THE MEAN SIXTEEN

Major Biosecurity Threats Facing U.S. Agriculture and How Policy Solutions Can Help

By Dr. Stephanie Mercier

FARM JOURNAL FOUNDATION

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By Dr. Stephanie Mercier

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EXECUTIVE SUMMARY

Farmers, ranchers, and producers in America are facing a barrage of new and emerging threats that have the potential to upend our entire food system.

Today, pest and disease outbreaks are affecting every single agricultural sector – from corn to cattle to cotton to citrus. These challenges are wrecking production in a number of markets, disrupting American business and trade, hurting farmers' profitability, and in many cases, leading to significantly higher food costs for consumers.

DISRUPTING BUSINESS + TRADING

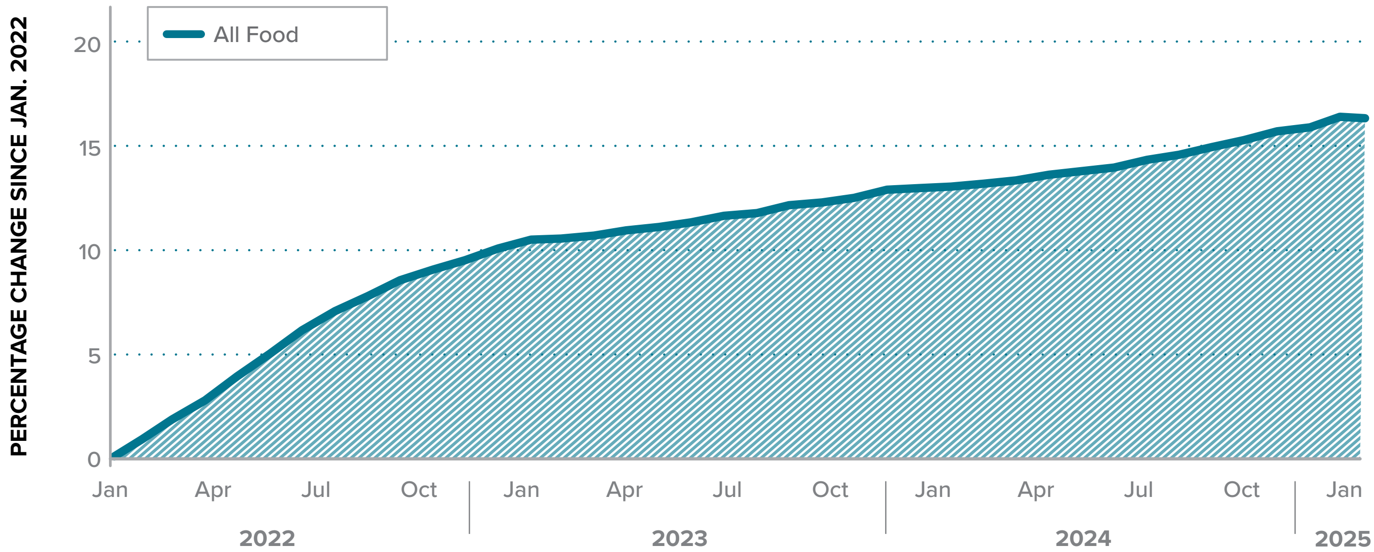
HURTING FARMERS' PROFITABILITY

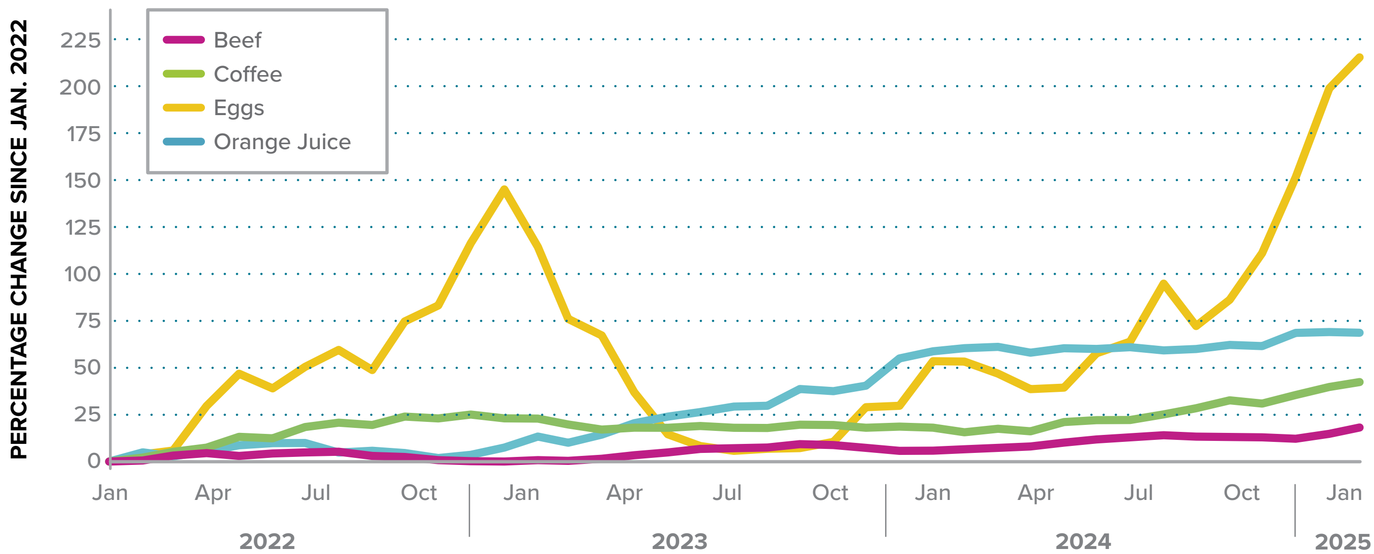
INCREASING PRICES FOR CONSUMERS

A few of these outbreaks, like avian influenza in poultry and New World screwworm in cattle, have captured the public's attention recently because of their impact on prices and markets. However, numerous other risks are flying under the radar, while causing significant damage to the national economy. In this paper, we call attention to a select list of 16 of the worst pest and disease threats facing American agriculture today, plus a handful of overseas outbreaks that are hurting beloved consumer products like bananas, chocolate, and coffee, and discuss their economic impact and the outlook for the future. This list drew from the expertise of many of agriculture science's leading national voices – but it's also incomplete. New pest and disease threats are constantly emerging, so it's difficult to know for certain what our next big outbreak will be. For this reason, it is absolutely crucial that the U.S. should support mechanisms to protect farmers from risks and make sure that our food supply chain can remain resilient even when challenges occur. To this end, this paper recommends that the U.S. government invest in three strategic categories – international coordination and related solutions, domestic solutions, and agricultural research and development – to ensure that U.S. agriculture remains strong even in the face of uncertain conditions.

For millions of Americans, the spectre of the global COVID-19 pandemic still looms large in our collective memory. From that disaster, we all learned just how rapidly diseases can jump between species, disrupt vital infrastructure systems, and spread around the world. Crop and livestock diseases are no different, and in some ways, these threats are even more significant due to their potential to harm a fundamental element of human existence – our food. Investing in agricultural research, development, and the long-term viability of our food supply chain is critical for protecting our national security and economy, and we are hopeful that our nation's leaders will rise to meet this challenge before it's too late.

The Consumer Cost of Pest and Disease Outbreaks





**American food prices have climbed about 17 percent since January 2022.
Eggs, orange juice, coffee, and beef are examples of products that have been hit by major recent pest and disease outbreaks, contributing to higher consumer costs.**

Sources: U.S. Bureau of Labor Statistics via the Federal Reserve Bank of St. Louis (FRED) for All Food CPI (CPIUFDSL), Orange Juice (APU0000713111), Coffee (APU0000717311), and Eggs (APU0000708111), and U.S. Bureau of Labor Statistics Average Price Data for Uncooked Ground Beef (user-provided dataset)

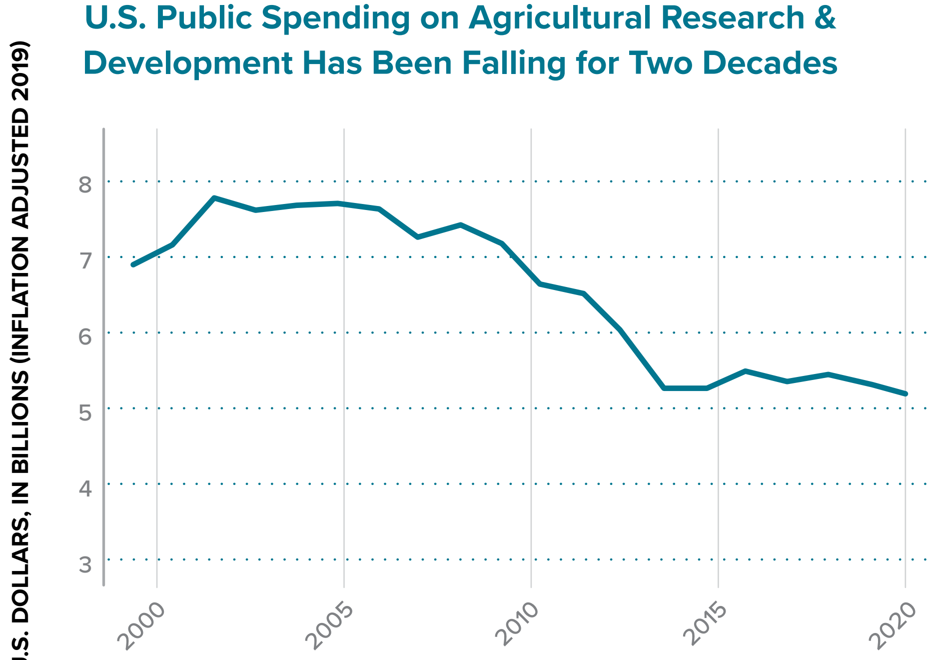
I. INTRODUCTION

American farmers, ranchers, and producers are under constant threat from outbreaks of diseases, pests, and pathogens that can significantly damage crop and livestock production and ultimately lead to higher food costs for consumers, lost farm profits, and reductions to the national GDP. Agriculture is one of the most important engines for the American economy; however invasive species alone cost the U.S. as much as $120 billion annually, according to U.S. Customs and Border Protection, and between 20 percent and 40 percent of crop production globally is lost to pests every year (CBP/DHS, 2024). Pests and pathogens can be introduced accidentally from overseas or elsewhere in the country by shippers or individual travelers, carried on storm systems or trade winds, or as a deliberate act of aggression against our agricultural sector, either as an act of terrorism or economic sabotage. While there has not been a documented case of deliberate foreign introduction of pests or pathogens into the U.S. agricultural sector to date, we cannot dismiss the possibility of such an action and must remain vigilant to protect our food security and national security.

At the farm level, significant outbreaks can reduce the revenue that producers would otherwise expect to receive, due to decreased crop yields or increased mortality rates in livestock, as well as higher production costs for inputs such as herbicides, pesticides, or veterinary services that may be needed for response measures. Data from the U.S. Department of Agriculture's Economic Research Service (USDA ERS) indicates that U.S. farmers spend an average of about $19 billion annually for pesticides just to protect their crops from endemic diseases and pests, but costs can go up astronomically for individual farmers facing a major outbreak. The agency's production expense data does not break out other individual cost categories that might be implicated in combatting outbreaks, such as veterinary care and animal carcass disposal costs.

Writ large, the threat of potential outbreaks to America's food and agriculture supply chains cannot be overstated, and every single sector within agriculture – from corn to cattle to cotton to citrus – faces its own unique and serious challenges. This paper will individually highlight some of the most significant pest and disease risks facing key U.S. crop and livestock sectors, reporting on the economic impact of damage due to lost farm income and trade, as well as U.S. public spending on crisis management, response plans, and remedies to combat these outbreaks. It will also analyze the potential future impact on certain markets, particularly if current looming threats are not resolved. Finally, this paper will also provide a list of key recommendations for U.S. policymakers to consider, focusing on the need to increase investment in public agricultural research and development, enhance biosecurity and trade measures through international collaboration, and strengthen monitoring, preparedness, and response plans.

U.S. Public Spending on Agricultural Research & Development Has Been Falling for Two Decades



Source: USDA, Economic Research Service (ERS) using data from the ERS data product Agricultural Research Funding in the Public and Private Sector.

Methodology: How We Chose the Mean 16

This paper offers a deep dive on 16 of the most economically significant biosecurity threats facing individual crop and livestock sectors in the U.S., looking at the potential economic impacts that such outbreaks might generate, and where available, the resulting repercussions for American consumers. We identified the specific pests, diseases, and pathogens discussed in this paper based in large part on conversations with numerous relevant stakeholder groups, including representatives of key farm and commodity organizations, and academic and extension experts in fields such as plant pathology, entomology, animal science, and veterinary medicine. However, readers should keep in mind that pests, diseases, and pathogens can evolve and spread quickly, and new threats are constantly emerging on the global stage. The threats represented within this paper are a non-exhaustive list, and we acknowledge that new and emerging risks can increase in significance with surprising speed, and it is difficult to know what the future may hold.

Some of the known biosecurity threats analyzed in this paper are not currently present in the U.S., but they still pose significant risks for American agriculture. One example is foot and mouth disease (FMD), which is a viral disease that affects both domesticated animals such as cattle, sheep, and hogs, as well as wildlife including deer and elk. There is no current presence of this disease in the U.S., which has been FMD-free since 1929. However, its high morbidity rate (nearly 100 percent of animals exposed to FMD get infected) and the severe trade implications of an FMD outbreak make it an obvious choice for inclusion in this paper.

Other biosecurity threats, such as soybean rust, are present in this country but have not yet inflicted widespread damage due to climatic barriers, but those barriers may diminish as time goes on. This fungal disease was first detected in 2001 in Brazil—the U.S.'s largest competitor in the global soybean market—and is estimated to have cost that country's soybean producers about $2 billion per crop year in recent years, due to higher fungicide costs and lost production (Gottems, 2023).

In addition, some of the animal diseases examined in this paper constitute threats not only to the U.S. livestock sector, but to human health as well, due to their ability to cross over to different species and adapt over time. These are known as zoonotic diseases, and according to a 2010 report by the United Nations World Health Organization (UN WHO), around 60 percent of emerging human infections originate from either domestic or wildlife animal species. For example, the H5N1 strain of avian flu that has been present in the U.S. since at least 2024 has been found in at least 70 mammalian species around the world, including humans.

The food and agriculture industry is part of the backbone of America's economy, and its value chains are impacted by commodities grown and produced in the U.S., as well overseas. In addition to our main "Mean 16" list, we have included a few examples of threats to agricultural products that are widely consumed in the U.S., if not widely grown here, because of their potential repercussions to the American economy and way of life. One prime example is coffee, a $340 billion U.S. industry, which faces significant risks from crop diseases in Latin America (NCAUSA, 2023).

Finally, it is important to note that the order in which threats are discussed within this paper does not reflect any judgement on their relative severity or costliness – all of the pests, diseases, and pathogens found in this paper pose serious challenges for each of their respective markets. The number of biosecurity threats facing U.S. agriculture is far greater than 16, and new risks are constantly emerging for the industry to address. In acknowledgement of this, and to underline the fact that our Mean 16 list is non-exhaustive and likely to evolve, we have included a "Dishonorable Mentions" list in the annex of this paper to call attention to a number of additional major pests, diseases, and pathogens facing American agriculture today.

