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Morphological Identification of the Main Fungi Associated with Sesame in Burkina Faso

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Abstract

Several fungal species are responsible for diseases that damage sesame crop and cause production losses. These seed-borne fungi cause serious damage by reducing seed germination. To identify the fungi associated with sesame seeds in Burkina Faso, 72 sesame seed samples were collected from 24 localities in the main production areas (Sudanian zone, Sudano-Sahelian zone, Sahelian zone). These samples were submitted for seed health analysis using the blotting paper incubation method. The results obtained revealed that the seed samples were contaminated by various fungi, the main ones being: *Fusarium* spp. Link: Fr. infecting 97.22% of the samples, *Macrophomina phaseolina* (Tassi) Goid. (90.28%), *Alternaria sesamicola* E. Kawamura (83.33%), *Curvularia lunata* (Wakker) Boedijn (76.39%), *Cercospora sesami* A. Zimmerm. (73.61%), *Phoma sorghina* Boerema, Dorenbosch, & Van Kesteren (73.61%), *Aspergillus flavus* Link: Fr. (69.44%), *Cladosporium sphaerospermum* Penz. (56.94%), *Rhizopus* sp. Ehrenb. (40.28%) and *A. niger* Tiegh. (36.11%). In each seed sample, 0.25% to 94% of the seeds host one or more fungal species. Regarding the climatic zones, the results revealed that *A. sesamicola* and *A. flavus* were more represented in the Sudanian zone than in the Sudano-Sahelian and Sahelian zones; while *P. sorghina*, and *C. sphaerospermum* were more encountered in the Sahelian zone than in the other two zones. This study showed that the majority of sesame seeds produced and used by farmers in Burkina Faso host one or more species of fungi at high levels.

Keywords

Sesame, Fungi Associated with Seeds, Seed Health Analysis, Burkina Faso

1. Introduction

In Burkina Faso, sesame production is a major component of the agricultural sector. It ensures the livelihood of many households. It is one of the main sources of income for 2/3 of the agricultural households [1]. Sesame exports reached FCFA45 billion in 2012 [2]. This crop ranks second in exports after cotton among the economically viable cash crops in Burkina Faso. From 2010 to 2016, sesame export revenues were estimated at more than FCFA350 billion [3]. According to statistics from 2012 to 2017, Boucle du Mouhoun, East, Hauts Bassins and Cascades were the four largest sesame producing regions, with 69.04% of the national production and 70% of the total area planted [3]. In the same period, sesame productivity also increased in the West Central and East Central regions. However, sesame is subject to pest attacks at different levels, which causes lower yields and bad seed quality. According to [4], production losses in Burkina Faso caused by diseases and pests range from 20% to 25% of the yields. In Nigeria, research on sesame diseases reveals that those caused by fungi are major constraints in both seed production and storage [5] [6].

In Burkina Faso, sesame production is confronted with numerous problems such as wilting, root rot and damping-off. These diseases are due to attacks by soil- or seed-borne fungi. Recent investigations undertaken on infected sesame seedlings collected from different localities in the country revealed that more than 85% of infected seedling samples studied harbored several fungi species belonging to the genera Macrophomina, Cersospora and *Fusarium* [7]. Seeds are often a key medium of disease dissemination because the circulation of seeds, with its associated inoculum, introduces diseases (fungi disease) into new and previously healthy areas. Fungi can make food products unsafe due to the production of toxic metabolites such as mycotoxins that affect human and animal health [8] [9] [10]. However, little information exists at the national level on the dreaded seed-borne fungi diseases of sesame. The objective of the present study is to identify the major fungi associated with sesame seeds produced in Burkina Faso and to determine their distribution in the country's Sudanian, Sudano-Sahelian and Sahelian climatic zones.

2. Methodology

2.1. Study Zone

Sesame seed samples were collected in 24 localities in the provinces of Bazèga (Gaongo), Boulgou (Zabré, Zonsé, Tenkodogo), Comoé (Banfora, Niangoloko), Gourma (Fada, Matiacoali), Houet (Satiri, Fô, Toussiana), Koulpélogo (Dourtenga, Ouargaye), Kouritenga (Koupèla), Mouhoun (Douroula, Ouarkoye, Dédougou, Bondonkuy), Nayala (Kougny), Séno (Dori), Sourou (Gomboro), Tapoa (Kantchari, Partiaga) and Zoundwéogo (Gogo) (**Figure 1**). The different experiments were carried out, at the Centre de Recherches Environnementales, Agricoles et de Formation (CREAF) of Kamboinsé precisely in the Phytopathology laboratory.

The CREAF is research center of Institut National de l'Environnement et de la Recherche Agricole (INERA).

