Proceedings of ICEGEE 2025 Symposium: Impact of Technological Innovation on Energy Efficiency in European Countries
DOI: 10.54254/2753-8818/2025.MUR24070

Impact of Climate Change on the Distribution of Crop Diseases: A Case Study of Corn Smut

Yuxin Li

College of Plant Protection, South China Agricultural University, Guangzhou, China
1771302538@qq.com

Abstract: The shifts of the climate system, driven by rising temperatures, disrupted rainfall patterns, and increased extreme weather events, highlights the influence of global climate change. These changes strongly affect climate-sensitive agricultural systems. As a major global staple, corn is essential to food security and highly vulnerable to climate variability. However, corn cultivation is challenged by corn smut, a serious disease that reduces both yield and quality. As climate change intensifies, the occurrence patterns and severity of corn smut may shift, presenting new challenges for corn cultivation as well as disease prevention and control. Thus, this paper explores the mechanism of climate change in the agricultural ecosystem, its impact on the epidemiological characteristics of corn smut, and expounds on the challenges and strategies for its prevention and control under the background of climate change. The results indicate that climate change impacts the distribution, epidemic intensity, and transmission pathways of corn smut by altering factors like temperature, precipitation, and humidity. To effectively address these issues, it is essential to refine existing strategies, build climate-based early warning systems, adopt climate-smart farming technologies, and advance research into biological control.

Keywords: Climate Change, Corn Smut, Crop Disease Distribution, Prevention and Control Strategies

1. Introduction

In Northeast China, the influences of climate change are especially pronounced, with temperature increases exceeding the global average rise of 0.74°C observed over the past century [1]. This has had a severe impact on the agricultural ecosystem and the occurrence of crop diseases. Currently, though there are some studies on specific regions and individual meteorological factors in this field, research on the combined effects of multiple climatic variables and the ecological heterogeneity of specific diseases remains limited. As a staple food crop worldwide, corn is adversely affected by corn smut, which significantly reduces its productivity and quality [2,3]. As such, the paper seeks to clarify the influence of climate change on the distribution and epidemiology of corn smut. It focuses on the pathogen's response to multiple climate variables, the variability of epidemic patterns across climatic conditions, and the assessment of current disease management strategies in terms of their effectiveness and limitations. Investigating how climate change influences plant pathogens and crop disease risks offers valuable insights, forming a critical foundation for analyzing the dynamics of corn smut in a changing climate. Meanwhile, in Africa, various pathogens have caused significant losses to cereal production, highlighting the urgency of studying the relationship between corn smut and

© 2025 The Authors. This is an open access article distributed under the terms of the Creative Commons Attribution License 4.0 (https://creativecommons.org/licenses/by/4.0/).

DOI: 10.54254/2753-8818/2025.MUR24070

climate change to ensure food security [4]. Employing a mixed-methods approach based on meteorological and disease data, it aims to enhance agricultural disease control, promote sustainable farming practices, and inform future research on similar plant diseases.

2. Impact of climate change on agricultural diseases

2.1. Ecological consequences of climate change in agriculture

The global climate pattern has undergone substantial alterations due to climate change, particularly in critical factors such as temperature, precipitation, and humidity. These shifts have considerably influenced the agricultural production environment. Notably, a consistent global warming trend has been observed. In Heilongjiang Province, for example, the average temperature during the maize growing season has increased by 1.89 °C per decade [1]. Elevated temperatures alter the timing and progression of key crop growth stages. In parts of Heilongjiang, rising temperatures have advanced the average sowing date of corn by 3-5 days, and prolonged the flowering period by 2-3 days, thus resulting in a 10-15% reduction in yield and a decline in grain quality [2]. The shift in precipitation patterns has introduced additional challenges, notably a roughly 20% decline in total rainfall in parts of North China over the past decade. Drought has led to an approximate 30% reduction in crop yields. In contrast, several southern regions have experienced more intense rainfall events, with rainstorm-induced flooding impacting up to 15% of cultivated land. These flood events have caused oxygen deficiency in crop root zones, contributing to substantial yield losses [5]. Humidity changes should not be overlooked, as high humidity creates favorable conditions for pathogen development. For instance, in greenhouse environments where humidity consistently exceeds 80%, the incidence of diseases like powdery mildew and downy mildew increases by over 50% compared to conditions with normal humidity. The combined effects of these climate factors disrupt agroecological balance, modify crop growth conditions, weaken disease resistance, and substantially raise disease risk [6].

