Plant Disease

Synopsis

This qualitative assessment evaluates the risk of an unintentional plant disease outbreak resulting in a national level event. Three themes were identified from the reviewed literature: (1) globalization and threats from imported pathogens and pests; (2) climate change; and (3) cultural shifts—the impact of the organic and non-genetically modified organism (GMO) movements on plant disease.

Generally, the literature reflected that there is a constant battle against plant disease. One of the key risk factors about plant disease is its nature to evolve and mutate in order to gain resistance to pesticides and other mitigation techniques. The literature also reflected that the U.S. Government has an established and effective infrastructure to prevent, detect, respond to, and mitigate this evolving threat. The literature encouraged continued research to stay ahead of emerging plant diseases. While the threat is not necessarily increasing, it presents a dynamic landscape that requires close scrutiny.

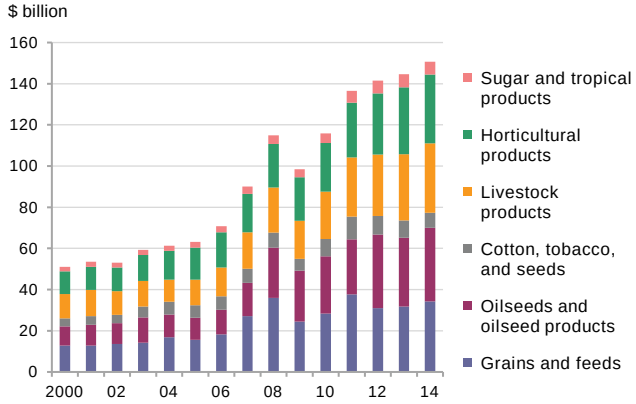
Literature Review

Introduction

Event Description

For purposes of this assessment, Plant Disease is an outbreak of a plant pathogen or pest that has the potential to reduce or destroy plants so significantly that it results in a national level event. The scope of this assessment is primarily on unintentional outbreaks or accidental releases through commerce or a lab accident.[404] For purposes of this assessment, we are characterizing a national level event to be a plant disease outbreak of such significance that it has the potential to threaten the nation's food supply or cause substantial economic loss (reductions in exports and foodstuffs losses).[405]

U.S. agricultural exports, 2000-14



Source: USDA, Economic Research Service using data from U.S. Department of Commerce, U.S. Census Bureau, Foreign Trade Database.

Event Background

The Value of Plants

Plants play a vital role in our society.[406] Healthy plant systems are necessary for the health and welfare of our citizens, animals, and economy. Stack and Fletcher argue that the "human, animal, and plant systems are

[404] Intentional outbreaks—caused by an adversary intentionally releasing a plant pathogen or pest—are considered an Adversarial Hazard and are addressed by other topics in the SNRA.

[405] "More than two-thirds of cropland in the United States is devoted to the production of just four crop species—maize, wheat, soybeans, and cotton" - http://bioscience.oxfordjournals.org/content/59/2/141.short

[406] Stack, James P. and Jacqueline Fletcher, "Plant Biosecurity Infrastructure for Disease Surveillance and Diagnostics", pp. 95-105, Global Infectious Disease Surveillance and Detection: Assessing the Challenges-Finding Solutions, National Academy of Sciences Press. (2007).

intricately linked; the intersection of these three systems form the basis of our economy, our culture, and our standard of living."[407] We depend on plants in a number of ways that we often do not think about. Plants generate oxygen, provide food for us and our animals, clothe us through their fibers, shelter us with their timber, and increasingly power our technology through the fuels they provide.[408]

The agriculture sector produces sizeable exports that contribute to the U.S. economy. From 2006 to 2014, U.S. agricultural exports more than doubled. Demand from developing countries, along with higher farm commodity prices, explains recent growth in the value of U.S. exports. Foreign demand for wheat, soybeans, cotton, corn, and their processed products accounts for about half of U.S. export value. U.S. farm exports to developing countries are now more than double what are exported to developed countries. Purchases by developing countries consistently have been greater than developed countries since 1994.[409] In the last century, the U.S. prosperity was due in part to its agriculture providing a "safe, inexpensive, and dependable food supply system."[410]

Plant Diseases

Destructive plant pests and pathogens come from a variety of sources including insect pests and plant pathogens such as fungi, oomycetes, bacteria, viruses, nematodes, protozoa, and parasitic plants. Currently there are several prioritized lists of high consequence plant pathogens and pests.[411] Some of these lists have hundreds of agents. It is difficult to define a set of characteristics that identify which plant pests or pathogens could cause the greatest plant damage to the Nation's ecosystem.[412] Furthermore, many plant pests and pathogens are resilient in the sense that it is not feasible to completely eliminate them from the environment.

