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Occurrence and Diversity of Seed Associated Fungi in Stored Sorghum from Maekel and Debub Regions of Eritrea

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Abstract

Sorghum (*Sorghum bicolor* L.) is considered one of the most important cereal crops after wheat, rice, maize, and barley in terms of cultivated area and production. This study investigated sorghum seed associated fungi stored in two different types of containers (*koffo* and plastic sacks) in Zoba Debub and Zoba Maekel. Germination rates and moisture content were assessed to identify fungal species that could flourish and cause significant deterioration to sorghum grains. A substantial level of fungal contamination was detected in the analyzed samples. The most frequently isolated and identified fungal genera included *Alternaria* sp., *Aspergillus flavus, Aspergillus niger, Aspergillus terreus, Absidia* sp., *Cladosporium sp., Curvularia sp., Fusarium* sp., *Hemicola* sp., *Mucor* sp., *Rhizopus* sp., *Stemphylium* sp., and an unidentified white sterile mycelium. Among these, *Aspergillus flavus* and *Aspergillus niger* were the most dominant, each accounting for 80% of the isolates. Higher germination percentages were observed in grains stored in *koffo* containers compared to plastic sacks, attributed to the lower moisture content in *koffo*. The traditional storage container, *koffo*, maintains temperature through micro-pores which enhance proper aeration, creating conditions that are less conducive to fungal growth. Consequently, *koffo* not only preserves higher germination rates but also inhibits fungal colonization and contamination. It is therefore recommended as a preferable alternative to plastic sacks for storing sorghum seeds.

Keywords: *Germination, Koffo, Moisture Content, Plastic Sack, Seed-mycoflora, Sorghum.*

Introduction

Sorghum [*Sorghum bicolor* (L.) Moench] is one of the main food crops in the lowlands where rainfall is erratic, but it is grown in nearly all zobas (zones), including the highlands of Eritrea, which spans 124,432 km², with altitudes ranging from 60 to 3,180 m above sea level. Farmers commonly grow local sorghum landraces selected for their grain, stalk qualities, and adaptation to specific ecologies (Mann *et al.,* 1983). Despite sorghum's drought resilience, late-maturing varieties are often neglected due to their poor adaptation to erratic rainfall patterns and the short growing seasons prevalent in the country (Mekbib, 2006). Average yields of sorghum in Eritrea are about 0.5 t ha^{-1}. The most common reasons for low yields are drought, pests, diseases, and weeds (*Shatter cane*, *Striga*, wild sorghums and their intermediates with cultivated sorghum) and lack of improved practices (Tesfamichael, 1999; Obilana *et al.,* 2002). A survey

of diseases in major sorghum-growing areas was carried out under the collaborative sorghum and pearl millet cereal that should be stored at 8%-12% moisture content in Eritrea (Danida-Eritrea ICRISAT collaboration). Farmers store sorghum seeds for sowing in different storage containers for next season.

In Eritrea, the major constraints in sorghum storage include prevalent diseases such as covered smut, loose smut, long smut, and anthracnose (Anonymous, 2012). However, the covered smut is the most widespread, leading to significant economic losses for small-scale subsistence farmers, before harvesting. During storage, sorghum seeds are susceptible to attacks by fungi like *Aspergillus flavus*, *Rhizopus nigricans*, and *Alternaria solani*, particularly when stored in containers, such as *koffo* and plastic sacks. The length of the storage period impacts seed vitality and germination rates, as seed deterioration cannot be fully prevented under normal storage conditions, exposing seeds to environmental fluctuations that harm their viability. Storage type has a significant ($p<0.05$) effect on seed germination (Dubale et al., 2012). The loss of germination in molded seeds reduces the seed's value, and mycotoxins produced by storage fungi, including species of *Aspergillus* and *Penicillium*, pose health risks to humans, animals, and poultry, leading to food-borne diseases (Bhat et al., 1997).