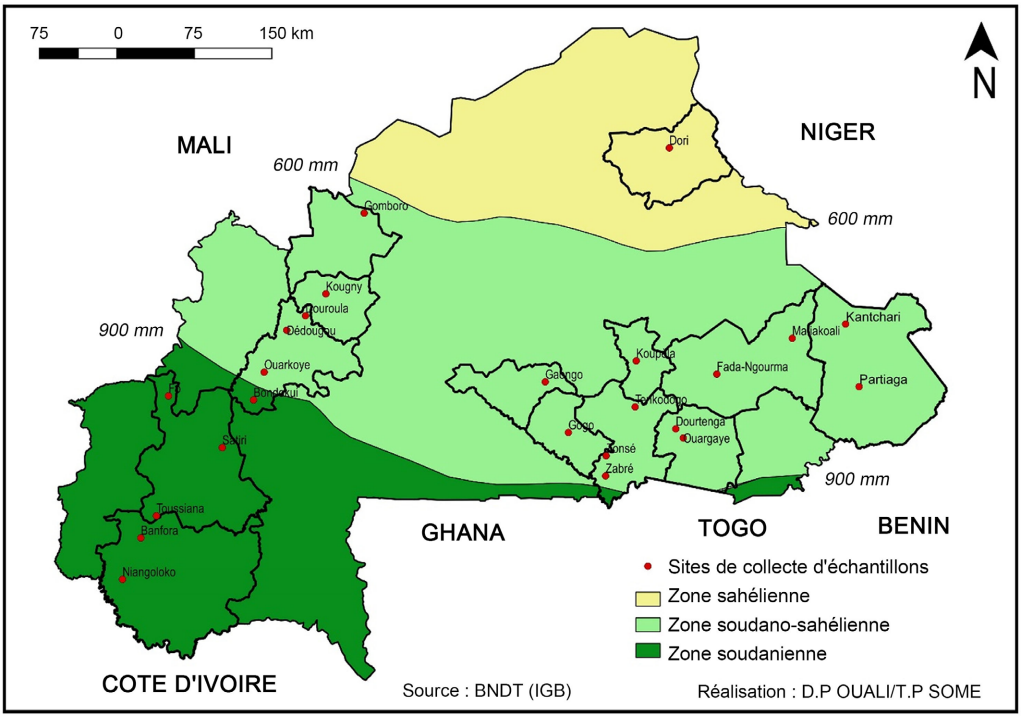

Figure 1. Sesame seed collection sites in the three climatic zones of Burkina Faso in 2020.

2.2. Collection of Sesame Sample

A total of 72 seed samples were collected in 2020 from farmers at identified sites and at a rate of 200 g of seed per sample. Each sample collected was labeled with the date and location of collection. Samples were packaged in plastic bags and stored in the freezer until use.

2.3. Seeds Health Analysis

The blotting paper method, developed by ISTA [11], which involves maintaining seeds in an environment favorable to fungi development, was used to diagnose fungi associated with sesame seeds. The completely randomized Fischer block experimental design with 4 replicates was used to evaluate each seed sample. For each sample, 400 sesame seeds were arranged at equal distance from each other in Petri dishes containing three layers of blotting paper soaked in sterile distilled water, with 25 seeds per dish. Petri dishes containing the seeds were incubated in a chamber at 20˚C - 25˚C under an alternating cycle of 12 hours of near ultra-violet light and 12 hours of darkness per day for seven days. Incubated seeds were individually examined under binocular loupe for the possible presence of fungi. All detected fungi were automatically subjected to morphological identification by stereo microscope and/or routine microscope observation, referring to the fungi identification key proposed by [12]. The species of fungi present on each seed were noted and the percentage of seeds infected by a given fungus was

calculated for each seed sample. At the national level and in each agroecological zone, the prevalence rates or percentages of seed samples contaminated by each fungus were also calculated.

2.4. Statistical Analysis of Data and Presentation of Results

The data collected were analyzed using SAS software (Staistical Analysis System, 2001). An analysis of variance, followed by a comparison of means using Duncan's test with a threshold of 5%, were performed on the average prevalence rates of fungi in the seed samples and on the average rates of seeds infected by each fungus. For each seed sample assessed by the blotting paper method, the average rate of seeds infected by a given fungus was expressed as a percentage of the number of seeds attacked by said fungus out of a total of 400 seeds observed. The prevalence of each fungus in the seed samples was expressed as a percentage of the number of seed samples infected with said fungus out of the total number of seed samples assessed. The prevalence of each fungus in a given agro-ecological zone was expressed as a percentage of the number of samples originating from said zone infected with said fungus out of the total number of seed samples collected in the zone in question. The average rate of seeds infected by each fungus in a given agro-ecological zone was expressed as a percentage and corresponds to the average rate of infection of seeds from samples originating in the said zone by the fungus in question.

