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Article

Incidence of Seed-Borne Fungi of Stored Sunflower Seeds (*Helianthus annuus*) in Tanzania and Their Influence on Seed Viability and Vigour

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Abstract: This research was conducted to study the incidence of seed-borne fungi in stored sunflower seeds under ambient conditions as well as their influence on seed viability and vigour. Certified seeds, Quality Declared Seeds (QDS) and Farmer saved seeds (FSS) were stored for six months. Seed samples were taken every month testing for fungal infection percent (FIP), germination percentage (G%) and seedling vigour index (SVI). Eight fungal species namely as *Aspergillus flavus*, *A. niger*, *Alternaria padwickii*, *A. zinniae*, *Botrytis cinerea*, *Curvularia lunata*, *Fusarium vericillioides* and *Rhizopus arrhizus* were identified. At the end of experiment, the maximum species infection percentage were recorded on *F. vericillioides* (14.39), *B. cinerea* (14.28) in FSS and the minimum by *A. zinniae* (1.83) with QDS. Maximum total fungal infection incidence was recorded with FSS (73.11%) and minimum with QDS (66.94%) and certified seeds (67.06%). The QDS recorded the highest G% (81.56) and certified seeds (81.33%), the maximum SVI (96.76) was in certified seeds and 95.69 (in QDS). The minimum G% (60.67) and SVI (65.98) were found in FSS. The highest G% and SVI were recorded in seeds with minimum FIP. These results suggest that, fungal infections may negatively affect the seed viability and vigour. For the first time, the incidence of seed-borne fungi in stored sunflower seeds have been determined in Tanzania.

Keywords: packaging material; seed class/type; Certified seeds; FSS; QDS

1. Introduction

Sunflower (*Helianthus annuus*) is among the major oil seed crop grown globally due to its short growing season (FAO, 2017). Sunflower is grown for edible oil and seeds consumed by human, domesticated animals, and birds (Konyali, 2017). Sunflower is produced in more than 27 million of hectares worldwide (Muradov *et al.*, 2019). Tanzania is among the top ten sunflower producers in the world, producing about 2.4% of the World production and 34% of African production (Guney *et al.*, 2017; Isinika and Jeckoniah 2021). In Tanzania, sunflower crop is grown in many areas by small-scale farmers (BOT, 2017). The central zone regions which include Singida and Dodoma are the major sunflower producers, contributing about 61% of the country total production (Tibamanya, 2021). Sunflower production improves smallholder farmers income, which in turn contributes to the country's income generation (Sebyiga, 2020).

Despite of being among top ten sunflower major producers in the World, Tanzania can meet only about 30 to 45% of internal demand for edible oil while importing about 55 to 70% (Balchin *et al.*, 2018). Among the factors contributing to low production of sunflower is unavailability of quality seeds to smallholder farmers.

Seed health is among important factors for successful cultivation and yield exploration of a crop (FAO, 2017). Researches show seed borne fungal infections reported to cause about 9.7% annual yield

loss worldwide (Kumar, 2020). Seed borne fungal infection reduces germination, seedling vigour and cause variation in plant morphology after seed deterioration through seed abortion, shrinking, reduced size, seed rot as reported by Niaz and Dawar, (2009) and Sserumaga *et al.*, (2015).

Furthermore, the infection rate of stored seeds depends on some environmental conditions such as high relative humidity, suitable temperature, and high level of moisture content in seed. The study of seed-borne pathogens is necessary to determine seed health and to improve germination potential of seed which finally leads to increase of the crop production (Masomeh *et al.*, 2012). Since small holder farmers store their produced seeds for the next planting season, the seeds become contaminated by seed borne fungi including pathogenic fungi during storage which could reduce seed germination and vigour as described by Gebeyaw, (2020).

Seed health testing to detect seed-borne pathogens is an important step in the management of crop diseases. According to Abd-El-Aziz and El-Satar, (2016), ten (10) fungi were identified from four sunflower seed genotypes. These were as *Alternaria alternata*, *Aspergillus flavus*, *A. niger*, *Aspergillus spp.*, *Cladosporium herbarum*, *Fusarium equiseti*, *Paecilomyces variotii*, *Penicillium spp.* and *Rhizopus arrhizus*. However, little is known about the status of fungal pathogens in stored sunflower seeds in Tanzania. This information is necessary for local seed growers as well as smallholder farmers to understand the seed-borne fungal pathogens infecting stored sunflower seeds. The aim of this study, therefore, was to identify seed-borne mycoflora of stored sunflower seeds under ambient conditions in the country and their influence on seed viability and vigour.

2. Materials and Methods

2.1. Collection of Seed Material

The Quality Declared Seeds (QDS), Certified OPV, and Farmer Saved Seeds (FSS) samples of sunflower that were gathered from sunflower QDS producers, Agricultural Seed Agency (ASA), and farmers in the 2022–2023 growing season were utilized. The seeds were stored in three distinct types of packaging: sisal bags, polypropylene bags, and plastic containers. The seeds were allowed to air dry naturally until their moisture content dropped to 9%. A high temperature oven procedure was used to determine the moisture content of the seeds.

