

Spatiotemporal Dynamics of Fungal Disease Incidence, Severity, and Prevalence in maize across Dry and Wet Seasons in the Hadejia Agroecological Zone, Nigeria

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ABSTRACT

Maize (Zea mays L.) is a key staple crop in sub-Saharan Africa, yet its productivity is frequently constrained by fungal diseases that affect plant health, grain yield, and quality. Understanding the spatial and seasonal dynamics of these diseases is essential for developing effective management strategies in maize-based farming systems. This study investigated the spatiotemporal dynamics of fungal disease incidence, severity, and prevalence in maize farms across five maize-producing villages Ganuwar Kuka, Gatafa, Gudunchin, Jiyan, and Turabu in the Hadejia agroecological zone of Jigawa State, Nigeria. Field surveys were conducted during the dry and wet seasons of 2022 and 2023 using a repeated cross-seasonal survey approach. Disease incidence, severity, and prevalence were assessed through field observations of symptomatic plants and analyzed using analysis of variance with mean separation by the Least Significant Difference test at the 5% probability level. The results showed significant variation in disease parameters across locations and seasons. In 2022, fungal disease incidence ranged from 26.3% in Gatafa to 46.9% in Turabu during the dry season, while wet-season incidence ranged from 23.3% in Jiyan to 40.0% in Ganuwar Kuka. In 2023, incidence values increased, reaching 48.7% in Jiyan and 47.4% in Gatafa during the wet season. Disease severity followed similar patterns, with maximum severity values of 48.7% recorded in Jiyan (2022 wet season) and 44.4% in Turabu (2023 dry season). Disease prevalence also varied significantly, ranging from 13.1% to 47.7% across seasons and locations. These findings demonstrate pronounced spatial and seasonal variability in maize fungal diseases in the Hadejia area and highlight the need for location-specific and season-sensitive disease management strategies to enhance sustainable maize production.

Keywords: Maize fungal diseases, disease incidence, spatiotemporal disease severity, Sudan

INTRODUCTION

Maize (*Zea mays* L.) is one of the most important cereal crops globally and plays a crucial role in food security, nutrition, and rural livelihoods, particularly in developing regions such as sub-Saharan Africa. The crop serves as a

major staple food for millions of people and provides essential raw materials for animal feed, agro-industries, and biofuel production. In Nigeria and many other African countries, maize production has expanded significantly in

savanna agroecology



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recent decades due to its high yield potential, adaptability to diverse agroecological zones, and increasing demand for food and feed products (Benjamin et al., 2024). Despite its economic and nutritional importance, maize productivity remains constrained by several biotic and abiotic stresses, among which plant diseases represent a major limiting factor. Among these diseases, fungal pathogens are considered particularly destructive because they can infect maize plants at different growth stages and cause significant yield and quality losses. Numerous fungal pathogens including *Fusarium* spp., *Aspergillus* spp., *Exserohilum turcicum*, *Cercospora zeina*, and *Bipolaris maydis* are widely reported to infect maize crops worldwide and are capable of causing foliar blights, stalk rots, and ear rots that reduce both grain yield and market quality (Nsibo et al., 2024; Deressa et al., 2025). In addition to direct yield losses, many of these pathogens produce harmful mycotoxins that contaminate maize grains and pose serious risks to human and livestock health. For example, *Fusarium* species are known producers of fumonisins and other toxins that can accumulate in maize during field infection or storage, creating significant food safety concerns in maize-dependent regions (Hudu et al., 2024; Thierry et al., 2025). Recent global analyses indicate that fungal diseases can reduce maize yields by 10–30% under moderate infection conditions, while severe outbreaks may cause much greater losses, especially in tropical agricultural systems where environmental conditions favor pathogen development (Benjamin et al., 2024; Cui et al., 2024). As a result, understanding the epidemiology and distribution of fungal diseases in maize production systems has become increasingly important for developing sustainable crop protection strategies.