Pests, diseases, and pathogens pose massive risks for farmers and consumers, as well as the broader American economy, but there are many solutions that can help the U.S. address these challenges. The final section of this paper includes a list of policy recommendations for combatting potential threats – namely, by increasing investments in agricultural research and development, enhancing international cooperation, supporting public and private-sector collaboration, and strengthening surveillance and response plans. The U.S. administration and Congress are uniquely positioned to enact much-needed measures to strengthen our agricultural industry against biosecurity risks, and to ultimately protect our country's food security, national security, and economic growth.

II. THE MEAN SIXTEEN

Agriculture, food, and related industries account for a significant share of the U.S. economy, contributing over $1.5 trillion annually to the national GDP (Zahniser, 2024). Yet the industry is extremely vulnerable to risks from pests, pathogens, and diseases. Recent outbreaks – such as the global COVID-19 pandemic, which likely resulted from a virus jumping from animals to humans (World Health Organization, 2025), as well as the U.S. avian influenza outbreak that caused egg prices to skyrocket in 2025 – have served as global wakeup calls. More must be done to shore up farmers and our food value chain against outbreaks that can have catastrophic consequences for farmer livelihoods, consumer food security, and public health.

Below, we highlight 16 of the most significant pests, diseases, and pathogens facing American agriculture today. Each of these threats have had a persistent, costly impact, and adequate protections such as effective herbicides or pesticides for crops, genetic resistance, or vaccines for livestock, have not yet been developed.

Looming Threats: Pests and Diseases on America's Doorstep

The pests and diseases listed below aren't currently present or widespread in the U.S.However, many are spreading around the world and could have devastating consequences for American food supplies if they were to reach our borders.

LIVESTOCK

Cattle, Swine, and Other Ruminant Animals

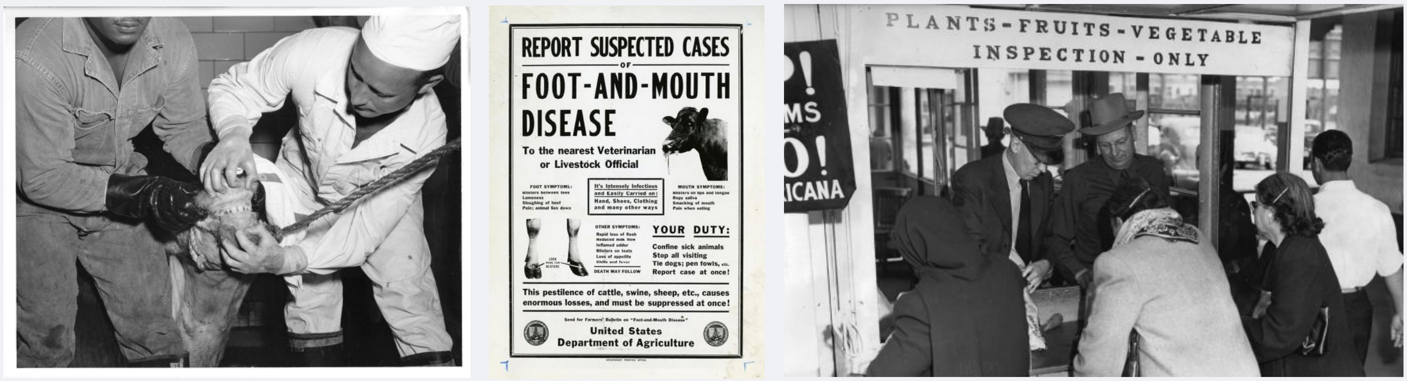
Foot and Mouth Disease (FMD)

This disease (enteroviral vesicular stomatitis with exanthem (EVS)) has been causing problems for livestock producers since the early 16th century (Grubman and Baxt, 2004). FMD was the first animal disease that was identified as being transmitted by a virus, which has the potential to infect a wide range of animal species in the ungulate order, also known as cloven hooved animals. Vulnerable species include a large number of domesticated animals such as cattle, swine, sheep, and goats, and more than 70 species of wildlife such as deer, antelope, bison, giraffes, and moose. Although mortality rates from FMD are relatively low among adult animals, estimated at between 1-5 percent, they are higher for young animals, between 20 and 50 percent. The disease is highly transmissible and can be spread by contact with other infected animals, through the air, and through contact with contaminated equipment or surfaces.

Fairly recent outbreaks of FMD have hit Taiwan (1997) and the United Kingdom (2001), both of which had been classified previously as FMD-free by the World Organization for Animal Health (WOAH). A 2002 study published in the Revue Scientifique et Technique estimated the comprehensive cost of the U.K. outbreak at up to $16 billion, including direct and indirect costs to both the U.K. agricultural sector and other economic sectors as well as the loss of revenue from reduced domestic and international tourism (Thompson et al., 2002).[1] The U.K. government compensated agricultural producers for about 80 percent of the costs they incurred. It is worth noting that most of the animals that were destroyed as part of the U.K.'s disease control effort were sheep, a species that makes up only a modest share of the vulnerable livestock population (less than three percent) in the United States should an outbreak occur here.

The United States has been classified as FMD-free since 1929 and has in place similar disease control protocols as other developed countries to prevent its spread. It is also fortunate that both of our immediate neighbors, Canada and Mexico, are also classified as FMD-free. Those two countries accounted for about 95 percent of the live animal imports into the United States on average in 2023-24 (FAS/USDA, 2025), although live cattle imports from Mexico have been cut off intermittently in 2025 due to fears about the possibility of another serious pest incursion, of the so-called New World screwworm (more on this pest in sections below).

1.) The net cost to the United Kingdom's economy may have been lower than this estimate as some expenditures may have been shifted to other sectors rather than foregone entirely.



The U.S. worked with Mexico in the 1940s to help contain and eradicate foot and mouth disease outbreaks there, stamping out the disease in North America and contributing to a more secure U.S. livestock industry. | Photo Credit: USDA National Agricultural Library.

A 2015 study from Kansas State University found that an FMD outbreak in the United States could cost nearly $200 billion to the U.S. economy if no emergency vaccination program were to be implemented (Pendell et al., 2015). However, if such a program was established quickly in the region where the initial cases were detected, overall costs could be reduced to $57 billion. This analysis assumes the initial detection of FMD occurs in the Midwest, which has large populations of FMD-vulnerable livestock. If an initial FMD detection were to occur in another part of the country, the overall economic damage might not be quite so severe.

> ***A 2015 study from Kansas State University found that an FMD outbreak in the United States could cost nearly $200 billion to the U.S. economy if no emergency vaccination program were to be implemented.*** *– Pendell et al., 2015*

Various vaccines are available to prevent animals from being infected by FMD, but they are generally not administered to animals in FMD-free countries and regions because it is not always easy to differentiate between vaccinated and FMD-infected animals in a clinical setting. This matter puts livestock trade at risk, since WOAH protocols allow trade bans to be imposed on countries using such vaccines. Research indicates that available vaccines reduce an animal's chance of becoming infected by about 70 percent compared to unvaccinated animals, but immunity can sometimes be short-lived (Wubshet et al., 2024). In 2014, scientists working at the ARS/DHS quarantine facility on Plum Island, partnering with scientists from the animal health industry, developed a new FMD vaccine that does not use live or killed FMD virus, so its use would make it easier to distinguish between vaccinated and infected animals (DHS Science and Technology Directorate, 2014). A provision of the 2018 farm bill included mandatory funding to establish an animal vaccine bank in case of a widespread animal disease outbreak. USDA chose FMD as the first disease to stockpile vaccines against (American Veterinary Medical Association, 2019).

Swine

African Swine Fever (ASF)

Until the past decade or so, outbreaks of African Swine Fever (ASF) had primarily occurred within the continent of Africa, where the disease has been endemic for more than 100 years. ASF is a viral disease, and the virus can be carried through infected pork products, the carcasses of swine that died from the disease, as well as waste products from swine, such as feces and urine. The virus can survive for up to several months on pork products if stored at low temperatures. It is also known to survive on a wide variety of media, including clothing, boots, on car tires for days, and on hard, non-porous surfaces for weeks. The virus causes a hemorrhagic fever-like illness with an exceptionally high case fatality rate for infected livestock (Fischer et al., 2020). Domesticated hogs and feral swine are equally susceptible to the disease.

2.) A vaccine for ASF was developed and approved for use in Vietnam in 2023.

A handful of ASF cases were confirmed in Eastern Europe in 2014-15, but it was the massive ASF outbreak in China that started in August 2018 that raised alarm bells around the world. By the time the outbreak in China was largely contained about a year later, an estimated 50 percent of the country's swine herds either died from the disease directly or had to be culled, amounting to about 225 million animals. A 2021 study in Nature Food estimated that the outbreak cost the entire Chinese economy about $111 billion (You et al., 2021).

CHINA'S AFRICAN SWINE FEVER CRISIS

- In 2018, an outbreak of African swine fever in China cost the country's economy about $111 billion.
- Half of the country's swine herd either died from the disease or had to be culled, amounting to about 225 million animals.
- Pork prices in China more than doubled to reach record levels, and remained high for 14 months.

Source:
USDA Economic Research Service

The disease appeared in neighboring countries in Asia in following years, and in 2021, ASF cases were confirmed in both Haiti and the Dominican Republic on the island of Hispaniola, located a scant 330 miles away from the U.S. territory of Puerto Rico and about 700 miles away from Miami, Florida on the U.S. mainland. A 2023 study estimated that an outbreak of ASF in the United States would cost the U.S. economy nearly $80 billion over ten years, primarily from loss of exports and reduced revenue for the pork industry, stemming from both lower production and lower prices (Carriquiry et al., 2023). The U.S. crop sector would be affected as well, due to lower livestock feed demand and likely resulting in modest corn and soybean prices.

The existence of a feral hog population of between six and nine million in at least 35 U.S. states would be an additional complication to the introduction of the ASF virus in this country, because it would make it even more difficult to contain and eradicate the disease.

No vaccine is currently available for ASF on a global basis[2], nor is any reliable form of treatment known. Biosecurity protocols are used to try to moderate its spread when it appears. Research is underway at several laboratories around the world to address this gap, including USDA Agricultural Research Service (ARS) scientists working at the National Bio and Agro-Defense Facility (NBADF) in Manhattan, Kansas, with most scientists utilizing a live attenuated virus in their research efforts. However, one downside of pursuing this model is that the duration of protection offered by such vaccines is generally fairly limited (Van Diep, 2025).

Countries with reported African Swine Fever Cases since 2018

Beef and Dairy Cattle

New World Screwworm

NWS Fly
Photo Credit: APHIS/USDA

This disease results from an infestation of the larvae (or maggots) of the New World screwworm (NWS) fly (Cochliomyia hominivorax). The female fly lays eggs in an animal's skin, and when they hatch into larvae, they consume the animal's flesh starting from the site of the initial wound to inside the animals' body. The infection can be fatal. Once a handful of animals in a given herd are affected, the other animals in that herd are at risk as well.

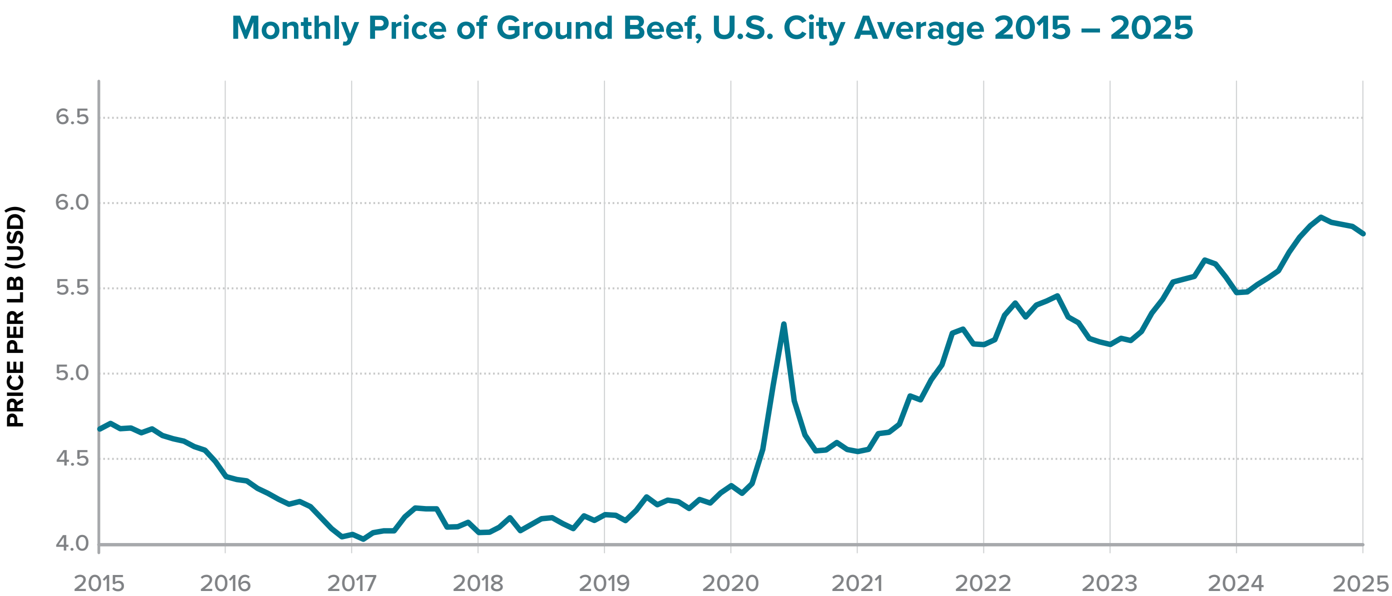
The NWS fly is endemic in several countries in Central and South America such as Cuba, the Dominican Republic, Argentina, Bolivia, and Brazil. For many decades, there were no countries in the Western Hemisphere north of Panama with this pest present, but since the beginning of 2025, outbreaks have been detected in Guatemala, Belize, El Salvador, Honduras, and most concerningly, in Mexico about 70 miles from the U.S.-Mexico border (Robles-Gil, 2025).

The NWS fly was eliminated in the United States in 1966 through use of a biological control technique (introduction of male insects sterilized using radiation into the population to prevent the breeding of new generations), which also allowed quick containment of a small outbreak in the Florida Keys in 2017. The NWS fly can infect a variety of animals, including birds, dogs and cats, ruminant livestock and wildlife, and even humans on rare occasions, but the most important species at risk economically from this pest in the United States are the beef and dairy cattle populations.