2.2. Seed Preservation

The laboratory experiment on storage was conducted at the African Seed Health Lab within the Department of Crop Science and Horticulture at Sokoine University of Agriculture. Each seed class/type weighed 1.5 kg, were packaged individually in sisal bags, polypropylene bags, and plastic containers. The plastic containers were securely closed with their plastic coverings, and the sisal and polypropylene bags were expertly sewn together using strings.

Subsequently, the seeds were placed in the laboratory for ambient preservation, each in its own packaging material for six months, from December 2022 to June 2023. Seed samples were collected every month to evaluate the seed health, seed viability and vigour of stored seeds. In accordance with ISTA, (2022) requirements, the sunflower seeds were tested for fungal infestation and infection, viability and seedling vigour prior to storage in order to determine the seeds' initial quality.

2.3. Experimental Design

The experimental design consisted of three classes of sunflower seeds (QDS, certified seeds, and FSS) as the sub-plot factor, and three types of packaging materials (plastic containers, polypropylene bags, and sisal bags) as the main factor. The storage period was the sub-sub plot factor, with six levels spanning from month-one to month-six. This trial was therefore conducted using a split-split-plot arrangement in a randomized complete block design, with three replicates.

2.4. Collected Data

2.4.1. Seed-Borne Fungal Microbes

Two hundred (200) seeds from each treatment were plated in petri-dishes on a monthly basis, with ten seeds per dish utilizing blotter papers. The blotter paper method was chosen as it had been previously reported by other researchers such as Patil *et al.*, (2018) and Nahar *et al.* (2005), to be the most effective approach for detecting a variety of seed-borne mycoflora in crops, including sunflower.

Prior to plating, the sunflower seeds were submerged in a 2% NaOCl₂ solution for five minutes, followed by three minutes of sterile water rinsing. The cultures were then maintained at room temperature for seven days, with light and dark cycles. On the eighth day, the seeds were examined under a stereomicroscope to monitor the growth of the fungus. A compound microscope was then used to examine the fungal conidia and conidiomata on slides, and different magnifications were employed to look at the spores and mycelia produced by each group of fungi. Fungal species were identified as per Mathur and Kongsdal (2003).

Equations (i-ii) below were used to get fungal infection incidence, Ghiasian *et al.*, (2004):

$$\text{Fungal infection (\%)} = \frac{\text{No. of seeds infected by a fungus}}{\text{Total number of seeds tested}} \times 100\% \dots\dots\dots(i)$$

$$\text{Total fungal infection incidence (\%)} = \frac{\text{No. of seeds infected}}{\text{Total number of seeds}} \times 100\% \dots\dots\dots(ii)$$

2.4.2. Germination Test

Two hundred seeds from each respective sample were sown in four replications. The test was assessed by placing the seedlings in germination bowls filled with sterile sand soil. The soil was watered as needed to keep it at the necessary moisture content. Every day for ten days after the seeding date, germination was monitored.

Germination percentages of the seedlings were determined as per ISTA (2022) formula:

$$\text{Germination \%} = \frac{\text{Number normal seedlings}}{\text{Total number of seeds sown}} \times 100 \dots\dots\dots(iii)$$

2.4.3. Seedling Vigour Index

This was performed simultaneously with standard germination. At the final count (10 days), all seedlings, which had complete morphological parts were selected and regarded as vigorous seedlings and average seedling dry weight of 20 seedlings were determined, which were then taken for determination of seedling vigour index using the formula (iv) as suggested by Abdul-Baki and Anderson (1973).

$$\text{Seedling vigour index} = \text{Germination (\%)} \times \text{seedling dry weight (g)} \dots\dots\dots(iv)$$

2.5. Statistical Analysis

Analysis of Variance (ANOVA) was applied in analysing the collected data using ‘The 16th version of GenStat Discovery Statistical Package’. The Tukey Honest Significance Difference test (HSD) was used for means separation at a significance threshold of 0.05.

3. Results

3.1. Seed-Borne Fungi

3.1.1. Fungal Infection Percentage, Seed Germination Percentage and Seedling Vigour Index as Influenced by Packaging Material, Seed Class/Type and Storage Period on Stored Sunflower Seeds

The study's findings revealed that the prevalence of fungal infection on stored sunflower seeds, as influenced by packaging material, seed type, and storage duration, was found to be significantly different ($P < 0.001$). The data presented in **Table 1** indicated that sisal bags showed the highest fungal infection rate (7.56%) followed by polypropylene bags (6.91%), while plastic containers had the lowest rate (6.63%). Moreover, the results demonstrated that the effect of seed type on fungal infection was also significantly different ($P < 0.001$). Farmer-saved seeds had the highest infection rate (7.70%) followed by Quality Declared Seeds (6.75%) while certified seeds had the lowest rate (6.64%), (**Table 1**).

Table 1. Fungal infection percentage, seed germination percentage and seedling vigour index as influenced by packaging material, seed class/type and storage period on stored sunflower seeds.

