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Distribution of fungal pathogens of groundnut (*Arachis hypogaea* L.) across the agro-ecological zones of Senegal

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ABSTRACT

In Senegal, groundnut (*Arachis hypogaea* L.) is one of the main sources of income for rural farming households. Despite its importance, production is increasingly compromised by various pests-most notably phytopathogenic fungi. These organisms pose a dual threat, undermining agricultural yields while simultaneously jeopardizing consumer safety through mycotoxin. The incidence and spatial dissemination of fungal pathogens are closely tied to the specific environmental and climatic parameters of the cultivation area. This present study was therefore carried out through surveys, to diagnose the main fungal diseases of groundnut throughout the main production areas in Senegal. The surveys were conducted in six regions (Ziguinchor, Kolda, Tambacounda, Kaffrine, Louga and Thiès), covering the four peanut producing agro-ecological zones of the country, namely the Groundnut Basin Agricultural Zone, the Ferlo Sylvo-Pastoral Zone, the Central and Southeastern Agro-Sylvo-Pastoral Zone, and the Southern Forest Zone (Casamance). In each region, three sites were visited and, for each site, five fields were surveyed. Disease incidence and severity were recorded for all symptomatic plants displaying cercospora leaf spot and rust. In cases where field identification was inconclusive, representative samples were collected for subsequent laboratory isolation and fungal characterization. The results led to the identification of 19 fungal genera associated with 15 types of symptoms: *Curvularia*, *Colletotrichum*, *Fusarium*, *Pythium*, *Rhizoctonia*, *Macrophomina*, *Alternaria*, *Bipolaris*, *Rhizopus*, *Nigrospora*, *Cercospora*, *Phomopsis*, *Gliocladium*, *Aspergillus*, *Chaetomium*, *Phoma*, *Cladosporium*, *Lasiodiplodia* and *Puccinia*. The most frequent genera were *Curvularia* (27.23%), *Colletotrichum* (20.59%) and *Fusarium* (15.10%). Cercospora leaf spot and peanut rust were the predominant diseases in the Groundnut Basin. Their severity level reached up to 51.83% for cercospora leaf spot and 29.33% for peanut rust. This study highlights the diversity of fungal diseases associated with groundnut and provides a scientific basis for the development of management strategies.

Keywords: *Arachis hypogaea*, Fungal diseases, Incidence and severity, Leaf spot, Rust, Senegal

INTRODUCTION

Groundnut (*Arachis hypogaea* L.) is a member of the Fabaceae family originating from southern Bolivia and northern Argentina (Stalker, 2017). It is cultivated in more than 100 countries (Ntare *et al.*, 2008) and ranks fourth among the most widely cultivated oilseed crops in the world, with a production of 57.56 million tons in 2024 (FAOSTAT, 2025b).

More than half of the global production comes from China and India, followed by Nigeria and the United States, with much lower production levels (FAOSTAT, 2025a). According to FAOSTAT (2026), Senegal was the world's seventh-largest groundnut producer in 2024. In Senegal, groundnut is cultivated mainly in the Groundnut Basin and the southern regions (DAPSA, 2023). It is a crop of great economic and strategic importance as it represents one of the main sources of income for rural households (ANSD, 2021). Peanut is the leading cash crop in terms of cultivated area, with 1,225,172 hectares (i.e., 70% of the area devoted to cash crops), and in terms of production volume, with 1,501,498 tons in 2022 (DAPSA, 2023). In January 2023, Senegal's export volume increased by 32.3% due to a strong substantial shipments of unroasted groundnuts, with a monetary value rising from 1.2 billion CFA francs to 46.0 billion CFA francs (ANSD, 2023). The production is intended for household consumption, but also for both industrial and artisanal oil processing of oil (Noba *et al.*, 2014). Groundnut kernels contain, on average, 48 to 50% oil and 26 to 28% protein and represent a rich source of dietary fiber, minerals, and vitamins (Ntare *et al.*, 2008). Alongside groundnut haulms, the press cake is extensively used as a high-protein feed supplement for livestock (Schmidt and Mejia, 2014).

