MSI Journal of
Multidisciplinary Research (MSIJMR)

# SOCIO-ECONOMIC IMPACTS OF PLANT DISEASES ON HUMAN CIVILIZATION: A RECAP OF THE PAST, PRESENT AND THE FUTURE

**[1]Kutama, A. S. and [2]Zafar, S.**

[1*] Department of Plant Biology, Federal University Dutse.

[2] Department of biological science, North West university, Kano, Nigeria.

*** Correspondence:** Kutama, A. S.

*The authors declare that no funding was received for this work.*

OPEN ACCESS

Received: 20-December-2025

Accepted: 15-January-2026

Published: 19-January-2026



This article is published in the **MSI Journal of Multidisciplinary Research (MSIJMR) ISSN 3049-0669 (Online)**

The journal is managed and published by MSI Publishers.

**Volume: 3, Issue: 1 (January-2026)**

**ABSTRACT:** Plant diseases pose significant threats to agricultural production and can have profound socio-economic consequences for countries worldwide. This paper aims to explore the impact of plant diseases on the socio-economic status of a country by examining the existing literature and synthesizing key findings. A systematic literature search was conducted to identify relevant studies published within the last 15 years. Studies focusing on the socio-economic impact of plant diseases at the country level were selected based on predefined inclusion criteria. The review revealed that plant diseases have far-reaching effects on various aspects of a country's socio-economic status. Agricultural productivity is significantly affected, leading to reduced crop yields, decreased income for farmers, and increased food prices. Plant diseases also disrupt international trade, affecting export earnings and import dependencies. Moreover, the socio-economic impacts extend beyond the agricultural sector, influencing employment rates, rural livelihoods, poverty levels, and overall economic growth. The findings highlight the substantial socio-economic implications of plant diseases on a country's development. The vulnerability of agricultural systems, coupled with the increasing prevalence and severity of plant diseases, underscores the urgent need for effective

disease management strategies. To address the socio-economic challenges posed by plant diseases, this review essay recommends implementing integrated pest management strategies, promoting farmer education and capacity building, and enhancing international collaborations and partnerships. Additionally, policymakers should prioritize investments in plant health infrastructure, surveillance systems, and research and development to foster resilient agricultural systems and safeguard the socio-economic well-being of countries.

**Keywords:** *Plant diseases, Socio-Economic Impacts, human civilization, review.*

## Introduction

Humans are dependent upon plants for their very existence. Dependence on plants by man dates as far back as 14,000 years ago. Perhaps, there are enough evidences in the literature that man has started the practice of farming as early as 7000BC (Kutama *et al*., 2012). As man tried to domesticate these plants, he often observed with dismay that some of these plants possess some unusual signs of symptoms which consequently resulted in the death of the plant and or production of low yield. This, he discovered, if not properly checked would surely temper with his food security. So, man started to study these disease symptoms with the sole aim of curing or at least minimizing their effects. He contacted and consulted many religious documents that would help him avail the situation. This shows that since the beginning of human civilization, plant diseases had played a role in shaping the life style and well being of the ancient man (Mustapha *et al*., 2022).

Globally, enormous losses of the crops are caused by the plant diseases. The loss can occur from the time of seed sowing in the field to harvesting and storage. Important historical evidences of plant disease epidemics are Irish Famine due to late blight of potato (Ireland, 1845), Bengal famine due to brown spot of rice (India, 1942), Rosette of ground nut epidemy in Nigeria (1975) and Coffee rust (Sri Lanka, 1967). Such epidemics had left their effect on the economy of the affected countries (Kutama *et al*., 2022). Plant diseases have a significant impact on socio-economic systems, affecting agriculture, food security, livelihoods, and the overall economy. The consequences of plant diseases can be wide-ranging, leading to reduced crop

yields, increased production costs, market instability, and trade disruptions. Plant diseases can cause substantial crop losses, leading to decreased agricultural productivity and economic losses for farmers (Mundt, 2014). Crop diseases can reduce yields, affect crop quality, and result in the rejection of infected produce in the market. These losses can have severe implications for food security, particularly in regions heavily reliant on agriculture for sustenance.