3. Results

3.1. Sesame Sample Collection Results

Table 1 shows the number of samples collected per province. A total of 72 seed samples were collected from 13 provinces in three climatic zones. Among the provinces were the seeds were collected, 10 belong to the Sudan-Sahel zone, two to the Sudanian zone and one to the Sahelian zone.

Table 1. Number of samples collected and their origin.

Provinces	Number of collection districts	Number of samples used in the study	Agro-ecological zone of collection
Bazéga	1	2	Soudano-Sahélienne
Boulgou	3	10	Soudano-Sahélienne
Comoé	2	8	Soudanienne
Gourma	2	4	Soudano-Sahélienne
Houet	3	6	Soudanienne
Koulpélogo	2	3	Soudano-Sahélienne
Kouritenga	1	7	Soudano-Sahélienne
Mouhoun	4	8	Soudano-Sahélienne
Nayala	1	1	Soudano-Sahélienne
Séno	1	1	Sahélienne
Sourou	1	1	Soudano-Sahélienne

Continued

Tapoa	2	20	Soudano-Sahélienne
Zoundwéogo	1	1	Soudano-Sahélienne
Total	**24**	**72**	

3.2. Sesame Seed Mycoflora

3.2.1. Rate of Seed Samples Contaminated by Fungi

Health analysis of the 72 samples revealed the presence of 10 major fungal species in the samples collected (Table 2). All samples studied were contaminated by at least one fungal species. The percentages of samples infected by species ranged from 36.11% to 97.22%. Fungal species contaminated more than 50% of samples, with the exception of *Aspergilus niger* and *Rhizopus* sp. which had lower prevalence rates (36.11% and 40.28%, respectively). Of the fungi identified, *Fusarium* spp. was the most prevalent, with 97.22% of samples infected (Table 2).

Table 2. Prevalence rate of fungi species in seed samples.

Fungi species	Number of infected seed samples	Prevalence of fungi (%)
Fusarium spp.	69	97.22
Macrophomina Phaseolina	62	90.28
Alternaria sesamicola	60	83.33
Cercospora sesami	53	73.61
Phoma sorghina	53	73.61
Curvularia lunata	55	76.39
Aspergillus niger	26	36.11
Aspergillus flavus	50	69.44
Rhizophus sp.	29	40.28
Cladosporium sphaerospermum	41	56.94

3.2.2. Indexs of Fungal Infection Detected in Sesame Seed Samples

Table 3 presents the results of the health analysis carried out on sesame seeds collected in Burkina Faso's agrosystem. Ten (10) major fungi regularly contaminating sesame samples with variable infection indexs were identified. Seventy (70) of the 72 seed samples were contaminated by *Fusarium* spp. with infection indexs ranging from 0.25% to 32.75%. *Macrophomina phaseolina*, *Alternaria sesamicola*, *Cercospora sesami*, *Phoma sorghina*, *Curvularia lunata*, *Apergillus niger*, *A. flavus*, *Rhizopus* sp. and *C. sphaerospermum* were found in seeds at infection rates of up to 36%, 91%, 12.5%, 10.25%, 20.50%, 10.25%, 81%, 44.25%, 44.25% and 94% respectively. The highest infection levels were noted with *C. sphaerospermum* (94%), *A. sesamicola* (91%) and *A. flavus* (81%). Among the seed samples analyzed, CN6 was free of any fungal infection and TK13 was lightly infected, with only two fungi: *M. phaseolina* (2.25% infection index) and *A. sesamicola* (1%).

Table 3. Infection rate of 72 sesame seed samples from Burkina Faso by various fungi.