However, despite its importance for the country, the yields are still low (around 1.3 t/ha) compared to countries like China and Argentina, with 4 t/ha and 3.4 t/ha, respectively (FAOSTAT, 2025b). These low yields could be attributed to different factors such as poor climatic conditions and associated weather phenomena (irregular rainfall), as well as the limited use of organic and mineral fertilizers on soils that are often very poor (CIRAD, 2021).

In addition to these abiotic constraints, groundnut is subjected to a strong pest pressure, which represents the main constraint to its production (Surendra *et al.*, 2015). Various phytopathogenic fungi are responsible for diseases affecting groundnut. Among these fungal agents, the genus Cercospora (responsible for early and late leaf spot) and the genus Puccinia (responsible for peanut rust) have been extensively studied. The symptoms caused by these pathogens are observed on leaves, with a reduction of the photosynthetic capacity of the plant in addition to competition for plant metabolites (Zinsou *et al.*, 2019). In addition to these two major diseases, other foliar diseases are commonly observed on this crop. Therefore, a good understanding of the disease pressure and the causal agents in the different production basins should form the backbone of an efficient control strategy and represents an important step towards improving of productivity and competitiveness.

The present study was therefore conducted with the objectives of identifying and characterizing the fungal pathogens of groundnut, as well as determining the incidence and severity of the two main diseases affecting this crop, namely leaf spot and groundnut rust, in different agro-ecological zones of Senegal.

MATERIALS AND METHODS

Study area

The study was conducted in six (6) regions covering four (4) agro-ecological zones of Senegal:

1. Ziguinchor and Kolda, representing the Southern Forest Zone (Casamance), characterized by a Sudano-Guinean type climate and rainfall ranging between 700 and 1300 mm (Ba, 2006; Dieye, 2022).
2. Tambacounda, representing the Central and Southeastern Agro-Sylvo-Pastoral Zone, located

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between the Sudanian and Sudano-Guinean climatic domains, with rainfall ranging between 600 and 1200 mm (Ba, 2006; Faye *et al*., 2019).

3. Kaffrine and Thiès, representing the Groundnut Basin Agricultural Zone, characterized by rainfall ranging between 400 and 600 mm in its northern part and between 600 and 800 mm in its southern part (Ba, 2006).
4. Louga, representing the, a very arid Ferlo Sylvo-Pastoral Zone area particularly exposed to bushfires during the dry season under the influence of the Harmattan (ANSD, 2025).

In each region, three (3) sites were surveyed.

Plant material

The plant material used in this study consisted of samples of plant organs groundnut plants (leaves, roots, and stems), as well as whole plants showing symptoms suspected of fungal diseases.

Sampling

Sampling was carried out randomly in all the localities visited (Fig. 1). At each site, surveys were conducted in groundnut fields. Samples of different plant organs (leaves, roots, and stems) showing distinct or suspected symptoms of fungal diseases were collected in order to obtain the greatest possible diversity of symptoms. The samples were then placed in plastic bags containing blotting paper moistened with water to maintain a certain level of humidity and were finally transported to the Laboratory of Phytochemistry and Plant Protection (LPPV) of Cheikh Anta Diop University (UCAD) in Dakar for analysis.