Recent Confirmed Detection of New World Screwworm in Mexico

In 2025, the U.S. beef cattle sector is projected to have production valued at nearly $96 billion, placing it first among beef-producing countries around the world. The USDA estimates that an NWS outbreak in Texas would cost that state's economy at least $1.8 billion (APHIS, 2025). Failure to contain such an outbreak within that initial state could raise those costs astronomically, potentially putting at risk the entire U.S. livestock sector. In response to this looming threat, USDA took several significant steps in 2025, including 1) halting the importation of live cattle from Mexico, 2) constructing a new facility in Texas to expand production of sterile flies to supplement the output of similar facilities in Panama and Mexico, 3) investing up to $100 million to develop innovative approaches to combat this deadly pest, 4) intensifying monitoring efforts in Mexico in collaboration with that country's government, and 5) ramping up efforts to prevent migration of infected wildlife across the U.S.-Mexico border (USDA, 2025). On September 30, 2025, the U.S. Food and Drug Administration (FDA) provided conditional approval for an injectable drug (Dectomax-CA1) for use in treating NWS infestation in cattle (Scott, 2025).

U.S. beef prices were already elevated by the summer of 2025 due to a reduced cattle herd size (down one percent since 2023) and the smallest calf crop on record (Nelson, 2025(b)). A continued ban on live cattle imports from Mexico, which have accounted for between 1.2 and 1.5 million head on average in recent years, or about 4.5 percent of all cattle marketed in the United States, could push beef prices even higher.



Source: Bureau of Labor Statistics, U.S. Department of Commerce

ROW CROPS

Soybeans

Asian Soybean Rust

The United States is the world's second largest soybean producing country, behind Brazil, and in most years, soybeans account for the second most planted acres among U.S. crops, behind corn. Soybean meal is the second most common ingredient in U.S. livestock feed rations, also just behind corn, so price movements in this commodity also affect the profitability of livestock operations. This foliar disease is caused by a fungus *(Phakopsora pachyrhizi)* that is spread by light-weight spores that can be carried by the wind up to several hundred miles while remaining viable. The disease mainly affects soybeans, but other legume species are also vulnerable to it. After first being detected in Brazil in 2001,[3] the disease has impacted that country's soybean production ever since. It is estimated that for the 2003-04 crop year, soybean rust cost Brazil about $3.3 billion in terms of both lost soybean yield and higher input costs due to multiple applications of fungicides on affected fields (Ishiwata and Furuya, 2020). More recent studies from 2012 estimate control costs, primarily fungicide treatments, at between $1.5 and $2 billion annually, but don't include crop losses in those figures (Godoy et al., 2016). Especially in the early years, many Brazilian farmers experienced yield losses of up to 80 or 90 percent on untreated fields.

Asian Soybean Rust | Photo Credit: Purdue University

3.) Scientists believe that the Asian soybean rust spores were initially carried by winds from tropical storms originating off the west coast of Africa to Brazil.

Officially, Asian soybean rust arrived in the United States in November 2004, found on the leaves of soybean plants in a field in the state of Louisiana, a finding that was confirmed by laboratory analysis. Scientists believe it is likely that the spores were carried on the winds of Hurricane Ivan, a powerful storm that made landfall on the Gulf coast in September of that year (Schneider et al., 2005). Since the initial case was identified well after harvest of most of the U.S. soybean crop for that year, USDA and the soybean sector had until the following spring to come up with a response. That effort included a so-called sentinel site system, in which small plots of soybeans (typically 2500 square feet in size) were planted across major soybean producing states in advance of normal planting dates, and then checked weekly for signs of rust. If soybean rust's presence were to be confirmed by laboratory analysis, warnings would be issued to local farmers (Leer, 2005). That system is still in place, funded with soybean checkoff funds and some resources from land grant universities in the Midwest (Dorrance et al., 2017). The response also included gearing up analytical and reporting systems and launching research into developing rust-resistant cultivars.

ASIAN SOYBEAN RUST: INDUSTRY ON ALERT

- The soybean industry in Brazil, a major competitor with the U.S., lost $3.3 billion in 2003-04 due to Asian soybean rust, and the disease continues to plague farmers in the country.
- Asian soybean rust first entered the U.S. in 2004 in Louisiana, with spores likely carried here by winds from Hurricane Ivan. Since then, it has been detected in southern states including Georgia and Mississippi.
- Scientists warn that warming winter temperatures may enable Asian soybean rust to migrate north to the Midwest, where most U.S. soybeans are grown.

To date, Asian soybean rust has not devastated U.S. soybean production nearly to the extent it has affected Brazil's soybean sector. In recent years, detected cases of soybean rust infection have been found primarily in southern states, including a few counties in Georgia and Mississippi in the 2023-24 crop year, although a handful of confirmed cases were found in the southern counties of Midwest states such as Illinois (in 2006 and 2020) and Missouri (in 2006, 2007, and 2009). Soybean rust spores do not survive in the harsh temperatures of Midwest winters, but have found a winter refuge in kudzu plants, which are taxonomically related to legumes and are quite widespread in southern states such as Florida and Alabama. Unfortunately, as winter temperatures have warmed in recent decades, kudzu plants have been identified in several Midwest states, including Ohio, Indiana, Missouri, Illinois, Michigan, Kansas, and Nebraska. This northern migration of kudzu raises the risk that soybean rust spores could overwinter in areas closer to the U.S. states where the bulk of soybeans are grown, increasing the probability that Asian soybean rust could take hold in those regions much earlier in the soybean growing cycle and cause significant damage.

Despite intensive research in recent decades, no Asian soybean rust-resistant varieties of soybean have been developed, much less been made available commercially. The main treatment used is fungicides, but research in Brazil suggests that the spores have been able to develop some resistance to commonly used types of fungicide (Godoy et al., 2016). A 2004 USDA study on the potential cost of a soybean rust outbreak in the United States, released two months before the first case was detected, found that economic losses to U.S. producers and consumers could range between $640 million and $1.3 billion in the first year of infestation (Daberkow, 2004). Obviously, that prediction was not borne out by what actually happened in 2005, but if winter temperatures continue to warm, we could see significant losses from soybean rust in the future. According to the data collected by the Office of the Illinois State Climatologist, average winter temperatures in the state have been trending between 2-3 degrees Fahrenheit higher over the last 100 years, with average nighttime minimum temperatures rising more quickly than daytime high temperatures (Wuebbles, 2021).

Asian soybean rust spores have found a winter refuge in invasive kudzu plants, which have been spreading northward to the Midwest.
Photo Credit: The Nature Conservatory; Katie Ashdown via Flickr (CC BY 2.0)

Current Threats: Pests and Diseases Actively Spreading in America

These pests and diseases are already wreaking havoc on agricultural markets and production in the U.S., creating huge challenges for farmers, threatening rural economic growth, and contributing to higher food costs for consumers.

HORTICULTURAL CROPS

Oranges, Grapefruits, Lemons, and Other Citrus Crops

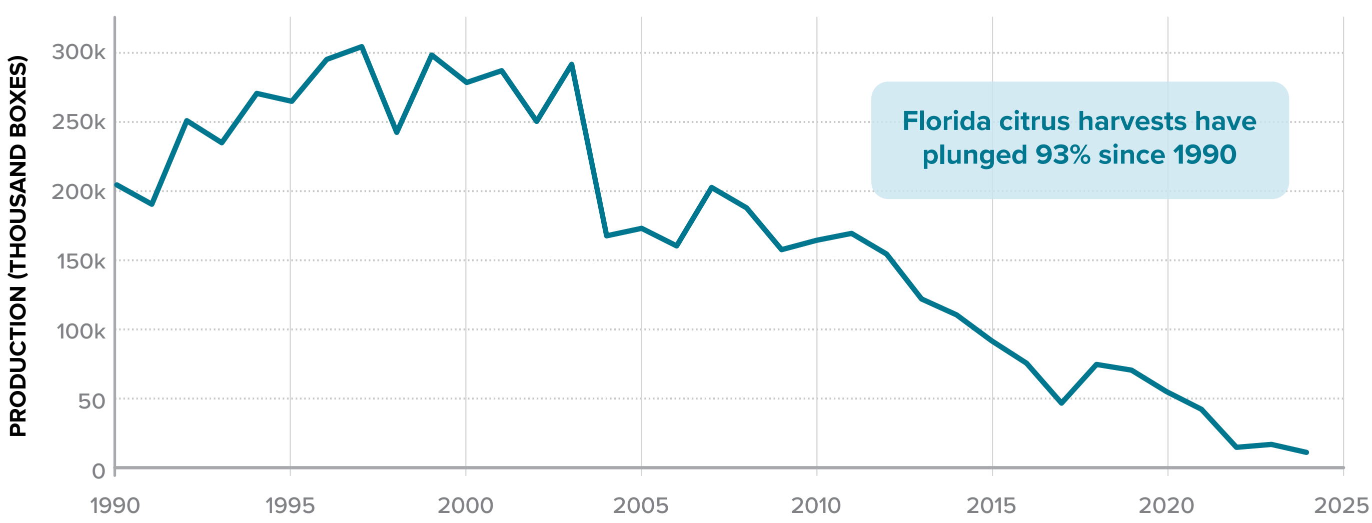
Citrus Greening

While the United States remains one of the world's top 10 citrus-producing nations, ranking seventh globally (USDA FAS, 2025), total production[4] has plunged more than 75 percent since it hit record levels in the mid-1990s. The primary reason for that decline is the severe damage that the Florida citrus industry has suffered in the last few decades from a bacterial disease known as citrus greening. In fact, all the major citrus-producing countries or regions in the world except for Chile and the European Union have been hit by this disease.

Citrus Greening | Photo Credit: APHIS/USDA

U.S. utilizable citrus production peaked at 17.3 million tons in the 1996-97 growing season. In that year, Florida accounted for 76 percent of the crop, followed by California at 19 percent, and both Texas and Arizona at 2 percent. As of the 2023-24 crop year, Florida's share had fallen to 17 percent of the total U.S. citrus crop, which was just over 4 million tons. A 2012 study released by the University of Florida found that citrus greening cost producers and consumers in the state of Florida a total of $4.5 billion over the period of 2006 through 2011, an average of more than $900 million per year (Hodges and Spreen, 2012).

Florida Citrus Production



Source: NASS/USDA, Florida Citrus Statistics

4.) Total citrus production figures include oranges, grapefruit, tangerine, and lemon/lime production data sourced primarily from USDA's Foreign Agricultural Service.

Citrus greening is thought to have originated in China about 100 years ago, where it is known as yellow dragon disease (or Huang Long Bing (HLB) in Chinese). It is transmitted by two species of psyllid insects, which are small winged insects that are also known as flying plant lice. The Asian citrus psyllid is one of the carriers and was first detected in Florida in 1998. The Asian strain of the bacteria, *Candidatus Liberibacter asiaticus,* was first found in Florida citrus groves in early September of 2005. That same strain of bacteria was also detected in Texas for the first time late in 2013. It was also detected in Arizona in 2015, and in Louisiana and Nevada in 2017. It has been present in a few counties in California since 2014 but has not yet heavily affected commercial citrus production there. As of November 2024, quarantines were in place in six California counties to restrict the movement of citrus fruit and plants from the affected areas (APHIS, 2024).

Citrus greening is not harmful to humans but is devastating to citrus trees. The psyllid insect feeds on the stems and leaves of the trees, infecting the trees with the bacteria that causes citrus greening. Greening impairs the tree's ability to distribute carbohydrates produced in the leaves, resulting in plant death within a few years. Even though infected trees can produce fruit, they are smaller and of poor quality, and typically have a sour taste, making them unacceptable to citrus processors. Greening affects commercial citrus trees, including oranges, grapefruits, lemons, limes, and clementines.

To date, no effective treatment has been developed for this disease once a tree is infected. At first, citrus farmers diligently sought to identify infected trees in their operations and destroy them as soon as detected, similar to a livestock producer who culls diseased animals to keep them from infecting the rest of their herds or flocks.[5] However, they could not keep up with the rate of spread – it is now estimated that up to 90 percent of citrus trees in Florida are already infected.

The most effective practices for controlling the disease include managing the introduction and spread of the psyllid. In areas where HLB established itself as endemic, growing trees in fine mesh enclosures (Citrus Under Protective Screen) is proving to be an effective practice, resulting in higher yields and protection from other pests and diseases. Trunk injections with chemicals that limit the spread of the pathogen can also be used at the first signs of infection.

Apples, Pears, Walnuts, and Other Fruit and Nut Trees

Codling Moth

This pest *(Cydia pomonella)* is a member of the Lepidoptera (butterfly and moth) family that can cause damage to several types of fruits and nuts that grow on trees, including apples, pears, and walnuts. The pest damages crops by landing on leaves and fruit on living trees and laying eggs. The caterpillars (larvae) hatch within 1-3 weeks, depending on the prevailing temperatures, and burrow into the fruit to feed for 3-4 weeks, then exit the fruit to undergo transformation from larvae to moth. A single larvae can destroy an entire piece of fruit.

Codling Moth I Photo Credit: Cornell University College of Agriculture and Life Sciences

The codling moth has been a known pest in the United States since the 18th century, believed by scientists to have been carried to this region from Eurasia through infested fruit or host plants, and moved with settlers as they migrated from east to west during the 19th century (Texas Invasive Species Institute). The pest is now found in fruit and nut tree orchards all over the world.

Codling Moth Damage I Photo Credit: Cornell University College of Agriculture and Life Sciences

Unmanaged infestations of codling moth can destroy up to 95 percent of an apple or pear orchard. There is an array of practices available to producers to help minimize losses, though none of them are fully effective in stopping an infestation. They include use of pheromone traps to monitor for the presence of male codling moths, cultural practices such as removing damaged fruit and removing fruit and leaf

5.) Poor results from a federal quarantine strategy applied to citrus canker in the early 2000's in Florida led USDA's Animal and Plant Health Service (APHIS) to forego such a strategy with respect to citrus greening.

debris from the ground underneath the orchard, biological control practices such as bringing in natural predators for the moth (such as parasitic wasps and nematodes), and application of pesticides such as bacillus thuringiensis and commercial pesticides approved for such use, like Gladiator and Besiege (Perkins and Wilson, 2024).

The economic impact of this pest on producers of fruit and nut tree crops is substantial, a combination of lost or damaged products—blemished fruit, even if otherwise sound, is often rejected by consumers–and the cost of treatments such as pesticides, as discussed above. Overall, apple producers in the United States have been able to largely mitigate the adverse impact of the codling moth on their production in recent years, as long as they employ a suite of control measures. However, it remains a serious concern to tree fruit and nut producers throughout the country, and lapses in control measures can be costly and time consuming to recover from.

Western Flower Thrip
Photo Credit: Center for Invasive Species Research

Lettuce

Impatiens Necrotic Spot Virus

In 2022, U.S. production of the major types of lettuce (romaine, iceberg, and leaf lettuce) was valued at about $4.1 billion. The Impatiens Necrotic Spot Virus (INSV) – first found in the Netherlands in the late 1980s – can cause significant damage to lettuce crops by creating brown leaf spots, yellowing of leaves, stunting, and plant death. It is typically transmitted by a flying invasive pest called a Western Flower Thrips, which carries the virus from infected plants to healthy ones in search of food, although this insect feeds on other horticultural crops as well. As a result of the insect's eclectic tastes, a number of other horticultural and herb crops grown in the United States, such as spinach, potatoes, basil, tomatoes, and peppers, have also reportedly been infected by INSV in recent years, though damage to those crops has been less severe to date than its impact on lettuce crops.