The four primary crops grown in the United States are maize, wheat, soybeans, and cotton. Their production takes up more than two-thirds of cropland in the United States. Experts have raised concerns that "homogenization of the American agricultural landscape could facilitate widespread disease and pest outbreaks, compromising the national food supply."[413]

Diseases affecting the major food crops, "cereal grains (wheat, rice, and maize), tubers (potato, cassava, yam, and taro), and vegetable crops (dry beans, peas, lentils and other legumes as well as cabbage and other brassicas)" have the greatest affect on human populations.[414]

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[407] Stack and Fletcher. (2007).
[408] Stack and Fletcher. (2007).
[409] The chart and this paragraph are from the USDA's Economic Research Service. Retrieved April 2015: http://www.ers.usda.gov/data-products/chart-gallery/detail.aspx?chartId=40077&ref=collection&embed=True&widgetId=39734
[410] Stack and Fletcher. (2007).
[411] Fletcher, Jacqueline, et al., "Emerging Infectious Plant Diseases", Chapter 18, Emerging Infections 9, Ed. W. M. Scheld, 2010, ASM Press, Washington, DC. Retrieved April 2015: http://www.ars.usda.gov/SP2UserFiles/Place/66180000/Fletcher%20et%20al_2010_%20Emerging%20Infectious%20Plant%20Diseases_%20ASM%20Press%20ch18.pdf
[412] Fletcher, J. (2010).
[413] Margosian, M., Garrett, K., Hutchinson, S., and With, K. (2009, February). "Connectivity of the American Agricultural Landscape: Assessing the National Risk of Crop Pest and Disease Spread." BioScience Magazine. Vol. 59 No. 2. 141-151. Retrieved April 2015: http://bioscience.oxfordjournals.org/content/59/2/141.full.pdf+html
[414] Fletcher, Jacqueline, et al., "Emerging Infectious Plant Diseases", Chapter 18, Emerging Infections 9, Ed. W. M. Scheld, 2010, ASM Press, Washington, DC. http://webcache.googleusercontent.com/search?q=cache:63DWp_YlflMJ:www.ars.usda.gov/SP2UserFiles/Place/66180000/Fletcher%2520et%2520al_2010_%2520Emerging%2520Infectious%2520Plant%2520Diseases_%2520ASM%2520Press%2520ch18.pdf+&cd=2&hl=en&ct=clnk&gl=us

"Underdeveloped countries lacking infrastructure to detect and mitigate diseases," have the greatest struggle, but diseases of these plants affect U.S. growers as well.

The "disease triangle" that characterizes all plant diseases consists of (1) a susceptible plant, (2) a virulent pathogen, and (3) a conducive environment. Without all three components, disease will not occur.[415] Plant diseases are categorized by symptoms. They can occur in the field or in storage.

U.S. Government Roles and Responsibilities

The United States Department of Agriculture (USDA) is the lead Federal agency tasked with identifying, controlling, and mitigating the effects of plant pests and pathogens.[416] Specific to agriculture health, the USDA has the following responsibilities:[417]

- Developing plant pest and disease exclusion systems and coordinating implementation across the interagency mitigating the risk of introduction of exotic plant pest and disease from foreign countries into the United States (foreign responders, equipment, supplies, and food).
- Developing and maintaining biosurveillance systems to detect exotic plant pests and disease and coordinating surveillance activities with local, state, tribal, and territorial governments.
- Identifying and confirming the presence of newly detected exotic plant pests and disease in the United States.
- Coordinating emergency response to newly detected plant pests and disease of economic or environmental significance with local, state, tribal, and territorial governments.
- Mitigating the interstate movement and potential spread of exotic plant pest and disease in the United States (applies to equipment and supplies moving in and out of quarantine zones, debris removal, and movement of agricultural commodities or soils).

A large infrastructure exists in the U.S. consisting of Federal and state agencies and related research laboratories responsible for surveillance, prevention, detection, and recovery from destructive plant pests and pathogens. This infrastructure regularly demonstrates that it can control and mitigate the effects of plant pests and pathogens in the environment.

Preventing and Interdicting Pests

The Department of Homeland Security assists, supports and enforces USDA regulations within the designated areas of responsibility such as the ports of entry. To mitigate the effects of destructive plant agents in the U.S., the USDA, through the Animal and Plant Health Inspection Service Plant Protection and Quarantine (APHIS PPQ), and the DHS, through Customs and Border Protection (CBP), share responsibility for preventing the introduction of new plant pathogens and pests into the U.S.

[415] Fletcher, J. (2010).
[416] In addition to their statutory responsibilities, the USDA is also the lead for Emergency Support Function (ESF) #11 – Agriculture and Natural Resources Annex. http://www.fema.gov/media-library-data/20130726-1914-25045-2457/final_esf_11_ag_and_natural_resources_20130501.pdf
[417] This is only a portion of USDA's plant health related responsibilities. This list is from ESF #11.