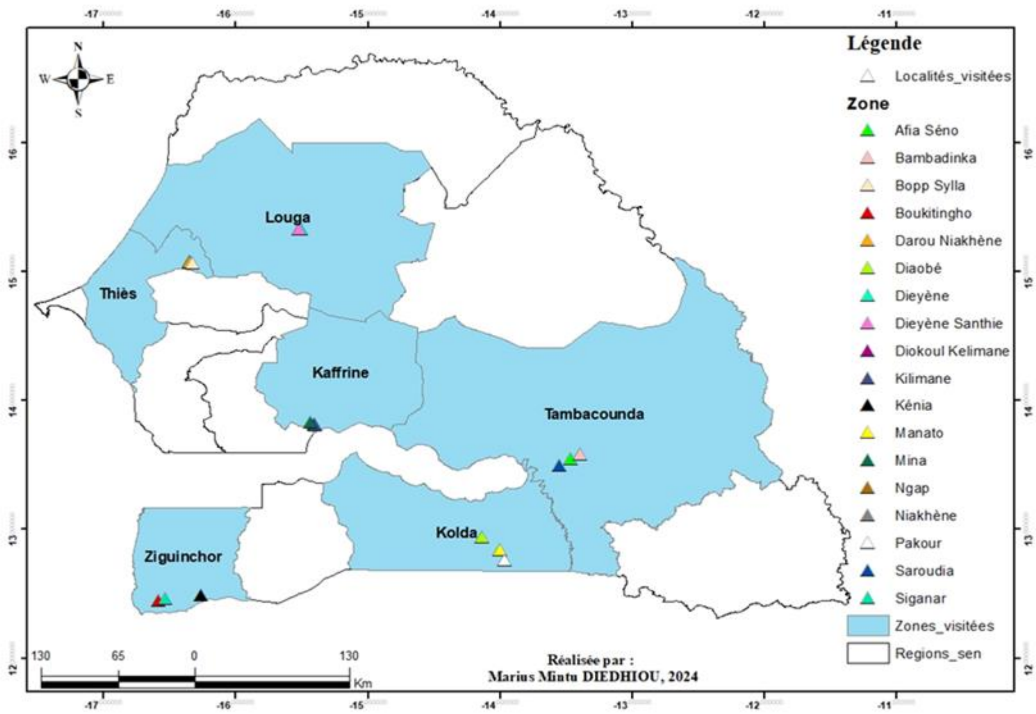

Fig. 1. Map showing the location of the survey sites

Disease assessment (Cercospora leaf spot and rust)

During field surveys, two diseases were assessed: cercospora leaf spot of groundnut and rust. However, no distinction was made between the two types of Cercospora disease (early and late leaf spot) during the scoring of incidence and severity due to the difficulty of distinguishing the symptoms with the naked eye in the field. The diseases were assessed on crops at the pod formation and maturity stages across all visited sites, with five (5) fields assessed per site. For each field, the evaluation was carried out on fifteen (15) plants randomly selected in order to cover the largest possible area.

Disease incidence

Disease incidence was calculated using the following formula:

I (%)= (NPS / NTP) × 100, where: I = incidence; NPS= number of plants showing disease symptoms; NTP= total number of plants observed.

Disease severity

The average disease severity was determined using the following formula, widely used in phytopathology (Chiang *et al.*, 2017):

$$S (\%) = (\sum (Ni \times Si) / (N \times iM)) \times 100$$

where:

Ni= number of plants with severity level i; Si= severity level i of the disease on the plant ; N = total number of plants observed; iM= maximum index of the scale used.

The assessment was carried out using a rating scale ranging from 0 to 4, where:

0= no symptoms observed on the plant;

1= 1 to 25% of the leaf area of the observed plant shows symptoms;

2 = 26 to 50% of the leaf area of the observed plant shows symptoms;

3= 51 to 75% of the leaf area of the observed plant shows symptoms;

4= ≥ 76% of the leaf area of the observed plant shows symptoms.

Isolation and characterization of phytopathogenic fungi

In the laboratory, samples were disinfected in 1% sodium hypochlorite (NaClO), and explants were cut from the advancing front of the symptoms. These explants were then immersed in 70% ethanol for one minute and rinsed three times with sterile distilled water before being inoculated onto Petri dishes containing Potato Dextrose Agar (PDA) medium. After 48 hours of incubation in an oven at 28 °C, the mycelium emerging from the explants was transferred to the center of new PDA Petri dishes to obtain pure isolates.

After purification, the morphological characterization of the pathogens was carried out in two steps: the features of the mycelium on the top and reverse of the Petri dish is described and classified. ; furthermore the microscopic characteristics of the spores and other components of the mycelium are assessed under an optical microscope at 40× magnification, using the identification keys for fungi provided by Barnett and Hunter (2006) and Watanabe (2002).

Frequency of the various fungal genera isolated from peanuts

The frequency of the various fungal genera was calculated based on the isolates obtained using the following formula: F(%)= Ng / Nt × 100, where: F (%)= frequency of the fungal genus (%) ; Ng= number of isolates of the genus in question ; Nt= total number of isolates obtained.

Statistical analysis

Data on disease incidence and severity (cercosporiosis and rust) were analyzed using RStudio (version 4.4.2). A one-way analysis of variance (ANOVA) was performed using the aov function in R. This was followed by multiple comparisons of means using Tukey's HSD (Honest Significant Difference) test at a 5% significance level, with the HSD.test() function from the agricolae package.

