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SYMPTOMATOLOGY OF FUNGAL DISEASES OF CULTIVATED GINGER (*ZINGIBER OFFICINALE* ROSCOE) IN THE MAIN PRODUCTION AREAS IN CÔTE D'IVOIRE

Nougnon Sétou Silué, Assiri Elloh Patrice Kouamé, N'guessan Wilfried Yao, Hortense Atta Diallo
Natural Science Department, Laboratory of Plant Protection, Université Nangui Abrogoua, BP 801 Abidjan 02, Côte d'Ivoire.

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ABSTRACT

Ginger (*Zingiber officinale*) is a plant widely recognized worldwide for its nutritional and medicinal qualities. However, its cultivation faces various challenges, including fungal diseases, which are responsible for significant losses. This study aims to assess the symptoms of diseases caused by fungi in ginger cultivation in Côte d'Ivoire. To achieve this, a phytosanitary survey was conducted in five major ginger production areas (Tiassalé, Hermankono, Koun-Fao, Soubré, and Bongouanou). The observed symptoms were described, and their prevalence and severity were evaluated. Subsequently, the fungi associated with these symptoms were isolated and identified. The results obtained allowed the identification of four different types of symptoms: chlorosis, necrosis, wilt, and leaf spot. All these disease symptoms were observed in all the ginger plots in the surveyed localities. The leaf spot symptom was the most frequently observed, with the highest prevalence of 87.15% in the Soubré area and a lower prevalence in Bongouanou which was 45.17%. Symptom severity varied by locality. Fourteen genera of fungi were isolated from symptomatic ginger leaves and stems. These included *Aspergillus*, *Colletotrichium*, *Curvularia*, *Fusarium*, *Leptosphaeria*, *Penicillium*, *Pestalotiopsis*, *Pythium*, *Rhizoctinia*, *Rhizopus*, *Sclerotium*, *Trichoderma*, and two unidentified genera, referred to as unknown 1 and unknown 2. The isolation frequencies of fungal genera varied by locality, with *Fusarium* having the highest isolation frequency among all the isolated fungi. This initial study on fungal diseases in ginger cultivation in Côte d'Ivoire could provide valuable insights for guiding control methods.

Corresponding Author: Nougnon Sétou Silué
Email: valynougnonsilue@gmail.com

INTRODUCTION

Ginger (*Zingiber officinale* Roscoe) is a perennial herbaceous plant which is commonly cultivated around the world for its rhizomes (Bharati et al., 2019). India is the world's largest producer with a yield of 2.225 million tons (FAOSTAT, 2021). It is generally used in different fields. Medicinally, it is an excellent stimulant (Wang, 2020). It is also known for its carminative, digestive or appetizing power. It cures nausea, reduces fever, and prevents ulcers and scurvy (Sati and Bala, 2017). In terms of food, the spice is appreciated for its delicate aroma and its slightly burning flavor for the preparation of many dishes. Ginger is also used in confectionery. Moreover, ginger essential oil is used in perfumery, cosmetology and in the manufacturing of alcoholic liqueurs (Robin, 2017). In Côte d'Ivoire, ginger is sold in various forms, including dried, fresh, or processed into powder, lozenges, juice, and candy, which are available on the streets (Adou et al., 2018). It is mainly produced in the cities of Bongouanou, Divo, Gagnoa, Soubré, Tiassalé and Koun-Fao (FIRCA, 2020). The city of Koun-Fao is the main ginger-producing area in the country, with nearly production of 100,000 tons/year (Oussène, 2018).

Despite this importance, ginger cultivation faces many diseases around the world. Indeed, those caused by fungi are responsible for huge losses. Among these diseases, the most devastating ones are soft rot of rhizomes, yellowing of leaves and stems, *Phyllosticta* spot, wilt, and chlorotic spots (Gupta and Manisha, 2017). Ginger rhizome rot caused by a species of the *Pythium* genus can cause yield losses up to 90%, as was the case in Anqiu (China) in 2010 (Mahdi et al., 2013). Similarly, according to Gupta and Tennyson (2019), *Fusarium oxysporum*, the causative agent of Fusarium wilt can cause yield losses up to 70%. Ginger leaf spot caused by *Phyllosticta zingiberi* is a major constraint to ginger cultivation in India (Singh, 2015). Similarly, ginger wilt is known for its ability to completely destroy the harvest in some parts of the world (Zhang et al., 2001). According to Qin et al. (2013), in addition to yield losses, these diseases also affect the quality of harvests and are the main factors that limit high-quality ginger yield. In Côte d'Ivoire, the ginger sector is still poorly known to the public authorities. It generally does not benefit from any development program. As a result, there is still no official data available regarding this crop. This is the case of fungal diseases in cultivation. The main objective of this study is to evaluate the symptoms of diseases caused by fungi in ginger cultivation in Côte d'Ivoire.