Sorghum faces fungal contamination during storage, posing significant economic and health risks to humans and livestock. Humidity and temperature promote fungal growth in the field and during storage, but studies on the mycoflora of sorghum in Eritrea are lacking. This study aims to isolate and identify fungal species from sorghum seeds stored in various containers in the Maekel and Debub Regions, key zones for sorghum storage. Additionally, the study examines the germination percentage and moisture content of grains from these regions to assess the impact of storage containers on seed viability. The occurrence of storage fungi and the comparison of moisture content and germination rates between seeds stored in *koffo* and plastic sack containers were also investigated.

Material and Methods

Area and Period of Survey

Sorghum is a major crop growing in zoba-Anseba (Fig.1), but Maekel and Debub zobas are important zones for storage to make them available for sale to farmers and consumers when they are needed during the cultivation period. The average temperatures of the Maekel and Debub regions are 17.9°C - 18.12°C and 18°C - 23°C, respectively. The relative humidity of zoba Maekel is 46% and 29% for zoba Debub. Climatic conditions are warm to cool semi-arid in both zobas, and the annual average rainfall of the central highland occurs in summer (June-September), ranges from 400mm to more than 700mm, and the potential evaporation is 1300-1800mm. Stored grains were procured from three villages per sub-zobas in each of the two-zobas (Table 1). Grain collections were done in October 2022 (one month after harvesting the crop) and February 2023 (after a four-month storage period).

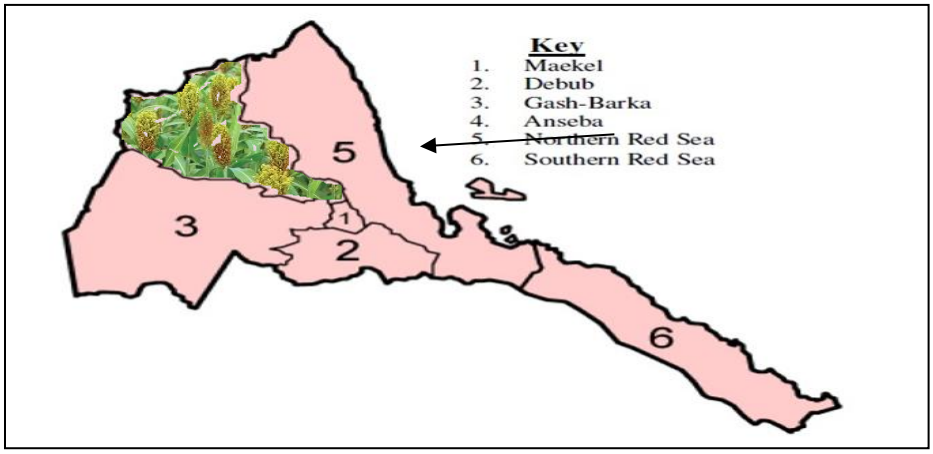

Fig. 1. Sorghum growing area - zoba-Anseba.

Table 1. Seed Samples Collected from Three Sub-Zobas of Two Zobas

Zoba	Sub-zobas	Villages
		Beleza
	Serejeka	Embaderho
		Serejeka
		Tseazega
Zoba Maekel	Berikh	Tsaeda Christian
		Hazega
		Kitmoulie
	Galanefhi	Abardae
		Himbrti
		ShekaWedi Bsrat
	Debarwa	Adigeda
		Shketi
		Hadish Adi
Zoba Debub	Segeneyti	Maeraba
		Adibaekel
		Wutuh
	Dekemhare	Awliexeru
		Gunae

These grains were stored by the consumers/vendors in two types of storage containers (*koffo*- a traditional storage container and *meshame* - plastic sacks) (Fig. 2).


a

b

Fig. 2. Storage Containers *koffo* (a) and *meshame* plastic sack (b).

Moisture Content

Each seed sample (5g) was ground in a blender, and the known weight of the resultant powder was dried in an oven at 105 °C for 24 hours, cooled in a desiccator, and reweighed. The moisture content (MC) was expressed as the percentage of the wet weight lost (Neergaard, 1977; ISTA, 1996).