Samples	Percentage of seed infected by fungi									
	Fusarium spp.	*M. Phaseolina*	*A. sesamicola*	*C. sesami*	*P. sorghina*	*C. lunata*	*A. niger*	*A. flavus*	*Rhizophus* sp.	*C. sphaerospermum*
T2	32.75a	7.00hi	7.25cd	3.00fg	0.50fg	0.75c	0.25ij	0.25g	0.50i	0.50i
TK7	23.00b	7.25hi	3.50gh	1.25fg	2.25fg	0.00c	0.25ij	0.00g	0.00i	0.00i
HT2	22.75b	69.00c	2.25gh	0.00g	0.25fg	0.00c	0.00j	0.00g	0.00i	0.00i
T1	20.25bc	39.00de	12.50a	2.50fg	0.25fg	0.00c	2.25ij	9.25cd	1.50i	1.50i
KPL2	18.50cd	4.25hi	4.00gh	1.75fg	0.00g	0.00c	18.25d	0.50g	8.75h	8.75h
SG	17.50de	6.75hi	0.00h	2.00fg	20.50a	0.25c	11.25e	0.00g	16.00g	16.00g
KPL5	17.50de	35.25e	9.50ab	0.50g	0.75fg	0.00c	0.50ij	2.75fg	1.25i	1.25i
GM3	16.75de	2.00hi	0.00h	3.75ef	2.25fg	0.50c	1.00ij	0.00g	0.25i	0.25i
TP1	15.25ef	1.25hi	0.25gh	0.25g	0.25fg	1.50bc	3.50ij	0.00g	0.50i	0.50i
HF4	14.00fg	83.75b	8.50bc	0.00g	0.50fg	0.00c	0.00j	0.00g	1.00i	1.00i
T4	13.75fh	0.75hi	3.50gh	0.75g	0.25fg	0.50c	31.75c	9.75c	0.00i	0.00i
TP4	13.25hi	0.75hi	0.25gh	0.00g	1.25fg	0.00c	0.00j	0.00g	0.25i	0.25i
KO	12.00ij	46.00d	3.75gh	0.25g	13.75b	0.00c	0.00j	0.25g	9.75h	9.75h
T7	10.50jk	0.75hi	2.25gh	0.50g	0.25fg	0.00c	9.00ef	4.50fg	0.00i	0.00i
MO1	10.25kl	20.50f	0.75gh	2.75fg	0.25fg	0.25c	1.25ij	0.00g	0.50i	0.50i
MO2	9.25lm	15.50fg	300gh	7.00bc	0.50fg	0.00c	0.50ij	0.00g	0.00i	0.00i
MB1	9.00mn	1.50hi	0.50gh	10.25a	1.5fg	0.00c	0.25ij	0.00g	0.00i	0.00i
KPL7	8.00no	1.50hi	5.50ef	2.50fg	2.00fg	0.75c	3.00ij	0.00g	2.25i	2.25i
TK14	8.00no	19.00f	6.25de	4.00de	10.75c	0.00c	1.25ij	0.00g	0.25i	0.25i
T6	7.75op	1.25hi	4.50fg	2.75fg	0.75fg	0.50c	0.25ij	1.75fg	0.25i	0.25i
T3	7.50pq	1.50hi	3.50gh	0.75g	1.75fg	0.25c	3.50ij	0.25g	2.50i	2.50i
HF3	7.50pq	91.00a	4.25gh	0.50g	0.25fg	0.00c	0.00j	1.50fg	0.00i	0.00i
T5	6.75qr	1.25hi	1.50gh	0.75g	0.50fg	0.25c	4.5ij	3.50fg	2.00i	2.00i
BZ	6.50rs	66.00c	0.75gh	0.25g	3.00d	0.00c	0.00j	0.00g	94.00a	94.00a
BZ2	6.50rs	4.25hi	3.75gh	8.50ab	2.00fg	0.00c	0.00j	0.50g	68.25d	68.25d
MDO2	5.75rs	44.50d	0.75gh	0.75g	0.50fg	0.00c	1.25ij	0.00g	0.00i	0.00i
BZ1	5.50rs	1.75hi	1.00gh	6.50bc	0.00g	0.00c	0.00j	0.00g	83.25b	83.25b
TK6	5.50rs	1.25hi	0.00h	1.00fg	0.75fg	0.00c	0.25ij	0.25g	0.00i	0.00i
MB2	5.50rs	3.00hi	0.75gh	3.75ef	0.75fg	0.00c	0.00j	0.00g	0.00i	0.00i
TK12	5.25rs	1.25hi	0.50gh	1.00fg	0.50fg	0.00c	2.00ij	0.00g	0.00i	0.00i
BG1	5.00rs	0.00i	1.00gh	0.00g	2.00fg	0.50c	0.50ij	0.00g	61.50e	61.50e
DK2	5.00rs	8.25hi	3.50gh	2.50fg	0.25fg	0.50c	9.00ef	5.75fg	1.00i	1.00i
KPL4	4.50rs	1.00hi	0.00h	1.50fg	1.25fg	0.00c	4.00ij	0.50g	2.50i	2.50i
HS	4.25rs	34.00e	3.00gh	3.00fg	2.50ef	0.00c	0.00j	0.00g	45.00f	45.00f
KPL6	4.00rs	2.50hi	12.00a	4.75cd	1.00fg	0.25c	6.50fg	21.50b	1.00i	1.00i
HF	4.00rs	0.00i	0.00h	0.00g	0.00g	0.00c	81.00a	0.00g	0.00i	0.00i
GM2	4.00rs	1.75hi	0.50gh	0.25g	1.00fg	0.00c	0.50ij	2.75fg	1.00i	1.00i