The occurrence and severity of fungal diseases in maize are strongly influenced by environmental conditions, host plant susceptibility, and pathogen population dynamics. Disease development is often determined by the interaction between the host plant, the pathogen, and the environment, a relationship commonly described as the disease triangle in plant pathology. In many maize-growing regions of the world, especially in tropical and subtropical climates, seasonal variations in temperature, humidity, and rainfall create favorable conditions for fungal pathogen growth and dissemination. Studies have shown that warm temperatures combined with high humidity levels during the rainy season significantly enhance the germination and spread of fungal spores, resulting in increased disease incidence and severity in maize fields (Nsibo et al., 2024; Abera et al., 2025). In contrast, dry environmental conditions may limit the spread of some pathogens but can also favor other fungal species capable of surviving under moisture stress or infecting weakened plants. Consequently, seasonal fluctuations often lead to substantial variations in disease incidence and severity across cropping cycles. Several recent epidemiological studies have demonstrated that the spatial and temporal

distribution of maize fungal diseases is highly dynamic and can vary considerably among locations even within the same agroecological zone (Deressa et al., 2025; Cui et al., 2024). Differences in soil characteristics, cropping systems, maize varieties, planting dates, and farm management practices further contribute to these variations. For instance, field surveys in African maize-growing regions have shown that foliar diseases such as northern corn leaf blight and gray leaf spot often exhibit uneven spatial distribution across farms due to microclimatic differences and variations in host resistance (Abera et al., 2025). Similarly, ear rot pathogens such as *Fusarium* and *Gibberella* species have been reported to display strong seasonal patterns related to rainfall distribution and crop phenology (Hunde, 2025). These findings highlight the importance of spatiotemporal disease surveillance in understanding pathogen dynamics and guiding effective disease management strategies. Monitoring disease incidence, severity, and prevalence across locations and seasons can provide valuable insights into how fungal pathogens respond to environmental conditions and agricultural practices.

In Nigeria, maize is cultivated across several agroecological zones, including the Sudan savanna region, where climatic conditions and farming practices may significantly influence disease development. The Sudan savanna zone is characterized by distinct dry and wet seasons, moderate rainfall, and relatively high temperatures, conditions that can affect both maize growth and the proliferation of fungal pathogens. Although maize is widely grown in northern Nigeria, limited information exists regarding the spatial and seasonal dynamics of fungal diseases in many local production systems. Previous studies have indicated that fungal pathogens are responsible for substantial crop losses in maize fields across West Africa, yet detailed field-based epidemiological data from specific agroecological zones remain scarce (Benjamin et al., 2024; Thierry et al., 2025). Moreover, climate variability and changing agricultural practices may further alter the distribution and severity of maize diseases over time. Climate-driven changes in rainfall patterns and temperature regimes have been reported to influence fungal pathogen populations and increase the frequency of disease outbreaks in cereal crops (Gbashi et al., 2024). Consequently, localized studies that evaluate disease patterns across seasons and production environments are essential for improving disease forecasting and developing targeted management strategies. Assessing disease incidence, severity, and prevalence across multiple locations provides a more comprehensive understanding of the epidemiological status of fungal pathogens within maize production systems. Such information is particularly valuable for identifying high-risk areas, evaluating the influence of environmental factors on disease development, and supporting the design of integrated disease management programs. Therefore, the present study aimed to

investigate the spatiotemporal dynamics of fungal disease incidence, severity, and prevalence in maize across dry and wet seasons in the Hadejia agroecological zone of Jigawa State, Nigeria. By examining disease patterns across multiple villages and cropping seasons, the study provides important baseline data that can contribute to improved disease monitoring and sustainable maize production in the region.

MATERIALS AND METHODS

Study area

The study was carried out in five maize-growing villages in the Hadejia area of Jigawa State, Nigeria: Ganuwar Kuka, Gatafa, Gudunchin, Jiyar, and Turabu. Hadejia lies within the Sudan savanna agroecological zone and features distinct dry and wet seasons, making it ideal for assessing seasonal changes in fungal disease occurrence in maize farming systems. Field assessments were conducted during the 2022 and 2023 growing seasons under both dry and wet season conditions.

Study design and field survey

A repeated cross-seasonal field survey design was used to study the distribution of fungal diseases in maize across different locations and seasons. Surveys took place in each of the five villages during the dry and wet cropping seasons of 2022 and 2023. Maize farms chosen for assessment were visited during the peak crop growth period when disease symptoms were clearly visible for field diagnosis. To ensure consistent observations across years and seasons, the same assessment procedures, symptom recognition criteria, and scoring methods were applied at all surveyed sites.