Treatment	Fungal infection (%)	Germination (%)	Seedling vigour index
Packaging materials (Pm)			
Pm1	6.63a	83.97a	119.8a
Pm2	6.91b	81.47b	107.6b
Pm3	7.56c	78.58c	100.2c
Mean	7.031	81.34	109.19
SE	0.0929	0.128	0.734
P-value	<.005	<.001	<.001
Seed type (ST)			
ST1	6.64a	88.17a	123.0a
ST2	6.75a	87.28a	115.8b
ST3	7.70b	68.58b	88.8c
SE	0.085	0.292	0.699
P-value	<.001	<.001	<.001
Mean	7.031	81.34	109.19
CV%	2.3	0.3	1.2
Storage period			
M0	5.45a	87.00a	133.7a
M2	6.52b	83.93b	117.2b
M4	7.58c	79.93c	99.7c
M6	8.58d	74.52d	86.1d
Mean	7.031	81.34	109.19
SE	0.0186	0.263	1.001
CV%	2.3	0.3	1.2

P-value	<.001	<.001	<.001
Pm1=Plastic container, Pm2=Polypropylene bags and Pm3=sisal bags; ST1=certified seed, ST2=QDS and ST3=Farmer saved seeds; SE=standard error of means and CV=coefficients of variation. The means with the same letter(s) in the same column imply non-significantly different at $P \leq 0.05$ due to Tukey's 95% confidence intervals.			

Besides, the Analysis of Variance (ANOVA) revealed that the fungal infection percentage was significantly influenced by the storage period, with a p-value of <0.001. The fungal infection rate increased significantly with the duration of storage, starting from 5.45% at the control (Month 0) to 6.52%, 7.58%, and 8.58% at Month 2, Month 4, and Month 6 of storage, respectively (**Table 1**).

3.1.2. Fungal Infection Percentage, seed Germination Percentage and Seedling Vigour Index as Influenced by Combination Effect of Packaging Material, Seed Class/Type on Stored Sunflower Seeds

The impact of packaging materials and seed class on fungal seed-borne infection of stored sunflower was not found to be statistically significant different ($P=0.386$), as shown in **Table 2**.

Table 2. Fungal infection percentage, seed germination percentage and seedling vigour index as influenced by combination effect of packaging material, seed class/type on stored sunflower seeds.

Packaging material (Pm) x seed type (ST)	Fungal infection (%)	Germination (%)	Seedling vigour index
Pm1 ST2	6.20a	90ab	123.9b
Pm1 ST1	6.30a	90.5a	138.1a
Pm2 ST1	6.35a	88.5bc	121.5b
Pm2 ST2	6.79b	87.5c	113.5c
Pm3 ST2	7.25c	84.33d	110c
Pm3 ST1	7.27c	85.5d	109.3c
Pm1 ST3	7.37c	71.42e	97.4d
Pm2 ST3	7.57c	68.42f	87.7e
Pm3 ST3	8.17d	65.92g	81.3e
Mean	7.031	81.34	109.19
SE	0.1519	0.433	1.231
CV%	3.6	1.1	1.9
P-value	0.386	0.86	<.001

Pm1=Plastic container, Pm2=Polypropylene bags and Pm3=sisal bags; ST1=certified seed, ST2=QDS and ST3=Farmer saved seeds; SE=standard error of means and CV=coefficients of variation. The means with the same letter(s) in the same column imply non-significantly different at $P \leq 0.05$ due to Tukey's 95% confidence intervals.

However, a difference in numerical values was observed among the treatments, where farmer-saved seeds packed in sisal bags had the highest fungal infection percentage (8.17) followed by those packed in polypropylene bags (7.57). In contrast, quality declared seeds and certified seeds recorded the lowest fungal infection percentages with values of 6.20% and 6.30%, respectively.

The study findings identified eight fungal species from the three seed classes/types of sunflower seed that were tested. These species were *Aspergillus flavus*, *Aspergillus niger*, *Alternaria padwickii*, *Alternaria zinniae*, *Botrytis cinerea*, *Curvularia lunata*, *Fusarium vericillioides*, and *Rhizopus arrhizus*. Among these fungi, *Fusarium vericillioides* had the highest percentage of infection at 13.1%, followed by *Botrytis cinerea* at 12.5%, and the lowest incidence was observed with *Alternaria zinniae* at 1.2%. This information is presented in **Figure 1A**.