The economic impact of plant diseases extends beyond the agricultural sector. It affects the entire value chain, including input suppliers, processors, distributors, and exporters (Oerke, 2006). In addition to direct losses from reduced crop yields, plant diseases result in increased production costs due to the need for disease management practices, such as pesticides and fungicides. The financial burden falls on farmers and can disrupt the profitability and sustainability of agricultural operations.

Plant diseases can cause market instability and volatility. When disease outbreaks occur, supply disruptions can lead to fluctuations in commodity prices, affecting both producers and consumers (Barnes *et al.,* 2020). Reduced supply due to crop losses can drive prices higher, impacting consumers' purchasing power and increasing the cost of food. Market instability can also discourage investment in the agricultural sector and hinder economic growth. Plant diseases can result in trade barriers and restrictions on the movement of agricultural commodities (Pautasso *et al.,* 2012). Many countries have phyto sanitary regulations in place to prevent the introduction and spread of plant diseases. In the event of disease outbreaks, import restrictions may be imposed, limiting market access for affected regions or countries. Trade disruptions can have adverse socio-economic impacts, particularly for nations heavily reliant on agricultural exports.

Plant diseases can devastate rural communities that rely on agriculture for their livelihoods. Small-scale farmers, in particular, are vulnerable to the impacts of crop diseases as they often lack resources, knowledge, and access to disease management tools (Fuglie *et al.,* 2020). The loss of crops and income can lead to increased poverty, food insecurity, and migration from rural to urban areas.

Plant diseases pose a threat to global food security by compromising the availability and affordability of nutritious food. The loss of crops due to diseases can exacerbate existing food insecurity issues, particularly in regions where agriculture is the primary source of livelihood and food supply (Fisher *et al.,* 2012). Ensuring the health of plants and managing diseases effectively is crucial for maintaining stable food production systems and addressing food security challenges.

## A. Impact of plant diseases on Agriculture

### 1. Crop Yield Reduction

Plant diseases have a significant impact on crop yield reduction, leading to substantial economic losses and food insecurity. Pathogens, including fungi, viruses, bacteria, nematodes, and other plant pests, can cause various diseases that affect plant health and productivity. These diseases can directly reduce crop yield or indirectly impact yield through other factors such as plant growth, nutrient uptake, and photosynthesis (Savary *et al.,* 2019). Understanding the impact of plant diseases on crop yield reduction is essential for implementing effective disease management strategies. The main factors contributing to yield reduction include:

i. Reduced Photosynthesis: Many plant diseases can affect photosynthesis, the process by which plants convert sunlight into energy. Pathogens may cause leaf discoloration, necrosis, or lesions, reducing the plant's ability to capture and utilize light energy effectively. As a result, the plants have limited energy resources for growth, fruit development, and yield formation.

ii. Impaired Nutrient Uptake: Plant diseases can disrupt the absorption and translocation of essential nutrients, leading to nutrient deficiencies and imbalances. Nutrient deficiencies weaken plants, affecting their overall growth, development, and yield potential. For example, fungal pathogens may interfere with root function, reducing the plant's ability to take up water and nutrients from the soil.

iii. Stunted Growth and Reduced Plant Vigor: Many plant diseases result in stunted growth and reduced plant vigor. Infected plants may exhibit reduced stem and root development, resulting in smaller plants with limited biomass accumulation.

Stunted growth directly affects yield potential as it reduces the number of flowers, fruits, or grains produced by the plant (Garrett *et al.,* 2006).

iv. Flower and Fruit Abnormalities: Plant diseases can interfere with the development of flowers and fruits. Infected plants may produce fewer flowers, experience flower drop, or develop deformed fruits. Such abnormalities directly impact crop yield by reducing the number of potential fruits or negatively affecting fruit quality and market value (Garrett *et al.,* 2006).

v. Premature Plant Senescence and Defoliation: Some plant diseases cause premature senescence, where plants undergo aging and die prematurely. Premature senescence leads to early plant death and subsequent yield loss. Additionally, diseases that result in defoliation, such as certain fungal infections, can reduce photosynthetic capacity, further impacting crop yield (Garrett *et al.,* 2006).

vi. Crop Losses due to Disease Management Practices: In an effort to control plant diseases, farmers often resort to disease management practices such as fungicide applications, crop rotation, and planting disease-resistant cultivars. However, these practices come with costs and may reduce overall crop yield due to additional expenses or limitations on crop choices (Garrett *et al.,* 2006).