Continued

BG2	4.00rs	0.50hi	3.75gh	0.75g	2.75de	1.00bc	0.50ij	0.00g	83.50b	83.50b
TK5	4.00rs	0.25i	0.00h	0.00g	0.00g	0.00c	0.25ij	0.00g	0.25i	0.25i
KPL3	3.75rs	1,00hi	2.75gh	3.75ef	0.50fg	0.00c	1.50ij	0.00g	1.00i	1.00i
TK2	3.50rs	1.25hi	0.00h	3.00fg	1.25fg	2.25b	0.75ij	0.00g	0.00i	0.00i
SD	3.50rs	700hi	2.25gh	3.75ef	0.25fg	0.25c	1.00ij	0.25g	77.50c	77.50c
NK1	3.25rs	9.50gh	2.00gh	0.50g	1.00fg	1.25bc	16.00d	1.25fg	0.25i	0.25i
CN1	3.25rs	0.25i	1.25gh	0.00g	0.25fg	0.50c	0.00j	0.00g	0.00i	0.00i
TP3	3.00rs	0.00i	0.00h	0.25g	0.00g	0.00c	0.00j	0.00g	0.00i	0.00i
TK10	3.00rs	5.25hi	1.00gh	0.00g	1.5fg	0.00c	0.00j	0.00g	0.00i	0.00i
MDO1	2.75rs	3.00hi	1.00gh	0.25g	0.00g	0.00c	0.00j	7.25de	0.00i	0.00i
KPL1	2.75rs	3.75hi	0.50gh	7.75b	0.00g	0.00c	0.50ij	0.00g	3.00i	3.00i
TP6	2.75rs	0.00i	0.25gh	0.25g	0.75fg	0.00c	0.00j	0.00g	0.00i	0.00i
TK8	2.50rs	4.00hi	1.50gh	0.25g	0.25fg	0.00c	2.50ij	0.00g	1.50i	1.50i
CN2	2.25rs	2.25hi	3.75gh	0.25g	1.25fg	1.00bc	1.00ij	0.75g	4.00i	4.00i
MD1	2.25rs	2.50hi	0.75gh	1.75fg	0.25fg	0.00c	0.25ij	1.50fg	1.50i	1.50i
CN3	2.25rs	2.50hi	0.00h	0.00g	0.75fg	0.00c	0.00j	0.00g	0.25i	0.25i
GM1	2.00rs	67.50c	0.50gh	0.50g	0.50fg	0.00c	0.75ij	0.00g	0.00i	0.00i
GF1	1.75rs	8.75hi	1.75gh	0.75g	1.5fg	1.00bc	5.50gh	3.75fg	8.50h	8.50h
DK1	1.75rs	0.00i	0.00h	1.00fg	0.00g	0.00c	0.75ij	0.00g	0.00i	0.00i
TK1	1.50rs	0.75hi	1.75gh	0.25g	0.25fg	1.00bc	1.75ij	0.75g	0.50i	0.50i
ZG	1.50rs	0.00i	0.00h	0.00g	0.00g	0.25c	2.25ij	1.25fg	3.75i	3.75i
HT1	1.25rs	0.00i	1.50gh	0.00g	0.25fg	0.00c	75.50b	0.00g	0.00i	0.00i
CN7	1.25rs	0.00i	0.00h	0.00g	0.00g	0.00c	0.00j	0.00g	0.00i	0.00i
CN5	1.25rs	0.50hi	0.50gh	0.25g	0.25fg	0.00c	0.00j	0.00g	0.00i	0.00i
CB1	1.00rs	0.50hi	0.00h	0.00g	0.00g	0.25c	12.00e	44.25a	0.25i	0.25i
TK11	1.00rs	6.50hi	0.25gh	1.75fg	1.25fg	0.00c	0.50ij	0.00g	0.00i	0.00i
TK3	1.00rs	3.75hi	0.00h	0.50g	0.50fg	10.25a	2.50ij	4.00fg	0.00i	0.00i
TP5	0.75rs	0.00i	0.00h	0.00g	0.00g	0.00c	0.25ij	0.00g	0.25i	0.25i
TK9	0.75rs	0.50hi	0.25gh	0.00g	0.75fg	0.00c	0.25ij	0.00g	0.00i	0.00i
MD2	0.75rs	0.25i	0.25gh	1.75fg	0.25fg	0.00c	0.00j	0.00g	0,00i	0.00i
TP2	0.75rs	0.00i	0.00h	2.50fg	0.00g	0.00c	0.00j	0.25g	0.00i	0.00i
TK4	0.50rs	0.25i	0.00h	0.00g	0.00g	1.25bc	0.50ij	0.00g	0.00i	0.00i
CN4	0.25rs	0.00i	0.00h	0.00g	0.00g	0.50c	4.75hi	6.50ef	0.25i	0.25i
CN6	0.00s	0.00i	0.00h	0.00g	0.00g	0.00c	0.00j	0.00g	0.00i	0.00i
TK13	0.00s	0.25i	1.00gh	0.00g	0.00g	0.00c	0.00j	0.00g	0.00i	0.00i
CV	**58.08**	**50.22**	**48.18**	**118.7**	**106.86**	**99.87**	**229.86**	**56.23**	**167.84**	**37.08**
Moyenne	**6.39**	**6.27**	**10.53**	**1.98**	**1.57**	**1.29**	**0.38**	**4.57**	**1.9**	**8.21**
Pr > F	**<0.0001**	**<0.0001**	**<0.0001**	**<0.0001**	**<0.0001**	**<0.0001**	**<0.0001**	**<0.0001**	**<0.0001**	**<0.0001**