MATERIAL AND METHODS

Study site

Surveys were carried out from June to July 2022 in 15 fields of the five largest ginger-producing localities in Côte d'Ivoire. These included Bongouanou, Hermankono, Koun-Fao, Soubré, and Tiassalé. These localities are distributed in five different agro-ecological zones. Bongouanou is located in the Moronou region in the south-east of the country with an average temperature of 27.4°C. Hermankono is located in the Lôh-Djiboua region in the south of the country with an average temperature of 26.1°C. The average annual temperature is around 26°C in Tiassalé (Agnéby-Tiassa region). Located in the north-east of Côte d'Ivoire in the Gontougo region, Koun-Fao has an average temperature of 24.4°C. As for Soubré, it is located in the south-west of Côte d'Ivoire with an annual temperature of 26.1°C.

Materials

The materials consisted of symptomatic organs of leaves and stems from ginger in cultivation. These organs were used to isolate fungi associated with them.

Methods

Symptomatology of fungal diseases of ginger in cultivation

Symptom description

Symptoms of diseases caused by fungi were observed on the plants in the ginger visited fields and were then described. Symptom description was made taking into account their appearance, shape and coloring (Gupta and Tennyson, 2019; Vijayan et al., 2020).

Assessment of prevalence and severity of disease symptoms

In the study, all the ginger plots were divided into four sub-plots, and an X-pattern was created within each sub-plot. For symptom assessment, sixty plants were selected along two diagonals. Along each diagonal, 30 plants were observed at roughly equal intervals. The number of plants displaying each type of symptom was then counted and the prevalence of each symptom was calculated using the formula developed by Ackah et al. (2008):

$$P\ (\%) = \frac{NI}{NT} \times 100$$

Where P (%) = Prevalence

NI = Number of symptomatic plants

NT = Total number of plants of the considered pattern

Severity was also assessed by observing the 60 plants selected on the two diagonal lines of the X-pattern. Symptom severity was scored using a disease severity rating scale of 1 to 5 proposed by Mignouna et al. (2001). With: 1 = no visible symptom; 2 = 1 to 25 % of leaf and/or stem organs showing ginger fungal symptoms; 3 = 26 to 50 % leaf and/or stem organs showing ginger fungal symptoms; 4 = 51 to 75 % of leaf and/or stem organs showing ginger fungal symptoms; 5 = more than 76 % of leaf and/or stem organs showing ginger fungal symptoms. The severity scores obtained were used to calculate the average severity index for each symptom using the formula (Kranz, 1988; Galanihe et al., 2010).

$$Is\ (\%) = \frac{(\sum (Xi \times Ni)}{(N \times Z)} \times 100$$

Where Is (%) = mean severity index;

Xi = severity class or score;

Ni = number of ginger plants with the same severity score;
N = total number of ginger plants observed and
Z = highest severity score, 5.

Sample collection

Diseased ginger plants, due to fungal infections, aged 3-4 months, were collected from June to August 2021 and from June to July 2022 from ginger production areas in Côte d'Ivoire. These collections were carried out in five production regions in Côte d'Ivoire. A total of 15 sites were sampled. Symptomatic plants were collected from ginger plantations. Sixty symptomatic plants were collected from different representative locations in the field, approximately 5 meters apart, in order to avoid as far as possible collecting plants with the same symptoms. After sampling, the symptomatic ginger plants from each field were classified according to symptoms, placed in paper envelopes, labelled, placed in a cooler and transported to the laboratory for isolation of the associated fungi at the Plant Health Unit of the Plant Production Research Pole of Nangui Abrogoua University.