Germination Percentage

A sample of sorghum seeds were surface sterilized using 70% ethanol by submerging in the solution for 1 min to eliminate surface contaminants; then dried using blotter papers. The sorghum seeds were placed on two layers of moisture blotters (soaked with sterile distilled water) and incubated for 3-5 days at ±25°C to evaluate germination percentage. Germination was assessed by observing seedlings in a Petri dish with the help of a pocket lens following the method by de Temp. (1970). On moist blotter paper, 25 seeds were placed in Petri dishes arranged in three circles: fifteen seeds in the outer circle, nine in the middle circle, and one in the center, ensuring sufficient space for germination. Germination percentage was recorded in two phases: first month after harvesting and the fourth month during the storage period (Fig. 3). Germination counts were taken after an inoculation period of 5- 7 days.

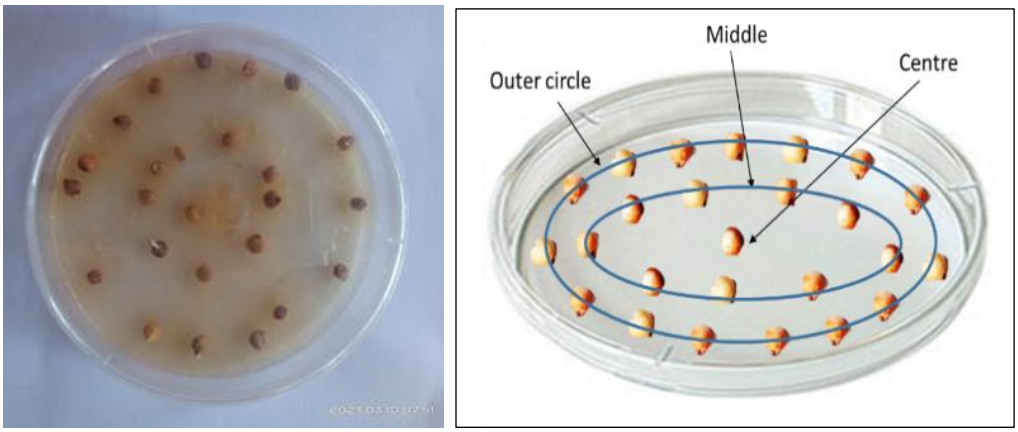

Fig. 3: Procedure of seed placing in a Petri dish

Isolation and Identification

Sorghum seeds were surface sterilized using 70% ethanol by immersing them in the solution for 1 min to eliminate surface contaminants; then dried using blotter papers. Fungal isolation was done by placing the surface sterilized seeds on Potato Dextrose Agar (PDA) media prepared by dissolving 39 grams of PDA in 1000 ml of distilled water in sterile petri dishes that were sealed using parafilm. The Petri plates were incubated at room temperature of ±25°C for 5 days, until pathogen proliferation on the agar surface (ISTA, 1996). The occurrence of fungal pathogens in a gram of seed was analyzed for the fungal numbers (colony forming units/ gram of seed) (Waksman, 1916 and 1922) by using the following formula:

Colony forming units /g seed (*cfu*/gx10^3) = (Colonies x dilution factor)/g wt. (AOAC 1995).

Fungal colonies were examined and identified based on their growth habits, colonial morphology, mycelial structure, and spores. Slide preparations were made and observed under compound microscope for characteristics of colonies such as the colour, margin, elevation and texture. The pathogenic and non-pathogenic microbes were identified by using standard identification keys (Aneja, 2004; Barnet and Hunter, 1972; Ellis, 1971; Rifai, 1969; Gilman, 1957; and Nagamani *et al*., 2006). Each colony was examined under the microscope at low power (10x10) and high power (40x10). Fungal identifications were carried out based on the characterization of colonies and the prepared stained slides examined under a compound microscope by isolating the minute young colony taken from a culture grown on PDA medium (Gilman, 1957; Raper and Fennell, 1965; Ellis., 1971; Bernet and Hunter, 1972; Nagamani *et al.,* 2006).

Data Analysis

Data analysis was done using GENSTAT version 15. Means of moisture content, colony-forming units, and germination percentage were compared using Tukey LSD at 5%.