The impact of plant diseases on crop yield reduction is influenced by various factors such as the pathogen's aggressiveness, the susceptibility of the crop, environmental conditions, and crop management practices. Integrated disease management strategies that combine cultural, biological, and chemical control methods are crucial for minimizing crop yield losses and maintaining sustainable agricultural production (Savary *et al.,* 2019).

**2. Decreased Quality of Agricultural Products**

Plant Diseases Reduce the Quantity and Quality of Plant Produce. The kinds and amounts of losses caused by plant diseases vary with the plant or plant product, the pathogen, the locality, the environment, the control measures practiced, and combinations of these factors. The quantity of loss may range from slight to 100%. Plants or plant products may be reduced in quantity by disease in the field, as indeed

is the case with most plant diseases, or by disease during storage, as is the case of the rots of stored fruits, vegetables, grains, and fibers. Sometimes, destruction by the disease of some plants or fruits is compensated by greater growth and yield of the remain-ing plants or fruits as a result of reduced competition.

The impact of plant diseases on the decreased quality of agricultural products is significant and can have severe economic and environmental consequences. Plant diseases can affect various aspects of crop quality, including yield, appearance, nutritional value, taste, and marketability. The impact of plant diseases on the decreased quality of agricultural products include:

i. **Reduced Yield**: Plant diseases can cause significant reductions in crop yields. Diseased plants may exhibit stunted growth, reduced fruit or grain production, and premature senescence. Pathogens can damage plant tissues, disrupt nutrient uptake, and interfere with photosynthesis, leading to decreased productivity and lower overall crop yields (Mundt, 2014). Reduced yield can directly impact farmers' income and food availability.

ii. **Quality Defects**: Plant diseases can result in various quality defects in agricultural products. For example, fungal diseases can cause fruit rot, mold growth, discoloration, and surface blemishes (Rosenberger *et al.,* 2012). Bacterial diseases can lead to wilting, water-soaked lesions, and decay in fruits and vegetables (Lindow and Brandl, 2003). Viral diseases can cause deformities, mosaic patterns, and necrotic spots on plant tissues (Whitham *et al.,* 2006). These quality defects render the affected products unmarketable or less desirable to consumers.

iii. **Nutritional Losses**: Some plant diseases can lead to nutrient losses in agricultural products. For example, certain pathogens can cause nutritional imbalances, reducing the content of essential nutrients such as vitamins, minerals, and antioxidants in crops (Graham and Vance, 2003). This can compromise the nutritional value of the affected products, affecting both consumer health and the overall nutritional adequacy of the food supply.

iv. Increased Post-Harvest Losses: Plant diseases can also contribute to increased post-harvest losses. Infected crops are more susceptible to spoilage during storage and

transportation, resulting in additional economic losses for farmers and the supply chain. Fungal pathogens, in particular, can cause post-harvest diseases such as storage rots and mold growth, leading to significant losses in harvested crops (Bautista-Baños *et al.,* 2008).

v. Marketability and Consumer Confidence: Plant diseases can impact the marketability of agricultural products. Crops affected by diseases may fail to meet quality standards and certifications required by retailers, exporters, and regulatory authorities. This can lead to reduced market access, lower prices, and limited consumer demand for the affected products. Additionally, outbreaks of plant diseases can erode consumer confidence in the safety and quality of agricultural products, affecting long-term market relationships and trade.

**B. Economic Consequences of Plant Diseases**

1. **Increased Production Costs**

Plant diseases have a significant impact on agricultural production costs. When crops are affected by diseases, farmers often incur additional expenses to manage and mitigate the damage. Increased production costs can arise from several factors:

i. Disease management measures: Farmers need to invest in various disease management practices, such as the application of fungicides, pesticides, and other control methods, to prevent or control the spread of plant diseases. These disease management measures require financial resources and can significantly contribute to increased production costs (Barnes *et al.,* 2020).

ii. Loss of inputs: Plant diseases can lead to the loss of valuable inputs, including seeds, fertilizers, and irrigation water. Farmers may need to replant affected crops, resulting in additional expenses to purchase new inputs (Fuglie *et al.,* 2020).

iii. Reduced crop yields: Plant diseases often result in reduced crop yields and quality. Decreased productivity means that farmers are producing fewer marketable crops, leading to lower revenues. To compensate for the loss of yield, farmers may need to increase the scale of production, invest in additional resources, or adopt alternative

cropping strategies, all of which contribute to increased production costs (Oerke, 2006).