Detecting Outbreaks

The National Plant Diagnostic Network (NPDN) under the USDA provides infrastructure for the detection and diagnoses of destructive plant agent outbreaks. The NPDN collaborates with the National Institute for Food and Agriculture (NIFA) (formerly the Cooperative State Research, Education, and Education Service [CSREES]), APHIS, and other organizations to detect outbreaks.

Responding to Outbreaks

To respond to a destructive plant agent, the U.S. set up the National Plant Disease Recovery System (NPDRS) within the USDA's Agriculture Research Service (ARS). NPDRS has the responsibility of responding to high consequence plant pests and pathogens with pest control measures and the use of disease resistant seeds. NPDRS gets seeds from the U.S. National Plant Germplasm System. NPDRS involves APHIS, NIFA, and state departments of agriculture.

Research

As of 2002, USDA and APHIS, were spending more than $1 billion annually in research, risk assessment, and emergency response plans to outbreaks.[418] USDA's ARS and the U.S. Forest Service conduct in-house research and support basic and applied plant pathology research through formal (NIFA) and informal (APHIS) extramural grant programs. The National Science Foundation and other funding sources also fund basic research on plant-microbe interactions. Individual states fund plant pathology research at land grant universities (LGUs) in various academic departments (plant pathology, microbiology, horticulture, and agronomy, etc.). In addition, Cooperative Extension Service (CES) personnel conduct applied field research and provide advice directly to producers and serve as first responders to pathogen outbreaks.

Research is also sponsored and conducted by state agencies and private sector organizations. State Department of Agriculture (SDA) laboratories often addresses diseases and pathogens specific to the state's climate and commodities. Several large commodity groups, representing the agricultural production sector, collect "checkoff" funds from growers to support research on pathogens attacking that commodity, and seed companies monitor and conduct research on plant pathogens emerging in the U.S., as well as in countries where offshore nurseries are used to generate seed for subsequent planting in the U.S.[419]

Literature Review

Globalization and threats from imported pathogens and pests

Plant disease outbreaks are not solely natural occurrences. Human actions are extensively implicated in the spread and outbreak of disease, thus making it difficult to determine the precise drivers, impacts, and regulations of the disease.[420] Human-induced globalization is increasing the spread of plant disease; organisms are transported more easily as a result of extended trading

[418] Margosian 2009
[419] Fletcher, J. (2010).
[420] Wilkinson, K., Grant, W., Green, L., Hunter, S., etc. (2011, May). "Infectious diseases of animals and plants: an interdisciplinary approach". Philosophical Transactions of the Royal Society. Vol. 366, 1933-1942. Retrieved April 2015: http://classic.rstb.royalsocietypublishing.org/content/366/1573/1933.full

systems.[421] There are 10 new types of insects or pathogens introduced to American farms each year.[422]

Imported pathogens are considered an existing as well as an emerging threat to the U.S. agricultural scene. The threat of foreign pathogens to native vegetation has been recognized internationally and steps are in place to control this threat to an extent. Lessons learned have pointed to trends in diseases and their "ability to coevolve with new hosts and to rapidly exploit the environments with which they come into contact…" posing "…both a scientific and management challenge."[423] While recognized and actively mitigated, it was widely agreed that further research is necessary for continued management as new, exotic, and resistant pathogens emerge.[424]

Concerns were put forth not only for pathogens and pests brought in through food bearing plants, but also in recreational plants. As discussed below, any type of foreign agriculture can introduce diseases into the food supply.

> Huge markets exist for international trade of live ornamental plants. Flowers and other ornamentals include a wide variety of plant species that host a multitude of diseases. The movement of commercial ornamental propagation activities to tropical offshore facilities has generated new pathways for movement of exotic plant diseases into the United States. For example, Ralstonia solanacearum race 3 biovar 2, a serious pathogen of potato and tomato designated a "select agent," was introduced into the United States in 2003 on propagated geranium plants from Central America and again in 2004 from West Africa, causing growers to destroy their inventories. Because plant pathologists and regulatory authorities were concerned that the pathogen would threaten U.S. potato and tomato production if it escaped from nursery facilities, geranium growers who had received infested shipments were directed to destroy their inventories.[425]

Another concern with imports is the reintroduction of previously mitigated risks to plant health. The U.S. and most developed countries have encountered basic pathogens and have either wiped out the cause, or have developed plants that are resistant to common forms of the disease. In 1999, the developing nation of Uganda unwittingly re-introduced a strain of wheat stem rust, which was thought to have been eradicated. This instance provided "a humbling example of the capacity of pathogens to mutate in response to selective pressure, acquiring new virulence traits and overcoming resistance genes."[426]

Climate Change

Climate change is another issue impacting the spread of diseases. Disease organisms may find more favorable conditions for reproduction and transmission as a consequence of global