RESULTS

Symptomatology diseases and fungi associated

The surveys conducted in the groundnut fields revealed a high diversity of symptoms of fungal diseases, most of which were observed on the leaves. Fifteen types of symptomatic tissues suspected to be caused by fungal diseases, coded from S1 to S15, were identified. Isolations performed from these symptomatic tissues, together with direct observations of diseased plant organs, led to the

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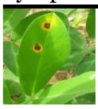
identification of 19 fungal genera: *Curvularia*, *Colletotrichum*, *Pythium*, *Fusarium*, *Macrophomina*, *Alternaria*, *Bipolaris*, *Rhizopus*, *Rhizoctonia*, *Nigrospora*, *Cercospora*, *Phomopsis*, *Gliocladium*, *Aspergillus*, *Chaetomium*, *Phoma*, *Cladosporium*, *Lasiodiplodia*, and *Puccinia* (Table 1).

Table 1. Disease symptoms and associated fungal isolates recovered from symptomatic groundnut tissues across diverse Senegalese production regions

Symptom	Description of symptoms	Region	Isolated fungal genera
 S1	Brown lesions, ranging from oval to angular in shape, characterized by irregular margins and distinct chlorotic haloes.	Ziguinchor Kolda Tambacounda Kaffrine Louga Thiès	*Cercospora*, *Curvularia*, *Gliocladium*
 S2	Triangular beige spots exhibiting dark brown peripheral borders and a distinct central brown area, surrounded by prominent yellow haloes.	Ziguinchor Kolda Tambacounda Kaffrine Louga Thiès	*Bipolaris*, *Fusarium*, *Phomopsis*, *Lasiodiplodia*
 S3	Punctiform black spots disseminated throughout the whole leaf surface.	Ziguinchor Kolda Tambacounda Kaffrine Louga Thiès	*Alternaria*, *Colletotrichum*, *Nigrospora*, *Curvularia*
 S4	Dark brown to black subcircular spots exhibiting distinct yellow haloes.	Ziguinchor Kolda Tambacounda Kaffrine Louga Thiès	*Cercospora*, *Phoma*, *Pythium*, *Colletotrichum* *Chaetomium*
 S5	Brown necrotic lesions localized along the leaf margins, characterized by the presence of peripheral black punctiform spots.	Kaffrine Louga Thiès	*Curvularia*, *Fusarium*, *Colletotrichum* *Bipolaris*
 S6	Severe systemic wilting and tissue dehydration, culminating in terminal senescence and plant death	Kolda Tambacounda Kaffrine Louga Thiès	*Rhizoctonia*, *Rhizopus*, *Fusarium*
 S7	Brown necrotic spots, oval in shape, characterized by concentric rings and irregular borders	Ziguinchor Kolda, Tambacounda Kaffrine Louga Thiès	*Colletotrichum*
 S8	Brown rectangular spots exhibiting gray necrotic centers or shot-hole symptoms, surrounded by distinct yellow haloes.	Ziguinchor Kolda Tambacounda Kaffrine Louga Thiès	*Fusarium*, *Aspergillus*,
 S9	Darkly pigmented necrotic areas localized along the leaf margins and bordered by chlorotic haloes.	Ziguinchor Kolda Tambacounda Kaffrine Louga Thiès	*Curvularia*, *Alternaria*
 S10	Orange-brown rust pustules, primarily distributed on the abaxial leaf surface.	Ziguinchor Kolda Tambacounda Kaffrine Louga Thiès	*Puccinia*

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 S11	Small- to medium-sized necrotic spots, exhibiting irregular margins and distributed throughout the foliar surface.	Kaffrine Louga Thiès	*Cladosporium*, *Fusarium*, *Phomopsis*, *Curvularia*, *Colletotrichum*
 S12	Oval beige lesions with dark brown margins.	Kolda Kaffrine	*Alternaria* *Curvularia*, *Chaetomium* *Nigrospora*, *Phomopsis*
 S13	Circular to oval light brown lesions exhibiting dark brown margins	Thiès	*Colletotrichum*, *Macrophomina*
 S14	Brown necrotic lesions characterized by dark brown, irregular margins.	Thiès	*Fusarium*
 S15	Rotting of the stem and basal leaves of affected plants	Louga Thiès	*Macrophomina*, *Aspergillus*