The first reported cases of INSV were detected in lettuce fields in Monterey County, California, in 2006 (Koike et al., 2008). In addition to several regions of California, INSV has been detected in horticultural crops in several other states, including Arizona, Oregon, Washington, New York, Pennsylvania, and North Carolina.

Losses from INSV infections in lettuce fields can reach up to 100 percent if not detected and treated on a timely basis. In the Salinas Valley of California alone, losses to lettuce producers in the 2020 crop year from INSV were estimated to be as much as $100 million (Wang, 2022). There is no fully effective treatment for this virus once it arrives in a field of lettuce, so producers must utilize a variety of practices to minimize their losses. These include a range of agronomic practices, such as:

- Scouting for both leaf damage and the presence of the Western Flower Thrips insects,
- Inspecting starter plants for presence of infection before introducing them into greenhouse or open fields,
- Destroying damaged plants,
- Controlling weeds to minimize presence of potential hosts for thrips, and
- Applying insecticides to control the thrips population.

Research is underway to identify and reinforce resistance to INSV in traits that can be incorporated into commercial lettuce varieties and other vulnerable crops. In 2016, a U.S. patent was granted to research which describes lettuce genotypes that were identified with a monogenic, partial recessive resistance to INSV and tomato spotted wilt virus (TSWV) based on work done at a Dutch seed company Rijk Zwaan (Simko et al., 2023).

Losses from INSV infections in lettuce fields can reach up to 100 percent if not detected and treated on a timely basis. In the Salinas Valley of California alone, losses to lettuce producers in the 2020 crop year from INSV were estimated to be as much as $100 million. *– Wang, 2022*

Corn, Soybeans and Other Row Crops

Palmer amaranth (Pigweed)

This plant species (*Amaranthus palmeri S. Watson*), also known to American farmers as pigweed, is native to the southwestern United States and northern Mexico, but was spread accidentally to other parts of the United States more than 100 years ago and is regarded as an invasive species. It was first detected outside of its native region in Virginia in 1915 and in recent decades, has become a persistent presence in cultivated fields across the country, plaguing producers of both row crops and horticultural crops. Palmer amaranth has also been found in other countries in recent years, including in Australia and within Europe.

Palmer Amaranth (Pigweed) in Soybean Field
Photo Credit: Alan Cressler

This plant species is dioecious, meaning that there are both male and female plants which need to both be present for reproduction to occur. A single female plant can produce as many as 500,000 seeds in its lifetime of three to five years, and the plants are both difficult to kill and grow very rapidly, up to three inches per day (Hensleigh and Pokorny, 2017). It does not directly attack the crops being grown for market in a given field but competes with those crops for resources like sunlight, nutrition, and water, and can take over fields if not managed properly.

Known modes of transportation for Palmer amaranth seed include contaminated bags of commercial seed, shipments of feed or hay across state lines, on improperly cleaned farm equipment that is either sold or leased to new users, as well as by birds and other wildlife. Due to its unusual biology, it can cross-breed with other members of the pigweed family and adapt rapidly, allowing it to develop resistance to most types of herbicides, including glyphosate. There are no states that claim Palmer amaranth-free status, although its presence is currently limited in New England, the Pacific Northwest, and scattered other states such as Minnesota and Montana.

Studies have shown that Palmer amaranth reduced corn yields between 11 percent and 91 percent and reduced soybean yields by 17 percent to 68 percent. Consuming the plant as forage can also be toxic to livestock due to its high concentrations of nitrates (Yu et al., 2021). Best management practices for Palmer amaranth typically include a combination of intensive scouting, mowing, diversifying both crop rotations and herbicide application (with different modes of action to slow development of resistance), use of cover crops, and careful cleaning of farm equipment after harvest (Mohseni-Moghadam, et al., 2008).

There have not been any national-scale analyses of the costs associated with treating Palmer amaranth, although a 2018 study in Nebraska found that using a pre-emergent cocktail of herbicides to tackle weeds (including Palmer amaranth) produced a higher benefit/cost ratio than using a post-emergent herbicide application (Sarangi and Jhala, 2019). In 2024, scientists at Colorado State University received a $650,000 grant through USDA's National Institute of Food and Agriculture (NIFA) to develop a biological herbicide to combat Palmer amaranth because of how rapidly the plant has been able to develop resistance to chemical herbicide applications (Colorado State University, 2024).

Corn

Corn Ear Rot

Aspergillus on Corn
Photo Credit: Texas A&M University-Kingsville

The U.S. corn industry is the largest in the world, with a crop valued at nearly $65 billion in the 2024-25 crop year. The term corn ear rot is used to describe a broad category of diseases affecting corn (*Zea mays*) through the medium of fungal infection. Each of the major types of corn ear rot manifest somewhat differently on an ear of corn, but all of them can reduce both the yield and test weight of the crop that is harvested out of a field that has been infected. In the case of an infection by some species of the fungus Aspergillus (such as *Aspergillus flavus*), fusarium, or gibberella, the resulting mold can produce mycotoxins in corn kernels which are highly toxic, even carcinogenic, if consumed above negligible levels by certain mammalian species, including humans. Corn ear rot is widespread in many other major corn-producing countries as well, such as China, Argentina, Ukraine, and South Africa.

The first U.S. cases of corn ear rot infections were reported in Illinois in the early 1900s, this one called Diplodia ear rot. Historical reports from the American Society of Agronomy found losses of 4.5 and 2 percent of the Illinois corn crop in 1906 and 1907 respectively (Steckel, 2003). This particular type of ear rot is still occurring in the United States, although other types of corn ear rot disease, particularly those that generate mycotoxins, such as aflatoxin from Aspergillus flavus or fumonisin from fusarium, are seen as more problematic than diplodia. The elevated concern associated with these types of corn ear rot is because any presence of mycotoxins in corn above minimal levels prescribed by the U.S. Food and Drug Administration (FDA) restricts the kind of markets the corn can be sold into. These restrictions on marketing outlets would also likely lead to a discount on the price received for the infected crop, on top of whatever yield decline the farmer faces.

Many of the types of fungal spores that cause corn ear rot can survive over the winter months in the soil or crop residue in the field after the crop is harvested. When during the course of corn's growing cycle that plants are first infected will dictate how significant the yield impact on the field will be. If infected early, as during the tasseling phase (VT), the entire ear of corn could eventually be infected, even though signs of infection may not yet be visible. Under such circumstances, the spores are likely to have spread quite widely across the field and suppressed yields significantly. If the infection occurs later in the growing cycle, such as in the dent stage (R-5), it is likely to be less widespread at harvest time.

AFLATOXINS IN CORN: WHAT YOU SHOULD KNOW

- Corn infected by fungi such as Aspergillus can produce chemicals called aflatoxins that are highly toxic to both humans and livestock.
- Symptoms of aflatoxin exposure include nausea, vomiting, abdominal pain, convulsions, and acute liver injury. Aflatoxin exposure is also associated with an increased risk of liver cancer.
- While the threat of mycotoxins including aflatoxin to U.S. food supplies is low, due to food safety testing and regulations, contamination of crops in the field carries a high cost for farmers.
- According to one estimate, corn ear rot infections and related contamination cost U.S. farmers about $8.6 billion in lost yields from 2012-2023.

Sources:
Crop Protection Network, National Library of Medicine, University of Missouri – Extension

Different types of corn ear rot thrive in varying types of weather and climatic conditions. For example, *Aspergillus flavus* is quite common in the southern states in a typical year but only arises as a problem in the core Midwest growing region in abnormally hot and dry weather conditions, such as in 1988 and 2012 (Hurburgh, 2012). Recent studies estimate that such outbreaks are likely to become more frequent in the Midwest in the decades to come due to warming weather patterns due to climate change (Yu et al., 2022). They find that nearly 90 percent of corn-growing counties in 15 states will experience more aflatoxin infection during the period 2031-2040 than in the period 2011-2020. On the other hand, fusarium infections of corn are more likely to occur in warm weather and to fields already damaged by hail or insects.

According to a study reported by the Crop Protection Network and funded through a grant from USDA's National Institute of Food and Agriculture, corn ear rot infections were estimated to have cost U.S. corn producers about $8.6 billion in lost yields over the 2012-23 period, or about $780 million per year (Wise et al., 2024). A separate analysis estimated that the U.S. corn sector could suffer as much as $1.7 billion in losses due to widespread aflatoxin contamination such as was seen in 2012 (Mitchell et al., 2016).

Farmers facing corn ear rot in their fields can apply fungicides to limit the damage, but it is important for them to scout their fields regularly in order to detect the infection early on. Research has been underway in the United States since the 1950s to identify resistance traits to fungal infections in corn, with a particular focus on Aspergillus flavus starting in the 1990s (Brown, 1999). Scientists continue their work today, using new technology such as CRISPR/CAS9 to refine their work with corn lines already identified as being resistant to fungal infection (Foundation for Food and Agriculture Research (FFAR), 2023). Similar research is underway in other countries, such as China and South Africa.

Other row crops are vulnerable to Aspergillus flavus as well, including peanuts (known as groundnuts in the rest of the world), other cereals such as grain sorghum and rice, and oilseeds such as soybeans and cotton. Aflatoxin contamination of food is a significant human health concern in Sub-Saharan Africa and in other tropical countries such as Haiti because it is quite common in those regions' corn (maize) and peanut (groundnut) crops, and supply chains there generally do not have the same robust testing capabilities or requirements as is the case in the United States and other developed countries. Both maize and groundnuts are major staple food crops in these countries.

Wheat

Wheat Rust

Rust on Wheat
Photo Credit: USDA/ARS

As with many of the major diseases affecting row crops today, wheat rust diseases are caused by fungal infections, and have been a problem for wheat farmers around the world for more than 2,000 years. Wheat blight or mildew, identified by modern scientists as rust diseases, was referenced several times in the Old Testament, including Deuteronomy and the Book of Haggai as affecting the people of Israel, and the Roman pantheon of gods and deities included Robigus, who was identified as the god of wheat rust and propitiated by farmers with sacrifices of live rust-colored dogs or cattle to stay away from their crops (Angier, 2009). Wheat stem rust was the disease that Dr. Norman Borlaug, the winner of the 1970 Nobel Peace Prize, first worked on early in his career, and a more recent variation called UG99 that afflicted wheat crops throughout Africa and Asia early in the 21st Century was a preoccupation of Dr. Borlaug's toward the end of his career as well.

A report on wheat crop losses from diseases experienced by wheat growers in the United States (in 29 states) and Canada (in 2 provinces) found that such losses accounted for 8.3% of the U.S. wheat crop and 27% of the Canadian wheat crop in the 2024-25 crop year.

As was the case with corn ear rot disease, there are many types of wheat rust disease, although all are caused by variations of the same fungus genus, *Puccinia*. The major types are primarily differentiated either by where on the wheat plant (stem, leaf, etc.) that the fungus first infects, or on the appearance of the pustules as the infection manifests on the plant (like stripe rust). This disease is well-known for its ability to spread rapidly and reduce wheat yield and quality (Salgado, 2016). It is not uncommon for the same wheat field to be infected by both leaf and stem rust, especially in warm and humid weather conditions (University of Missouri Extension).

Spores of rust fungus can survive over the winter in warmer climates like Mexico and the U.S. South, then are typically carried by the wind during the spring and summer to wheat-growing regions in the Midwest and West. The spores typically affect spring wheat crops late in their growing season in July or August, and the winter wheat crop is susceptible to leaf rust early in its growing season before the crop goes dormant over the winter. Yield losses can range from 20 percent to 80 percent of infected wheat fields, depending upon when during the growing season the disease is established.

A report on wheat crop losses from diseases experienced by wheat growers in the United States (in 29 states) and Canada (in 2 provinces) found that such losses accounted for 8.3 percent of the U.S. wheat crop and 27 percent of the Canadian wheat crop in the 2024-25 crop year, amounting to about 326 million bushels that would otherwise have been produced, valued at about $1.8 billion between the two countries. Farmer losses attributed to either stripe or leaf rust accounted for about 22 percent of that total (Anderson et al., 2025).

As was the case with the corn ear rot disease discussed above, there are fungicides available to combat outbreaks of wheat rust disease, but early detection of the infection is key to minimizing yield losses. Other useful practices include scouting for and destroying volunteer wheat plants in fields, and rotating wheat crops with non-host crops to break the disease cycle.

Early research in this area focused on identifying and eradicating plants that were secondary hosts for the Puccinia spore, such as the barberry bush, more than 100 years ago (Peterson, 2025). In recent decades, considerable resources have been allocated to identifying and replicating rust resistant varieties of wheat, but unfortunately such resistance is largely race-specific and does not extend across the universe of rust disease strains.

Rice

Rice Delphacid

Rice Delphacid
Photo Credit: USA Rice Federation

A relative newcomer to the array of pests and pathogens affecting U.S. farmers who grow rice on a regular basis, is the rice delphacid (*Tagosodes orizicolus*). This flying, plant-hopping insect lands on rice plants in fields and feeds on them, extracting sap and depriving the plant of essential nutrients. The damage they cause, known as "hopperburn," is initially characterized by yellowing leaves, which can easily be mistaken for nutrient deficiency. Advanced damage culminates in premature senescence of rice plants and complete plant death. The pest also can create secretion of 'honeydew' on leaves under heavy infestation conditions, encouraging growth of a black mold, thus impeding the plant's ability to convert sunlight into plant matter through photosynthesis (Wilson, 2017). The delphacid pest is also known to be a carrier of the hoja blanca virus, which further impedes the growth of affected rice plants. Yield losses have been estimated at up to 50 percent in some rice fields to date.

While the insect was found in rice in Louisiana, Florida, and Mississippi in the late 1950s and early 1960s, it disappeared until it was again detected in U.S. rice fields in Texas in 2015, likely having migrated from South or Central America.[6] Over the past several years, it has inflicted the bulk of its damage on the so-called ratoon crop, a second harvest of rice after the initial crop is harvested from the stubble left in the field.[7] This second crop typically can only be harvested in Texas and southern Louisiana rice fields, as winter sets in too early in Arkansas and other U.S. rice-producing states to allow a second crop to grow to maturity (Wang et al., 2021). Because they only need to apply irrigation water and nitrogen fertilizer to the field to generate regrowth for a second crop, many rice producers in those two states indicate that it is the profit from the ratoon crop that allows them to make money in a crop year, even though its yields are typically 30-50 percent that of the first crop (Linscombe, 2025).

However, extension specialists in the region indicate that the insect inflicted some damage on the first, main rice crop in the 2024-25 crop year and even more extensive damage is being seen in the 2025-26 crop year. The pest has spread beyond Texas and Louisiana into Arkansas and Mississippi for the first time, magnifying the potential total losses that it can engender (Ledbetter, 2025). These four states accounted for 76 percent of total U.S. rice area planted in 2024 (National Agricultural Statistics Service, 2025(a)).

6.) The delphacid pest made a brief appearance in Arkansas in the 1960s but did not stick around very long and researchers apparently lost interest in it.
7.) Sugar cane producers in Florida and Louisiana also frequently harvest a second "ratoon" crop.