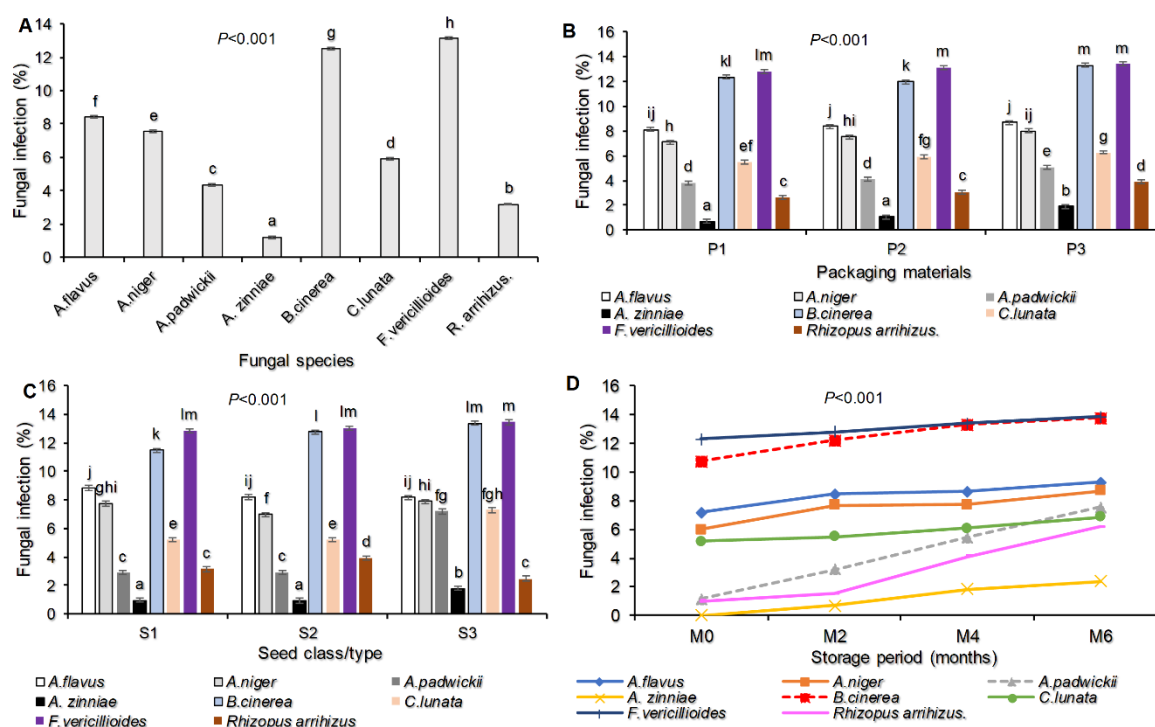


Figure 1. Fungal infection percentage as: identified in stored seeds and their species (A), influenced by interaction of fungal species and packaging material (B); influenced fungal species and seed class/type (C); influenced by fungal species and storage period (D) on stored sunflower seeds. Where P1=Plastic container, P2=Polypropylene bags and P3=sisal bags, S1=certified seed, S2=QDS and S3=Farm saved seeds.

Regarding the packaging material and seed class, the fungal infection percentage was highly significantly different ($P<0.001$) **Figure (1B-C)**. The *Fusarium vericillioides* was recorded with the greatest fungal infection percentage (13.38) in sisal bags followed by *Botrytis cinerea* (13.29) recorded in the same packaging materials. The smallest fungal infection percentage was recorded with the *Alternaria zinniae* (0.71) followed by *Rhizopus arrhizus* (2.63) in seeds packed in plastic container (**Figure 1B**). In the seed class, the *Fusarium vericillioides* was also recorded with the highest infection percentage (13.44) in Farmer saved seeds followed by *Botrytis cinerea* (13.36) in the same seed type. The smallest fungal infection percentage was recorded with the *Alternaria zinniae* (0.93) in Quality Declared Seeds (**Figure 1C**). Still, the fungal infection percentage for seed borne fungal pathogens and saprophytes varied due to storage period, from **Figure 1D** it shows that at the end of month six *Fusarium vericillioides* recorded the highest infection percentage of 13.85 followed by *Botrytis cinerea* (13.78) while *Alternaria zinniae* (2.41) recorded the smallest infection percentage.

3.1.3. Fungal Infection Percentage as Influenced by Seed Class/Type and Packaging Materials

The infection percentage was also highly significantly affected by interaction of seed class/type and packaging materials and fungal species ($P<0.001$), (**Figure 2A-C**). *Fusarium vericillioides* recorded the highest infection percentage (14.13) in the Farmer saved seeds packed in sisal bags followed by *Botrytis cinerea* (13.63) observed in the same seed type and packaging materials. The smallest fungal infection percentage was recorded by *Alternaria zinniae* (0.5) with certified and Quality declared seeds packed in plastic containers (**Figure 2A-C**).