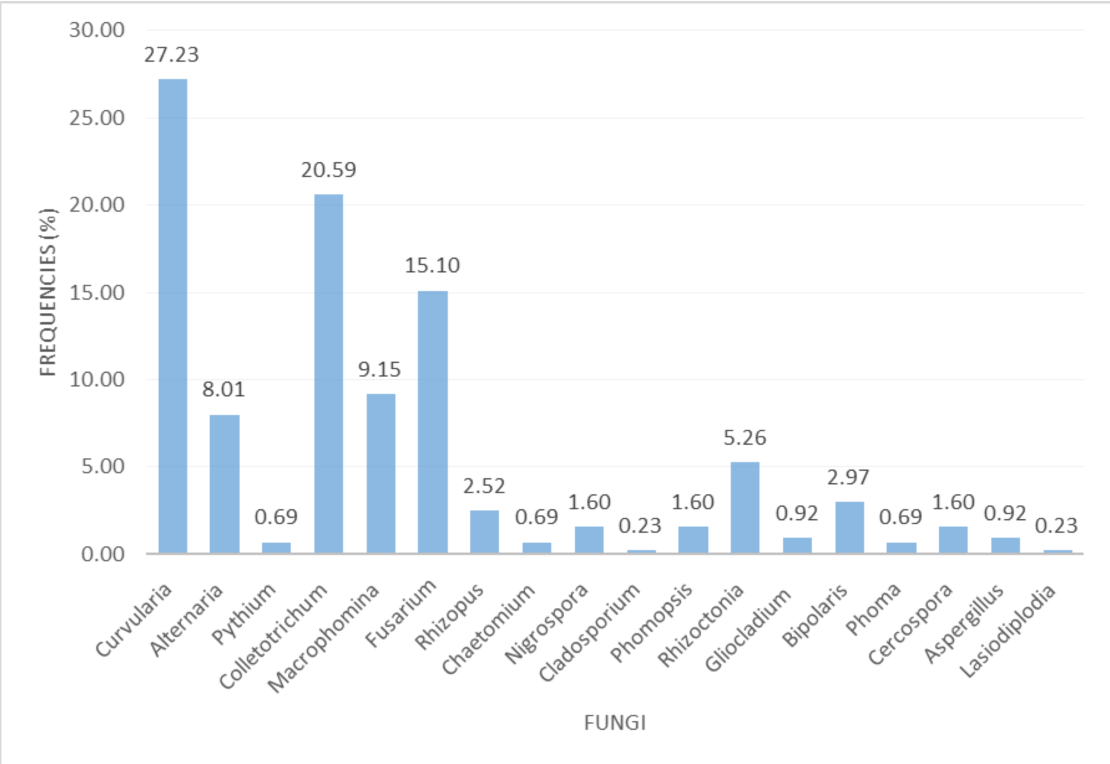

Fig. 2. Relative frequency of fungal genera associated with groundnut (*Arachis hypogaea* L.) pathologies recovered from symptomatic tissues

Frequency of different fungal genera obtained from isolations

The frequency of the different fungal genera identified after isolation from the symptoms is shown in Fig. 2. The most frequent genus was *Curvularia*, with a frequency of 27.23%, followed by *Colletotrichum* (20.59%), *Fusarium* (15.10%), *Macrophomina* (9.15%), *Alternaria* (8.01%), *Rhizoctonia* (5.26%), *Bipolaris* (2.97%), *Rhizopus* (2.52%), and the genera *Cercospora*, *Phomopsis*, and *Nigrospora* (1.60%). The other genera represented less than 1%.

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Geographic distribution and phytosanitary importance of foliar fungal diseases in groundnut-producing areas Disease incidence and severity of groundnut leaf spot caused by *Cercospora* spp.

The incidence of leaf spot across the different agro-ecological zones is shown in Fig. 3. It was high in all surveyed zones, ranging from 93.33% to 98.67%. Statistical analysis revealed no significant differences between the zones.