Disease assessment and Disease incidence

Field assessment focused on visible fungal disease symptoms displayed on maize leaves, stems, ears, and cobs. For each surveyed field, both symptomatic and non-symptomatic plants were examined and recorded, and disease observations were compiled by location and season. Three epidemiological parameters were assessed: disease incidence, disease severity, and disease prevalence (Aliyi., 2018). Disease incidence was calculated as the proportion of assessed maize plants showing visible fungal symptoms relative to the total number of plants examined, expressed as a percentage.

$$\text{Disease incidence (\%)} = \frac{\text{Number of infected plants}}{\text{Total number of plants assessed}} \times 100$$

Disease severity

Disease severity was visually estimated based on the extent of fungal symptoms on infected plant parts and expressed as a percentage severity. Severity values were determined by the observable degree of tissue damage on affected plants, using a standardized field rating approach applied consistently across all study sites (Bock *et al.*, 2022). Where a percentage-based field estimate rather than ordinal scores was used, severity indicated the average percentage of plant tissue affected by disease symptoms within each sampling unit.

Disease prevalence

Disease prevalence was determined as the proportion of surveyed farms in which fungal disease symptoms were detected within a given location and season, expressed as a percentage:

$$\text{Disease prevalence (\%)} = \frac{\text{Number of fields with disease presence}}{\text{Total number of fields surveyed}} \times 100$$

Data analysis

Data generated for fungal disease incidence, severity, and prevalence were subjected to analysis of variance to test for differences among locations within each season and year. Mean separation was performed using the Least Significant Difference test at the 5% probability level. Results were presented as mean values in tabular form, and means followed by the same letter within a column were considered not significantly different at $P \leq 0.05$.

Quality control and consistency of assessment

To reduce observer bias and enhance the reliability of field data, disease assessment criteria were standardized prior to field scoring, and the same observational framework was used throughout all survey periods. Assessments were performed carefully and consistently in all villages to ensure that differences in disease estimates reflected actual field conditions rather than variations in the scoring process.

RESULTS

Fungal Pathogens Disease Incidence and Severity in Hadejia Area Maize Farms under Dry and Wet Seasons Farming in 2022 and 2023

Fungal Disease Incidence

The results of fungal disease incidence observed on maize farms in selected villages of the Hadejia area during the

dry and wet seasons of 2022 and 2023 are presented in (Table 1). The findings show that the incidence of fungal diseases varied by location and season over the two-year period. In the 2022 dry season, Turabu village had the highest incidence (46.9), followed by Jiyan (41.3) and Ganuwar Kuka (38.3), while Gatafa had the lowest incidence (26.3). During the same year's wet season, Ganuwar Kuka recorded the highest incidence (40.0), with Gatafa (36.4) and Gudunchin (35.4) following, whereas Jiyan (23.3) and Turabu (26.3) had lower incidence rates. In the 2023 dry season, Gudunchin and Turabu showed the highest incidence (40.0 each), followed by Gatafa (36.8), while Jiyan (31.4) and Ganuwar Kuka (32.1) experienced lower levels. During the 2023 wet season, Jiyan (48.7) and Gatafa (47.4) had the highest incidence, followed by Gudunchin (44.0) and Turabu (42.2), with Ganuwar Kuka recording the lowest incidence (38.2). The LSD values indicate statistically significant differences among locations at $P \leq 0.05$.