Results and Discussion

Moisture Content and Fungal Pathogens

There is no statistically significant difference in the mean moisture content and mean microbial load in the grains stored in koffo compared to plastic bags since the p - value is much greater than the common significance level of 0.05 (Table 2). The highest percentage of moisture content (30.6%) was recorded in Tseazega, Berikh sub-zone of the Maekel region in plastic sack. In the Debub region, the highest moisture content (23%) was recorded from samples collected in Hadish Adi sub-zone Segeneyti in *koffo*. The lowest moisture content (5%) was recorded in samples collected from Himbrti sub-zoba Galanefhi of Zoba Maekel in koffo while the lowest moisture content (3%) was found in samples collected from Shketi sub-zone Debarwa in plastic sacks. On average, grain samples that had been stored in plastic sacks had higher moisture content (10.3%) compared to those that had been stored in koffo (9.48%). This could be attributed to the ability of plastic materials to retain moisture thus preventing ventilation. Consequently, the higher moisture content was associated with high storage fungi isolation.

Plastic sacks are made up of highly compacted plastic lacking micro-pores which allows aeration. But *koffo* a traditional storage structure made up of a combination of clay, dung, and softwood has micro-pores that allows for aeration helping to regulate the temperature of the container. These results indicate that the moisture content can influence the occurrence of fungal growth. The average moisture content for samples stored in koffo bags (9.48%) is slightly lower than those in plastic bags (10.29%). There were significant differences between the villages, with *Tseazega* village having the least moisture content in Koffo 3.6% and the highest in plastic sack (30.6%). The highest fungal population was recorded in the plastic sack from *Kitmoulie* village; this could be due to the moisture content present in the containers. It is well established that high moisture content plays a major role in the incidence of fungal populations (Table 2).

The highest moisture content in *koffo* samples collected from zoba Debub was 8.26% and this corresponded with the highest observed colony-forming units (12.2). Since optimum moisture is a key requirement for the fungal growth, this finding provides evidence of its influence. The increase in moisture content could also be because of post-harvest handling of sorghum grains. According to Koehler. (1938), certain fungi require moisture levels in equilibrium with a relative humidity of more than 90 percent to grow, which support the observation in this case. Samples form *Sheka Wedi Bsrat* recorded the highest moisture content in *koffo* (16.7%), while the lowest moisture content in *koffo* was found in Shketi (1.6%). In plastic sacks, the highest moisture content was found in Hadish Adi (15.7%) whereas Shketi had the lowest MC (3.0). Interestingly, there was high fungal occurrence in Hadish Adi village. On the other hand, high *cfu* was observed in *koffo* from the same village. This variation may be due to the post-harvest handling practices and the extent of damage caused by the farmers during harvesting. According to Suleiman et al. (2017) poor pre and postharvest practices such as untimely harvesting, inadequate drying, poor threshing and cleaning techniques and substandard storage methods, can lead to rapid deterioration of grain quality, dry matter losses and mold contamination. These practices can lead to conditions that favour mold growth which is associated with production of toxic mycotoxins which is hazardous to human beings. Fatima et al. (2006) opines that fungi can be present as contaminants and exist as dormant mycelium within the tissues of the pericarp or seed coat. These findings also explain that moisture content levels play important roles in fungal growth, seed spoilage, and the promotion of fungal advancement and decay.

Table 2: Moisture content percentage and Colony forming units 10^3 / g (*cfu*/g) of Sorghum Collected from Different Storage Containers of Zoba Maekel and Zoba Debub