Rice producers in Texas have been using two kinds of neonicotinoid pesticides to combat the pest under an emergency exemption approval from EPA, but their effectiveness has been limited, especially in the 2025-26 crop year. Researchers at Texas A&M University and Louisiana State University have been conducting trials to test other insecticides' efficacy, as well as trying to identify rice varieties with some resistance to the pest. ARS scientists have been collaborating with their counterparts in Texas and Louisiana on some of these projects.

Quantitative estimates of the economic damage being caused by the delphacid insect are still being assembled, since the expanded area it has been infecting is a relatively new development. However, reports from the field indicate that as much as 30 percent of the ratoon crop in Texas has already been abandoned as a result of delphacid infestation (Ledbetter, 2025).

Soybeans

Soybean Cyst Nematode

In most years, soybeans are the second most important row crop grown in the United States, averaging about $52 billion in value per year between 2022 and 2024 (NASS/USDA, 2025(b)). It is a relative newcomer to the universe of major row crops grown in this country, only topping 10 million planted acres in the late 1940s, after the solvent extraction process for separating meal and oil in processing facilities became widely adopted (Shurtleff and Aoyagi, 2016).

Cyst Nematodes on Soybean Plant Roots
Photo Credit: Purdue University

Within a few years after passing this threshold, the first cases of soybean cyst nematode (SCN) infestation, which is a microscopic roundworm that lives underground, were discovered and identified, in a soybean field in North Carolina in 1954. Since then, this pest that comes from the soil and infects the plant's roots has been found in every U.S. soybean-producing state except for West Virginia as of 2023 (Brooks, 2025). Soybean cyst nematode infestations can result in poor stands, stunted plants, and yellow foliage, resulting in low soybean yields. Losses can range from five percent to 90 percent of the yield potential of a given field, depending on how early the infestation is detected. Because the bulk of the damage occurs to the root structure of the plant and may not manifest in the above-ground portions of the plant, many farmers never detect the infestation before harvest. Other legume species, such as dry beans and clover, as well as some types of weeds, have also been known to serve as hosts for the nematodes during the off-season.

A 2020 analysis found that between 1996 and 2016, SCN caused an estimated $32 billion in yield losses in the United States, or an average of $1.5 billion annually (Bandara et al., 2020).

> ***A 2020 analysis found that between 1996 and 2016, SCN caused an estimated $32 billion in yield losses in the U.S., or an average of $1.5 billion annually.***
> *– Bandara et al., 2020*

More recently, an analysis of the amount of soybean production lost to various pests and pathogens in the United States published in 2025 found that SCN was responsible for the loss of 89 million bushels of soybeans in the 2024-25 crop year, with an estimated value of nearly $940 million at the average 2024-25 market price for soybeans (Sikora et al., 2025).

Farmers use a variety of approaches to minimize the impact of SCN infestation, including agronomic practices like rotating soybeans with non-legume crops and planting different soybean varieties with resistance to SCN on a rotating basis as well. They also can regularly test their soil for the presence of SCN and try to minimize the presence of weed species which are known to serve as hosts to SCN. There are also nematicide seed treatments on soybeans available which help combat SCN, but they are not always effective.

Cotton

Areolate Mildew

Areolate Mildew on Cotton Plant I Photo Credit: Mississippi State University, photo by Tom All

This fungal disease caused by one of two pathogens, *Ramularia gossypii* or *R. pseudoglycines*, has emerged recently as a problem for upland cotton producers in the southern region of the United States. Also known as Ramularia leaf spot, false mildew, or grey mildew, it was first detected and identified in Alabama in 1890, but only recently became a serious economic threat to cotton producers in several states, including Alabama, Georgia, Tennessee, and Florida, with sporadic cases appearing so far in other cotton-producing states as well (Strayer-Scherer and Baryah, 2024). These four states accounted for about 25 percent of U.S. cotton production in recent years (NASS/USDA, 2025(a)).

Spores of this fungal pathogen can overwinter on crop debris in fields, and infections of areolate mildew thrive in summer weather with moderate temperatures and high humidity (80 percent or more). The infection typically begins to manifest as tiny, irregularly shaped lesions around three months into the growing cycle, a few weeks after first bloom occurs. Further infection results in the appearance of a wide powdery growth, and eventually turn necrotic, causing leaves to shed prematurely. The earlier the infection occurs, the more significant the yield loss—under such conditions, that loss can reach 300 pounds per acre, or about one-third of the average yield for the 2024 crop year (Rowsey, 2022).

In 2024, this pathogen is estimated to have cost cotton producers just under 17,000 bales of production, or less than one tenth of one percent, but if it were to spread in a broad-based way to other major cotton growing states such as Texas, Mississippi, and Arkansas, the overall impact would be far larger (Faske et al., 2025).

As with the other fungal diseases described in this paper (Asian soybean rust, corn ear rot, wheat rust), there are a variety of practices a farmer can adopt to reduce the impact of areolate mildew. They include rotating with a non-host crop, removing crop debris to get spores out of fields, planting a resistant variety of cotton, scouting fields regularly to check for signs of disease (not just areolate mildew but others as well) and if an infection is detected, timely application of approved fungicides. Research by scientists at Texas A&M University and the University of Arkansas have identified existing cotton varieties with partial resistance to areolate mildew, but have not yet identified or created traits in cotton varieties with full resistance to the infection (Beasley et al., 2024).

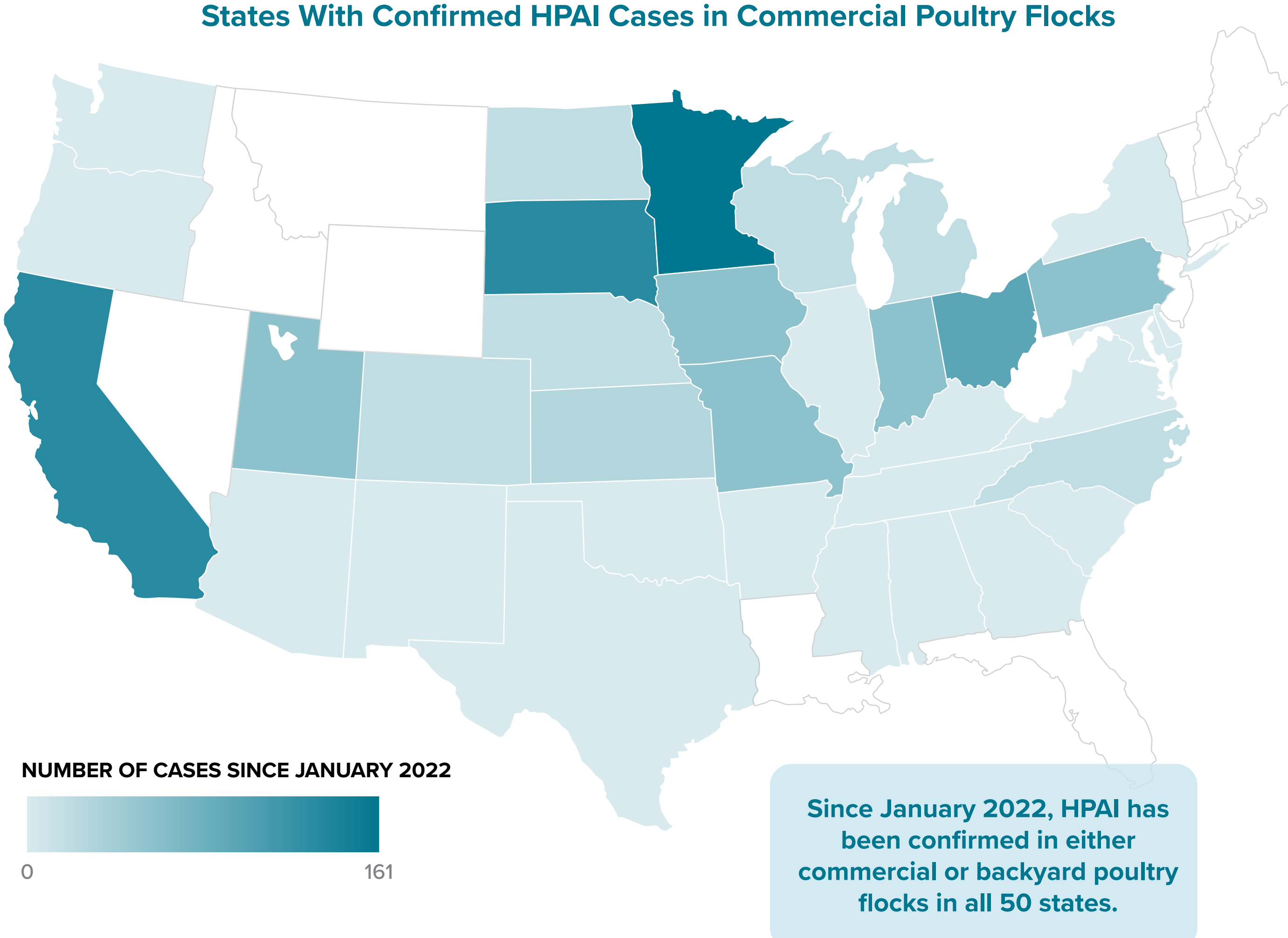
Poultry and Livestock

Highly Pathogenic Avian Influenza (HPAI)

The U.S. poultry and egg industry has been devastated twice in the last decade or so by major outbreaks of highly pathogenic avian influenza (HPAI). The first outbreak, initially detected December 2014 in backyard flocks in the northwest United States, spread to commercial operations a little more than a month later. This outbreak was a combination of H5N2 and H5N8 strains. By the time USDA determined that the outbreak was under control in June 2015, cases has been detected in 21 states,[8] with more than 50 million commercial chickens and turkeys having died or been depopulated to control the spread of the disease (APHIS, 2016).

The latest bird flu outbreak in the United States, featuring primarily the H5N1 strain, was first detected in wild bird flocks in January 2022, and in commercial poultry operations and backyard flocks a month later. In March 2024, an H5N1 strain of avian influenza was detected in dairy herds in Texas and Kansas, a phenomenon that drew greater public attention to the outbreak. As of April 2025, USDA estimates that around 169 million birds have been lost due to the outbreak, in all 50 U.S. states as well as Puerto Rico.

States With Confirmed HPAI Cases in Commercial Poultry Flocks



Source: USDA

8.) This tally included 15 states with outbreaks in domestic poultry or captive birds and six states with H5N1 detections in wild birds only.

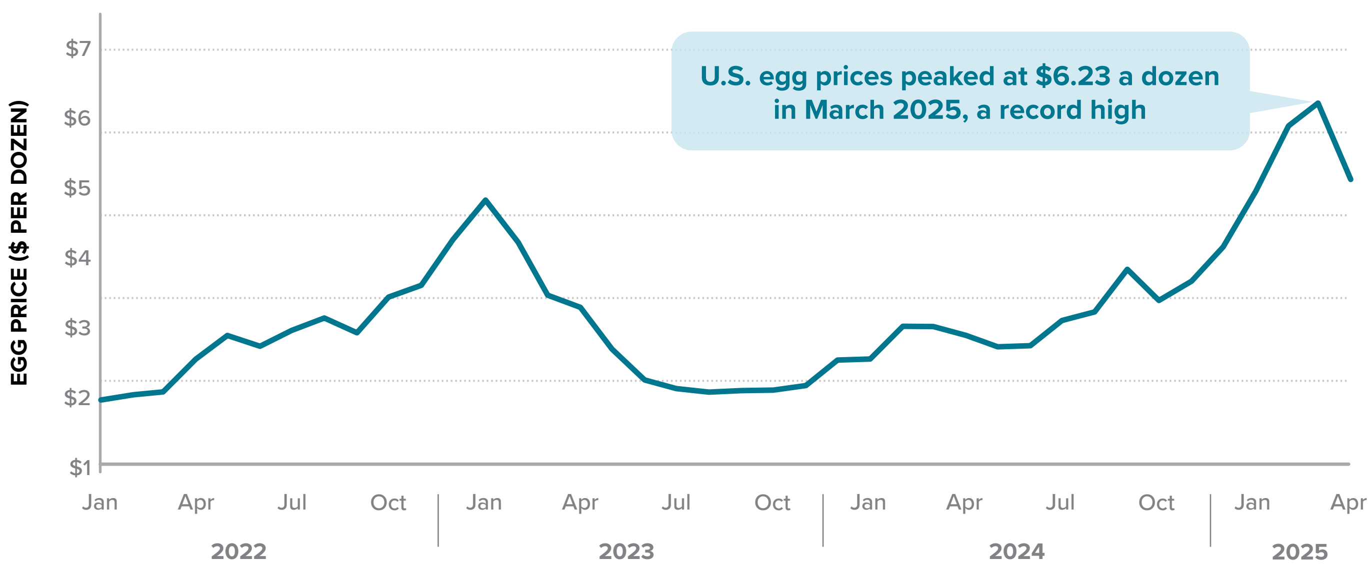
Typically, HPAI has a mortality rate among both wild and domesticated birds between 75 and 100 percent, so culling birds from infected flocks serves to protect biosafety as well as a mercy killing. HPAI is known to cross species quite readily, otherwise known as zoonotic transmission. In addition to dairy cattle, the H5N1 strain has also infected humans (70 confirmed cases in the United States, with one fatality) and dozens of mammalian species, including hogs, cats, dogs, dolphins, sea otters, rats, and squirrels (FAO, 2025). To date, there is no confirmed case of human-to-human transmission of this HPAI strain.

It is estimated that the 2014-15 outbreak of HPAI in the United States cost the federal government $879 million, most of it to either depopulate infected poultry operations or to compensate poultry producers for their lost income (APHIS, 2016). A separate study found that the broader U.S. agricultural sector experienced welfare losses in excess of $1 billion for the same outbreak, encompassing substantial losses to the poultry and soybean processing sectors (because soybeans are used in animal feed), as well as losses in land value and value-added activities (Seitzinger and Paarlberg, 2016).

That outbreak was concentrated among turkey and egg-laying chicken operations in the Midwest, so the main U.S. consumer impact was substantially higher egg prices, persisting until the end of 2015. U.S. egg prices in September 2015 were 36.2 percent higher than in September 2014 (Kuhns and Harvey, 2016). The subsequent bird flu outbreak in 2024-25 caused even more extreme spikes in U.S. egg prices. A March 2025 report in Farm Bureau's Market Intelligence found that U.S. egg prices rose 350 percent as compared to one year earlier (Nelson, 2025(a)). U.S. milk prices have not been affected by the HPAI infections among dairy herds, and FDA scientists have found that the flu virus does not transmit to humans through consumption of pasteurized dairy products (FDA, 2025).

During the 2014-15 outbreak, the U.S. government was able to convince its trading partners that the outbreak was concentrated in a single part of the country, which allowed U.S. exporters to continue shipping poultry and egg products from unaffected regions of the country. Nonetheless, a 2017 study estimated that the U.S. lost about $1.3 billion worth of trade in broilers, egg products, and turkey in 2015 compared to 2014 primarily as a result of anxiety about the U.S. HPAI outbreak in that year (Ramos et al., 2017).