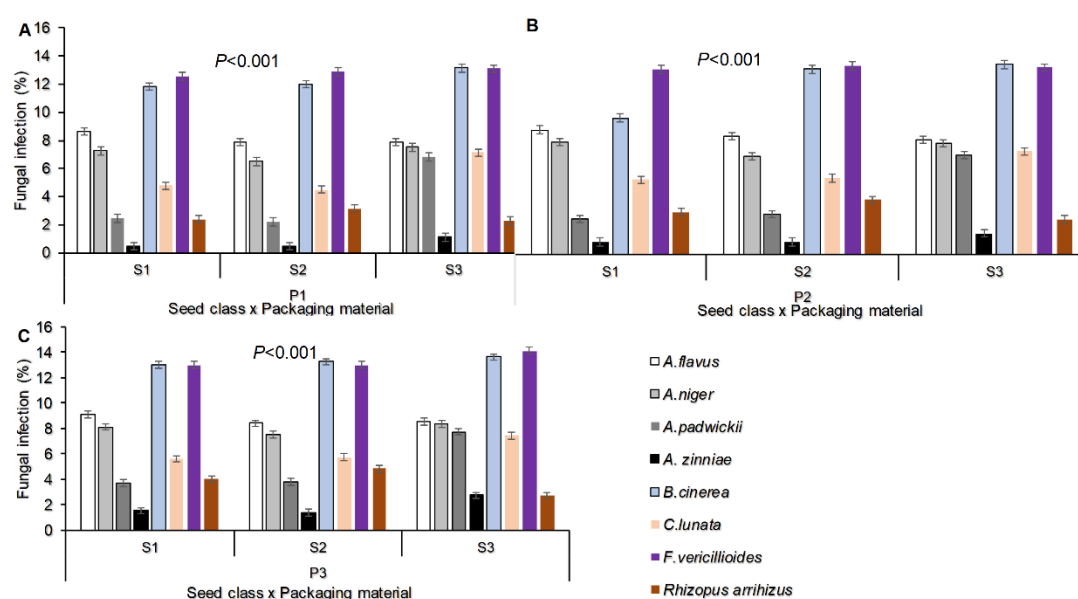


Figure 2. Fungal infection percentage as influenced by seed class/type and packaging materials (A-C) Where S1=certified seed, S2=QDS and S3=Farm saved seeds; P1=Plastic container, P2=Polypropylene bags and P3=sisal bags.

3.1.4. Fungal Infection Percentage as Influenced by Storage Period and Seed Class/Type

The seed borne fungal pathogens incidence was affected by the storage periods whereby significant different was observed among seed classes/types ($P < 0.001$), (**Figure 3**). Until the end of the storage period of month six, *Fusarium vericillioides* recorded the maximum infection percentage with Farmer saved seeds (14.39) followed by *Botrytis cinerea* (14.28) recorded in the same seeds. On the other hand, at the end of month six, the minimum fungal pathogen infection was recorded by *Alternaria zinniae* (1.83) with Quality Declared Seeds, (**Figure 3A-C**).

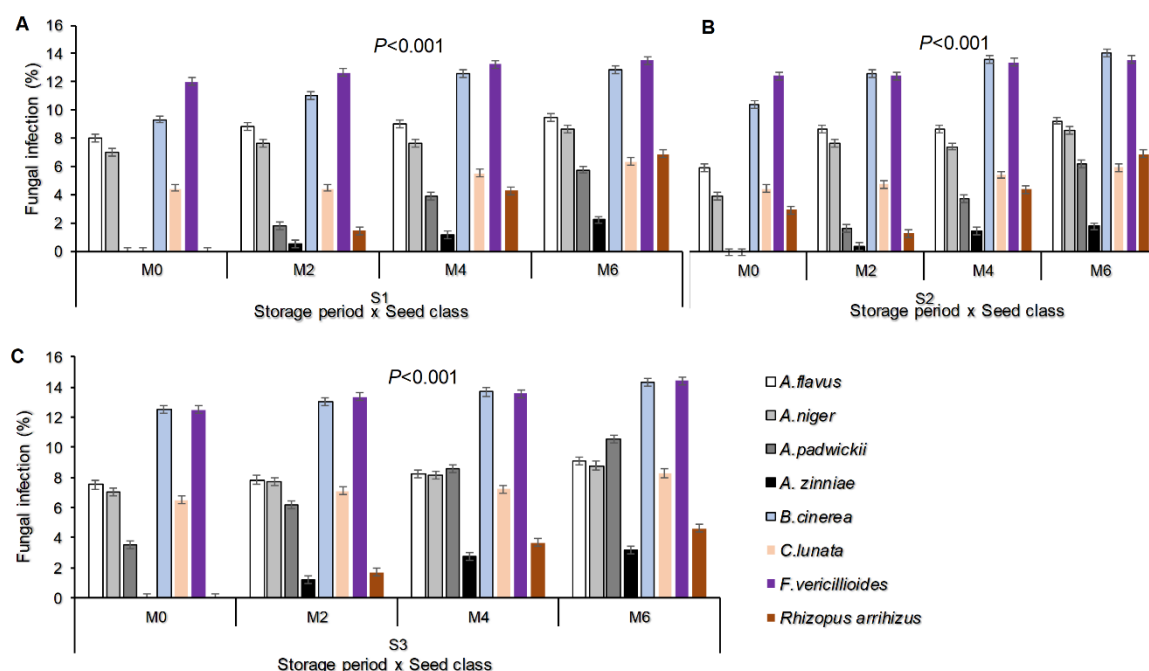


Figure 3. Fungal infection percentage as influenced by storage period and seed class/type (A-C) Where M0, M2, M4 and M6 are Month 0 (Before storage), month 2, month 4 and month 6 respectively; S1=certified seed, S2=QDS and S3=Farmer saved seeds.