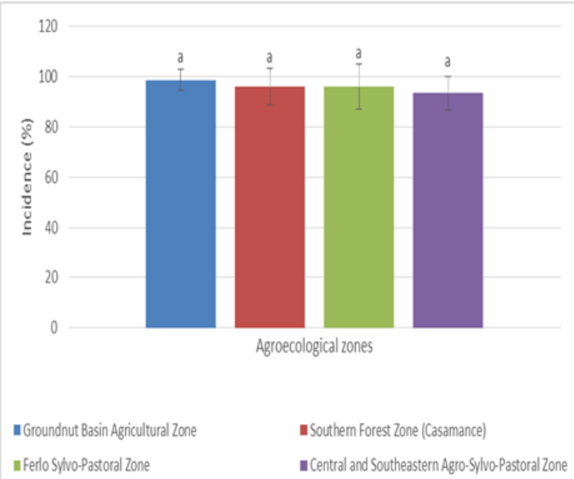

Fig. 3. Incidence of groundnut *Cercospora* leaf spot across distinct agro-ecological zones

Means followed by the same letter are not significantly different according to Tukey's test ($p < 0.05$).

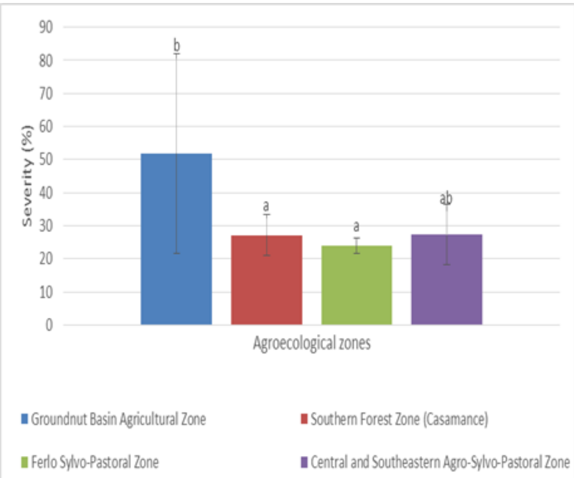

Fig. 4. Severity of groundnut *Cercospora* leaf spot across distinct agro-ecological zones

Means followed by the same letter are not significantly different according to Tukey's test ($p < 0.05$).

With respect to disease severity in the different agro-ecological zones (Fig. 4), a significant difference ($p < 0.05$) was observed, with the Groundnut Basin showing the highest severity (51.83%). No significant differences ($p > 0.05$) were noted between Casamance, the Ferlo, and Eastern Senegal. Furthermore, a high variability in disease severity was observed among the different fields within the Groundnut Basin.

Disease incidence and severity of groundnut rust (*Puccinia arachidis*)

The incidence of rust across the different agro-ecological zones is shown in Fig. 5. Analysis revealed the presence of two significantly distinct incidence groups (Tukey test at 5% significance level): the first group includes the Groundnut Basin and the Ferlo, with incidences of 99.33% and 94.66%, respectively; the second group, comprising Casamance and Eastern Senegal, is characterized by incidences of 16% and 42.66%, respectively.

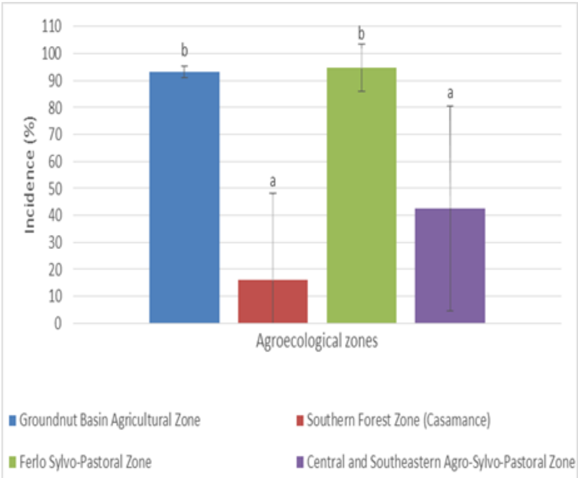

Fig. 5. Incidence of peanut rust across different agro-ecological zones

Means followed by the same letter are not significantly different according to Tukey's test ($p < 0.05$).

The severity of rust according to agro-ecological zone is presented in Fig. 6. Analysis shows that severity was generally low in all zones, below 30%. However, it was statistically higher in the Groundnut Basin (29.33%) and the Ferlo (23.66%), and lower in

Casamance (4.33%) and Eastern Senegal (12%). In addition, no significant difference was observed between the Ferlo and Eastern Senegal ($p > 0.05$).