2. **Loss of Export Opportunities**

Plant diseases can have severe consequences for agricultural economies by causing a loss of export opportunities. Export markets often have strict phytosanitary regulations and quality standards to protect against the introduction and spread of plant diseases. The presence of diseases can result in trade barriers and restrictions, leading to a loss of export opportunities for affected countries or regions.

i. Trade bans and restrictions: When plant diseases are detected in a region or country, trading partners may impose temporary or permanent bans on the importation of affected crops. These trade restrictions aim to prevent the introduction and spread of diseases into their own agricultural systems. As a result, farmers and exporters face significant losses in revenue due to limited access to international markets (Barnes *et al.,* 2020).

ii. Quality concerns: Plant diseases can negatively impact the quality and appearance of crops, making them less desirable in export markets. Buyers may reject or offer lower prices for diseased produce, further affecting the income and profitability of farmers and exporters.

3. **Food Security Concerns**

Plant diseases pose a threat to global food security by impacting crop production and availability. Food security concerns arise due to the following reasons:

i. Reduced crop productivity: Plant diseases can cause significant yield losses, compromising the overall availability of food. When crops are affected by diseases, the quantity and quality of harvested produce can be significantly reduced, affecting the availability of nutritious food for both local consumption and global food markets (Fuglie *et al.,* 2020).

ii. Vulnerability of staple crops: Many plant diseases target staple food crops that form the basis of diets in certain regions or countries. Diseases affecting crops such as

rice, wheat, maize, and potatoes can have severe consequences for food security, as these crops often provide the main source of calories and nutrition for populations.

iii. Increased food prices: When crop yields decline due to plant diseases, the reduced supply of affected crops can lead to increased food prices. Higher prices can limit access to food for vulnerable populations and contribute to food insecurity (Fisher *et al.,* 2012).

The impact of plant diseases on increased production costs, loss of export opportunities, and food security concerns emphasizes the need for effective disease management strategies, international collaboration, and investment in research and development to develop resistant crop varieties and sustainable agricultural practices.

4. **Loss of Income for Farmers**

Plant diseases have significant economic consequences for farmers, resulting in the loss of income. When crops are affected by diseases, farmers experience reduced yields, lower-quality produce, or complete crop failure. These outcomes directly impact their income generation. Farmers may face financial hardship due to:

i. Reduced crop yields: Plant diseases can cause substantial reductions in crop yields, leading to decreased production and subsequent decline in the quantity of marketable crops. As a result, farmers receive lower prices for their produce or may not be able to sell their crops at all, leading to a loss of income (Oerke, 2006).

ii. Increased production costs: Farmers must invest in disease management strategies, including purchasing fungicides, pesticides, and other control measures. These additional costs contribute to a decrease in overall profitability, leading to a loss of income (Barnes *et al.,* 2020).

5. **Unemployment in the Agricultural Sector**

The economic consequences of plant diseases extend beyond the individual farmers to the broader agricultural sector. Severe disease outbreaks can result in increased unemployment in the agricultural industry. The following factors contribute to unemployment:

i. Reduced labor demand: When plant diseases lead to decreased crop yields or loss of entire crops, there is less demand for agricultural labor. Farmers may need to downsize their workforce or reduce seasonal employment opportunities, resulting in increased unemployment rates in rural communities (Sutherland *et al.,* 2018).

ii. Impact on related industries: Plant diseases can also affect industries that rely on agriculture, such as food processing, packaging, and transportation. Reduced agricultural production due to plant diseases can lead to job losses in these associated industries, exacerbating unemployment rates (Gadhave *et al.,* 2019).

6. **Reduced Revenue for Agricultural Businesses**

Plant diseases have a detrimental impact on the revenue of agricultural businesses. As farmers face crop losses and reduced yields, the revenue generated by agricultural businesses, such as farms, cooperatives, and agribusinesses, also declines. The consequences include:

i. Decreased sales and profitability: With reduced crop productivity, agricultural businesses experience lower sales volumes and profitability. The lower revenue hampers their ability to invest in research, technology, and infrastructure, which are essential for sustainable growth (Fuglie *et al.,* 2020).

ii. Loss of market share: Plant diseases can damage a company's reputation and reduce consumer trust in the quality and safety of their products. This loss of market share further impacts the revenue of agricultural businesses as co ttttttnsumers may switch to alternative, disease-free products (Barnes *et al.,* 2020).

