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IS CLIMATE CHANGE A BLESSING OR CURSE? THE CHANGING CLIMATE INFLUENCE ON PLANT DISEASES AND PESTS DEVELOPMENT: A NARRATIVE STUDY.

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Abstract
The study investigates the impact of climate change on the development of plant diseases and the emergence of novel plant diseases, the conditions for disease development, mitigation strategies, and adaptation strategies for pest control. Climate change and variability may have indirect effects on animal diseases that are more significant than direct consequences. However, there has been little focus on the impact of climate change on agriculture, particularly concerning insect pests; because rising temperatures hasten insect life cycles, migration, and nutrition. It is concluded that it is necessary to construct and reinforce barriers that stop the arrival of exotic infections, develop tools for quick diagnosis of novel diseases, and train technical personnel to use these techniques once they are in place.

***Keywords**: Climate, Disease and Pest, Global warming, Nutrient Management, Thresholds*
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Introduction
The shifting climate presents a double-edged sword for agriculture, rendering the study of its impact on plant diseases and pests essential. While some regions across the world may experience milder winters, longer growing seasons, and increased crop productivity (Turyasingura et al., 2023), these changes also create a hospitable environment for the proliferation of pests and diseases. Warmer temperatures can accelerate the life cycles of pathogens and pests, leading to more frequent outbreaks and heightened severity of infestations. Additionally, altered precipitation patterns can create conditions favoring certain pathogens or pests while challenging the resilience of crops. Garrett et al. (2021) report that understanding the intricate interplay between climate change and the dynamics of plant diseases and pests is crucial for agricultural sustainability and food security thus, need for the study. This knowledge enables farmers and policymakers to implement proactive strategies for disease and pest management, such as developing resistant crop varieties, optimizing pest control measures, and implementing adaptive agricultural practices (Turyasingura et al., 2023).

In addition, more information on the effects of climate change on the emergence of new plant pests and diseases is needed globally, and little effort has been made up to date (Harvey et al., 2018; Garrett et al., 2021). The research delves into the impact of climate change on the development of plant diseases and the emergence of novel plant diseases (Chhogyel et al., 2020), conditions for disease development, mitigation strategies, and adaptation strategies for pest control. Numerous factors impacting factors affect plant diseases (Yáñez-López et al., 2012). The consequences of carbon dioxide and mitigation strategies, on the other hand, were not extensively addressed (Turyasingura et al., 2023).

According to Turyasingura and Rogers (2022), since maize is planted during the warmer and wetter summer months, which creates an ideal home for insect pests to multiply quickly and spread to new regions, pests cause major damage to maize harvests (El-Naggar et al., 2020; Wang et al., 2021). Effective control should therefore be implemented because it is hard to avoid this pest without implementing long-term management (Chavula, 2022; Karlsson et al., 2020). Insects play an important role in pollination (Thomson & Page, 2020; Khalifa et al., 2021; Dymond et al., 2021), detritus (Tooker & Giron, 2020), nutrient cycling (Parr et al., 2019; Crespo-Pérez et al., 2020; Stepanian et al., 2020), and providing food for birds, mammals, and amphibians worldwide (Freire et al., 2021). For example, it is believed that 80% of wild plants rely on insects for pollination, while 60 percent of birds rely on insects as a primary food source. The value of ecosystem services offered by wild insects in the United States is $57 billion per year (Losey & Vaughan, 2006). As a result, any decrease in insect numbers and variety will hurt ecosystem