Isolation and identification of fungal isolates

The isolation of fungi from infected ginger plant organs was carried out on glucose-enriched potato medium (PDA) solidified in Petri dishes. First, small pieces (explants) of ginger leaves and stems were taken from the growth front of the symptoms on the collected organs; and then disinfected with 96° ethanol diluted to 70%. The explants were then seeded on to the culture medium and labeled according to symptom, organ, plantation and location. In each dish, 4 explants were placed at the two ends of the diameters of the dish. A total, of three boxes per symptom were seeded. The dishes were incubated at ambient laboratory temperature for 2 days. The different fungal colonies developed on the same dishes were separately subcultured on other culture media in order to get homogeneous colonies. Two weeks later, the isolates obtained were observed under an optical microscope (OPTIKA) and then identified using the fungal identification keys developed by Botton et al. (1990) and Champion (1997). The identification was based essentially on the cultural characters and the propagules morphology. In terms of cultural characters, their growth rate, texture, margin, thickness and color of the colony; agar pigmentation and production of exudate were noted.

Isolation frequency

The percentage isolation frequencies of identified fungal isolates were determined according to the formula described by Iqbal and Saeed (2012):

$$FI\ (\%) = \frac{NF}{NT} \times 100$$

Where FI = Isolation frequency;
NF = Number of samples (symptoms) from which the given isolate was obtained;
NT = Total number of samples (symptoms)

Statistical analysis

The data obtained were subjected to statistical analysis using Statistica version 7.1 software. The disease prevalence and the symptoms severity were subjected to an analysis of variance in order to determine which symptom was the most prevalent, which was the most severe and which area was most affected by the disease. For this purpose, the homogeneity of variance test was performed. In the case of a significant difference ($P < 0.05$), the non-parametric Kruskal-Wallis test was used to compare the means. In the case of a significant difference between means, the post-hoc test was used to determine homogeneous groups. When variances were homogeneous ($P > 0.05$), the ANOVA test was used to compare means. An ANCOVA test was performed using XLSTAT software to test whether symptom severity was related to location or to other symptoms. A Principal Component Analysis (PCA) was carried out to determine whether symptoms differed according to locality, and to identify variables that characterize any groups formed.

RESULTS

Symptoms observed on ginger plants

At the end of the conducted surveys, four different types of symptoms were observed. These included: chlorosis, necrosis, wilting and leaf spots.

Two variants of chlorosis were observed, namely marginal chlorosis and general chlorosis. Marginal chlorosis started by a yellowing at the edges (margins) of the lower leaves, gradually spread and covered all of the leaves. It started from the lower leaves and gradually spread upwards. In the advanced stage, infected plants showed intense yellowing symptoms. Later, the old leaves dried first, followed by the young ones (Figure 1A). As far as general chlorosis is concerned, it started by the yellowing of the surface of the leaves scattered over the plant. In the advanced stage, the infected ginger plant showed intense symptoms of chlorosis (Figure 1B). Affected plants dried out, but did not fall to the ground.

Infected plants often showed yellowing, premature collapse, patchy or whole-bed desiccation, and stunting.

Regarding necrosis, it came in three forms. These included apical necrosis (Figure 1C), leaf blade necrosis (Figure 1D), and midrib necrosis (Figure 1E). It manifested itself in the form of more or less extensive brown lesions. It appeared either at the edge of the apex or on the blade or on the midrib of the lower leaves of affected plants. Subsequently, these rather localized lesions spread rapidly. Eventually, brown patches of dry appearance gradually reached the interior of the leaf blade. Then a more or less marked yellowing was observed on the margins of the lesions.

With regard to wilting, the visible symptoms were yellowing followed by the leaves wilting and the affected plants pseudostem (Figure 1F). Regarding the symptom of leaf spots on leaves, small spindle-shaped spots from oval to elongated appeared on the leaves (Figure 1G). These spots developed over time into a white center and dark brown margins surrounded by yellow halos. They increased in size and coalesced to form larger lesions which led to the reduction of the effective photosynthetic area on the leaves. Affected leaves are shredded and then undergo significant desiccation. Symptoms first appeared on young leaves. When the plants produced fresh leaves, the latter got infected later.

Figure 1: Symptoms observed on ginger plants in cultivation in different production areas in Côte d'Ivoire.

Distribution of symptoms observed on ginger plants depending on localities

Fungal disease symptoms were observed in all surveyed localities, including leaf spot, marginal chlorosis, wilting, apical necrosis, and general chlorosis. Rib and marginal necroses, however, were only observed in the localities of Bongouanou, Koun-Fao, and Soubré (Table 1).