3.1.5. Total Fungal Infection Incidence as Influenced by Interaction of Storage Period and Packaging Materials, Storage Period and Seed Class/Type on Stored Sunflower Seeds

The **Figure 4** indicates that, the total fungal pathogens infection incidence was significantly different ($P<0.001$) due to packaging materials as well as seed class. At the end of storage period, month six, the seed packed in sisal bags recorded the maximum infection incidence (74.33%) followed by seeds packed in polypropylene materials (68.61%). Seeds packed in plastic container recorded the minimum infection incidence (64.17%). Regarding the seed class/type, maximum fungal infection incidence was recorded with Farmer saved seeds (73.11%) and minimum infection incidence was recorded with certified seeds (67.06%) which was not significantly different from the infection incidence recorded with the Quality declared seeds (66.94%), **Figure (4A-B)**.

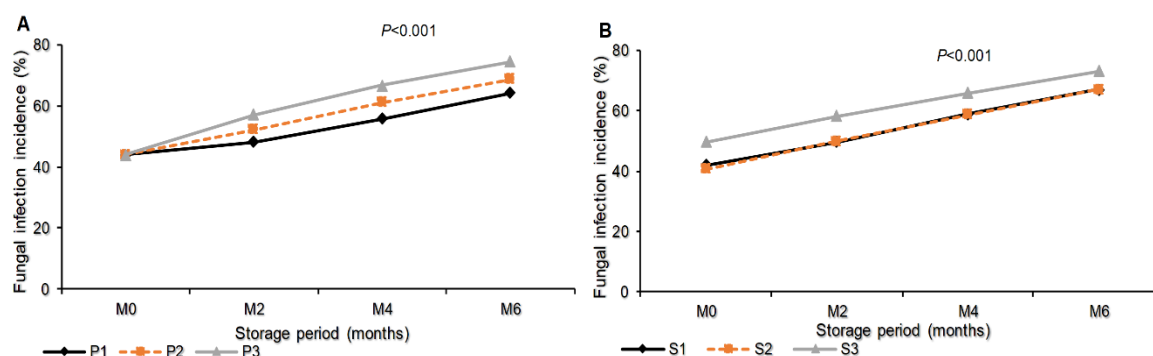


Figure 4. Total Fungal infection incidence as influenced by interaction of: Storage period and packaging materials (A) Storage period and seed class/type (B) on stored sunflower seeds. M0, M2, M4 and M6 are Month 0 (Before storage), month 2, month 4 and month 6 respectively; P1=Plastic container, P2=Polypropylene bags and P3=sisal bags, S1=certified seed, S2=QDS and S3=Farm saved seeds.

3.2. Influence on Germination Percentage (%) and Seedling Vigour Index

From **Table 1**, the findings show that seed germination percentage and seedling vigour index were influenced by seed borne fungi, packaging material, seed class/type and storage period on stored sunflower seeds, highly significant different ($P<0.001$). The seeds stored in sisal bags recorded the smallest germination percentage and seedling vigour index, 78.58% and 100.2 respectively. Followed by the seeds stored in polypropylene bags while the plastic container recorded the highest germination percentage and seedling vigour index (83.97% and 119.8 respectively), **Table 1**.

Additionally, the influence of seed class/types on germination percentage and seedling vigour index of stored sunflower seeds was highly significantly different ($P<0.001$) (**Table 1**). Regarding seed class/types of germination percentage and seedling vigour index was recorded smallest in the Farmer saved seeds (68.58% and 88.8 respectively) in seed class with highest fungal infection percentage followed by Quality declared seeds while the maximum germination percentage and seedling vigour index was recorded in certified seeds (88.17% and 123 respectively). In addition, the results show that germination percentage and seedling vigour index was significantly different ($P<0.001$) due to storage period. As the storage period increased, both germination percentage (%) and seedling vigour index decreased significantly from 87,83.93,79.93 and 74.52 for germination percentage and 133.7,117.2,99.7 and 86.1 for the seedling vigour index (**Table 1**).

The **Table 2** shows that the germination percentage was not significantly differentially influenced by the combination of packaging materials and seed class ($P=0.86$). However, seedling vigour index was significantly and highly affected by the combination of packaging materials and seed class ($P<0.001$). The highest seedling vigour index (138.1) was recorded with certified seeds packaged in plastic materials, while the smallest value (81.3) was noted in farmer-saved seeds packed in sisal bags (**Table 2**). The interaction effect between packaging materials and storage period expressed high significance with a P -value of <0.001 on seed germination percentage (**Figure 5A**) and seedling vigour index (**Figure 5B**). Until the end of the storage period (month six), the highest germination percentage

(80.22%) and highest seedling vigour index (106.67) were recorded in seeds packed in a plastic container. This was followed by seeds packed in polypropylene bags with a seed germination percentage of 74.44% and a seedling vigour index of 85.76. The least germination percentage (68.89%) and seedling vigour index (66.0) were noted in seeds packed in sisal bags (**Figure 5A-B**).