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functioning. Turyasingura and Chavula (2022), concluded that policies should promote both practices and services, such as financial services and pest management strategies. Climate change may have indirect effects on animal disease that are more significant than direct consequences (Linders et al., 2019; Lacetera, 2019). However, there has been little focus on the impact of climate change on agriculture, particularly on insects, because rising temperatures hasten insect life cycles, migration, and nutrition. Crop pests are responsible for over 57% of farm productivity losses (Yáñez-López, 2012; Stathers et al., 2020; Chhogyel et al., 2020). Changes in pest activity caused by climate change are predicted to have a variety of effects on agricultural production (Shrestha, 2019). As climate change proceeds, insect damage will compound and combine with plant stress as a result of direct effects on crops owing to changes in temperature, precipitation, and CO2 levels (Turyasingura & Rogers, 2022; Chavula, 2022). Climate change has resulted in an upsurge in the number of insect pests, bug outbreaks, the number of generations, and the development of resistant biotypes (Kambrekar et al., 2015). This would undoubtedly intensify the insect's damage, resulting in lower agricultural yields, high crop protection costs, and adverse effects on the economy (Oerke & Dehne, 2004). According to this study, there are few strategies for dealing with increased pest and disease occurrence that focus on building regional, national, and local capacity and disease management systems that are based on sound science, and this needs to be improved to increase crop productivity. This study is expected to produce robust conclusions that could be relevant to climate change's effect on pests. The study aims to assess the influence of climate change on plant disease development, conditions for disease development, mitigation strategies, and adaptation strategies for pest control.

Materials and Methods

A narrative literature search from 1992 and 2022 was conducted using relevant keywords and phrases. This research was conducted using journals from "Google Scholar, Crossref metadata, DOAJ, Dimension, SCOPUS, and Research Gate. The study employed a systematic narrative review to arrive at the articles for the study, additionally, the keywords that they used in the literature search included climate change about plant diseases; nutrient management; weather patterns; and novel plant and animal diseases. Causes of climate change on crop and global warming in developing countries.

To prepare this document, articles, books, and reports were retried and reviewed from the aforementioned databases as shown in Table 1. The preparation of this manuscript complied with narrative review guidelines, and additional pertinent e-books, conference proceedings, policy briefs, and government and farmer group reports at local, national, regional, and international levels from both developing and developed countries were referred.

To achieve the objectives of the study an inclusion and exclusion criteria was adopted. Inclusion criteria are used to select publications that directly pertain to the research topic, such as those discussing the impact of climate change on plant health and the dynamics of diseases and pests. These criteria ensure that the chosen publications provide relevant insights into the specific phenomenon under investigation, helping researchers to build a comprehensive understanding of the subject matter. Conversely, exclusion criteria are equally important as they help to filter out publications that are not directly pertinent to the research focus. This might include studies on unrelated topics or those that lack sufficient depth or reliability. In other words, by excluding irrelevant publications, researchers can maintain the integrity and coherence of their study, ensuring that the data and insights gathered are aligned with the research objectives. The adoption of inclusion and exclusion criteria thus contributes to the rigor and validity of the research process. It helps researchers focus their efforts on accessing and analyzing information that is most likely to yield valuable insights into the relationship between climate change and plant diseases and pests. Hence, by selecting relevant publications while filtering out irrelevant ones, researchers can effectively address their research questions and contribute meaningfully to the existing body of knowledge in the field.

Table 1: Searching the Web of Science (WOS) and Scopus databases using "Climate-Change" AND "Plant Disease Development."

Search Platform	Total no. of articles reviewed	Papers excluded from the study	Total no. used papers
Papers from Scopus databases	287	267	20
Papers from WOS	360	332	28
Papers selected in this study	687	639	48

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Conditions for Disease Development

A susceptible host plant, a favorable environment, and a live pathogen are all required for disease development. For disease to arise, all three of these components must be present as shown in Figure 1 (Zayan, 2019). The disease triangle can be broken and disease development prevented by modifying the susceptibility of host plants, the surrounding environment, and/or the viability of pathogens.