Zoba	Subzoba	Villages	Moisture Content %		(cfu/g)10^{-3} /g	
			Koffo	Plastic bag	*Koffo*	Plastic bag
Maekel	Serejeka	Beleza	8.2	6.4	8.0	10.0
		Embaderho	8.0	8.4	10.0	6.0
		Serejeka	7.6	7.4	11.0	8.0
	Berikh	Tseazega	3.6	30.6	13.0	12.0
		Tsaeda Christian	20.6	5.8	13.0	6.0
		Hazega	7.4	7.0	11.0	15.0
	Galanefhi	Kitmoulie	9.6	9.4	10.0	20.0
		Abardae	9.6	10.2	9.0	16.0
		Himbrti	10.7	7.4	5.0	17.0
average			**9.48**	**10.29**	**10.00**	**12.22**
r - value			**1.54**	**2.58**	**0.83**	**1.69**
LSD (0.05%)			**3.56**	**5.95**	**1.92**	**3.90**
T- statistics			**-0.2225**		**-1.0173**	
p-value			**0.8295**		**0.3388**	
Zoba	Subzoba	Villages	Moisture Content %		(cfu/g)10^{-3} /gram	
			Koffo	Plastic bag	*Koffo*	Plastic bag
Debub	Debarwa	ShekaWedi Bsrat	16.7	10.1	7.0	4.0
		Adigeda	5.5	9.6	10.0	11.0
		Shketi	1.6	3.0	14.0	14.0
	Segeneyti	HadishAdi	10.0	15.7	23.0	7.0
		Maeraba	3.8	4.9	10.0	18.0
		Adibaekel	6.0	6.0	16.0	9.0
	Dekemhare	Wutuh	8.3	7.6	12.0	15.0
		Awliexeru	12.3	8.9	5.0	15.0
		Gunae	10.1	7.0	13.0	9.0
average			**8.26**	**8.09**	**12.22**	**11.33**
r - value			**1.5**	**1.2**	**1.7**	**1.5**
LSD (0.05%)			**3.553**	**2.81**	**4.06**	**3.45**
T- statistics			**0.1305**		**0.3384**	
p-value			**0.8994**		**0.7438**	

Germination Percentage and Colony Forming Units

Seed infections originate in the seed primordium during seed germination, either through direct transmission or from the mother plant via external contamination as many pathogens are carried on the surface of the seed (Nallathambi et al., 2020). The germination of the seed generally depends on the storage period and the storage container types. Prolonged storage of seeds lessens viability and increases deterioration by fungi. In traditional storage containers (Koffo), the germination percentage was very high during the first month of storage in Embaderho village of Serejeka-subzoba, whereas, the fungal population was recorded at $15x10^{-3}$ /g of seed. In contrast, germination rates were 60% in Shkeri and Hadish Adi villages of Debarwa and Segeneri subzoba respectively. Wutuh village (Dekemhare Sub Zoba) recorded the lowest germination percentage with about $4x10^{-3}$ colony-forming units (Table 3).

After a month of observation during storage, no sorghum seeds germinated in samples from Abardae and Bsrat villages of Galaneghi and Debarwa sub-zobas respectively. Maximum germination percentage of 56% was recorded in Shketi village of Debarwa; and Adibaekel village of Segeneyti. Interestingly, in these

villages, *cfu* per gram of seed were 3% and 8% respectively. Wutuh village from Dekemhare subzoba showed a higher percentage of germination (36), but *cfu* was only $1x10^{-3}$ /g of seed. In Maekel zoba, Tsaeda Christian village showed 28% seed germination and 20 *cfu* in a *koffo* container. These results indicate that when a high number of *cfu* is present the seed germination percentage is interrupted. Many seed-borne fungi such as *Fusarium, Asperhillus* and *Penicilium* colonizes the seed and penetrate embryo interfering t=with structural integrity of the seed making it less viable (Mancine and Romanazzi, 2014). In Zoba Maekel, the seeds retrieved from *koffo* exhibited high germination potential and relatively low *cfu* counts. These results agree with earlier reports that the storage fungi decrease germination potential of grains (Rao *et al*., 2011). Similarly, Dubale, *et al*. (2014) observed that during the storage, a reduction in germination percentage of maize grain was recorded for the *Gombisa* container. Germination percentages reduced from 98% and 97.5% to 68.5% and 80.5% for grains stored in *Gombisa* and Sacks, respectively. The progressive loss in germination potential of grains in *Gombisa* and Sacks with increase in storage time might be due to fungal invasion.