The Principal Component Analysis carried out showed that factorial axes 1 and 2 explained respectively 30.19 and 45.89% of the variability between symptoms; that is, 76.08% of this variability. Axis 1 was correlated with necrosis ($r = 0.94$) and leaf spot ($r = 0.74$) symptoms while axis 2 was correlated with chlorosis ($r = 0.75$) symptom.

The projection of the localities in the factorial plane 1 and 2 revealed two groups (Figure 2). Group 1, consisting of the localities of Koun-Fao and Soubré, was characterized by necrosis and leaf spot symptoms. As for group 2, it was made up of the localities of Hermankono, Tiassalé and Bongouanou, where chlorosis symptom predominated.

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Table 1: Distribution of symptoms observed on ginger plants in cultivation in the different localities surveyed.

Localities	Symptoms						
	Leaf spot	Marginal chlorosis	General chlorosis	Wilting	Apical necrosis	Rib necrosis	Marginal necrosis
Her-mankono	+	+	+	+	+	-	-
Tiassalé	+	+	+	+	+	-	-
Koun-Fao	+	+	+	+	+	+	+
Soubré	+	+	+	+	+	+	+
Bongouanou	+	+	+	+	+	+	+

+ : Presence of symptoms ; - : No symptoms.

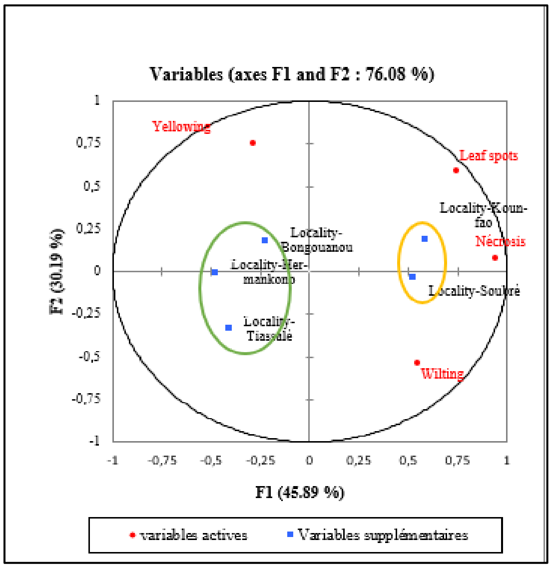

Figure 2: Principal component analysis of fungal disease symptoms of ginger depending on localities.

Prevalence and severity index of fungal disease symptoms observed on ginger plants

Chlorosis, necrosis, wilting and leaf spots were observed on ginger leaf and stem organs from all the visited localities. Their prevalence varied depending on the symptoms and the localities. Statistical analysis showed that there was no significant difference (P>0.05) between chlorosis, wilting and necrosis symptom prevalence. In contrast, these prevalences were significantly different (P=0.04) from that of leaf spot. In all the visited localities, leaf spot prevalence was the highest, hence the most dominant symptom. Its prevalence was 50.27%; 51.94%; 82.94%; 80.12%, and 45.17% in Hermankono, Tiassalé, Koun-Fao, Soubré and Bongouanou, respectively (Figure 3). Disease symptom prevalence therefore, varied depending on the localities surveyed. Thus, the highest disease prevalence was recorded in the locality of Soubré with 87.15% and the lowest one in that of Bongouanou with 45.17 %. Disease symptom prevalence was significantly different (P < 0.05) in the 5 surveyed localities (Figure 4).

As for symptom severity, it was significantly different depending on the localities (P < 0.05). The most severe symptom was necrosis, followed by leaf spot. Necrosis severity was 86.66% in the localities of Koun-Fao and Soubré (Table 2). The ANCOVA test showed that symptom severity was related to the locality (P < 0.05) and not to any symptom (P> 0.05).