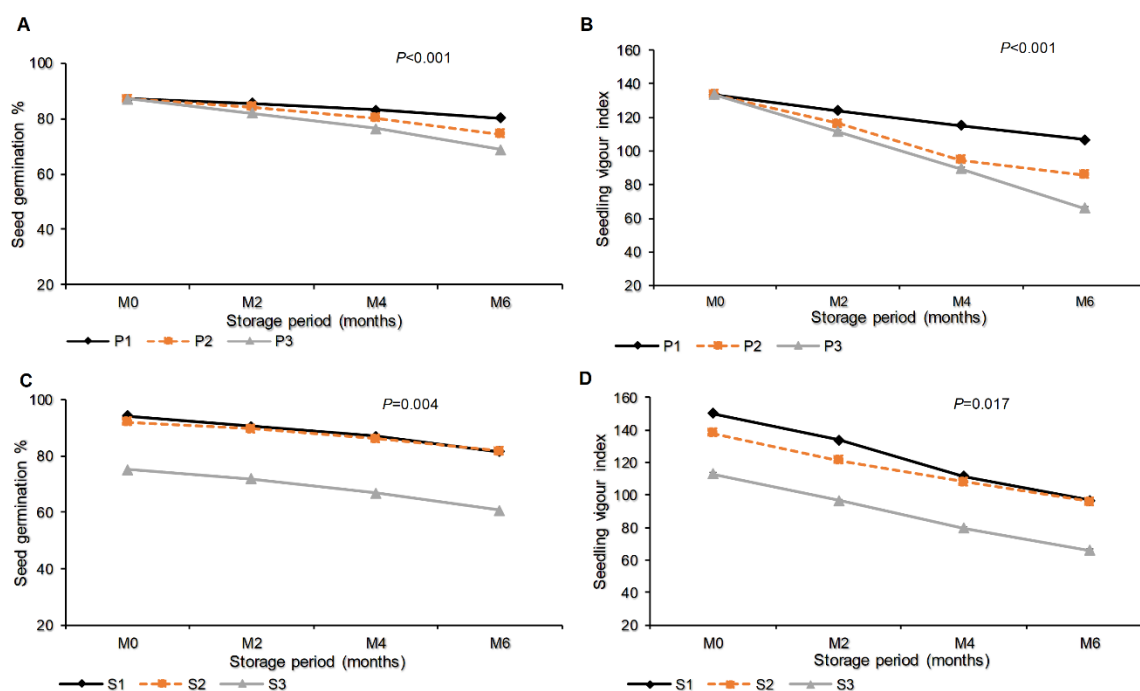


Figure 5. Germination percentage and seedling vigour index as influenced by interaction effect of packaging materials and storage period (A-B), interaction effect of storage period and seed class/type (C-D). Where M0, M2, M4 and M6 are Month 0 (Before storage), month 2, month 4 and month 6 respectively; P1=Plastic container, P2=Polypropylene bags and P3=sisal bags, S1=certified seed, S2=QDS and S3=Farm saved seeds.

Moreover, the interaction effect of seed class or seed type and storage period showed that the germination percentage and seedling vigour index were influenced significantly by $P=0.004$ and $P=0.017$ respectively. This shows that, the Quality declared seeds were observed to record the highest germination percentage (81.56%) which was not significantly different with 81.33% that recorded in certified seeds, the maximum seedling vigour index (96.76) was observed in certified seeds which did not differ significantly with 95.69 that recorded in Quality declared seeds. The minimum germination percentage (60.67%) and seedling vigour index (65.98) were recorded in Farmer saved seeds (**Figure 5C-D**).

4. Discussion

4.1. Seed-Borne Fungi

Differences in the incidence of seed-borne fungi infection among treatments in sunflower seeds were clearly observed during storage. Sisal bags, as packaging materials, exhibited the highest infection percentage. This could be attributed by their high permeability to moisture in the storage room, resulting in elevated seed moisture content. Consequently, the rapid multiplication of fungi occurred compared to less permeable packaging materials like plastic containers. The findings align with previous studies conducted by Shabana *et al.* (2015), Asha (2012), and Martín *et al.* (2022), who reported that highly permeable materials contribute to increased seed moisture content and thereby enhance the likelihood of fungal growth. Hasan *et al.* (2017) also found that seed moisture content significantly influences seed viability and contamination by storage fungi.

Variations in infection rates among seed classes/types may be attributed to disparities in initial seed quality among the seed classes/types used in the study. This conclusion aligns with the reports by FAO (2018) and Patharkar *et al.* (2013), which highlight that seed quality during storage depends on factors such as seed type, initial seed quality, seed moisture content, temperature, and relative humidity. Additionally, other researchers have noted varying percentages of fungal infection in stored seeds as the duration of storage increases, as observed by Wiewióra (2009) in spring barley, Kandhare (2018) in green-gram, Shabana *et al.* (2015) in maize, and Saeed *et al.* (2020) in cotton and wheat seeds.