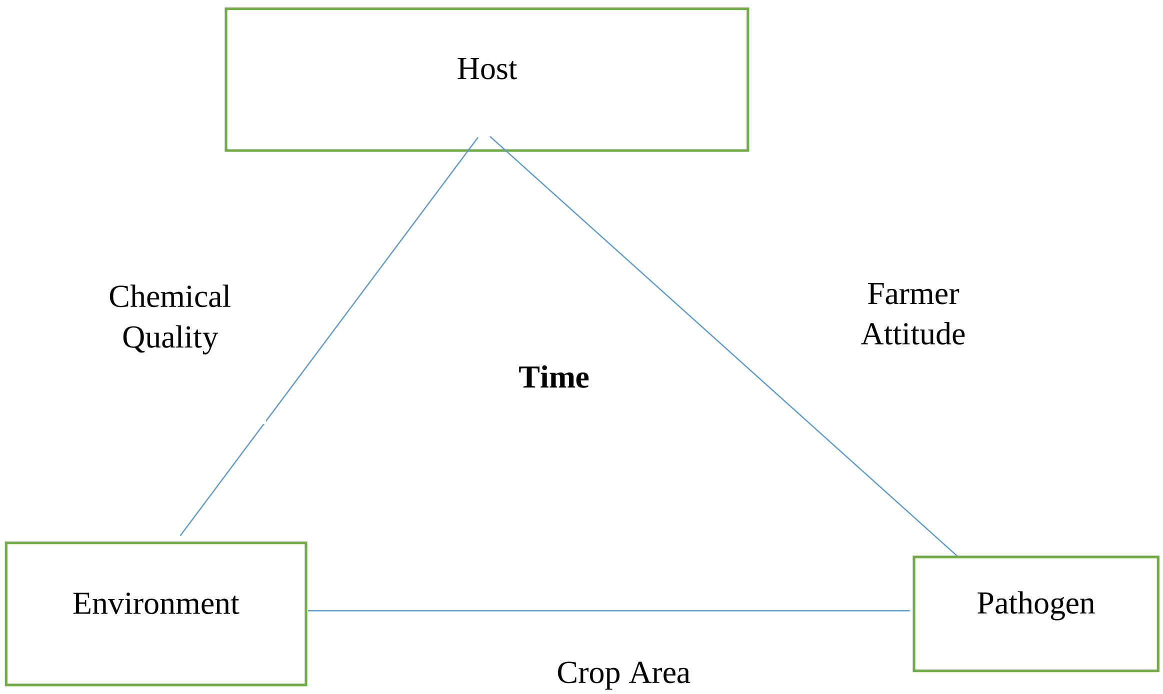

Figure 1: Interactions that influence the development of plant diseases (Adopted from Zayan, 2019). The genetic makeup of the host plant dictates its disease vulnerability (Gu et al., 2022). The plant's susceptibility is determined by a variety of physical and physiological parameters (Grossiord et al., 2020), and the disease development is influenced by the environment (Cavalli & Heard, 2019). To infect and disseminate, pathogens typically require specific environmental conditions. Thus, pathogens must be present and alive. Infected plant portions and other pathogen remains are removed, making them inaccessible to infection. Climate change will have a varied impact on each place, and its effects will be felt over time. Due to the great reliance on agriculture as the primary driver of most African economies, understanding the possible consequences of changing climate on plant diseases is a critical problem. Climate change is projected to raise the likelihood of disease-related output losses in Africa. Rising temperatures, changes in the quantity and pattern of precipitation, increased CO2 and ozone levels (Grace et al., 2019), drought, and other effects of human activity have had a significant impact on the climate and ecosystems (Barnes et al., 2019). Because plant disease is the result of interaction between a susceptible plant, a virulent pathogen, and the environment, any change in ecosystems can affect plant diseases (Liu & He, 2019).

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According to Turyasingura et al., (2022), climate change and global warming are major concerns for African agriculture and are among the most hotly disputed topics affecting diversity resilience. Increased temperatures, rising CO2 levels in the atmosphere, and changing precipitation patterns all have a substantial impact on agricultural production and crop bug pests (Malhi et al., 2021). Climate change has a variety of effects on insect pests. They can lead to an increase in geographic distribution; increased overwintering survival; an increase in the number of generations; altered synchrony between plants and pests; altered interspecific interaction; increased risk of migratory pest invasion; increased incidence of insect-transmitted plant diseases; and reduced biological control effectiveness, particularly natural enemies (Chavula, 2022). Climate change is a primary cause of the pest population, and there is a need for adaptation and migratory management measures to deal with pests' shifting status (Chavula & Turyasingura, 2022). However, data on updated integrated pest control strategies, climate and pest population monitoring, and the use of modeling prediction tools is scarce.