2.2. Underlying mechanism of climate change and disease occurrence

Through its influences on pathogens, host plants, and transmission routes, climate change plays a critical role in promoting the development and dissemination of crop diseases. Temperature and humidity affect pathogenic microorganisms in varying ways, as different pathogens display distinct responses to changes in these climatic conditions. For example, the reproduction cycle of Ustilago maydis, the pathogen responsible for corn smut, is shortened by approximately 30% at temperatures between 26 °C and 30°C compared to lower temperature conditions. The spore germination rate of the pathogen of powdery mildew is approximately 5 times higher when the humidity is above 80% than when it is below 50%. Evidently, favorable temperature and humidity conditions can markedly enhance the reproduction and transmission of pathogenic microorganisms. Host plants' growth and immunity are impaired under adverse climate conditions. For example, under high-temperature and drought conditions, the photosynthesis efficiency of corn is reduced by 30%-40%. Also, the growth and development of corn plants are inhibited, and their immune responses are weakened, making them more vulnerable to pathogen attacks. In terms of transmission methods, strong winds in wind - borne transmission can carry pathogen spores farther [7]. In the context of insect-borne transmission, a temperature increase of 2 to 3°C combined with adequate precipitation can cause a higher number of aphid generations and an expanded activity range, thereby elevating the risk of crop infection.

2.3. Disease-specific responses to climate change in agriculture

The influences of climate change on crop diseases vary in severity across different pathogens. For example, the increasing frequency of high-temperature and high-humidity conditions has favored the

DOI: 10.54254/2753-8818/2025.MUR24070

occurrence of rice blast, with global warming in recent years facilitating the expansion of its geographic distribution. Corn wilt is primarily influenced by drought conditions. Insufficient water availability increases the plant's susceptibility to infection, ultimately leading to yield reduction. Similarly, corn smut is highly sensitive to climatic factors and is significantly affected by climate change. Higher temperatures enhance the overwintering survival rate of the pathogen and may lead to an expansion of its suitable habitat range, whereas altered precipitation patterns influence its transmission dynamics. For example, a climate with high temperature in the early stage and drought in the later stage is conducive to the outbreak of the disease, and extreme precipitation events may accelerate the spread of the pathogen [8,9]. Elevated temperatures can improve overwintering survival rates, thereby enlarging the pathogen reservoir and elevating the risk of disease occurrence. At the same time, changes in the precipitation pattern will also affect the occurrence of corn smut. For example, climatic conditions characterized by high temperatures in the early stage and drought in the later stage favor the development of corn smut, while excessive precipitation can facilitate pathogen dispersal via rainwater, expanding the infection range. With the progression of global climate change, the epidemiological patterns of corn smut are likely to become more intricate and unpredictable. Further temperature increases may shift the distribution of corn smut northward, allowing the disease to emerge in regions previously unsuitable for pathogen survival. Changes in precipitation may lead to an increase in the occurrence frequency and severity of the disease. In wet years, the pathogen spreads more rapidly and infection rates rise, while in drought years, reduced plant vigor and lower resistance also amplify disease risk. Besides, the rising frequency of extreme weather events may further intensify corn smut epidemics, threatening crop yields.