Fungi associated with symptoms observed on ginger plants

A variety of fungal genera were isolated from ginger symptomatic leaf and stem organs. A total of 14 genera of fungi were isolated. They included: *Aspergillus*, *Colletotrichium*, *Curvularia*, *Fusarium*, *Leptosphaeria*, *Penicillium*, *Pestalotiopsis*, *Pythium*, *Rhizoctinia*, *Rhizopus*, *Sclerotium*, *Trichoderma* and two other unidentified genera, named unknown 1 and unknown 2. Of these fungi, thirteen were isolated in Her-mankono and Tiassalé; fourteen in Koun-fao and Soubré and seven in Bongouanou. Depending on the symptoms observed on the ginger plants, different fungi were isolated and identified (Table 3).

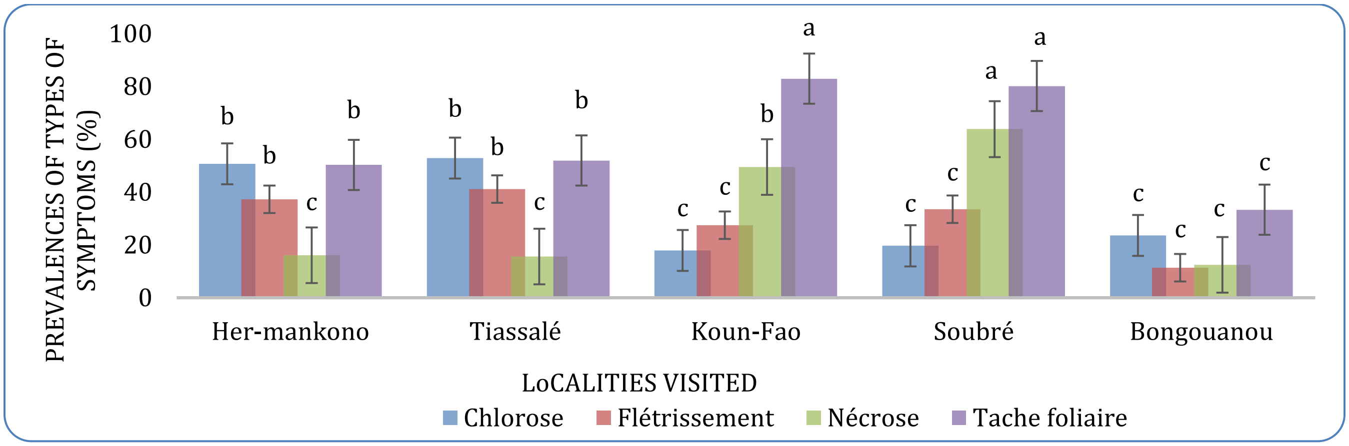

Figure 3: Prevalence of the different types of symptoms of ginger fungal diseases depending on the localities surveyed. The histograms with the same letters on the standard deviations are statistically identical according to Ficher's LSD test at 5 % threshold.

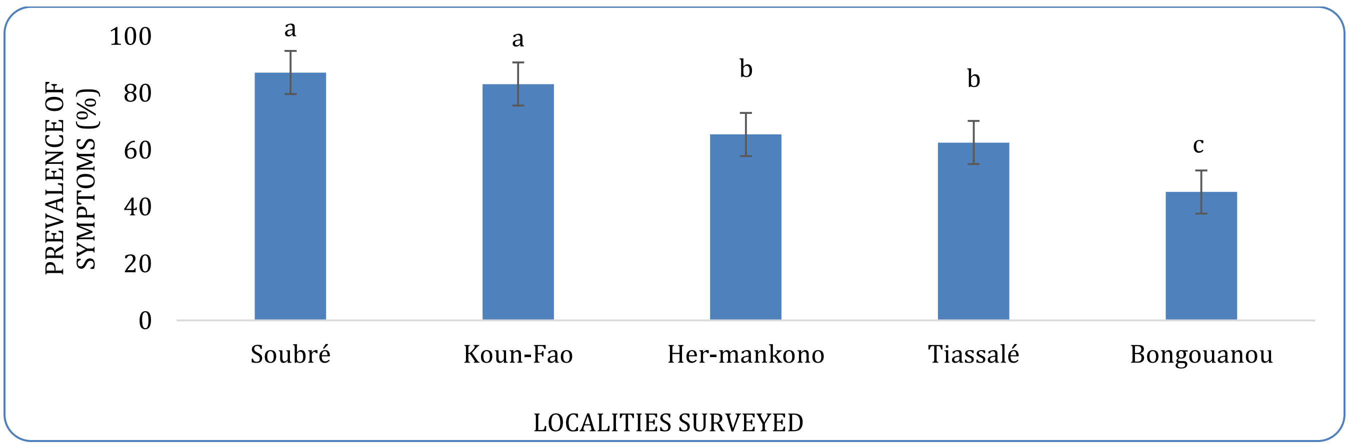

Figure 4: Prevalence of ginger fungal disease symptoms in each locality surveyed.
The histograms with the same letters on the standard deviations are statistically identical according to Ficher's LSD test at 5 % threshold.