The important fungal species recorded from stored seeds were *Fusarium vericillioides*, *Botrytis cinerea*, *Aspergillus* species, *Alternaria* spp., *Curvularia lunata* and *Rhizopus* species. Among these, the dominant seed-borne pathogenic fungi found were *Alternaria padwickii*, *Alternaria zinniae*, *Botrytis cinerea*, *Curvularia lunata* and *Fusarium vericillioides*. Also, three major saprophytic sunflower seed-borne fungi observed were *Aspergillus flavus*, *A. niger* and *Rhizopus arrhizus*. All of these pathogenic as well as saprophytic seed borne fungi were found to affect the seed viability and seedling vigour. These findings were somewhat in harmony with that found by Khalil *et al.*, (2014) and El-Wakil (2014) reported the association of large number of fungi with sunflower seeds and their list including; *Alternaria* species, *Fusarium* species, *Rhizoctonia* species etc. and that these seed mycoflora are of a great importance for seed deterioration and consequently lead to seed losses and this may be as a result of the secretion of mycotoxin and fungal secondary metabolites which reduce seed quality and quantity.

The findings also are somewhat similar with the study conducted by Patil *et al.* (2018), which identified *Alternaria alternata*, *Fusarium oxysporum*, as well as three saprophytic fungi (*Aspergillus flavus*, *A. niger*, and *Rhizopus stolonifer*) as the major phytopathogenic fungi present in the sunflower varieties examined. These seed-borne fungi are known to adversely affect seed health and vigour. Previous studies by Ghoneem *et al.* (2014), Kandhare (2018), and Chandel and Kumar (2017) have documented that, infected seeds serve as a means of disseminating various crop diseases to different regions. Factors such as high relative humidity, suitable temperature, and increased moisture content contribute to the establishment of pests and diseases within seeds. Infestation by these fungi has been observed in all parts of the seeds, leading to external or internal damage, including seed rot, necrosis, and seedling diseases (Deshmukh and Kare, 2010). Numerous researchers have previously reported that these fungi species cause deterioration of seeds, consequently reducing the viability and vigour of stored seeds.

4.2. Influence on Germination and Seedling Vigour Index

The detected seed borne fungi were found to influence the seed germination and seedling vigour index. Concerning seed class/types of germination percentage and seedling vigour index was recorded the smallest in the FSS (68.58% and 88.8 respectively) in seed class with the highest fungal infection percentage followed by QDS while the maximum was recorded in certified seeds (88.17% and 123 respectively), the seed class/type with less fungal infection. *Aspergillus* species (15.94), *Fusarium* species (13.11) and *Botrytis* species (12.53) were found to be higher followed by *Curvularia lunata* (5.90), *Alternaria* species (5.57) and least in *Rhizopus arrhizus* (3.2)

Fusarium species including *F. vericillioides* were reported to cause wilting and seedling rot as most protuberant symptoms exhibited in sunflower and other crops (Nagaraja & Krishnappa 2009 and Afzal *et al.*, 2010) reported in numerous crops, number of pathogenic and saprophytic seed borne fungi which affected harmfully the seed germination and seedling vigour index. In this situation, the findings of the current research become in harmoniousness with earlier conclusions of other researchers including Afzal *et al.*, 2010 in sunflower and those in other seed crops like Singh *et al.*, 2003 in pearl millet; Ahammed *et al.*, 2006 in soybean; Nagaraja and Krishnappa 2009 in niger crop. It has long been noted that seed-borne fungal pathogens arising from seed storage like *Aspergillus* species and *Alternaria* species are responsible for reducing seed quality, protein and carbohydrate contents, reduction of germination capacity and seedling vigour by damaging seedlings causing root collar, seed rot and damping off seedlings, which all together result in the reduction of crop yield

qualitatively and quantitatively. This was further reported by Anjorin & Mohammed, (2014); Masomeh *et al.*, (2012) and Lambat *et al.*, (2014)

Field fungi may cause weakening or death of embryos while storage fungi slowly kill the embryos of the seeds they invade. Furthermore, *Botrytis cinerea* causes grey-mould diseases in sunflower crop as found by Williamson *et al.*, (2007). Seedlings raised from such seeds lack the normal vigour (Gebeyaw, 2020). Seedborne pathogenic fungi can prevent germination, kill seedlings, or reduce plant growth by damaging the roots and vascular system, which prevents the transport of water and nutrients as also reported by Hatim *et al.*, (2022); Marcenaro & Valkonen, (2016) and Aslam *et al.*, (2015) in sunflower, common bean, and peanuts respectively.

5. Conclusion and Recommendation

Based on the current research, it can be deduced that, the fungi transmitted through the seeds were discovered to have a detrimental impact on both the viability of the seeds in terms of germination and the vigour index of the resulting seedlings in sunflower crops. As the duration of storage increased, a decrease in the percentage of seed germination and the seedling vigour index was observed. Consequently, it is strongly advised to utilize high-quality seeds including Certified and Quality declared seeds and employ appropriate storage materials in order to effectively preserve seeds for future sowing seasons. Such measures will help ensure optimal crop productivity and success.

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