.org/vasat/learning_resources/crops/pm/pm_diseases/html/m5l1/index.html
- http://www.icrisat.org/vasat/learning_resources/crops/pm/pm_diseases/ppt/m5l1.pps
- http://www.ars.usda.gov/IS/np/pearlmillet/tab1.htm
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BACTERIAL SPOT (*PSEUDOMONAS SYRINGAE*)

Websites

- http://www.ars.usda.gov/Research/docs.htm?docid=8896
- http://nt.ars-grin.gov/fungaldatabases/new_allView.cfm?whichone=all&thisName=Pseudomonas%20syringae&organismtype=Fungus&fromAllCount=yes

ZONATE LEAF SPOT (*GLOEOCERCOSPORA SPP.*)

Websites

- http://www.ars.usda.gov/IS/np/pearlmillet/fungzls.htm
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BANANAS

A list of common names and diseases (bacterial, fungal, nematodes and parasites, viral and viruslike agents, phytoplasmal and parasitic higher plants) of tomatoes is found on the American Phytopathological Society website: http://www.apsnet.org/online/common/names/banana.asp

FUSARIUM WILT “PANAMA DISEASE” (*FUSARIUM OXYSPORUM F. SP. CUBENSE*)

Websites

- http://home.spc.int/pps/PDF%20PALs/PAL_42%20Fusarium%20Wilt_reprint%202005.pdf
- http://www.plantmanagementnetwork.org/pub/php/management/bananapanama/
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BANANA BUNCHY TOP VIRUS (BBTV)

Websites

- http://www.issg.org/database/species/ecology.asp?si=141&fr=1&sts
- http://www.ebi.ac.uk/2can/genomes/viruses/Banana_bunchy_top_virus.html

BLACK SIGATOKA VALLEY (*MYCOSPHAERELLA FIJIENSIS*)

Websites

- http://www.apsnet.org/education/feature/banana/
- http://www.daff.gov.au/aqis/quarantine/naqs/naqs-fact-sheets/black-sigatoka
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YELLOW SIGATOKA VALLEY (*MYCOSPHAERELLA MUSICOLA*)

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EAST AFRICA BACTERIAL WILT (XANTHOMONAS CAMPESTRIS PV. MUSACEARUM)

Websites

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- http://www.farmradio.org/english/radio-scripts/71-2script_en.asp
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- http://www.asps.or.ug/index.php/documents/banana_bacterial_wilt
- http://c3project.iita.org/Doc/BXWethiopia.pdf

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- Kiiza, B; Rwomushana, G.; Lwasa, S.; and Diiro, G. “AN EVALUATION OF THE BANANA BACTERIAL WILT DISEASE AWARENESS CAMPAIGN IN UGANDA” US Agency for

International Development (USAID) and The Danish International Development Agency (DANIDA), August 2006 http://www.asps.or.ug/index.php/documents/banana_bacterial_wilt

TOMATOES

A list of common names and diseases (bacterial, fungal, nematodes and parasites, viral and viruslike agents, phytoplasmal and parasitic higher plants) of tomatoes is found on the American Phytopathological Society website: http://www.apsnet.org/online/common/names/tomato.asp

BACTERIAL WILT (*RALSTONIA SOLANACEARUM*)

Websites

- http://www.jstage.jst.go.jp/article/jsme2/19/1/19_53/_article
- http://www.bspp.org.uk/ndr/july2007/2007-50.asp
- http://edis.ifas.ufl.edu/PP127

EARLY BLIGHT (*ALTERNARIA SOLANI*)

Websites

- http://www.nysaes.cornell.edu/ent/hortcrops/english/eblight.html

FUSARIUM WILT (*FUSARIUM OXYSPORUM F. SP. LYCOPERSICI*)

Websites

- http://www.oznet.ksu.edu/dp_hfrr/extensn/problems/tomwilt.htm

WHITEFLY-TRANSMITTED GEMINI VIRUSES (WTGV)

Websites

- http://www.avrdc.org/LC/pepper/whitefly.pdf
- http://nar.oxfordjournals.org/cgi/content/abstract/19/24/6763
- http://www.oardc.ohio-state.edu/tomato/morales.pdf
- http://www.actahort.org/books/487/487_57.htm

Related Articles

- Polston, Jane and Anderson, Pamela "The Emergence of Whitefly-Transmitted Geminiviruses in Tomato in the Western Hemisphere" The American Phytopathological Society, Journal Plant Disease, 1997, Vol81, No. 12 http://apsjournals.apsnet.org/doi/pdf/10.1094/PDIS.1997.81.12.1358

TOMATO MOSAIC VIRUS (TOMV)