3. Epidemiological characteristics of corn smut and climate factors

3.1. Basic characteristics and transmission routes of corn smut

Corn smut is a significant plant disease caused by the basidiomycete fungus Ustilago maydis. Under optimal environmental conditions, notably 26-30°C and sufficient humidity, teliospores germinate into basidiospores, which give rise to secondary basidiospores capable of penetrating young corn tissues via various infection routes. Upon contact with the host, these spores germinate and generate infection hyphae that penetrate the epidermis and proliferate within the plant tissue. The progression of the pathogen within host tissues leads to the formation of tumor-like galls at infected sites. These galls contain large quantities of black smut spores, which are released upon rupture of the diseased tissue, becoming new main inoculum sources. The manifestation of corn smut is determined by the affected plant tissue. Infected leaves develop early chlorotic lesions that progress into hypertrophic galls, which rupture and release spores. Galls may also develop on stems, potentially disrupting the translocation of water and nutrients. However, the most severe symptoms occur on the ears, where the entire ear may become deformed and swollen into large smut masses. This greatly reduces yield and destroys commercial value, rendering the ears unsuitable for consumption or processing [8]. The disease is transmitted through diverse mechanisms such as airborne spores, insect carriers, and contaminated seed stock. Among them, wind transmission is the most prevalent and impactful in the field. Smut spores spread locally via light breezes and over long distances by stronger winds, facilitating widespread disease transmission. Insect-mediated transmission also occurs, particularly via aphids and leafhoppers, which transfer spores to healthy plants after feeding on infected ones. In addition, seed transmission represents another potential source of early infection, as teliospores on seed surfaces can infect seedlings after sowing and lead to early disease outbreaks.

DOI: 10.54254/2753-8818/2025.MUR24070

3.2. Effects of climate factors on the distribution of corn smut

Long-term trends in temperature, precipitation, and humidity are key climatic drivers influencing the geographic distribution and epidemic severity of corn smut. The advancement of climate change is redefining the geographic distribution and seasonal dynamics of disease emergence via changes in environmental factors. Temperature critically impacts the growth and pathogenicity of Ustilago maydis, with optimal activity from 26 to 30°C [10]. As average regional temperatures approach this optimal range, fungal activity and infection rates increase, causing more severe disease outbreaks. In Northeast China, rising mean annual temperatures in southern low-latitude areas have promoted pathogen development and increased disease prevalence, while formerly cooler northern regions are now experiencing a gradual northward expansion of corn smut. In addition, precipitation mainly affects the field-level dispersal of smut spores. In years of excessive rainfall, raindrop splashes and surface runoff facilitate teliospore spread to nearby plants or soil, thus expanding the infection area. In both Northeast China and the U.S. Midwest, extreme precipitation events in certain years have significantly facilitated the spread and intensified the impact of local epidemics. In contrast, despite reduced spore dispersal during drought, water stress compromises corn plant resistance,heightening disease susceptibility. Besides, high humidity promotes spore germination by retaining moisture on plant surfaces, which facilitates pathogen penetration and increases infection success. When relative humidity exceeds 80%, the germination rate of U. maydis spores increases markedly, and recent upward humidity trends in some regions have further intensified the risk of primary infections. More broadly, global warming is shifting the suitable habitat for corn smut to higher latitudes and elevations, driving a clear range expansion. Meanwhile, increased precipitation variability has made local outbreaks more unpredictable. In the U.S. Midwest, rapid spring warming and rainfall, like in 2018, advanced outbreaks by 1-2 weeks and increased intensity by 25%. Drought years, such as 2022, weakened plant resistance, worsening disease impact and yield loss.

3.3. Extreme climate events as accelerators of corn smut epidemics

The incidence and severity of corn smut can be notably intensified by short-term climatic extremes like heatwaves, heavy rainfall, droughts, and typhoons via their disruption of plant physiological responses and pathogen dissemination processes.

Moderate heat stress promotes the reproduction of Ustilago maydis, increasing the inoculum load in the field. At the same time, elevated temperatures disrupt plant metabolism and weaken defenses, increasing susceptibility to infection. Heavy rainfall accelerates spore dissemination through splash dispersal and runoff. Besides, excessive soil moisture can lead to root hypoxia, weakening plant vigor and disease resistance. In 2021, successive heavy rains during tasseling triggered widespread corn smut outbreaks in Jilin, with infection rates exceeding 40% in severely affected fields. Though drought restricts spore mobility, it hinders plant growth, disrupts rhizosphere balance, and weakens natural defenses. Furthermore, drought stress often increases the activity of insect vectors, indirectly enhancing disease spread. In 2022, a severe drought in parts of Inner Mongolia was associated with a sharp increase in corn smut incidence, as weakened plant defenses and high vector activity created favorable conditions for infection. Typhoons facilitate long-distance spore dispersal through strong winds and torrential rains, while the ensuing high humidity boosts infection potential. In southern China, typhoon-related weather in late summer has repeatedly been linked to sudden spikes in corn smut outbreaks. Despite the sporadic nature of these extreme events, their frequency and intensity are increasing under the context of global climate change, making it essential to integrate them into disease forecasting and control systems to improve crop management resilience.