7. **Increased Reliance on Imports**

Plant diseases can lead to an increased reliance on imports of agricultural products, which has economic implications for countries affected by disease outbreaks. The following factors contribute to this scenario:

i. Decline in domestic production: When plant diseases cause significant crop losses, domestic production of specific crops may decline. As a result, countries become

reliant on importing those crops from disease-free regions to meet domestic demand for food and agricultural commodities.

ii. Higher import costs: Importing agricultural products incurs additional costs, including transportation, tariffs, and import duties. Increased reliance on imports due to plant diseases can strain national budgets and lead to higher food prices for consumers, impacting overall economic stability (Fuglie *et al.,* 2020).

8. **Trade Imbalances**

Plant diseases can disrupt international trade and contribute to trade imbalances between countries. The economic consequences include:

i. Reduced exports: Plant diseases can lead to trade barriers and restrictions imposed by importing countries to protect their agricultural systems. This can result in reduced exports of affected crops, leading to trade imbalances and a decrease in foreign exchange earnings for exporting countries.

ii. Trade disputes and negotiations: Plant disease outbreaks may trigger trade disputes between countries due to concerns over the introduction and spread of diseases. Trade negotiations and agreements may be necessary to address phytosanitary issues, potentially impacting trade relationships and imposing further economic costs (Gadhave *et al.,* 2019).

Understanding the economic consequences of plant diseases highlights the importance of implementing effective disease management strategies, investing in research and development, and promoting international collaboration to safeguard agricultural economies and ensure food security.

**C. Social consequences of plant diseases**

Plant diseases not only have economic implications but also significant social consequences. These consequences affect human health, rural communities, and social well-being, and include:

## 1. Impact on Human Health

Plant diseases can have direct and indirect effects on human health. The social consequences include:

i. **Exposure of humans and animals to toxins:** one of the common ways by which plant diseases can affect human and animal health is through the secretion of poisons or toxins popularly called mycotoxins. For example, mycotoxins produced by certain fungal diseases can contaminate crops and pose health risks when consumed. Examples of fungal species producing mycotoxins include *Aspergillus flavus, Fusarium* spp. and *Penicillium* spp. There are several groups of mycotoxins under which several types are included. Aflatoxins are one of the most common and serious groups (types=B1, B2, G1 and G2), which are produced by some Aspergillus species. Aflatoxin B1 is one of the most serious mycotoxins, because it is lethal at high doses and is carcinogenic to humans at low doses and can result in reduced liver function, vomiting and abdominal pain.[4] Annual deaths in some parts of Africa due to the effect of aflatoxin have been reported to reach 250,000 annually. Mycotoxins can be found in several products, especially peanuts, pistachios and maize. Infection of these products by mycotoxin-producing fungi can occur in the field or during storage. In addition, mycotoxins can be consumed indirectly by humans through the consumption of meat from animals fed on food contaminated with mycotoxins. Ergot is also a disease of several cereals including bread wheat. It is caused by some fungi belonging to the Claviceps genus. Consumption of bread produced from contaminated flour can result in ergotism disease in humans.Ergotism has been reported to result in death, loss of peripheral sensation or hallucinations. Although most plant pathogens do not infect humans, it is advised to avoid consuming rotted or mouldy fruits and vegetables or food contaminated by toxin-producing fungi. Removing diseased parts of fruits may help reduce pathogen inoculum and rotted fruit parts. However, it may not ensure that all contamination has been excluded as some fungi and their toxins can diffuse into symptom-less parts of fruits. Although cooking may result in the decomposition of some mycotoxins, some mycotoxins are not destroyed by high heat. The effects of some mycotoxins can be reduced through the addition of some mycotoxin-binding

agents or through deactivation. More research is required on the direct effects of plant pathogens and diseases on humans. Special attention should be given to mycotoxin-producing fungi and their presence in human food. Efforts should be directed towards avoiding plant disease epidemics similar to the late blight disease of potatoes in Ireland through food diversification and the development of effective plant disease management strategies. Awareness of community about the ways by which plant diseases can affect human health is also important

ii. **Nutritional deficiencies**: When plant diseases reduce crop yields or limit the availability of certain crops, it can contribute to nutritional deficiencies among populations reliant on these crops for essential nutrients. This can lead to malnutrition and other health issues (Oerke, 2006).