Websites

- http://plant.neogeneurope.com/prodtype.asp?strParents=119,120&CAT_ID=278&numRecordPosition=1

- http://www.avrdc.org/pdf/tomato/ToMV.pdf

MANGOES

A list of common names and diseases (bacterial, fungal, nematodes and parasites, viral and viruslike agents, phytoplasmal and parasitic higher plants) of mangoes is found on the American Phytopathological Society website: http://www.apsnet.org/online/common/names/mango.asp

MANGO MALFORMATION (*FUSARIUM MANGIFERAE, F. STERILIHYPHOSUM*)

Websites

- http://apsjournals.apsnet.org/doi/abs/10.1094/PHYTO-96-0667
- http://apt.allenpress.com/perlserv/?request=get-abstract&doi=10.1043%2F0027-5514(2002)094%5B0722%3ATNSOFS%5D2.3.CO%3B2&ct=1
- http://www.bspp.org.uk/NDR/jan2008/2007-98.asp
- http://www.nt.gov.au/dpifm/Content/File/p/Plant_Pest/mango_malformation.pdf

BACTERIAL CANKER "BACTERIAL BLACK SPOT" (*XANTHOMONAS AXONOPODIS PV. MANGIFERAEINDICAE SENSU NOVO.*)

Websites

- http://www.nt.gov.au/dpifm/Content/File/p/Plant_Pest/605.pdf

ANTHRACNOSE (*COLLETOTRICHUM GLOEOSPORIOIDES*)

Websites

- http://www.oisat.org/pests/diseases/fungal/anthracnose.html

Related Articles

- Kuo, Ker-Chung "Sensitivity of Mango Anthracnose Pathogen, Colletotrichum gloeosporioides, to the Fungicide Prochloraz in Taiwan" Proc. Natl. Sci. Counc. ROC (B), Vol. 25, No. 3, 2001. pp. 174-179, November 2000 http://nr.stpi.org.tw/ejournal/proceedingB/v25n3/174-179.pdf
- Ploetz, Randy "Anthracnose: The Most Important Disease in Much of the Mango-producing World", The Newsletter of the Plant Pathology Department, Volume 3 • Issue 9, September 1999 http://plantpath.ifas.ufl.edu/Newsletter/Newsletters/Septmeber1999.PDF

POWDERY MILDEW (*OIDIUM MANGIFERAE BERTHET*)

Websites

- http://archive.constantcontact.com/fs082/1101940814295/archive/1101946711528.html
- http://www.horticultureworld.net/mango-india2.htm

Related Articles

- Galli, J., Silveira, L., Michelotto, M., Martins, A. "POWDERY MILDEW (Oidium mangiferae BERT.) INFECTION IN MANGO VARIETIES" Bioscience Journal, Uberlândia, v. 24, n. 2, p. 43-46 , Apr./June. 2008 http://www.biosciencejournal.ufu.br/include/getdoc.php?id=2592&article=414&mode=pdf

STEM END ROT (*BOTRYOSPHAERIA SPP.*)

Websites

- http://apt.allenpress.com/perlserv/?request=get-abstract&doi=10.1043%2F0027-5514(2005)097%5B0099%3APAMROT%5D2.3.CO%3B2
- http://plantpath.ifas.ufl.edu/takextpub/FactSheets/pp0023.pdf

PINEAPPLES

BLACK ROT (*CERATOCYSTIS PARADOXA*)

Websites

- http://www.ficciagroindia.com/production-guidelines/fruits/pineapple/diseases.htm
- http://nhb.gov.in/bulletin_files/fruits/pineapple/pin002.pdf

HEART ROT (*PHYTOPTHORA PARASITICA*)

Websites

- http://www.ficciagroindia.com/production-guidelines/fruits/pineapple/diseases.htm
- http://nhb.gov.in/bulletin_files/fruits/pineapple/pin002.pdf

BUTT ROT (*THIELAVIOPSIS PARADOXA*)

Websites

- http://nhb.gov.in/bulletin_files/fruits/pineapple/pin002.pdf

HEART AND ROT ROOT (PHYTOPHTHORA CINNAMOMI, NICOTIANAE)

Websites

- http://www.hort.purdue.edu/newcrop/morton/pineapple.html
- http://gilb.cip.cgiar.org/fileadmin/GILB/pdfs/Training_materials/Drenth_Phytophthora_Practical_guide9.pdf

FRUITLET CORE ROT (*FUSARIUM GUTTIFORME*)

Websites

- http://www.sbfito.com.br/cbf2008/Abstract%20Model%20CBF2008%20Shortversion%20Engli.pdf