DOI: 10.54254/2753-8818/2025.MUR24070

4. Challenges and strategies for managing corn smut under climate change

4.1. Multidimensional challenges of climate change to corn smut management

In recent years, accelerating global climate change has profoundly complicated the epidemiology and management of corn smut. Increasing thermal stress, precipitation anomalies, and the escalation of extreme climatic events have collectively reshaped the pathogen's physiological responses and ecological adaptability. As a result, the unpredictability of outbreak timing, transmission dynamics, and severity has intensified, compromising conventional management frameworks that depend on historical regularities and static agricultural scheduling.

One significant challenge lies in the decoupling of the synchrony between pathogen development and crop phenology. In many regions, the timing of corn smut outbreaks has shifted unpredictably, hence leading to mistimed interventions and reduced control efficacy. Moreover, extreme weather exacerbates the scale and frequency of epidemics. For instance, heavy rainfall raises soil moisture levels, promoting spore germination and dispersal; drought reduces plant physiological vigor and impairs immune responses; while typhoons contribute to rapid pathogen dissemination through strong winds and high humidity. Existing early warning systems are increasingly constrained by rapidly shifting environmental variables, limiting their predictive accuracy and operational utility. Unstable meteorological data, rapid pathogen adaptation, and time-lagged model parameters all constrain prediction accuracy. Further complicating disease management is the constrained ability of smallholder farmers to recognize and effectively respond to climate-driven changes in pathogen behavior. Due to restricted access to timely information and adaptive technologies, many farmers are unable to adjust their management practices proactively, thereby increasing crop vulnerability.

4.2. Structural limitations and diminishing efficacy of traditional control methods

The effectiveness of conventional corn smut management strategies, including agronomic measures, chemical control, and the use of resistant cultivars, is increasingly limited by accelerating climate change. Though historically effective, these strategies are now limited in scope and effectiveness amid evolving environmental pressures.

In agricultural management, the effectiveness of practices like crop rotation, removal of diseased residues, and optimal planting density depends on the controllability of soil and climatic conditions. The effectiveness of these practices declines sharply under prolonged drought or excessive rainfall, conditions which also predispose fields to heightened disease pressure through impaired residue breakdown and disrupted planting schedules. Chemical control, while capable of reducing pathogen loads in the short term, suffers from limited persistence. The leaching effect of heavy rain and the limited bioavailability under drought conditions both undermine fungicide performance. In addition, environmental concerns and the emergence of fungicide-resistant strains further compromise the long-term effectiveness of this strategy. While resistance breeding has historically mitigated corn smut, the pace of traditional methods falls short of the rapid genetic shifts occurring in pathogen populations. Recent studies demonstrated that smut fungi are more prone to genetic variation under high-temperature and high-humidity conditions, thus increasing the risk of resistance breakdown in once-effective cultivars. The deployment of integrated, climate-responsive approaches has become increasingly critical as climatic pressures drive rapid pathogen evolution and erode the effectiveness of conventional defenses.

4.3. Climate-adapted innovations and future prospects for integrated disease management

To manage corn smut effectively amid rapid climate change, it is crucial to transition from reactive to proactive strategies by incorporating advanced technologies, cross-disciplinary approaches, and