Table 2: Severity indexes of fungal disease symptoms observed on ginger plants in the different localities surveyed.

Localities visited	Severity indexes			
	Necrosis	Yellowing	Leaf spot	Wilting
Her-mankono	20 ± 0.23 [b]	36.66 ± 0.28 [a]	36.66 ± 0.28 [b]	33.33 ± 0.19 [ab]
Tiassalé	20 ± 0.1 [b]	23.33 ± 0.15 [b]	36.66 ± 0.49 [b]	30 ± 0.20 [ab]
Koun-fao	86.66 ± 0.30 [a]	26.66 ± 0.19 [ab]	80 ± 0.15 [a]	40 ± 0.40 [a]
Soubré	86.66 ± 0.30 [a]	30 ± 0.19 [ab]	76 ± 0.33 [a]	46.66 ± 0.45 [a]
Bongouanou	40 ± 0.23 [ab]	30 ± 0.20 [ab]	50 ± 0.47 [ab]	20 ± 0.23 [b]
F	18,13	1,223	10,76	2,11
P	0,0001	0,044	0,0001	0,012

Table 3: Fungi associated with the symptoms observed on ginger plants in the different localities surveyed.

Fungi identified	Symptoms						
	Marginal chlorosis	General chlorosis	Wilting	Apical necrosis	Marginal necrosis	Rib necrosis	Leaf spot
Aspergillus	+	+	+	+	+	+	+
Colletotrichium	+	-	+	-	+	-	-
Curvularia	-	-	+	-	-	-	-
Unknown 1	-	-	+	-	+	-	-
Unknown 2	-	-	-	-	+	-	-
Fusarium	+	-	+	-	+	+	-
Mucor	-	+	-	+	-	-	+
Leptosphaeria	-	-	+	+	-	-	-
Penicillium	-	-	-	-	+	+	-
Pestalotiopsis	+	-	+	-	+	-	-
Pythium	+	+	+	+	+	+	+
Rhizoctonia	+	+	+	+	+	+	+
Rhizopus	-	-	+	-	+	-	-
Sclerotium	-	+	-	+	+	-	+
Trichoderma	+	+	+	+	+	+	+
Total	7	6	11	7	12	6	6

Isolation frequency of fungi associated with disease symptoms

Fungi isolation frequencies varied depending on the symptoms of the diseases and the localities surveyed. Thus, they varied from 37.5 to 50% in Bongouanou; from 16.33 to 100% in Hermankono; from 12.5 to 62.5% in Koun-Fao; from 12.5 to 75% in Soubré and from 12.5 to 80% in Tiassalé. *Fusarium* had the highest isolation frequency in the localities of Hermankono and Tiassalé. In contrast, in the localities of Bongouanou, Koun-Fao and Soubré, the *Rhizoctonia* fungus was the most isolated (Figure 5). Of all the isolated fungi, *Fusarium* had the highest isolation frequency followed by *Rhizoctonia* on infected aerial organs.