Effect of Climate Change on Plant Diseases

Variations in pest development caused by climate change are likely to have a variety of consequences for agricultural production (Pham et al., 2019). Increased pest populations stress crop plants, increasing the risk of crop loss and lowering harvest yield and/or quality (Chavula, 2022). Furthermore, as climate change proceeds, insect damage will compound and combine with plant stress resulting in direct effects on crops owing to variations in heat, rainfall, and CO2 levels. Insects have a changeable body temperature; therefore, they are extremely sensitive to their environment, particularly the temperature. Insect outbreaks, migration, biodiversity shifts, species extinctions, host shifts, and the formation of novel pests could all be consequences of climate change (Skendžić et al., 2021). Tropical insects that are sensitive to temperature changes may be at higher risk as a result of global warming. They may become extinct if temperatures rise by 2-40C, such as the pod-sucking bug, which has a perilous limit of (15–32)0C and has already reached 330C in the tropics (Skendžić et al., 2021). For such insects, rising temperatures may be difficult to tolerate. Insect physiology and development can be affected directly or indirectly by temperature, depending on the physiology or presence of hosts. Temperature can have a variety of consequences depending on an insect's development plan (Willmott et al., 2022).

Historical Perspective of Pests and Diseases

Pesticides have been employed to minimize the damage that pests and vermin do to crops ever since the birth of civilization (Kogan, 1998). To fend off a plant stalk (*Puccinia graminis f.sp. tritici*), the Romans created the god Robigo, to whom they made sacrifices. Along with praying to the gods, more conventional methods of crop protection have been practiced for over 4,000 years. Early farmers used plant selection for disease resistance; they chose seeds from the best plants and conserved seeds to sow from year to year. Greek philosopher Theophrastus noted that crop diseases were more prevalent in the lowlands in 300 BC. As early as 200 BC, the Chinese are said to have used plant insecticides, as well as chemical agents to treat body lice. Additionally, around the middle of the 1600s, farmers in the south of England discovered that wheat cultivated from seed recovered from a shipwreck had a lower amount of bunt than other crops. Pesticides weren't created for plant disease management for another 2800 years. It was advised that wheat seed be soaked in brine before planting. In 1882, French chemist Millardet made the biggest stride toward chemically treating plant diseases. He noticed that applying a copper sulfate and lime solution to grapevines reduced the amount of downy mildew on them as well. The mixture was improved by Millardet, who gave it the name "Bordeaux Mixture." The Bordeaux mixture was colored "Paris Green" to prevent grape phylloxera. Insecticides based on natural substances, such as "pyrethrum and nicotine," were added in the early 1900s, increasing the dependency on pesticides. Lead arsenate was first used in pesticides in the 1890s. However, the widespread use of pesticides in agriculture was brought about by Paul Müller's discovery of dichlorodiphenyltrichloroethane (DDT) in 1939 while working for Geigy Chemical Company. Its low cost, endurance, low mammalian and plant toxicity, and broad-spectrum activity ensured its widespread adoption and use. Therefore, the success of DDT stimulated the development of new pesticides. The effectiveness of these poisons led to repeated downgrading or abandonment of research into other pest control strategies. This had a big impact on research areas that used live things. The publication of Rachel Carson's book Silent Spring in 1962 and subsequent allegations of excessive chemical use brought attention to the use of biological controls recently. DDT was eliminated and its use was outlawed globally. Recently, it has been suggested that DDT should continue to be used against malaria vectors in regions where the disease is prevalent. Agriculture has traditionally employed biological control as a component of pest management. Predatory ant colonies were used to control caterpillars. These farmers erected bamboo bridges between trees to aid ant migration. Russian entomologist Elie Metchnikoff used the insect pathogen Metarhizium anisopliae to control the sugar beet curculio in 1884. The first description of using fungal spores to control many pine trees was published in 1963.