Average Price of Grade A, Large Eggs in U.S. Throughout 2025



Source: Federal Reserve Economic Data, Federal Reserve Bank of St. Louis

Swine

Porcine Reproductive and Respiratory Syndrome (PRRS)

In 2023, U.S. pork producers generated cash receipts of more than $27 billion for their sales of hogs and pigs (National Pork Producers Council, 2024). The United States is the third largest pork producing country in the world, behind China and the European Union as a single entity. One of the top sources of economic harm to the sector in recent decades has been the infection of hogs by Porcine Reproductive and Respiratory Syndrome (PRRS) disease that frequently causes pregnant female hogs (i.e. sows) to lose their offspring through miscarriages, stillbirths, or mummified pigs and also causes respiratory problems to pigs and hogs of all ages, impeding normal growth cycles. It can be transmitted through the air, carried on contaminated clothing or equipment, or through feces, urine, or nasal secretions (Pig333.com). Once the PRRS virus has entered a hog confinement facility, it tends to stay there in an active state.

The first U.S. cases of PRRS were detected in North Carolina in 1987, although it appeared elsewhere in Midwest pork-producing states soon afterwards. There are two distinct types of PRRS virus, one that is predominant in Europe (type 1), and a distinctly different one (type 2) that dominates in North America and Asia. The disease is found in most major hog-producing countries, although there are a handful of countries, such as Australia, New Zealand, India, some Scandinavian countries, and some in South America that are deemed to be PRRS-free (World Animal Health Organization, 2024).

A recent study found that PRRS caused $1.2 billion in losses annually to U.S. pork producers between 2016 and 2020

A recent study found that PRRS caused $1.2 billion in losses annually to U.S. pork producers between 2016 and 2020, an 80 percent increase over the figure estimated in 2013 (Osemeke et al., 2025). Unlike many other animal diseases, there are not obvious signs of infection on the exterior of a hog or other external symptoms, so testing the blood of animals in the herd is the best way to confirm a diagnosis. An unusual number of difficult births among pregnant sows should also prompt serological testing.

There is currently no direct cure for hogs infected with PRRS, although producers can minimize the disease's impact through use of stringent biosecurity controls, vaccinations (which can control outbreaks), and management of secondary infections through use of antibiotics (Iowa State University). Since eradication of PRRS at individual operations currently seems out of reach, most producers decide to find ways to minimize clinical effects on their animals by limiting introduction of new animals into an already infected herd. Research has long been underway to identify genes which provide some resistance to PRRS, but efforts to convey such resistance to other animals have fallen short because the resistance is typically associated with multiple genes, not just a single gene. A PRRS-resistant hog has been developed using gene editing tools by a pig breeding company (PIC) in the United States, and use of this approach was just approved as safe and effective in April 2025 by the U.S. Food and Drug Administration (Nolen, 2025). However, it may take many years to introduce this new technology into the hog population, especially given uncertain consumer attitudes to foods from gene-edited animals.

Catfish

Enteric Septicemia of Catfish

Enteric Septicemia of Catfish
Photo Credit: Southern Regional Aquaculture Center

Aquaculture consists of raising aquatic species such as finfish or crustaceans under controlled conditions in either inland freshwater ponds or saltwater confinement facilities (such as pens, bays, or tanks) for food purposes. Globally, production through aquaculture was valued at $204 billion as of 2020, and in 2022 the amount of production of aquatic animals from this sector exceeded that generated from the capture fisheries sector for the first time (FAO, 2024). The United States is a modest player in the global aquaculture market, with total sales valued at just under $2 billion in 2023. Catfish is by far the top farmed fish species in the U.S. aquaculture sector, with production primarily located in four southern states—Mississippi, Alabama, Texas, and Arkansas—which accounted for 97 percent of total U.S. sales in 2020 (NASS/USDA, 2021).

Enteric septicemia of catfish (ESC) is a disease caused by the bacteria *Edwardsiella ictalurid*, which accounts for about one-quarter of disease cases submitted to fish diagnostic labs in the southern United States (Hawke, 2015). ESC was first identified as a new infectious disease in 1976, although the incidence of ESC cases did not occur widely across the catfish-producing regions until the mid-1980s.

Infected fish manifest a variety of symptoms, including erratic behavior such as swimming in tight circles, bloated abdomens, and red spots or ulcers. Fish are believed to be more susceptible to ESC when under stress from other factors, such as overstocking, poor water quality, and improper diet. The infection is generally transmitted in the tank when a sick fish sheds the pathogen through feces or a healthy fish eats dead fish carcasses. Mortality rates can range from 10 to 50 percent. Some strains of the bacteria causing ESC have developed resistance to antibiotics, which makes the problem even more difficult for producers to address.

A 1999 study estimated that ESC infections cost the U.S. catfish industry about $60 million annually (Klesius and Shoemaker, 1999). Improving environmental conditions in the facility can reduce transmission, as can cross-breeding with catfish species (such as blue channel catfish) which are more resistant to ESC. Live attenuated vaccines have been developed to combat ESC, which are typically administered to very young fish through an immersion bath or through their feed.

III. THREATS TO GLOBAL AGRICULTURE THAT CAN IMPACT AMERICAN FOOD SUPPLIES

The U.S. has one of the most diverse agricultural sectors in the world, blessed with a range of climates that allows production of many valuable crops and livestock species. However, U.S. farmers have limited ability to produce crops that thrive in tropical climates. These crops fall into the category of "non-competitive" imports, because there is limited or no meaningful competition for imports from domestic sources.

Many tropical crops are highly prized by American consumers, and they make significant contributions to the U.S. economy. For example, U.S. consumers spend approximately $110 billion every year on coffee, and the industry supports more than 2.2 million American jobs, even though more than 99 percent of the coffee consumed in the U.S. is imported (NCAUSA, 2023).

Numerous tropical crops that are important to American consumers face challenges from pests, diseases, and pathogens. In many cases, these threats are leading to lost global production and higher costs for American businesses and consumers. Below, we highlight a few of the most significant threats facing tropical agricultural products and the broader economic implications for the U.S.

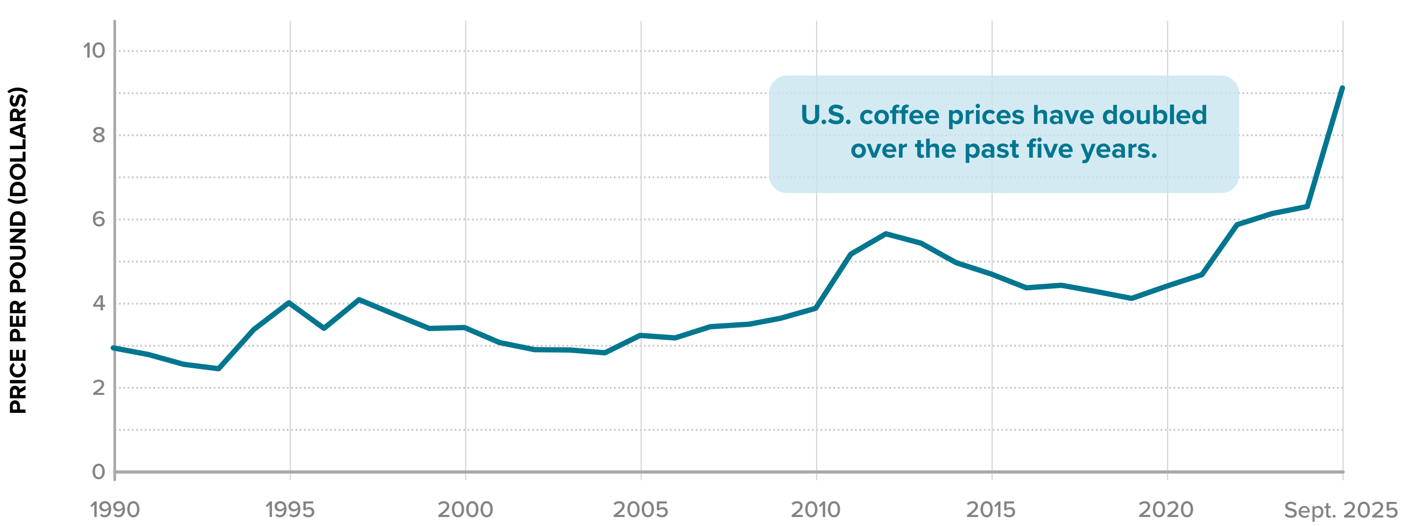
Coffee

Coffee Leaf Rust

Even though the coffee plant originated in Africa, the Arabica variety of coffee is grown primarily in Central and South America, accounting for about 80 percent of global production of that crop. This variety is considered the higher quality type of coffee by most American coffee drinkers, and it is widely used by leading coffee brands in the U.S. and round the world.

Unfortunately, however, Arabica is at risk of considerable damage from a range of pests and pathogens, including coffee leaf rust, which is widely known as roya in Spanish. According to World Coffee Research, the disease can lead to defoliation of plants, reduced coffee bean quality, and yield losses up to 75 percent in the most severe cases (World Coffee Research, 2025). The economic impact of this fungal disease is estimated at about $2 billion globally (McCook, 2019). Considerable research effort has already been devoted to developing rust-resistant strains of Arabica coffee trees, but the disease still remains a formidable threat. Coffee prices in the U.S. reached record levels in 2025 as global demand outstripped supply, which has also been impacted by weather challenges in numerous producing countries (Ogunrinde, 2025).

U.S. Average Price of Ground Roast Coffee



Source: Federal Reserve Bank of St. Louis

Bananas

Fusarium wilt

The banana is the most popular fresh fruit in the U.S., with per capita consumption estimated at nearly 27 pounds annually as of 2023. Domestic production of this fruit is limited to southern Florida and Hawaii and meets less than one percent of U.S. demand for bananas. The banana is also considered to be a staple crop in many regions of the world, especially in East Africa, the island nations in the Caribbean Sea, Central America, and northern South America.

Global banana production is under serious threat from a fungal disease known as Fusarium wilt, with a relatively new strain of that disease known as Tropical Race 4 (or TR4) being particularly damaging to the Cavendish cultivar of banana, which is grown around the world. A 2024 analysis found that widespread TR4 infection in banana plantations in Colombia could cost that country's producers as much as $700 million annually (Ritter, 2024). Famously, the banana industry has already undergone a crisis from Panama disease, which almost entirely wiped out the earlier main global variety, Gros Michel, from outbreaks starting in the 1950s. The Cavendish cultivar was developed as a result of this crisis, and now it unfortunately faces threats of its own. Further exacerbating the crisis is the fact that over 90 percent of bananas traded globally are Cavendish, and they are propagated from root sprouts, — which both limits genetic diversity and may aid in the disease spread.

Fusaium Wilt on Banana Tree | Photo Credit: CGIAR

Black Pod Rot on Cocoa Plant | Photo Credit: CGIAR

Cocoa

Black Pod Rot

The cacao plant that produces cocoa beans to make chocolate is grown primarily in West Africa, Latin America, and Indonesia. Similar to coffee and bananas, domestic production of cacao in the U.S. is extremely limited – the crop grows only on a few hundred acres in Hawaii, Florida, and Puerto Rico, and is primarily destined for niche artisan products.

There are a number of diseases that pose a threat to global cocoa production—one of the most significant is black pod rot, caused by several different species of Phytophthora and Moniliophthora fungi. This disease is found in every cocoa-producing region, and losses from infections can range from 30 percent to 100 percent. A 2025 study of the impact of black pod rot in the Nigerian cocoa sector found that it was responsible for the loss of 18 percent of that country's crop, valued at about $140 million in that country alone (Oladokun et al., 2025).

IV. POLICY RECOMMENDATIONS

While pests, diseases, and pathogens pose significant risks, there are a number of steps that the U.S. government can take to prevent future outbreaks and help ensure that American agriculture and our food value chain are both prepared and resilient when they happen. Below, we provide recommendations for how the U.S. can work both domestically and in collaboration with other countries and international organizations (Intergovernmental Science-Policy Platform on Biodiversity and Ecosystem Services (IPBES), 2023), to combat the serious risks presented by the 16 threats discussed in this paper, as well as many more, some of which are listed in the Annex of this document. Our policy recommendations fall into three categories:

1. International coordination and related solutions
2. Domestic solutions
3. Agricultural research and development

International Coordination & Related Solutions

- **Bolster global surveillance networks.** The U.S. Departments of Agriculture, State, and Homeland Security should establish new or restore previously existing surveillance networks to track the movement of serious pests and pathogens affecting agricultural sectors around the world that have not yet entered the U.S. When appropriate, the U.S. should provide countries with financial support to help them build the capacity, both physical (infrastructure) and human, to undertake this activity, either directly or through UN or CGIAR partner entities.
- **Develop data management tools to monitor and track risks.** The U.S. should support multinational efforts to create databases and interoperable information systems on particularly risky invasive species through appropriate UN agencies, such as the Food and Agriculture Organization (FAO) or the CGIAR system.
- **Expand sanitary and phytosanitary precautions in global trade.** The U.S. Department of Commerce should work with trading partners to ensure thorough sanitizing of the exterior of commercial shipping containers, packaging or pallets that contain products destined for U.S. ports.
- **Increase alert for agricultural bioterrorism.** The U.S. should train national security personnel to stay alert to intelligence chatter or other indications that an agricultural bioterrorism attack may be under consideration or preparation by U.S. enemies, state or non-state.
- **Strengthen checkpoints for international travelers and increase training for border personnel.** The U.S. should strengthen enforcement by U.S. personnel of U.S. quarantine rules on travelers entering or re-entering the United States by bolstering staffing at U.S. border crossings and international airports, and provide those staff with more extensive training on what to look for. The U.S. government should consider requiring vehicle dips for cars crossing into the country from Mexico or Canada, to sanitize the tires and the car's undercarriage in order to reduce their capacity to carry pests, bacteria, or fungal spores which could be a risk to U.S. agriculture.
- **Require additional biosecurity reporting for travelers.** The U.S. should tighten traveler declaration requirements on quarantine forms required at U.S. border stops, better inform the public about the importance of these rules, and conduct random spot checks to verify the accuracy of declarations. In the European Union, member countries are required to implement enhanced control measures, such as public information campaigns and annual surveys, to manage the risk of designated priority pests.
- **Champion streamlining of the global regulatory framework.** The use of chemical pesticides for the control of plant pests and diseases is sometimes not feasible due to economical, ecological or biological reasons. Modern biotechnologies offer an opportunity to develop chemical-free methods for pest control, however, there is limited investment in development of such tools due to the global regulatory uncertainty. The U.S. government should champion science-based and risk-appropriate measures for review and approval of modern biotechnological tools of pest control, especially for pests and pathogens that threaten global food security.