The average germination percentage noticed was high during first month of storage in both *koffo* and plastic sacks. Fungal colonies were observed more in the fourth month of storage, more or less similar trend is found in both containers. Fungal flora will proliferate in the seed due to the presence of moisture and at the optimum temperature where the containers are suitable for these environmental conditions. The average highest *cfu* (11.78%) was identified in plastic sacks during the fourth month of storage, while during the first month of storage about 8.22% of fungal colonies were recorded. The longer the storage period, the higher the fungal proliferations on the seed. Both containers showed a similar trend in *cfu* in the fourth month.

Table 3: Germination Percentage (GP) and Colony forming units/gram (*cfu*/g 10^{-3}) of Sorghum from Storage Containers (*Koffo* and Plastic sack) of Two Zobas

Zoba	Subzoba	Village	*Koffo*				Plastic sack			
			GP		*cfu*		GP		*cfu*	
			1st month	4th month	1st month	4th month	1st month	4th month	1st month	4th month
Maekel	Serejeka	Beleza	52.0	4.0	13.0	8.0	40.0	0.0	9.0	10.0
		Embaderho	56.0	52.0	15.0	10.0	36.0	16.0	12.0	6.0
		Serejeka	44.0	32.0	6.0	11.0	24.0	8.0	21.0	8.0
	Berikh	Tseazega	36.0	0.0	12.0	13.0	48.0	4.0	11.0	12.0
		Tsaeda Christian	28.0	28.0	20.0	13.0	24.0	0.0	19.0	6.0
		Hazega	32.0	16.0	12.0	11.0	32.0	32.0	4.0	15.0
	Galanefhi	Kitmoulie	24.0	52.0	4.0	10.0	28.0	36.0	8.0	20.0
		Abardae	28.0	54.0	9.0	9.0	0.0	20.0	8.0	16.0
		Himbrti	40.0	36.0	5.0	5.0	28.0	48.0	3.0	17.0
Debub	Debarwa	ShekaWedi Bsrat	48.0	0.0	11.0	7.0	0.0	20.0	4.0	4.0
		Adigeda	4.0	8.0	5.0	10.0	36.0	20.0	6.0	11.0
		Shketi	60.0	0.0	12.0	14.0	56.0	24.0	3.0	14.0
	Segeneyti	HadishAdi	64.0	20.0	11.0	23.0	4.0	34.0	4.0	7.0
		Maeraba	40.0	28.0	3.0	10.0	44.0	36.0	12.0	18.0
		Adibaekel	40.0	40.0	11.0	16.0	56.0	20.0	8.0	9.0
	Dekemhare	Wutuh	4.0	16.0	4.0	12.0	36.0	64.0	1.0	15.0
		Awliexeru	32.0	24.0	12.0	5.0	36.0	36.0	6.0	15.0
		Gunae	36.0	36.0	13.0	13.0	28.0	40.0	9.0	9.0
Mean			37.1	24.7	9.8	11.1	30.8	25.4	8.2	11.7
LSD ($p<0.05$)			8.2	9.0	2.3	2.1	8.2	8.5	2.7	2.3
SE			3.8	4.3	1.1	1.0	3.9	4.0	1.3	1.1

Occurrence of Storage Fungi

After one- and four-month storage periods, fungal contamination was prevalent on most of the seeds, with various fungal genera and species proliferating on the seed surface (Fig. 4).