3.2.3. Importance of Fungi by Province of Origin of Samples

The results presented in Table 4 showed that fungal seed infection rates varied according to the province of seed origin. Statistical analysis indicated significant differences between provinces for all fungal species encountered, with the exception of *A. niger* and *Rhizopus* sp. *Fusarium* spp., *M. phaseolina*, *A. flavus* and *C. sphaerospermum* were encountered in all provinces. The Sourou province was the most infected with *Fusarium* spp. (17.50% infection index), *M. phaseolina* (36%) and *C. lunata* (20.50%) compared with other provinces. *A. sesamicola* and *A. flavus* were more frequently encountered in the Houet province (46.29% and 26%, respectively) and *C. sesami* in Kouritenga (4.89%). *P. sorghina* and *C. sphaerospermum* were more frequently found in the Mouhoun and Séno (3.53% - 3.75%) and the Bazèga and Séno (72.50% - 77.50%) respectively. The province of Zounwéogo had little or no incidence of several fungi at the same time.

For each fungal species, two groups of provinces can be distinguished: the thirst group is made up of provinces with high rates of infected seeds, above 10%, and the second group is made up of provinces with relatively low rates of infected seeds, below 10%.

Table 4. Infection indices of various fungi species associated with sesame seeds collected in different provinces of Burkina Faso in 2020.

Provinces	*Fusarium* spp.	*M. Phaseolina*	*A. sesamicola*	*C. sesami*	*P. sorghina*	*C. lunata*	*A. niger*	*A. flavus*	*Rhizophus* sp.	*C. sphaerospermum*
Bazéga	4.50cd	15.00b	0.25bc	2.37bc	0.37cd	2.37c	0.75a	0.50c	0.00a	72.50a
Boulgou	11.75ab	9.52c	12.35bc	4.05ab	2.62bc	0.92c	0.22a	5.15bc	2.97a	25.22b
Comoé	1.43d	1.34d	0.75bc	0.68bc	0.06cd	0.25c	0.28a	2.21c	6.43a	0.59c
Gourma	6.12cd	1.93d	20.00b	0.68bc	1.31cd	1.31c	0.37a	1.93c	1.62a	2.43c
Houet	8.95bc	1.16d	46.29a	3.25bc	0.58cd	0.50c	0.00a	26.00a	0.25a	7.66c
Koulpélogo	6.25cd	8.83c	18.08bc	2.41bc	1.25cd	4.66b	0.16a	2.25c	2.00a	3.58c
Kouritenga	8.42cd	5.17cd	7.03bc	4.89a	3.21ab	0.78c	0.14a	4.89bc	3.60a	2.82c
Mouhoun	5.68cd	1.15d	11.34bc	0.96bc	3.53a	0.31c	0.03a	0.43c	0.26a	0.25c
Nayala	3.25cd	2.00d	9.50bc	2.00bc	0.50cd	1.00c	1.25a	16.00ab	1.25a	0.25c
Séno	3.50cd	3.00d	7.00bc	2.25bc	3.75a	0.00c	0.25a	1.00c	0.00a	77.50a
Sourou	17.50a	36.00a	6.75bc	0.00c	2.00cd	20.50a	0.25a	11.25bc	0.00a	16.00bc
Tapoa	4.76cd	4.75cd	2.67bc	0.83bc	0.81cd	1.11c	0.81a	0.85c	0.25a	0.17c
Zoundwéogo	1.50d	0.25d	0.00c	0.00c	0.00d	0.00c	0.25a	2.25c	1.09a	3.75c
Moyenne	**6.39**	**4.98**	**10.53**	**1.98**	**1.57**	**1.29**	**0.38**	**4.57**	**1.9**	**8.21**
CV	**103.09**	**104.21**	**167.34**	**155.04**	**150.51**	**172.14**	**382.17**	**261.6**	**336.21**	**189.56**
P	**<0.0001**	**<0.0001**	**<0.0001**	**<0.0001**	**<0.0001**	**<0.0001**	**0.38**	**<0.0001**	**0.007**	**<0.0001**

3.2.4. Importance of Fungi According to Climatic Zone of Origin of Samples

The results concerning the distribution of the fungi most commonly found in the three climatic zones are shown in Table 5. The frequencies of four fungal species (*A. sesamicola*, *P. sorghina*, *A. flavus* and *C. sphaerospermum*) in seeds varied according to the climatic zones in which the samples were collected. *A. sesamicola* and *A. flavus* were more prevalent in the Sudanian zone, with infection indexs of 19.36% and 12.36% respectively, than in the other two zones (Sahelian and Sudano-Sahelian). On the other hand, the Sudanian zone was less infected with *P. sorghina* (0.4%) than the Sahelian zone (3.75%). The Sudanian and Sudano-Sahelian zones were also less infected with *C. spherospermum* (4.44% and 7.98%, respectively) than the Sahelian zone (77.50%). For all other fungi, no significant differences in infection levels were noted between the three climatic zones (Table 5).