**2. Impact on Rural Communities**

Rural communities, especially those heavily dependent on agriculture, are particularly vulnerable to the social consequences of plant diseases. These consequences include:

i. **Loss of livelihoods:** Plant diseases can result in crop failures and reduced agricultural productivity, leading to a loss of income and livelihoods for farmers and agricultural workers. This can have a profound social impact, causing financial instability and poverty in rural communities (Gadhave *et al.,* 2019).

ii. **Migration and displacement:** In severe cases of reduced food unavailability to humans and animals, plant diseases can force people to migrate from rural areas to seek alternative sources of food, income and livelihoods. This can lead to the displacement of communities, disruption of social structures, and increased strain on urban areas (Sutherland *et al.,* 2018). Example, the early history has it that between 1845-1847, about one million persons died in Ireland and another one million migrated to Canada and USA.

### 3. Impact on Social Well-being

Plant diseases can have broader implications for social well-being, affecting community cohesion, cultural practices, and quality of life. The social consequences include:

i. Social unrest: In communities heavily reliant on agriculture, the social and economic impacts of plant diseases can lead to social unrest and conflicts. This can arise from competition over scarce resources, loss of livelihoods, and increasing socio-economic disparities (Gadhave *et al.,* 2019).
ii. Cultural heritage and traditions: Plant diseases can impact traditional agricultural practices, jeopardizing cultural heritage and the preservation of indigenous knowledge. The loss of crop varieties and traditional farming systems can erode cultural diversity and disrupt community identity (Fuglie *et al.,* 2020).

## Conclusion

Plant diseases have a significant impact on socio-economic development, affecting farmers, agricultural businesses, and national economies. The economic consequences of plant diseases include loss of income for farmers, unemployment in the agricultural sector, reduced revenue for agricultural businesses, increased reliance on imports, and trade imbalances. These consequences have far-reaching social implications, including food security concerns and decreased rural livelihoods.

## Mitigation strategies

Addressing plant diseases is crucial for sustainable development. Effective disease management strategies, such as integrated pest management practices, early detection and rapid response systems, crop diversification and rotation, investment in agricultural research and infrastructure, and farmer education, adopting the modern plant biotechnological concepts and processes among others, are essential for mitigating the socio-economic impact of plant diseases. By implementing these strategies, we can minimize crop losses, enhance agricultural productivity, and promote resilient and sustainable farming systems.

Efficient disease management strategies, including prevention, early detection, and control measures, are crucial to minimizing the impact of plant diseases on agricultural product quality. Integrated pest management practices, good agricultural practices, crop rotation, use of resistant cultivars, and timely application of appropriate fungicides, bactericides, and other control measures can help mitigate disease incidence and severity, preserving the quality and market value of agricultural products.

**REFERENCES**


1. Barnes, A. P., Szabo, L. J., & Liu, M. (2020). Economic impacts of wheat diseases and their management. *Annual Review of Phytopathology*, 58, 221-243.

2. Barnes, A. P., Szabo, L. J., &Schmale, D. G. (2020).Crop disease economics and impact assessment. *Phytopathology*, 110(1), 46-55.

3. Bautista-Baños, S., Hernández-López, M., Bosquez-Molina, E., Wilson, C. L., & Scott, G. E. (2008).A review of the use of botanicals for plant disease management. *Crop Protection*, 27(6), 637-647.

4. Fisher, M. C., Henk, D. A., Briggs, C. J., Brownstein, J. S., Madoff, L. C., McCraw, S. L., &Gurr, S. J. (2012). Emerging fungal threats to animal, plant and ecosystem health. *Nature*, 484(7393), 186-194.

5. Fuglie, K. O., Schimmelpfennig, D., Kascak, C., &Heisey, P. (2020). Economic impacts of Agricultural R&D and R&D policy: A review. *Applied Economic Perspectives and Policy*, 42(1), 66-90.