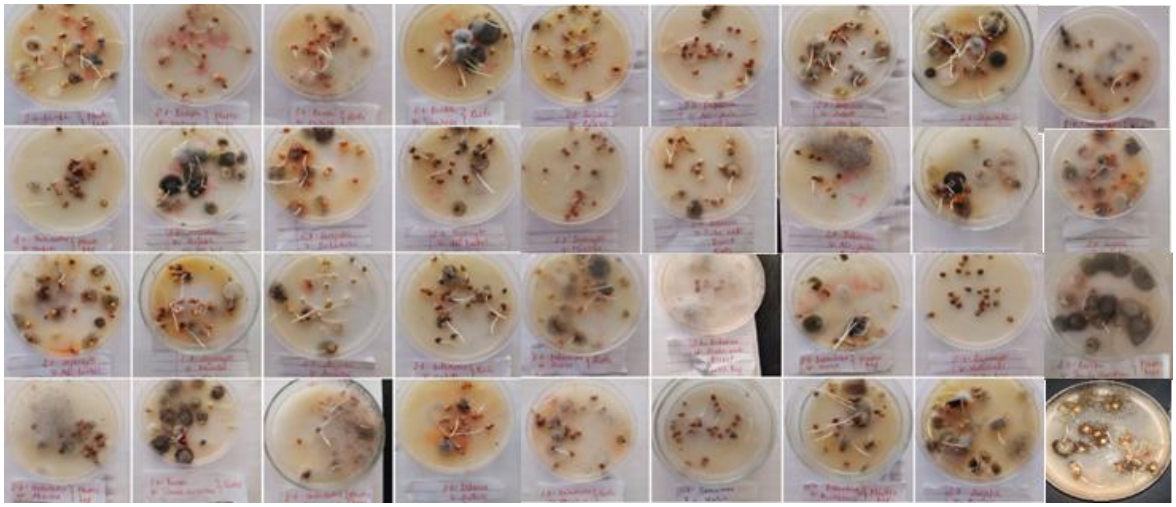

Fig. 4. Fungal colonies of different sorghum samples collected from two zobas

Occurrence and Identification of Storage Fungi in Sorghum

A total of, 13 storage fungi were identified from sorghum seeds during the first month of storage. These included *Absidia, Alternaria, Aspergillus flavus, Aspergillus niger, Aspergillus terreus,* species of *Cladosporium, Curvularia*, *Fusarium*, *Hemicola*, *Mucor*, *Phoma*, *Rhizopus*, and *Stemphylium.* These outcome mirrors those reported by Dania and Oge (2018) and Okumu et al. (2024) where similar fungal pathogens were isolated affecting cereal grains. According to the researchers, many of these fungi are adapted to wide range of temperatures found in storage containers. For example, *Absidia* is commonly found in stored grains and has been isolated in sorghum grains under high humidity and poor storage conditions. They are considered storage molds and contribute to the spoilage of grains. Field fungi such as *Alternaria, Fusarium, Cladosporium, cuvularia* and *Stemphilium* infect sorghum before harvest and remain dormant during storage. Storage fungi such as *Aspergillus, Penicilium, Mucor* and *Rhizopus* colonize grains after harvest especially when the moisture levels exceed the recommended levels of >13–14%. These storage fungi are of significant concern to human health due to their potential as allergens and mycotoxin producers (Wagacha et al., 2016). Many species within the Genera *Aspergillus, Penicillium, Fusarium,* and *Alternaria* are toxigenic. As a result fungal infection is of concern because it results in yield loss and contamination of grains with mycotoxins.

Table 4 illustrates the percentage occurrence of storage fungi in sorghum seeds from Zoba Maekel. *Rhizopus*, a contaminant fungus, was detected only in Embaderho (plastic sack). *Stemphylium* sp. was identified in storage seeds from Serejeka (*koffo* container) and in the plastic sack from Kitmoulie. The most dominant fungal species was *Aspergillus niger*, a cosmopolitan fungus known for its ability to suppress other species. Additionally, the storage of food commodities under inappropriate conditions further facilitates mold growth and the production of aflatoxins (Williams and Jaeske et al., 2011).

Table 5 presents the percentage occurrence of storage fungi in sorghum seeds collected from Zoba Debub. Notably, *Aspergillus flavus*, *Aspergillus niger*, and *Fusarium* species were prevalent across all villages within the Maekel Zoba and in both storage containers. These findings underscore the widespread presence and variability of pathogens in sorghum across different geographical regions. The widespread and occurrence of the different fungal contaminants was due to the fact farmers used the same type of storage material. In fact, according to Okumu et al. (2024) the presence and variability could be due to farmers practice of mixing old grains with new ones. Most farmers also leave koffo open for an extended period of time. These old storage structures provide openings through which pests gain entry to the stores. *Hemicola* was found in Adi-baekel from the container of koffo, whereas, *Mucor* and *Fusarium* were found only in plastic sacks collected from Awleixeru village.