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Mitigation Strategies

Utilizing Integrated Nutrient Management (INM) is a technique that combines all nutrient sources, including organic, inorganic (chemical fertilizer), and biofertilizer, and applies them to soils to improve crop growth, provide high-quality yields (Selim, 2020), and avoid spread of disease in the garden is essential to sustainable agriculture, which calls for resource management that meets evolving human requirements without harming the environment or depleting essential natural resources (Chavula & Hassen, 2022). Integrated nutrient management refers to the preservation of soil fertility and plant nutrient delivery at an optimal level for maintaining the target production by optimizing the benefits from all available sources (Sharma et al., 2019). Turyasingura and Rogers (2022) note that chemical fertilizer came under scrutiny in the early 1990s due to its widespread use in industrialized countries was perceived to be damaging the environment through nitrate leaching, eutrophication, greenhouse gas emissions, and heavy metal uptake by plants affecting crop yields.

Setting action thresholds

Integrated pest management (IPM) first establishes a threshold or a point at which the set of related variable levels specifies that appropriate control activities must be taken to control pest populations, before initiating any control decisions or actions. In addition, IPM helps to reduce pest diseases by approximately fifty percent hence, effective at pest management in African countries. Thus, the most common thresholds are:

1. **Density thresholds:** Indicates the level of insect population at which crop damage is noticed.
2. **Period thresholds:** These are the points in the life cycle of a crop when pests are more or less destructive than at other points.
3. **Economic thresholds:** The amount of damage or pest population density at which control actions should be implemented to avoid financial loss to the crop. The loss that would have happened if nothing was done should be less expensive than the cost of control as shown below.

Monitoring and identification of pests

Numerous insects, plants, and other living things are not seen as pests that need to be controlled (Nagy et al., 2022). Most of the creatures aren't dangerous; in fact, some of them are helpful. IPM programs must accurately identify and screen for pests to combine the action determination thresholds with proper management decisions (Scheff & Phillips, 2022; Karlsson et al., 2020). With this method, there is no longer a chance that pesticides will be used when they are unnecessary or that the wrong kind of pesticide will be used.

Prevention

IPM programs are created to manage the crop, lawn, or indoor space to prevent the appearance and development of pests to accomplish effective pest control. In the case of crops, this could entail employing suitable planting techniques, such as crop rotation, the use of pest-free rootstock, and the planting of resistant plant kinds (Zayan, 2019). These cost-effective control methods carry a lesser risk to the environment and public health while yet being very effective.

Adaptation Strategies

By biological definition, adaptation is the process by which a species adjusts to its environment; it results from natural selection operating over many generations on heritable variation. According to the Intergovernmental Panel on Climate Change (Aryal et al., 2020), adaptation is the process of making changes to natural or human systems in response to present or anticipated climatic stimuli or impacts to mitigate harm or take advantage of advantageous opportunities. Due to the increased likelihood of the occurrence of some anticipated climate changes and the fact that productivity and food security can only be guaranteed if we can develop a highly effective strategy to adapt agriculture to climate change, adaptation measures have drawn more attention in recent years (Brar et al., 2020). In addition, disease management under the scenario of climate change concluded that preventive control measures, such as the use of a variety of crop species in cropping systems, modification of sowing or planting dates, use of disease-resistant and abiotic stress-tolerant cultivars, application of an integrated management strategy, and effective quarantine systems, may become especially important (Rocklöv & Dubrow, 2020).

Conclusion

Climate change is a natural phenomenon with diverse effects, and agriculture is a significant component directly tied to both livelihoods and a major economic factor. Establishing trials to breed cultivars resistant to adaptability is essential, especially in areas where their effectiveness is most pronounced. Exotic pathogens are identified as a primary factor contributing to the emergence of diseases. Hence, it is crucial to build and strengthen barriers preventing the introduction of exotic infections, create tools for swift diagnosis of new diseases, and provide training for technical personnel to proficiently apply these techniques once implemented.

Conflict of Interests

The authors have not declared any conflict of interest.

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Data generated and analyzed during the current study are included in the body of this paper.

Authors Biography
All authors are MSc. Graduates from Africa Center of Excellence for Climate-Smart Agriculture and Biodiversity Conservation, College of Agriculture and Environmental Sciences, Haramaya University.

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