6. Fuglie, K., Wang, S. L., Klotz-Ingram, C., & Ballenger, N. (2020).Agricultural productivity growth and the role of investment in developing countries.*Journal of Agricultural Economics*, 71(3), 563-584.

7. Gadhave, K. R., Arora, V., Gokte-Narkhedkar, N., & Gupta, A. (2019). Plant diseases and food security: Economic importance, challenges, and policy implications. In Plant Health Under Biotic Stress (pp. 315-335). Academic Press.

8. Garrett, K. A., Dendy, S. P., Frank, E. E., Rouse, M. N., & Travers, S. E. (2006). Climate change effects on plant disease: Genomes to ecosystems. *Annual Review of Phytopathology*, 44, 489-509.

9. Graham, R., & Vance, C. P. (2003). Legumes: Importance and constraints to greater use. *Plant Physiology*, 131(3), 872-877.

10. Kutama, A. S., Adamu, M., Baita, H. U, Zafar, S. and, Hadiza, M. M. (2022): Review on the Contributions of Some Human Cultural Practices to Plant Disease Epidemiology. *Dutse Journal of Pure and Applied Sciences (DUJOPAS*),8(2b):12-20

11. Kutama, A.S. (2012): Studies on the Epidemiology and Control of Sorghum Head and Loose Smut Diseases in the Sudan and Sahel Savannah region of Nigeria. *A PhD thesis (unpublished).* Department of plant science, Bayero University, Kano. *Pp 01- 20*

12. Kutama, A.S., Emechebe, A.M; and Aliyu, B.S (2010): A Review on the Epidemiology and Control of Sorghum Head and Loose Smut Diseases in Nigeria. *Biological and Environmental Sciences Journal for the Tropics*, 7(4):155-163. ISSN 0794-9057

13. Lindow, S. E., &Brandl, M. T. (2003).Microbiology of the phyllosphere. *Applied and Environmental Microbiology*, 69(4), 1875-1883.

14. Mundt, C. C. (2014). Durable resistance: A key to sustainable management of pathogens and pests. Infectious Disease of Plants, 2(1), 8-19.

15. Mundt, C. C. (2014). Durable resistance: A key to sustainable management of pathogens and pests. Infection, Genetics and Evolution, 27, 446-455.

16. Mustapha, T., Kutama, A. S., Sultan, Z. and Musa, H. M. (2022). Resurgence of plant diseases in the era of climate change. *Biological and Environmental Sciences Journal for the Tropics*, 19 (2): 7-15.

17. Oerke, E. C. (2006). Crop losses to pests. *The Journal of Agricultural Science*, 144(1): 31-43.

18. Pautasso, M., Aistara, G., Barnaud, A., Caillon, S., Clouvel, P., Coomes, O. T., Delêtre, M., Demeulenaere, E., De Santis, P., Döring, T. F., Eloy, L., Emperaire, L., Garine, E., Goldringer, I., Jarvis, D., Joly, H. I., Leclerc, C., Louafi, S., Martin, P., Massol, F., ... Viard, F. (2012). Seed exchange networks for agrobiodiversity conservation. A review.*Agronomy for Sustainable Development*, 32(1), 241-257.

19. Rosenberger, D. A., Sutton, T. B., & Wilcox, W. F. (2012). Integrated fruit disease management—A holistic approach to reducing postharvest fruit losses. Plant Disease, 96(7), 898-908.

20. Savary, S., Willocquet, L., Pethybridge, S. J., Esker, P., McRoberts, N., & Nelson, A. (2019). The global burden of pathogens and pests on major food crops.*Nature Ecology & Evolution*, 3(3), 430-439.

21. Singh, R. P., Hodson, D. P., Huerta-Espino, J., Jin, Y., Bhavani, S., Njau, P.,...& Herrera-Foessel, S. A. (2015). The emergence of Ug99 races of the stem rust fungus is a threat to world wheat production. *Annual Review of Phytopathology*, 53, 419-436.

22. Sutherland, D. R., Pardey, P. G., & James, J. S. (2018). Agricultural research investment and policy reform in high-income countries. *Science*, 361(6406), eaar8320.

23. Whitham, S. A., Yang, C., Goodin, M. M., & editors. (2006). Global impact of plant diseases on food security. *Springer Science & Business Media*.