Fungal Disease Severity

The results of fungal disease severity in maize farms across the chosen villages of the Hadejia area during the dry and wet seasons of 2022 and 2023 are shown in (Table 2). The results indicate that fungal disease severity varied among the villages during the study period. In the 2022 dry season, Turabu and Gudunchin had the highest severity scores (40.0 each), followed by Gatafa (36.8), while Ganuwar Kuka (32.1) and Jiyan (31.4) had the lowest severity levels. In the 2022 wet season, Jiyan (48.7) and Gatafa (47.4) recorded the highest severity scores, followed by Gudunchin (44.0) and Turabu (42.2), whereas Ganuwar Kuka had the lowest severity score (38.2). During the 2023 dry season, Turabu had the highest severity (44.4), followed by Gudunchin (40.0), with Gatafa (35.2), Jiyan (31.4), and Ganuwar Kuka (27.9) showing lower severity levels. In the 2023 wet season, Gudunchin and Jiyan reported the highest severity scores (42.6 each), followed by Turabu (40.0), and while Gatafa had moderate severity (35.2) and Ganuwar Kuka had the lowest (30.0). The LSD values show significant differences among locations at $P \leq 0.05$.

Fungal Disease Prevalence

The results of fungal disease prevalence in maize farms across selected villages in the Hadejia area during the dry and wet seasons of 2022 and 2023 are shown in (Table 3). The findings reveal variations in disease prevalence among locations and seasons. In the 2022 dry season, Ganuwar Kuka (47.7) and Jiyan (46.3) had the highest prevalence, followed by Gatafa (37.4) and Turabu (37.1), while Gudunchin recorded the lowest prevalence at 25.1. During the 2022 wet season, Turabu had the highest prevalence at 34.4, with Jiyan at 31.3, whereas Ganuwar Kuka (29.7) and Gatafa (34.4) showed moderate levels,

and Gudunchin had the lowest at 21.3. In the 2023 dry season, Gudunchin had the highest prevalence of 24.2, followed by Gatafa with 17.3 and Turabu with 17.1, while Jiyan (29.7) and Ganuwar Kuka (25.5) recorded the lowest values. In the 2023 wet season, Gudunchin again had the highest prevalence at 24.2, followed by Gatafa at 24.1, with Ganuwar Kuka (20.9) and Jiyan (19.6) showing moderate levels, and Turabu recording the lowest at 17.9. The LSD values indicate that the differences among the villages were statistically significant at $P \leq 0.05$.

DISCUSSION

The results of this study showed differences in fungal disease incidence, severity, and prevalence across the selected maize farms in the Hadejia area during the dry and wet seasons of 2022 and 2023. These differences among locations and seasons suggest that environmental conditions, cropping practices, and pathogen distribution significantly influence the occurrence of fungal diseases in maize farms. Similar variations in disease incidence and severity among various locations and seasons have been reported in numerous maize disease surveys conducted in Africa and other maize-producing regions. For example, studies on maize ear rot and foliar diseases have demonstrated that disease occurrence often varies by location due to differences in climate, crop varieties, and agricultural practices (Opande et al., 2022). The higher incidence observed in some villages during the wet seasons may be linked to favorable environmental conditions that promote fungal growth and infection. Moisture and moderate temperatures during rainy seasons typically support the germination and spread of fungal spores on maize plants. Past research has shown that fungal pathogens such as *Exserohilum turcicum*, *Cercospora zeina*, and *Bipolaris maydis* flourish in humid conditions and can cause serious foliar diseases in maize fields across sub-Saharan Africa (Nsibo et al., 2024). The impact of seasonal weather conditions on disease incidence has also been noted in surveys where maize disease rates increased significantly during rainy seasons compared to dry seasons (Yusif et al., 2025).

The observed differences in disease severity across locations may be linked to the susceptibility of maize varieties cultivated in the study area and the presence of various fungal pathogens. Several fungal pathogens, including *Fusarium*, *Aspergillus*, *Stenocarpella*, and *Gibberella* species, are known to infect maize and cause severe symptoms such as ear rot and leaf blight (Opande et al., 2017). These pathogens can weaken plants, reduce grain quality, and produce harmful mycotoxins that threaten food safety and livestock health. Variations in disease prevalence among villages may also be influenced by agricultural practices such as planting dates, crop rotation, plant density, and field sanitation. Studies have shown that management practices and cultivation systems significantly impact the occurrence of fungal

Table 1: Fungal Disease Incidence in Maize Farms in 2022–2023 Dry and Wet Seasons in Hadejia Area.