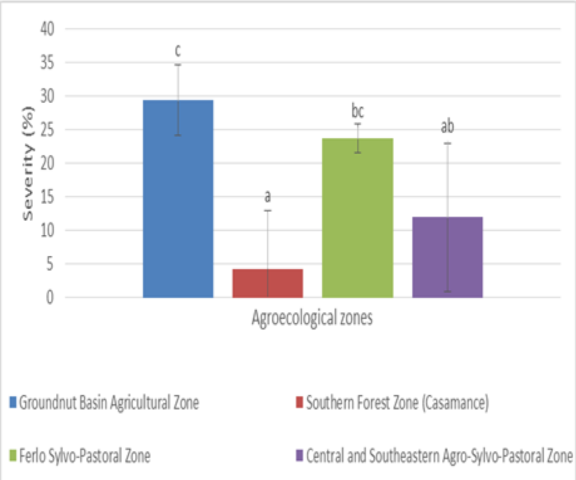

Fig. 6. Severity of peanut rust across different agro-ecological zones

Means followed by the same letter are not significantly different according to Tukey's test ($p < 0.05$).

DISCUSSION

This study conducted across four agro-ecological zones of Senegal highlighted the diversity of pathogens responsible for the main fungal diseases affecting groundnut. Fifteen (15) types of fungal disease symptoms with 19 genera/species associated with them were recorded. This indicates a high pressure of fungal pathogens on this economically important crop. Likewise in Côte d'Ivoire, Koffi *et al.* (2020) reported 12 types of foliar symptoms associated with a wide diversity of fungal genera (*Aspergillus*, *Basipetospora*, *Colletotrichum*, *Curvularia*, *Fusarium*, *Geotrichum*, *Griseum*, *Rhizoctonia*, *Pestalotiopsis*, *Pythium*, *Sclerotium*). In the present study, the diversity of the fungal pathogens of groundnut included *Curvularia*, *Colletotrichum*, *Fusarium*, *Pythium*, *Rhizoctonia*, *Macrophomina*, *Alternaria*, *Bipolaris*, *Rhizopus*, *Nigrospora*, *Cercospora*, *Phomopsis*, *Gliocladium*, *Aspergillus*, *Chaetomium*, *Phoma*, *Cladosporium*, *Lasiodiplodia* and *Puccinia*. Among the symptom types identified in this study, eight (8) were recorded in all surveyed agro-ecological zones, indicating a broad distribution of corresponding diseases regardless of the specific agro-ecological characteristics of each zone. This widespread distribution may be explained by the fact that many pathogens are generally well adapted to the different climatic conditions encountered in the surveyed areas. It has been documented that plant-pathogenic fungi possess significant resilience to variations in environmental parameters such as temperature and moisture levels (Větrovský *et al.*, 2019). Moreover, certain diseases such as cercospora leaf spot and rust are considered endemic on groundnut crops (Ashish *et al.*, 2014), which explains their presence across all localities.

The study identified 19 distinct fungal genera characterized by highly variable frequencies. The prevalence of *Curvularia* (27.11%), *Colletotrichum* (20.50%), *Fusarium* (15.03%), *Macrophomina* (9.11%), and *Alternaria* (7.97%) may be attributed to their association with various symptoms like foliar spots, necroses, and rots affecting the pods, roots, crowns, and stems of groundnut plants besides their occurrence on the leaves (Koffi *et al.*, 2020 ; Kumar *et al.*, 2022 ; Li *et al.*, 2025 ; Li *et al.*, 2024 ; Martínez-Salgado *et al.*, 2021). Pathogen identification was performed post-isolation using standard laboratory protocols. However, it should be emphasized that growth medium characteristics serve as a selective pressure, potentially influencing the observed fungal diversity by promoting the growth of certain species while inhibiting others. Recent evidence indicates that PDA enhances the isolation efficiency of *Colletotrichum* and *Alternaria* relative to other substrates, including water agar medium (WA) and Czapek Dox Agar (CDA) (Korkom *et al.*, 2025). In addition, several authors have reported that fungi of the genus *Cercospora* exhibit poor sporulation on PDA, which may influence the low frequency obtained for *Cercospora* (1.59%) among the identified genera, despite it being responsible for the most prevalent disease (early and late leaf spot) in all surveyed zones (El-Gholl *et al.*, 1982; Uppala *et al.*, 2019).