Table 4: Percentage of Fungal Occurrence of Sorghum Seeds Collected from Different Storage Containers of Zoba Maekel

Sub zobas	Serejeka						Berikh						Galanefhi					
Villages	Beleza		Embaderho		Serejeka		Tseazega		Tsaeda Christian		Hazega		Kitmoulie		Abardae		Himbrti	
Fungal Biota	koffo	Plastic bag	koffo	Plastic bag	koffo	Plastic bag	koffo	Plastic bag	koffo	Plastic bag	koffo	Plastic bag	koffo	Plastic bag	koffo	Plastic bag	koffo	Plastic bag
Aspergillus flavus	7.69				16.66	19.04	25.01	36.36		4.68	25	25	50					
Aspergillus niger	53.84	44.44	40	58.33	50.01	38.09	8.33	45.45			50	25	25	50	33.33	25	60	66.67
Aspergillus terreus										11.11								
Curvularia									80	84.21						12.5		
Fusarium	38.47	33.33	60	33.33		42.87	58.33		20		25	25	25	25	66.67	37.5	40	33.33
Hemicola		22.23					8.33	18.19										
Mucor												25				25		
Phoma sp.							7.69											
Rhizopis				8.34														
Stemphylium spp.					33.33									25				
Total Fungi	**3**	**3**	**2**	**3**	**2**	**3**	**5**	**3**	**2**	**3**	**3**	**4**	**3**	**3**	**2**	**4**	**2**	**2**

Table 5: Percentage of Fungal Occurrence of Sorghum Seeds Collected from Different Storage Containers of Zoba Debub

Sub zobas	Debarwa						Segeneyti						Dekemhare					
Villages	Sheka Wedi Bsrat		Adigeda		Shketi		Hadish Adi		Maeraba		Adibaekel		Wutuh		Awliexeru		Gunae	
Fungal Biota	koffo	Plastic bag	koffo	Plastic bag	koffo	Plastic bag	koffo	Plastic bag	koffo	Plastic bag	koffo	Plastic bag	koffo	Plastic bag	koffo	Plastic bag	koffo	Plastic bag
Absidia spp.										8.33	9.09						23.07	
Alternaria spp.						66.67	63.63				9.1					66.6		
Aspergillus flavus				83.33			36.36	100	33.33	75		100		100	8.3		30.77	
Aspergillus niger	81.82		100	16.67	58.34	33.33			33.33	8.33	81.81		25		41.7		46.16	11.11
Fusarium																16.6		
Hemicola											8.33							
Mucor																16.6		
Rhizopis	18.2	100			33.33								75		50			88.89
Stemphylium spp.									33.33									
Sterile mycelium					8.33													
Total fungi	**2**	**1**	**1**	**2**	**3**	**2**	**2**	**1**	**3**	**3**	**4**	**1**	**2**	**1**	**3**	**3**	**3**	**2**

Conclusion

The fungus species such as *A. flavus, A.niger, A. terrus, Curvularia, Fusarium, Hemicola, Mucor, Rhizopus, Phoma, Absidia, Alternaria, and Stemphyilum* were identified as the main fungi seed associated sorghum grains during storage in the two storage containers (*koffo* and plastic sack). *A. niger* was found in most of the villages (80%) because it is a dominant seed contaminant fungus. As the storage period increased the presence of common fungi was consistent. They influenced seeds in both storage containers and affected the viability (germination capacity). The germination of the sorghum seeds was found to be high in *Koffo* in comparison to the plastic sack; it could be the reason because there were fewer colony-forming units in *Koffo*. Due to the higher moisture content in plastic sacks, they were found to have increased fungal contamination, leading to the deterioration of sorghum seeds. It is suggested that *Koffo* is a more suitable storage container for sorghum seeds.

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Competing Interests

The authors have declared that no competing interests exist.

Authors' contributions

This work was carried out in association with all authors. Authors MS, NM, RR, HY, and GS designed the project study. Authors MS, NM, and HY, collected the data, and RR analyzed the data. GS prepared and reviewed the manuscript. All authors read and approved the final manuscript.

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