LOCATION	2022 DRY SEASON	2022 WET SEASON	2023 DRY SEASON	2023 WET SEASON
GANUWAR KUKA	38.3ab	40.0a	32.1b	38.2a
GATAFA	26.3c	36.4a	36.8ab	47.4a
GUDUNCHIN	31.5b	35.4a	40.0a	44.0ab
JIYAN	41.3ab	23.3b	31.4b	48.7a
TURABU	46.9a	26.3b	40.0a	42.2ab
LSD $P \leq 0.05$	10.10	6.52	7.02	8.46

Values within columns followed by the same letters are not significantly different at $P \leq 0.05$ according to LSD.

Table 2: Fungal Disease Severity in Maize Farms in 2022–2023 Dry and Wet Seasons in Hadejia Area.

LOCATION	2022 DRY SEASON	2022 WET SEASON	2023 DRY SEASON	2023 WET SEASON
GANUWAR KUKA	32.1b	38.2b	27.9d	30.0cd
GATAFA	36.8ab	47.4a	35.2b	35.2b
GUDUNCHIN	40.0a	44.0ab	40.0ab	42.6a
JIYAN	31.4b	48.7a	31.4c	42.6a
TURABU	40.0a	42.2ab	44.4a	40.0ab
LSD ($P \leq 0.05$)	7.02	8.46	6.62	6.70

Values within columns followed by the same letters are not significantly different at $P \leq 0.05$ according to LSD.

Table 3: Fungal Disease Prevalence in Maize Farms in 2022–2023 Dry and Wet Seasons in Hadejia Area.

LOCATION	2022 DRY SEASON	2022 WET SEASON	2023 DRY SEASON	2023 WET SEASON
GANUWAR KUKA	47.7a	29.7b	13.1c	20.9c
GATAFA	37.4b	25.5c	17.3b	24.1b
GUDUNCHIN	25.1c	21.3d	24.2a	28.7a
JIYAN	46.3a	31.3ab	13.2c	19.6cd
TURABU	37.1b	34.4a	17.1b	17.9d
LSD $P \leq 0.05$	6.47	3.48	2.472	2.576

Values within columns followed by the same letters are not significantly different at $P \leq 0.05$ according to LSD.

diseases in maize fields. For example, maize grown under different cropping systems may face varying levels of fungal infection depending on field management and environmental conditions (Kowalska et al., 2022).

Furthermore, fungal diseases are some of the most damaging constraints to maize production worldwide and can cause significant yield losses if not properly controlled. Charcoal rot caused by *Macrophomina phaseolina* has been reported to lead to yield reductions of up to 25–33% in maize during severe infections (Oder et al., 2025). Similarly, other fungal diseases such as late wilt and *Fusarium* wilt have been linked to decreased maize productivity by causing plant death, poor grain formation, and crop quality decline (Adedire et al., 2023; Degani et al., 2024). The differences in incidence, severity, and prevalence observed in this study underscore the impact of environmental factors and pathogen diversity on maize disease patterns. Epidemiological research indicates that disease development in crop fields is often influenced by the interaction between the host plant, the pathogen, and environmental conditions. When favorable environmental factors align with susceptible hosts and high levels of inoculum, disease outbreaks can happen quickly and spread across fields (Soonthompoc et al., 2001). Additionally, surveys in various maize-growing regions have found that disease distribution is often uneven within and between farms, which can explain the variability seen

among villages in this study. Such differences are usually affected by microclimates, soil features, crop varieties, and farm management practices (Kusa et al., 2025).

Conclusion

This study demonstrated that fungal diseases of maize in the Hadejia area vary significantly across locations, seasons, and years, confirming the strong influence of spatiotemporal factors on disease occurrence. The results showed clear differences in fungal disease incidence, severity, and prevalence among the surveyed villages during the dry and wet seasons of 2022 and 2023, with some locations consistently recording higher disease burdens than others. These findings suggest that local environmental conditions, seasonal moisture patterns, and field management practices likely contributed to the observed variability in disease expression. The higher disease levels recorded in several wet season farms further highlight the importance of favorable humidity and temperature conditions in promoting fungal infection and spread. Overall, the study provides valuable baseline epidemiological data on fungal diseases affecting maize in Hadejia and emphasizes the need for location-specific and season-sensitive disease management strategies to reduce crop losses, improve grain quality, and support sustainable maize production in the area.

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