Table 5. Infection indices of 10 major fungi associated with sesame seeds produced in three climatic zones of Burkina Faso.

Zones climatiques	Fungi infection indices (%)									
	F. spp.	*M. p*	*A. s*	*C. s*	*P. s*	*C. l*	*A. n*	*A. f*	*R* sp.	*C. sph*
Sahélienne	3.50a	3a	7.00b	2.25a	3.75a	0.25a	0.25a	1.00b	0.25a	77.50a
Soudano-Sahélienne	6.68a	5.39a	8.23b	2.07a	1.85ab	1.17a	0.44a	2.55b	1.50a	7.98b
Soudanienne	5.51a	3.5a	19.36a	1.66a	0.4b	1.78a	0.16a	12.36a	3.53a	4.44b
CV	113.4	142.77	196.58	171.26	162.24	253.17	383.76	285.93	343.72	251.6
Moyenne	6.39	4.98	10.53	1.98	1.57	1.29	0.38	4.57	1.9	8.21
P	0.39	0.18	0.001	0.7	0.0001	0.36	0.42	0.0001	0.091	0.0001

F. spp.: *Fusarium* spp., *M. p*: *Macrophomina phaseolina*, *A. s*: *A. sesamicola*, *C. sesame*, *C. l*: *C. lunata*, *A. n*: *A. niger*, *R.* sp.: *Rhizophus* sp., *C. sph*: *C. sphaerospermum*.

4. Discussion

Sesame seed samples were collected from all three climatic zones of Burkina Faso. Of a total of 72 samples collected, 76.38% came from the Sudano-Sahelian zone, 19.44% from the Sudanian zone, and only 1.38% from the Sahelian zone. According to statistics from 2012 to 2017, Boucle du Mouhoun, Est, Hauts Bassins and Cascades were the largest sesame producing regions with 69.04% of the national production and 70% of the total area dedicated to sesame [3]. All these four major producing regions belong to the Soudano-Sahelian and Soudanian zone. That justifies the importance of collecting data on these climatic zones. The Sudano-Sahelian and Sudanian zones are characterized by an average rainfall of over 600 mm, which is conducive to sesame production. On the other hand, the Sahelian zone, characterized by a relatively dry climate (rainfall below 600 mm), is not very favorable to sesame cultivation. In addition to that, access to the Sahelian zone has become very difficult due to the security crisis. As a result, we were unable to collect a substantial number of seed samples in this part of the country at this time (2020).

Health analysis of 72 sesame samples identified several associated fungal species. *Fusarium* spp., *M. phaseolina*, *Phoma sorghina*, *C. sesami*, *A. sesamicola*, *C. lunata*, *A. niger*, *A. flavus*, *Rhizopus* sp. and *C. sphaerospermum* were the main fungi found in sesame seeds in Burkina Faso. These results indicate that numerous fungal agents are associated with sesame seeds in the main production zones. These fungal agents could originate from the mother seed used by farmers, from the soil and/or from the air. The predominance of these fungi shows that sesame is a preferred host for these fungal agents. Similar results have been reported by other authors such as [7] [13], who identified the genera *Fusarium*, *C. sesami*, *A. sesamicola*, *M. phaseolina* and *Phoma* spp. as the main fungi associated with diseased sesame seeds and plants in Burkina Faso. Our results on fungal diversity in Burkina Faso are in line with those obtained by [14] describing a significant presence of fungi belonging to seven main genera on seeds produced in Pakistan. In China, [15] isolated 25 isolates of *Fusarium* spp. from wilted sesame plants. Also, [16], reported that root rot caused by *M. phaseolina* is an important sesame disease leading to yield losses of 5% - 100%. The works by [13] and [17] on sesame seeds produced in Burkina Faso corroborates our findings on the existence of similar fungi (*F. moniliforme*, *F. equiseti*, *P. sorghina*, *M. phaseolina*, *Aspergillus* spp. and *C. lunata*) at high frequencies in sesame production sites, thus revealing the existence of a fungal diversity associated with sesame in Burkina Faso. The fungi identified in Burkina Faso as likely to cause diseases on sesame could therefore have a significant impact on sesame cultivation. It should also be noted that the presence of these fungi in seeds, in very large quantities, is alarming, especially as genera such as *Fusarium*, Phoma and Aspergillus are known to produce mycotoxins that are hazardous to human health [13] [18].