Domestic Solutions

- **Develop a comprehensive, coordinated national biosecurity strategy for agriculture.** The U.S. government should convene a task force of federal policymakers, federal and land grant scientists, and representatives of agricultural stakeholder groups to develop a national strategy for tackling agricultural biosecurity threats. A first priority for this national strategy will be clear communication among USDA Animal and Plant Health Inspection Service (APHIS), Agriculture Research Service (ARS) and Foreign Agriculture Service (FAS) and with other federal agencies, like Customs and Border Patrol.
- **Establish clear guidelines for when compensation should be offered to producers for culling activities.** USDA's Animal and Plant Health Service (APHIS) has the legal authority to provide such compensation under emergency situations, but producers need reliable information about the circumstances under which that authority would be invoked.
- **Educate the public about biosecurity threats.** USDA should undertake a public awareness campaign to alert the public about the nature of this threat and the importance of public investment in tackling it.
- **Increase training for veterinarians on how to identify and report outbreaks.** The U.S. should mandate continuing education training for rural veterinarians and veterinary technicians on how to identify and report incipient outbreaks of animal diseases.
- **Provide ongoing education to agricultural extension specialists about new and emerging risks.** USDA's National Institute of Food and Agriculture should require state extension specialists to be regularly trained on identifying and reporting outbreaks of plant and animal diseases not previously seen in their area.
- **Increase support for vaccine stockpiling programs established in the farm bill.** The U.S. should bolster resources for the National Animal Vaccine and Veterinary Countermeasures Bank (NAVVCB) established in the 2018 farm bill.
- **Ease regulatory approvals process for serious emerging threats.** The U.S. should prioritize approvals of pesticides or herbicides needed to address newly emerging or looming pests or pathogens, such as New World screwworm. Regulatory uncertainty and burden associated with the use of Plant Incorporated Protectants derived using modern biotechnological tools further limits the toolkit of proactive solutions, especially in situations where the use of chemical pesticides is economically or environmentally not feasible.
- **Prioritize conservation projects that address biosecurity risks.** The U.S. should prioritize project proposals under USDA conservation programs that address the threat of invasive species against farms and ranchers, such as brush or weed management, prescribed burning, or fishpond management, either for individual producers (EQIP, CSP) or regional entities (RCPP).

Agricultural Research & Development

- **Increase research funding for developing pest- and disease-resistant genetic traits.** The U.S. should increase support for research in identifying and/or developing genetic traits that are resistant to or tolerant of infections by pests or pathogens, both in crops and livestock, in collaboration with select agricultural universities in foreign countries and key centers of the CGIAR system. This should include use of both conventional breeding techniques and biotech gene editing tools. A recent success in this area has been the development of transgenic papaya, which addressed a threat to Hawaiian papaya producers from persistent problems with papaya ringspot virus.
- **Bolster support for national germplasm collections and seed banks.** The U.S. should increase support for seed bank facilities and related activities, to preserve potential sources of genetic resistance to new pest and pathogen threats.
- **Develop research on how to increase species immunity against the most serious threats.** The U.S. should conduct research into immunity to avian influenza among various bird species, and how such immunity might be conveyed through breeding, to reduce use of vaccines.
- **Support international research collaboration.** The U.S. should foster collaboration with researchers in other countries working on similar tracks, utilizing the partnerships already established through a revitalized U.S. Innovation Lab system.
- **Increase support for research on biological control techniques.** The U.S. should prioritize research into developing biological control techniques for reducing incursion of pests that either directly attack crops or livestock or transmit diseases by carrying viruses or fungal spores.
- **Utilize high-tech solutions to tackle threats and analyze risks.** The U.S. should utilize appropriate research tools, including AI, to help design and implement a national strategy to tackle agricultural biosecurity threats, including developing decision-making tools and conducting risk analyses of how to prioritize the use of resources in this area.

V. ANNEX: "DISHONORABLE MENTIONS" LIST

While this paper has primarily highlighted 16 of the most economically significant pest and diseases currently facing U.S. agriculture, the fact is that the sector is contending with many more threats that have potential to do serious and lasting harm to the industry. New risks are constantly emerging, and outbreaks can spread rapidly, and it is difficult to predict what the future may hold. Below, we have listed a number of other pests, diseases, and pathogenic risks that are targeting various sectors across agriculture, and the industry remains vigilant to other challenges that may come.

INVASIVE SPECIES (PLANTS)
Marestail
Kochia
Kudzu (host for soybean rust spores, smothers other vegetation)

FUNGAL DISEASES
Fusarium head blight (wheat)
Tar spot (corn)
Fusarium oxysporum f. sp. vasinfectum (FOV) Race 4 (cotton)
Verticillium wilt (cotton)

VIRAL DISEASES
Wheat streak mosaic virus
Peanut stunt virus
Tomato yellow leaf curl virus

PEST INFESTATIONS
Aphids (multiple crops)
Asian Longhorned Tick (multiple livestock species)
Guava root-knot nematode (Meloidogyne enterolobii) – (cotton)
Mediterranean fruit fly (citrus fruit)
Two-spotted spider mites (strawberries)
Spotted lanternfly (various fruit tree species)
Two-spotted cotton leafhopper (cotton)

BACTERIAL DISEASES
Mycoplasma (M.) hyopneumoniae (hogs)
Fire blight (fruit tree crops)
Bacterial wilt (tomatoes and potatoes)

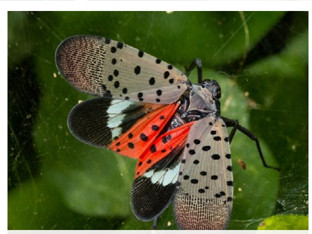
INVASIVE SPECIES (ANIMALS)
Feral swine

Kudzu | Photo Credit: USDA, Peggy Greb

Fusarium head blight on wheat | Photo Credit: Purdue University – Extension

Tar spot on corn | Photo Credit: Purdue University, Dan Quinn

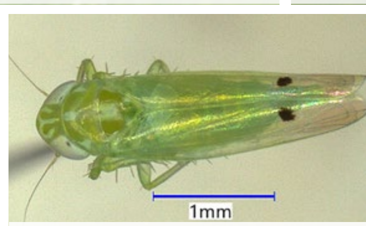
Aphids | Photo Credit: South Dakota State University Extension



Spotted lanternfly
Photo Credit: USDA

Bacterial Wilt
Photo Credit: USDA

Asian Longhorned Tick
Photo Credit: USDA



Two-spotted cotton leafhopper
Photo Credit: Texas Dept of Ag

Feral swine
Photo Credit: USDA

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REFERENCES

Anderson, Nolan, et al., 2025. "Wheat Disease Loss Estimates from the United States and Canada—2024." Crop Protection Network, March 24. Accessible at: https://cropprotectionnetwork.org/publications/wheat-disease-loss-estimates-from-the-united-states-and-ontario-canada-2024

Angier, Natalie, 2009. "Fungi: From Killer to Dinner Companion." New York Times, May 25. Accessible at: https://www.nytimes.com/2009/05/26/science/26angi.html

Animal and Plant Health Inspection Service, U.S. Department of Agriculture, 2016. "Final Report for the 2014-15 Outbreak of Highly Pathogenic Avian Influenza (HPAI) in the United States." Revised August 11. Accessible at: https://www.aphis.usda.gov/media/document/2086/file#:~:text=Incident%20Overview,as%20a%20Dangerous%20Contact%20Premises).

Animal and Plant Health Inspection Service, U.S. Department of Agriculture, 2024. "APHIS Expands the Citrus Greening (Huanglongbing) Quarantined Area in California." Accessible at: https://www.aphis.usda.gov/sites/default/files/da-2024-43.pdf

Animal and Plant Health Inspection Service, U.S. Department of Agriculture, 2025(a). "Historical Economic Impact Estimates of New World Screwworm in the United States." January. Accessible at: https://www.aphis.usda.gov/sites/default/files/nws-historical-economic-impact.pdf

American Veterinary Medical Association, 2019. "USDA Starts New Veterinary Vaccine Bank." Accessible at: https://www.avma.org/javma-news/2019-10-15/usda-starts-new-veterinary-vaccine-bank

Bandara, Ananda, et al., 2020. "Dissecting the Economic Impact of Soybean Diseases in the United States over Two Decades." PLOS-ONE, April 20. Accessible at: https://doi.org/10.1371/journal.pone.0231141

Beasley, Edward, et al., 2024. "Registration of CA 4011 cotton germplasm line with resistance to areolate mildew and tolerance to thrips." Journal of Plant Registrations. Accessible at: DOI: 10.1002/plr2.20395

Brooks, Rhonda, 2025. "SCN Continues To Spread: It's Now In Every Soybean-Producing State But One." AgWeb, January 16. Accessible at: https://www.agweb.com/news/crops/soybeans/scn-continues-spread-its-now-every-soybean-producing-state-one#:~:text=The%20latest%20update%2C%20spearheaded%20by,to%20the%20The%20SCN%20Coalition.

Brown, R.L. et al., 1999. "Advances in the Development of Host Resistance in Corn to Aflatoxin Contamination by Aspergillus flavus." Phytopathology, Volume 89, Issue 2, pp. 113-17.

Carriquiry, Miguel, Amoni Elobeid, and Dermot Hayes, 2023. "National Impacts of a Domestic Outbreak of Foot and Mouth Disease and African Swine Fever in the United States." Iowa State University, Working Paper 23-WP 650. Accessible at: https://www.card.iastate.edu/products/publications/pdf/23wp650.pdf

Customs and Border Protection, U.S. Department of Homeland Security, 2024. "Agriculture Fact Sheet." Accessible at: https://www.cbp.gov/sites/default/files/2024-12/fy24_agriculture_program_fact_sheet_-_508_compliant_5.pdf

Daberkow, Stan, 2004. "Economic Risks of Soybean Rust in the U.S. Vary by Region." Economic Research Service, U.S. Department of Agriculture, Amber Waves, September 1. Accessible at: https://www.ers.usda.gov/amber-waves/2004/september/economic-risks-of-soybean-rust-in-the-u-s-vary-by-region

Colorado State University, 2024. "Researchers Earn USDA Funding to develop weed herbicide for Palmer amaranth." Accessible at: https://natsci.source.colostate.edu/researchers-earn-usda-funding-to-develop-viral-weed-herbicide-for-palmer-amaranth/

Dorrance, Anne, and Jacqueline Nowakowiski, 2017. "Soybean Rust." Ohio State University Extension. Accessible at: https://ohioline.osu.edu/factsheet/plpath-soy-2

Economic Research Service, U.S. Department of Agriculture, 2025. "Farm Income and Wealth Statistics." Accessible at: https://www.ers.usda.gov/data-products/farm-income-and-wealth-statistics/data-files-us-and-state-level-farm-income-and-wealth-statistics

Faske, Travis, et al., 2025. "Cotton Disease Loss Estimates from the United States—2024." Crop Protection Network, March 7. Accessible at: https://cropprotectionnetwork.org/publications/cotton-disease-loss-estimates-from-the-united-states-2024

Fischer, Melina, et al., 2020. "Stability of African Swine Fever Virus in Carcasses of Domestic Pigs and Wild Boars Experimentally Infected with the ASFV 'Estonia 2014' Isolate." Viruses, October 1, Volume 12, No. 10.

Food and Agriculture Organization, United Nations, 2024. "FAO Report: Global Fisheries and Aquaculture Production Reach a New Record High." June 7. Accessible at: https://www.fao.org/newsroom/detail/fao-report-global-fisheries-and-aquaculture-production-reaches-a-new-record-high/en

Food and Agriculture Organization, United Nations, 2025. "Global Avian Influenza Viruses with Zoonotic Potential situation update." June 23. Accessible at: https://www.fao.org/animal-health/situation-updates/global-aiv-with-zoonotic-potential/bird-species-affected-by-h5nx-hpai/en

Foreign Agricultural Service, U.S. Department of Agriculture, 2025. "Citrus: World Markets and Trade." January. Accessible at: https://apps.fas.usda.gov/psdonline/circulars/citrus.pdf

Foundation for Food and Agriculture Research, 2023. "Developing Resistance to Fungal Threats to Corn." Accessible at: https://foundationfar.org/grants-funding/grants/developing-durable-resistance-to-fungal-threats-in-corn/

Galinato, Suzette, et al., 2018. "Economic Impact of a Potential Expansion of Pest Infestation: Apple Maggot in Washington State." Hort Technology, Volume 28, No. 5, October 1. Accessible at: https://journals.ashs.org/view/journals/horttech/28/5/article-p651.xml

Godoy, Cláudia, et al., 2016. "Asian Soybean Rust in Brazil: Past, Present, and Future." Pesquisa Agropecuaria Brasileira, Volume 51, No. 5, Accessible at: https://doi.org/10.1590/S0100-204X2016000500002

Gottems, Leonardo, 2023. "Soybean Rust Increased by 220% in Brazil, Costs BRL2 billion per Year." AgNews, Accessible at: https://news.agropages.com/News/NewsDetail---45811.htm

Grubman, Marvin, and Barry Baxt, 2004. "Foot-and-Mouth Disease." Clinical Microbiology Review, Volume 17, No. 2, pp. 465-93.

Hawke, John, 2015. "Enteric Septicemia of Catfish." Southern Regional Aquaculture Center, Publication No. 477. Accessible at: https://srac.msstate.edu/pdfs/Fact%20Sheets/477%20Enteric%20Septicemia%20of%20Catfish.pdf

Hensleigh, Nicholas, and Monica Pokorny, 2017. "Agronomy Technical Note: Palmer Amaranthus." Natural Resources Conservation Service, U.S. Department of Agriculture, MT-92. Accessible at: https://www.nrcs.usda.gov/plantmaterials/mtpmctn13127.pdf

Hodges, Alan, and Tom Spreen, 2012. ""Economic Impacts of Citrus Greening (HLB) in Florida, 2006/07–2010/11." University of Florida, Institute of Food and Agricultural Sciences, EDIS FE903.

Hurburgh, Charles, 2012. "Aflatoxin--Testing Corn." Iowa State University Extension, September 6. Accessible at: https://crops.extension.iastate.edu/cropnews/2012/09/aflatoxin-testing-corn#:~:text=By%20Charles%20Hurburgh%2C%20Department%20of,sell%20to%20local%20feed%20markets.

Intergovernmental Science-Policy Platform on Biodiversity and Ecosystem Services (IPBES), 2023. "Summary for Policymakers of the Thematic Assessment Report on Invasive Alien Species and their Control of the Intergovernmental Science-Policy Platform on Biodiversity and Ecosystem Services." Roy, H. E., Pauchard, A., Stoett, P., Renard Truong, T., Bacher, S., Galil, B. S., Hulme, P. E., Ikeda, T., Sankaran, K. V., McGeoch, M. A., Meyerson, L. A., Nuñez, M. A., Ordonez, A., Rahlao, S. J., Schwindt, E., Seebens, H., Sheppard, A. W., and Vandvik, V. (eds.). IPBES secretariat, Bonn, Germany. https://doi.org/10.5281/zenodo.7430692

Iowa State University. "Porcine Reproductive and Respiratory Syndrome (PRRS)." Swine Manual. Accessible at: https://webhost-dev.cvm.iastate.edu/swine-disease-manual/index-of-diseases/porcine-reproductive-and-respiratory-syndrome-prrs/#:~:text=Herds%20located%20in%20swine%2Ddense,useful%20in%20controlling%20secondary%20infections.

Ishiwata, Yuki, and Jun Furuya, 2020. "Evaluating the Contribution of Soybean Rust-Resistant Cultivars to Soybean Production and the Soybean Market in Brazil: A Supply and Demand Analysis." Sustainability. Accessible at: https://doi.org/10.3390/su12041422.

Klesius, P.H., and C.A. Shoemaker, 1999. "Development and use of modified live Edwardsiella ictalun vaccine against enteric septicemia of catfish." In Schultz R (ed.). Advances in Veterinary Medicine 41:523–537.