The analysis of varied symptomatic tissues frequently revealed pathogen consortia, indicating that disease manifestations are often associated with multi-species fungal complexes. This observation is consistent with Koffi *et al.* (2020), who documented the presence of diverse pathogens in solitary leaf lesions. Such poly-microbial infections may result from the colonization of pre-existing lesions by opportunistic secondary parasites with opportunistic, saprophytic or endophytic habits. This hypothesis is supported by findings from Prechsl *et al.* (2023), who showed that, on apple trees, *Alternaria* spp. does not act as a primary pathogen but rather as an opportunist, dependent on necrosis.

The diagnostic challenge poses further challenges by the fact that diverse fungal taxa produce overlapping symptomatic profiles. This is illustrated by the findings of Terna *et al.* (2024), whose pathogenicity assays revealed that species such as *Aureobasidium pullulans*, *Epicoccum nigrum*, *Curvularia lunata*, and *Fusarium incarnatum* induced phenotypically similar lesions, despite distinct degrees of virulence. This symptomatic convergence was also observed with *Nigrospora oryzae* (Kim *et al.*, 2024), *Cladosporium tenuissimum* (Geng *et al.*, 2022), and *Fusarium ipomoeae* (Xu *et al.*, 2021). Such findings suggest that nearly identical lesions may be caused by a variety of fungi, accounting for the recovery of multiple pathogens from a single symptom type.

Cercospora leaf spot and rust were systematically assessed in the field due to their status as major biotic constraints to groundnut production worldwide (Chaudhari *et al.*, 2019). The high and statistically comparable incidence of Cercospora leaf spot (93.33%–98.67%) across all agro-ecological zones underscores the endemic status of this disease. Similar findings were recorded in Ethiopia, where it is considered the most widespread disease, causing severe yield losses (Debele and Ayalew, 2015). Severity levels of *Cercospora* leaf spot peaked in the Groundnut Basin (51.83%), a finding consistent with its role as the source of 75% of Senegal's groundnut production (Ndour *et al.*, 2023). The elevated disease intensity in this region is likely driven by continuous cropping practices; the absence of rotation promotes the long-term survival of fungal inoculum in the soil, leading to increased infection rates (Ijaz *et al.*, 2019). In contrast to *Cercospora* leaf spot, the incidence and severity of rust exhibited significant spatial variability across the different zones. The highest incidence was recorded in the Groundnut Basin and the Ferlo. This variability may be primarily attributable to the prevailing climatic conditions in each region. As reported by Savary (1986), rust development is governed by specific meteorological requirements, such as optimal temperatures around 27 °C, whereas intense rainfall may act as a limiting factor for its dispersal. This may have contributed to the lower disease levels observed in Casamance and Eastern Senegal, regions both characterized by high annual precipitation (Nakalembe *et al.*, 2025).

CONCLUSION

A total of 15 fungal disease symptomatic expressions were recorded on groundnut throughout the various agro-ecological zones during the course of this study. These diseases expressions were associated with 19 fungal genera namely *Curvularia*, *Phoma*, *Colletotrichum*, *Fusarium*, *Pythium*, *Rhizoctonia*, *Macrophomina*, *Alternaria*, *Bipolaris*, *Rhizopus*, *Nigrospora*, *Cercospora*, *Phomopsis*, *Gliocladium*, *Aspergillus*, *Chaetomium*, *Cladosporium*, *Lasiodiplodia*, and *Puccinia*. The most frequent genera were *Curvularia* (27.23%), *Colletotrichum* (20.59%), and *Fusarium* (15.10%).

Assessment of disease incidence and severity showed that cercospora leaf spot and rust are widely distributed across groundnut-growing areas. The Groundnut Basin remains the most affected zone, with significantly higher severity levels, reaching 51.83% for cercospora leaf spot and 29.33% for rust.

The observed diversity and prevalence of fungal diseases in groundnut underscore the imperative to implement effective management strategies that prioritize both environmental sustainability and human health.

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