[421] Wilkinson, K. etc. (2011, May).
[422] Margosian. (2009).
[423] Potter, C., Harwood, T., Knight, J, and Tomlinson, I. (2011). "Learning from history, predicting the future: the UK Dutch elm disease outbreak in relation to contemporary tree disease threats." Philosophical Transactions of the Royal Society. Vol. 306. 1966-1974 Retrieved April 2015: http://classic.rstb.royalsocietypublishing.org/content/366/1573/1966.short
[424] Magarey, Roger D., et al., "Plant Biosecurity in the United States: Roles, Responsibilities, and Information Needs", pp. 875-884, Bioscience, Vol.59, No 10, November 2009. Retrieved April 2015: http://bioscience.oxfordjournals.org/content/59/10/875.short
[425] Fletcher, J. (2010).
[426] Fletcher, J. (2010).

warming. "Climate change affects disease transmission at three levels: firstly, it acts directly on the biology and reproduction of pathogens, hosts or vectors; secondly, it affects the habitats present in a region, the community of hosts that can live in them, and the lifecycles, or lifestyles, of those hosts; and thirdly, climate change induces social and economic responses, including adaptive and mitigating measures, which alter land use, transport patterns, human population movements, and the use and availability of natural resources."[427]

It was found that even small changes to the ecosystem could "have large impacts on the incidence of infection in a population, as pathogens more successfully jump species."[428] There is a cyclical impact: increased agricultural production leads to increased greenhouse gases, which further exacerbates climate change, leading to further issues with plant disease.[429]

Cultural Shifts: The Impact of the Organic and Non-GMO Movements on Plant Disease

Consumers' preference for food grown with minimal chemical pesticides has led to the presentation of GMOs into the agricultural scene. Due to the rise of pesticide-resistant pathogens and the introduction of foreign pests, "…chemical pesticide [use] continues to rise."[430] This rising incidence of plant diseases created a need for continued research in the area of biopesticides and other alternative strategies such as GMOs. However, consumer wariness of the use of these GMOs in food products makes the use of this as an alternative to pesticides difficult. More research should be done on the impact this has on the ecosystem and on end use products.

Some experts[431] have suggested the increased demand[432] for organically grown food and non-GMO food products may have an inadvertent negative affect on pests and diseases. The theory is that as more organic agriculture productions are stood up, it creates reservoirs for pests to thrive and provides time for pests to adapt to the pest-resistant GMO plants at a neighboring farm. No literature was discovered on this topic during the review. It is currently unknown what impact the increase of organic and non-GMO agriculture will have in the ecosystem.[433]

Conclusion

At this time, pathogen and disease concerns from developing countries do not directly affect our country but they have in the past. As the technology, crop productions, and import/export laws change, however, we will need to be vigilant in our methods of detection to ensure safety from new, or the reintroduction of eradicated, diseases that could impact agricultural supplies.

Generally, the literature reflected that there is a constant battle against the plant disease threat. One of the key risk factors about plant disease is its nature to evolve and change. The literature also reflected that the U.S. Government has an established and effective infrastructure to prevent, detect, respond, and mitigate this evolving threat. For a plant disease event to occur at such a

[427] Wilkinson, K. etc. (2011, May). P. 1934.
[428] Wilkinson, K. etc. (2011, May).
[429] There is extensive information on this topic in the literature, however Climate Change is addressed as a separate SNRA topic, thus it is treated in a limited way in this assessment.
[430] Wilkinson, K. etc. (2011, May).
[431] USDA Official
[432] The demand for organic food has seen double-digit increases each year for the past few years. USDA, Economic Research Service. http://www.ers.usda.gov/topics/natural-resources-environment/organic-agriculture/organic-market-overview.aspx
[433] We were unable to procure additional information on the topic of the impact of GMOs on the evolution of pests versus organic methods that do not employ pesticides.

level that it meets the criteria for a national level event it would likely be intentional (i.e., bioterrorism) or the cascading affect of some other disaster. Climate change may be an example of the latter.

The literature reviewed included discussions on biowarfare, and the potential for the deliberate introduction of pathogens within our country by state-sponsored threat actors. However, the main takeaway is that the country needs to increase awareness and research into detection, mitigation, and response for "deliberate use of plant pathogens to inflict harm on a person, company, industry, or nation."[434] While additional information is available on this topic, it is not within the scope of the topic for this assessment.[435]

Though the U.S. Government's approach to plant disease is well organized and effective, the literature encouraged continued research to stay ahead of existing plant disease as it continually evolves and mutates based on exposure to new resistant strains. The threat is not necessarily increasing, but it presents a dynamic landscape that requires close scrutiny.

[434] Fletcher, J. (2010).

[435] Intentional outbreaks—caused by an adversary intentionally releasing a plant pathogen or pest—are considered an Adversarial Hazard and are addressed by other topics in the SNRA.