Koike, S.T., et al., 2008. « First Reports of Impatiens Necrotic Spot Virus Infecting Lettuce in California." Plant Diseases, Volume 92, No. 8.

Kuhns, Annemarie, and David Harvey, 2016. "Retail Egg Price Volatility in 2015 Reflects Farm Conditions." Amber Waves, February 2. Accessible at: https://www.ers.usda.gov/amber-waves/2016/january-february/retail-egg-price-volatility-in-2015-reflects-farm-conditions

Ledbetter, Kay, 2025. "Texas A&M Agri-Life Tackles Rice Delphacid Devastation." September 18. Texas A&M University Extension. Accessible at: https://agrilifetoday.tamu.edu/2025/09/18/texas-am-agrilife-tackles-rice-delphacid-devastation/

Leer, Steve, 2005. "Sentinel Plots Stand Guard over Nation's Soybean Crop." Purdue University press release, May 26. Accessible at: https://www.purdue.edu/uns/html3month/2005/050526.Shaner.sentinels.html#:~:text=Sentinel%20plots%20have%20been%20used,where%20the%20rust%20pathogen%20overwintered.

Linscombe, Steve, 2025. "Personal Conversation with Author." September 18.

McCook, S., 2019. Coffee is not Forever: A Global History of the Coffee Leaf Rust. Athens, OH: Ohio University Press.

Mitchell, Nicole, et al., 2016. "Potential Economic Losses to the U.S. Corn Industry from Aflatoxin Contamination." Food Additives and Contaminants, Volume 33. Accessible at: https://doi.org/10.1080/19440049.2016.1138545

Mohseni-Moghadam, Mohsen, et al., 2008. "Palmer Amaranth Biology and Management." New Mexico State University Extension. Accessible at: https://pubs.nmsu.edu/_a/A617/#:~:text=The%20most%20effective%20management%20method,critical%20(Langcuster%2C%202008).

National Agricultural Statistics Service, U.S. Department of Agriculture, 2021. "Catfish Production." February 8. Accessible at: /https://esmis.nal.usda.gov/sites/default/release-files/bg257f046/8336hv35g/8910km71m/cfpd0221.pdf

National Agricultural Statistics Service, U.S. Department of Agriculture, 2025(a). "Crop Production: 2024 Summary." January. Accessible at: https://downloads.usda.library.cornell.edu/usda-esmis/files/k3569432s/nk324887m/qn59s0097/cropan25.pdf

National Agricultural Statistics Service, U.S. Department of Agriculture, 2025(b). “Crop Values." February. Accessible at: https://www.nass.usda.gov/Publications/Todays_Reports/reports/cpvl0225.pdf

National Pork Producers Council, 2024. “U.S. Pork Industry Fuels American Jobs and Economic Growth: New Report Unveiled." July 23. Accessible at: https://nppc.org/news/nppc-economic-contribution-report-7-23-24/#:~:text=%E2%80%9CProducers%20are%20committed%20to%20delivering,at%20nearly%20$13%20billion%20annually.

NCAUSA, 2023. “Coffee’s Economic Impact.” Accessible at: https://www.ncausa.org/advocacy/economic-impact#:~:text=The%20total%20economic%20impact%20of,billion%20in%20wages%20per%20year

Nelson, Bernt, 2025(a). “Egg Prices Continue Setting Records.” Market Intelligence, American Farm Bureau Federation, March 11. Accessible at: https://www.fb.org/market-intel/egg-prices-continue-setting-records

Nelson, Bernt, 2025(b). “Reinstated July Cattle Inventory Shows Continued Herd Contraction." Market Intelligence, July 31, American Farm Bureau Federation. Accessible at: https://www.fb.org/market-intel/re-instated-july-cattle-inventory-shows-continued-herd-contraction

Nolen, R. Scott, 2025. “FDA Approves Gene Editing Tech Creating PRRS-Resistant Pigs." AVMA News, May 6. Accessible at: https://www.avma.org/news/fda-approves-gene-editing-tech-creating-prrs-resistant-pigs

Ogunrinde, Kirk, 2025. “Coffee Prices Surge 20% Since Last Year—Here's What To Know As They Hit Record Highs.” Forbes, October 15. Accessible at: https://www.forbes.com/sites/kirkogunrinde/2025/10/15/coffee-prices-surge-20-since-last-year-heres-what-to-know-as-they-hit-record-highs/

Osemeke, Onyekachukwu, et al., 2025. “Economic Impact of Productivity Losses Attributable to Porcine Reproductive and Respiratory Syndrome in United States Pork Production, 2016-2020." Preventive Veterinary Medicine, November, Volume 244.

Pendell, Dustin, et al., 2015. “Economic Impact of Alternative FMD Vaccination Strategies in the Midwestern United States." Kansas State University Extension Publication, July 20. Accessible at: https://agmanager.info/livestock-meat/economic-impact-alternative-fmd-emergency-vaccination-strategies-midwestern-united

Perkins, Jackie, and Juliana Wilson, 2024. “Codling Moth Management Options for Michigan Apple Producers." Michigan State University Extension, June 12. Accessible at: https://www.canr.msu.edu/news/codling-moth-management-options-for-michigan-apples#:~:text=There%20are%20pre%2Dmix%20insecticides,the%20development%20of%20insecticide%20resistance.

Peterson, Paul, 2025. “Barberry Eradication Program, 1918-1980." MNOpedia, April 14. Accessible at: https://www3.mnhs.org/mnopedia/search/index/thing/barberry-eradication-program-1918-1980#:~:text=The%20common%20barberry%20bush%20was,operations%20of%20the%20eradication%20program.

Pig333.com. “PRRS." Accessible at: https://www.pig333.com/pig-diseases/prrs_97#:~:text=Symptoms,strains%20are%20clinically%20more%20severe.&text=Short%20periods%20of%20inappetence.,Weak%20piglets%20at%20birth.

Oladokun, Y., et al., 2025. “Assessing the Economic Burden of Black Pod Disease and Cherelle Wilt on Cocoa Farmers in Nigeria." African Journal of Agricultural Science and Food Research. Volume 18, No. 1. Accessible at: https://afropolitanjournals.com/index.php/ajasfr/article/view/621

Ramos, Sean, Matthew McLachlan, and Alex Melton, 2017. “Impacts of the 2014-15 Highly Pathogenic Avian Influenza Outbreak on the U.S. Poultry Sector." Economic Research Service,

Ritter, Thea, et al., 2024. “A socioeconomic and cost benefit analysis of Tropical Race 4 (TR4) prevention methods among banana producers in Colombia." PLOS-One. Accessible at: doi: 10.1371/journal.pone.0311243

Robles-Gil, Alexa, 2025. “Screwworm case detected less than 70 miles from U.S. Mexico Border." New York Times, September 24. Accessible at: https://www.nytimes.com/2025/09/24/science/screwworm-cattle-mexico.html

Rowsey, Ginger, 2022. “Areolate Mildew Found in Midsouth Cotton." Farm Progress, October 12. Accessible at: https://www.farmprogress.com/crop-disease/areolate-mildew-found-in-midsouth-cotton

Salgado, Jorge D. et al., 2016. “Rust Diseases of Wheat." Department of Plant Pathology, Ohio State University. Accessible at: https://ohioline.osu.edu/factsheet/plpath-cer-12#:~:text=There%20are%20three%20different%20rust,leaf%2C%20stripe%20and%20stem%20rust.

Sarangi, Debalin, and Amit Jhala, 2019. “Palmer Amaranth (Amaranthus palmeri) and Velvetleaf (Abutilon theophrasti) Control in No-Tillage Conventional (Non–genetically engineered) Soybean Using Overlapping Residual Herbicide Programs." Weed Technology, Volume 33 , Issue 1 , February, pp. 95 - 105

Science and Technology Directorate, U.S. Department of Homeland Security, 2014. “Foot and Mouth Disease Vaccine." Accessible at: https://www.dhs.gov/sites/default/files/publications/Foot%20and%20Mouth%20Disease%20Vaccine-508.pdf

Schneider, R.W., et al., 2005. “First Report of Soybean Rust Caused by Phakopsora pachyrhizi in the Continental United States." Plant Disease, Volume 89, No. 7. Accessible at: DOI: 10.1094/PD-89-0774A

Scott, Jessie, 2025. “First FDA-Approved Solution Targets New World Screwworm in Cattle Herds." Successful Farming, October 1. Accessible at: https://www.agriculture.com/first-fda-approved-solution-targets-new-world-screwworm-in-cattle-herds-11822424

Seitzinger, Anne, and Phillip Paarlberg, 2016. “Regionalization of the 2014 and 2015 Highly Pathogenic Avian Influenza Outbreaks." Choices Magazine, 2nd Quarter. Accessible at: https://www.choicesmagazine.org/UserFiles/file/cmsarticle_508.pdf

Shurtleff, William, and Akito Aoyagi, 2016. “History of Soybean Crushing: Soyoil and Soybean Meal (980-2016)." Soyinfocenter, October 25. Accessible at: https://www.soyinfocenter.com/books/196#:~:text=About%2066%25%20of%20the%20way,crushed%20for%20oil%20and%20meal.

Sikora, Edward, et al., 2025. “Soybean Disease Loss Estimates in the United States and Ontario, Canada-2024." Crop Protection Network, March 14. Accessible at: doi.org/10.31274/cpn-20250317-1

Simko, Ivan, et al., 2023. « Genetic and Physiological Determinants of Lettuce Partial Resistance to Impatiens Necrotic Spot Virus." Frontiers in Plant Science. Accessible at: doi: 10.3389/fpls.2023.1163683

Steckel, Sandy, 2003. “Biology and Management of Diplodia (Stenocarpella Maydis) Ear and Stalk Rot." Journal of Natural Resources and Life Science Education, Volume 3, pp. 5-7.

Strayer-Scherer, Amanda, and Karamjit Kaur Baryah, 2024. “Areolate Mildew of Cotton." Alabama A&M and Auburn University Extension Service, September 20. Accessible at: https://www.aces.edu/blog/topics/crop-production/areolate-mildew-of-cotton/#:~:text=Areolate%20mildew%2C%20also%20known%20as,%2C%20North%20Carolina%2C%20and%20Tennessee.

Texas Invasive Species Institute. “Codling Moth." Accessible at: https://tsusinvasives.org/home/database/cydia-pomonella#:~:text=History,imported%20into%20the%20United%20States.

Thompson, D., et al., 2002. “Economic Costs of the Foot and Mouth Disease Outbreak in the United Kingdom in 2001." Revue Scientifique et Technique, Volume 21, No. 3, pp. 675-687.

U.S. Department of Agriculture, 2024. “Livestock, Dairy, and Poultry Market Outlook.” LDPM-282-02, December. Accessible at: https://www.ers.usda.gov/publications/pub-details?pubid=6281

U.S. Department of Agriculture, 2025. “USDA Announces Sweeping Plans to Protect the United States from New World Screwworm. August 15. Accessible at: https://www.usda.gov/about-usda/news/press-releases/2025/08/15/usda-announces-sweeping-plans-protect-united-states-new-world-screwworm

U.S. Food and Drug Administration, 2025. “Investigation of Avian Influenza A (H5N1) Virus on Dairy Cattle.” March 14. Accessible at: https://www.fda.gov/food/alerts-advisories-safety-information/investigation-avian-influenza-h5n1-virus-dairy-cattle

University of Missouri Extension. “Winter Wheat Diseases and their Management." IPM-1022. Accessible at: https://extension.missouri.edu/media/wysiwyg/Extensiondata/Pub/pdf/agguides/pests/ipm1022_Pp17-26.pdf

Van Diep, Nguyen, et al., 2025. “Safety and Efficacy Profiles of the Live Attenuated Vaccine AVAC ASF Live for Preventing African Swine Fever in Pigs." Transboundary Emerging Diseases, June 20. Accessible at: https://pmc.ncbi.nlm.nih.gov/articles/PMC12204747/#:~:text=Abstract,post%2Dvaccination%20(dpv).

Wang, Yue-chao, et al., 2021. “Effects of Nitrogen Management on the Ratoon Crop Yield and Head Rice Yield in the South USA." Journal of Integrative Agriculture, Volume 20, Issue 6. Accessible at: https://doi.org/10.1016/S2095-3119(20)63452-9

Wang, Yu-Chen, 2022. “Salinas Valley Agriculture: Infections of INSV on Spinach and Celery." University of California College of Agriculture and Natural Resources. Accessible at: https://ucanr.edu/blog/salinas-valley-agriculture/article/infections-insv-spinach-and-celery

World Animal Health Organization, 2024. “Porcine Reproductive and Respiratory Syndrome (PRRS), August 16. Accessible at: https://rr-asia.woah.org/en/projects/porcine-reproductive-and-respiratory-syndrome-prrs/

World Coffee Research, 2025. “Coffee Leaf Rust Knows No Borders–Neither Does Coffee Science.” June 13. Accessible at: https://worldcoffeeresearch.org/news/2025/coffee-leaf-rust-knows-no-borders-neither-does-coffee-science

World Health Organization, 2025. “WHO Scientific Advisory Group Issues Report on Origin of COVID-19.” June 27. Accessible at: https://www.who.int/news/item/27-06-2025-who-scientific-advisory-group-issues-report-on-origins-of-covid-19

World Health Organization. “Asia Pacific Strategy for Emerging Diseases: 2010.” Manila: WHO Regional Office for the Western Pacific. Accessible at: https://iris.who.int/bitstream/handle/10665/204797/B0130.pdf?sequence=1&isAllowed=y

Wubshet, Ashenafi, et al., 2024. “Foot and Mouth Disease Vaccine Efficacy in Africa: A Systematic Review and Meta-Analysis.” Frontiers in Veterinary Science, June. Accessible at: | https://doi.org/10.3389/fvets.2024.1360256

Wuebbles, D., et al., 2021. “An Assessment of the Impact of Climate Change in Illinois." The Nature Conservancy. Accessible at: https://databank.illinois.edu/datasets/IDB-1260194

Wise, Kiersten, et al., 2024. “An Overview of Ear Rots." Crop Protection Network, November 12. Accessible at: doi.org/10.31274/cpn-20190620-001

You, Shibing, et al., 2021. “African Swine Fever Outbreak in China Led to Gross Domestic Product and Economic Losses." Nature Food, Volume 2, pp. 802-08.

Yu, Eric, et al., 2021. “Timeline of Palmer Amaranth (Amaranth Palmeri) Invasion and Eradication in Minnesota." Weed Technology, Volume 35, No. 5, pp. 802-810.

Yu, Jina, et al., 2022. “Climate Change will Increase Aflatoxin Presence in U.S. Corn." Environmental Research Letters, Volume 17. Accessible at: https://doi.org/10.1088/1748-9326/ac6435

Zahnisher, Steven, 2024. “What is Agriculture’s Share in U.S. GDP?” Economic Research Service, U.S. Department of Agriculture, December 19. Accessible at: https://www.ers.usda.gov/data-products/chart-gallery/chart-detail?chartId=58270#:~:text=According%20to%20data%20from%20the,0.8%20percent%20of%20U.S.%20GDP