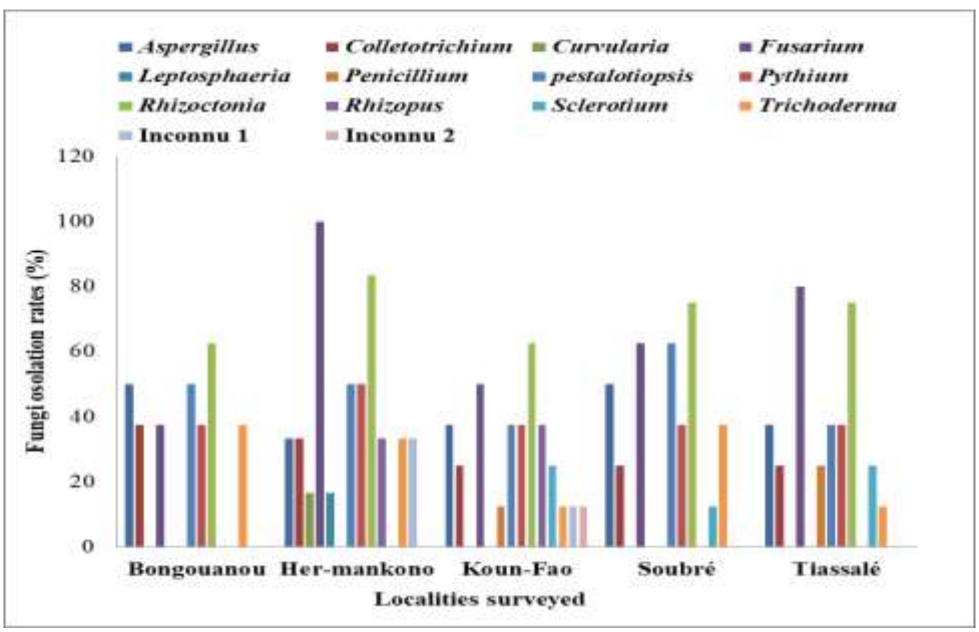

Figure 5: Isolation frequency of fungi associated with disease symptoms observed in surveyed localities.

DISCUSSION

Survey of the study sites made it possible to observe a diversity of fungal disease symptoms on ginger leaves and stems in Côte d'Ivoire. This diversity of observed symptoms could be explained by the activity of several genera of plant-pathogenic fungi with various mechanisms of action that can be physical, physiological or biological (Huguenin, 2016). The interaction of factors (plant age, temperature, strain) is likely to cause variation of the epidemiology of the induced disease (Julien, 2010). Furthermore, the same symptoms were found in all the localities surveyed. This could be because the seeds come from a common source. The symptoms of chlorosis, necrosis and leaf spot have frequently been reported in ginger cultivation by several authors in different producing countries. Thus, Gupta and Manisha (2017) and Gupta and Tennyson (2019) have also reported chlorosis and leaf spot on ginger leaves in cultivation in India. These symptoms are attributed to plant-pathogenic fungi. According to Gupta and Tennyson (2019), temperatures of 23-28°C with intermittent rains favor the appearance of leaf spot disease. As for chlorosis, it is widespread and prevails in hot and humid environmental conditions. Indeed, plant-pathogenic fungi have various life cycles; to this is added a strong functional diversity. One or more hosts may be involved in the life cycle of the pathogen, which would favor the development of several symptoms.

Prevalence and severity index varied depending on the symptoms observed on ginger organs. The prevalence of ginger disease was high in the areas of Koun-Fao, Soubré, Hermankono and Tiassalé, which showed that ginger disease was indeed present in production areas in Côte d'Ivoire. The severity of the disease in these areas could also be explained by the cultivation of taro, groundnuts, etc. in crop rotation. These plants have the same pathogens as ginger, which maintains the pathogen cycle. The lower disease prevalence recorded in the Bongouanou zone seems to be correlated with the climate, which is very hot and oppressive throughout the year, and with an environment that is less favorable to potential reservoirs of pathogenic fungi and ginger pathogens.

The variations in the prevalence of symptoms would be due to the nature of the interaction that exists between the pathogen and the host. Moreover, the manifestation of symptoms depends on the physical and chemical factors of the environment. The effects of the disease that constitute the symptoms are therefore the consequences of the presence of the pathogen and the host in a given environment. The predominance of leaf spot and necrosis with high severity indexes would be explained by the threshold of harmfulness of the pathogens involved in these diseases, which would be very high. According to Coyne et al. (2010), this threshold is influenced by several factors including the biology of the pathogen, its virulence, its concentration in the host plant and environmental factors. Higher intensity of rain accompanied by wind seems to exert a greater impact on the target leaf, so that the spores are splashed over greater distances, resulting in the release of a huge amount of spores and an increase in the incidence of leaf spot disease. Leaf spot disease is considered to be an important disease because of its severe leaf spots, which eliminate chlorophyll tissue, and cause significant yield losses in ginger. This disease causes yield losses ranging from 13 to 66% depending on its severity Merga (2021). Several fungi were associated with ginger disease symptoms in the main production areas and their isolation frequency varied per locality. The diversity of fungal genera in cultivation areas could be explained by the variation of environmental factors (temperature, rain, relative humidity) and cropping history from one locality to another. Indeed, according to Vacher et al. (2008), temperature is an important factor in explaining the diversity of plant-parasitic fungi. The presence of several fungi within a symptom can be explained by the effect of co-infection or is probably related to the age of the infected plant material or other host plants. According to Moutassem (2020), the same host can react in the same way to the attacks of different parasites, because the means at their disposal to express the disorders inflicted on them by the parasites are limited in number, especially in plants. The high isolation rate of the *Fusarium* and *Rhizoctonia* genera could be explained by their strong presence on the different plots. *Fusarium* is responsible for several diseases in ginger (Vijayan et al., 2020).