DOI: 10.54254/2753-8818/2025.MUR24070

supportive policies to build a resilient, sustainable control system. In particular, the development of climate-informed early warning systems should be prioritized. Integrating detailed climate data with disease models enables early detection of high-risk areas and timeframes. Technologies like remote sensing, AI, and in-field sensors turn forecasts into actionable guidance for farmers. Moreover, to adapt crop management to increasing environmental variability, it is vital to promote climate-smart practices. By utilizing precision agriculture tools such as variable-rate systems, sensors, and remote sensing, resource efficiency is improved, and crop resilience is strengthened. Besides, adapting crop rotations and agronomic practices to climate changes can also limit pathogen persistence in the soil. In the realm of plant breeding, gene editing technologies such as CRISPR offer substantial promise. In contrast to conventional breeding, gene-editing tools offer precise control over resistance traits, facilitating the swift development of cultivars with broad-spectrum resistance aligned with evolving pathogenic and climatic challenges. These are key to long-term field resilience. At the same time, biological control should be a crucial part of integrated management. The ecological antagonism of beneficial microorganisms, natural predators, and microbial metabolites offers a viable, sustainable substitute for conventional chemical control. Under climatic stress, resilient soil and phyllosphere microbiomes help control pathogens by outcompeting them for resources or releasing inhibitory compounds, offering sustainable disease management. Furthermore, robust farmer education and supportive policies are crucial for promoting technology adoption and enhancing adaptive resilience. Climate-resilient disease management relies on both innovation and broad implementation. Training, incentives, and digital tools help farmers make timely decisions and adopt new technologies for climate-related crop diseases.

5. Conclusion

The study revealed that climate change impacts the growth, reproduction, and spread of corn smut pathogens by altering temperature, precipitation, and humidity, thus leading to more complex and unpredictable disease outbreaks. Traditional prevention and control strategies, including agricultural management, chemical treatments, and the use of disease-resistant varieties have lost effectiveness due to the rising frequency of extreme weather events and pathogen evolution. Future research should bridge climate-smut dynamics to actionable solutions by translating interaction studies into precision forecasting frameworks, implementing forecast-informed adaptive agricultural practices, utilizing insights to engineer climate-resilient CRISPR-edited cultivars, and strategically integrating biocontrol measures, thus establishing a cohesive strategy to mitigate climate-driven yield volatility in maize production systems.

References

[1] *Wang, S., Shi, F.M., Pei, Z.J., et al. (2019). Impact of climate change on the occurrence of corn diseases and insect pests in Heilongjiang Province. Heilongjiang Agricultural Sciences, (06), 20-26.*

[2] *Wang, L., Huo, Z.G., Zhang, L., et al. (2012). Impact of climate change on the occurrence of crop diseases in China. Chinese Journal of Ecology, 31(7), 1673-1684. https://doi.org/10.13292/j.1000-4890.2012.0282*

[3] *Jian, G.L., Qi, F.J. and Zhang, W.W. (2011). Impact of climate change on plant diseases. Modern Agricultural Science and Technology, (07), 148, 150.*

[4] *Juroszek, P., Racca, P., Link, S., et al. (2019). Overview on the review articles published during the past 30 years relating to the potential climate change effects on plant pathogens and crop disease risks. Plant Pathology, 69(1), 179-193.*

[5] *Yao, Y.P., Zhu, Y.G. and Chu, H.Y. (2024). Strengthening the innovation and breakthrough of plant pathogenic fungi control technologies under the background of climate change. Journal of Agro-Environment Science, 43(3), 473-475.*

[6] *Feng, G.M. (2014). Identification and diagnosis of infectious crop diseases. Rural Science & Technology, (23), 24. https://doi.org/10.19345/j.cnki.1674-7909.2014.23.021*

[7] *Ning, R. (2022). Occurrence and prevention of corn head smut and silk smut. Modern Agriculture, (17), 13-14.*

DOI: 10.54254/2753-8818/2025.MUR24070

[8] Wang, Z.H., et al. (2002). Research progress on corn silk smut. Journal of Maize Sciences, (04), 61-64.
[9] Jin, Q.M., Wang, X.M., Wang, Z.Y., et al. (2003). Causes and countermeasures for the outbreak of corn silk smut in the spring maize region of Northeast China. Journal of Maize Sciences, (01), 86-87.
[10] Benjamin, J., Oyedokun, D.O., Oziegbe, E.V., et al. (2024). Cereal production in Africa: The threat of current plant pathogens in changing climate-A review. Discover Agriculture, 2(33), 1-24.