The samples analyzed showed a high infection rate (over 36%). These rates reveal the extent of contamination of apparently healthy seeds. Each sample analyzed was at least infected by one or more fungal species. [13] reports that the fungal infection rate of sesame samples ranged from 1% to 100% for the genera *Fusarium*, *Alternaria sesamicola*, *Macrophomina phaseolina* and *Phoma* spp. on three seed samples analyzed. These results corroborate our own. As the infection rate of the samples is high, this could have a serious impact on the germinative capacity of the seeds and the vegetative development of the plants during the growing season, or on the conservation of the sesame. Indeed, [19] reports that fungi belonging to the genera *Fusarium*, *Phoma*, *Curvularia* reduce the germination of sorghum and millet seeds by 4% to 12%, are transmissible to plants at rates ranging from 63% to 100%, and cause the death of 15% to 65% of emerged seedlings.

Fungal infection indexs vary from province to province. This indicates a variable distribution of fungal species in the provinces. The present work reveals that some provinces are more infested with certain fungi than others. For example, *Fusarium* spp., *M. phaseolina* and *C. lunata* are more prevalent in Sourou

province, and *C. sphaerospermum* is more prevalent in Bazèga and Séno provinces than in other provinces. The high frequency of these fungi in these provinces could be explained by the sensitivity of the varieties used by farmers. For fungi as a whole, the distribution appears to be homogeneous in several provinces. This situation could be explained by the failure to observe good agricultural practices and the absence of equipment for adequate drying of sesame seeds, which favors contamination in the field, during post-harvest operations or during storage. According to [20] [21] inappropriate harvesting, drying and storage practices contribute to the development of fungi, mainly those of the Aspergillus genus. Many diseases of plants and agricultural products, from harvesting to processing, are caused by Aspergillus. The Aspergillus genus is widely distributed geographically, but is most frequently found in warmer climates. The majority of Aspergillus species prefer temperatures between 25˚C and 40˚C for optimal growth. That is why they grow very well in food products. Precautions must therefore be taken during sowing, post-harvest and storage activities to avoid contamination of sesame crops by these fungi.

The identification of fungi in the provinces enables the initiation of control methods that will target the predominant fungus in the province. As many of these fungi cause damage and even disease in humans, it is necessary to assess their pathogenicity.

Significant differences exist between the Sudanian, Soudano-Sahelian and Sahelian zones with regard to *A. sesamicola*, *P. sorghina*, *A. flavus* and *C. sphaerospermum*. *A. sesamicola* and *A. flavus* were more important in the Sudanian zone, while *P. sorghina* and *C. sphaerospermum* were more important in the Sahelian zone. Among the fungi detected in the study, some genera have been previously isolated from other crops in Burkina Faso by other authors: [22] report that *F. moniliforme*, *F. pallidoroseum*, *F. solani*, *C. lunata* and *P. sorghina* are the main fungi found in sorghum seed samples in Burkina Faso. The variation in infection index across climatic zones is consistent with work [21] [23] revealing that contamination, fungal development and mycotoxin production vary according to environmental conditions such as temperature, humidity and storage conditions. Several authors [24] [25] [26] [27] also point out that optimal conditions for the development of various *Fusarium* species tend to be hot and dry. For [28], rainfall conditions are a determining factor in the expression of cercosporiosis. These various studies explaining the determining factors in the distribution of fungi in different ecologies support our findings on infection index in three of the country's climatic zones. Thus, fungal presence in seeds seems to be strongly dependent on environmental conditions.

5. Conclusions

The health analysis of the seeds established that sesame seeds in Burkina Faso are heavily contaminated by various fungi according to the following statistics:

- *Fusarium* spp., *M. phaseolina*, *Alternaria sesamicola*, *Cercospora sesami*,

Phoma sorghina, *Curvularia lunata*, *Apergillus niger*, *Apergillus flavus*, *Rhizopus* sp., *C. sphaerospermum* were the main fungi infecting 97.12%, 90.28%, 83.33%, 73.61%, 73.61%, 76.39%, 36.11%, 69.44%, 40.28% and 56.94% of the samples collected respectively.

- Their infection indexs also varied respectively from 0% to 32.75%, from 0.25% to 36%, from 0.25% to 91%, from 0.25% to 12.5%, from 0.25% to 10.25%, from 0.25% to 20.50%, from 0.25% to 10.25%, from 0.25% to 81%, from 0.25% to 44.25% and from 0.25% to 94%.

Given the abundance of these fungi in sesame samples, it would be wise to develop methods for controlling pathogenic fungal species.

Conflicts of Interest

The authors declare no conflicts of interest regarding the publication of this paper.

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