The genera *Fusarium* and *Rhizoctonia* are telluric mycopathogens that cause enormous losses and damage to plants in Côte d'Ivoire (Soro et al., 2008). The high isolation rate of these fungi could be related to their presence in the soil; whether pathogenic or not, when conditions are favorable, they germinate, penetrate the plant and spread to all parts of the plant. According to

Assigbetse (1989), the genus *Fusarium* comprises numerous phytopathogenic species, including *Fusarium oxysporum*, which is the most frequent and important parasitic species in the fungal microflora of cultivated soils. This species comprises a group of morphologically identical forms, but with sometimes very narrow parasitic specificities, which causes specific forms of symptoms. The least infected area in this study would be suitable for growing ginger in Côte d'Ivoire and for supplying ginger seed.

Plant diseases cause a significant reduction in yield in all crops, leading to significant losses in terms of quality and quantity. The presence of pathogens in ginger crops in Côte d'Ivoire is a threat to food security. Internationally, the cost of controlling plant diseases runs into billions of dollars each year (FAO, 2000). However, knowledge of the fungi that are associated with ginger disease symptoms is important information that could contribute to the development of appropriate control methods.

CONCLUSION

Symptoms of fungal diseases were observed on several ginger plantations in Côte d'Ivoire. A variety of symptoms, such as necrosis, yellowing, leaf spot and wilting were observed in the different sites surveyed. The prevalence and mean severity index varied between symptoms and locations. In addition, several fungi were associated with ginger disease symptoms in cultivation, and their isolation frequency varied according to location. These diseases damage ginger plants, reduce production and affect yield quality. Fungal diseases are therefore a constraint to ginger production in Côte d'Ivoire. This study has provided a lot of information about the state of ginger cultivation in Côte d'Ivoire. However, we are far from having answered all the questions related to the problems of the ginger sector in Côte d'Ivoire. However, research perspectives have been identified.

OUTLOOK

Sharing findings with farmers is crucial; it helps them make informed decisions. Beyond that, the work does not stop – it is an ongoing process of identifying ginger pathogens at a molecular level, exploring the tiny details. This leads to a better understanding of the intricacies involved. And of course, it does not end there either; the goal is to not just identify but also to find effective methods to control these pathogens, ensuring a healthier and more robust ginger crop. It is a cycle of discovery, understanding, and application, all aimed at supporting growers and enhancing agricultural practices.

RECOMMENDATIONS FOR IMPROVED PRODUCTION

When venturing into ginger cultivation, it is crucial to adhere to a set of practices that ensure a thriving and robust yield. Begin with the foundation - always opt for healthy rhizomes when initiating the cultivation process. The vitality of ginger crop hinges on the quality of the seed, so it is wise to source ginger seed from regions or fields with minimal disease presence, setting the stage for a healthier growth cycle. Implementing crop rotation emerges as a strategic move; let the land breathe and recover by switching crops for a span of 3-4 years, mitigating the risk of diseases establishing a permanent residence. When it comes to storage, be meticulous in your selection - opt for fully mature seed rhizomes, ensuring they are untouched by the ravages of insects and diseases, safeguarding the future of your ginger harvest. To further fortify your cultivation against potential threats, integrate appropriate pest and disease control measures into agricultural regimen, fostering a resilient and flourishing ginger culture.

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AUTHORS' CONTRIBUTIONS

NSS designed the study; NSS and NWY conducted the surveys and collected the data; NSS analyzed the data; NSS wrote the manuscript; AEPK and HAD supervised the work and AEPK proofread the manuscript.

CONFLICT Of INTEREST

The authors declare no conflict of interest.

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