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Investigations on Seed-Borne Fungi Associated with Maize Varieties and Their Control

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ABSTRACT

Maiz is one of the important crops being grown at Pakistan and worldwide. The study investigates seed-borne fungi in maize varieties and recommends fungicides and plant extracts for enhancing seed germination and plant health. Six different fungi were isolated from maize seeds, with Aspergillus niger being the predominant fungus, followed by Penicillium spp., *Fusarium oxysporum*, *Curvularia lunata*, *Rhizopus oryzae*, and *Macrophomina phaseolina*. Infected seeds showed reduced germination compared to healthy seeds, indicating the negative impact of seed-borne fungi on germination percentage. All six fungi were present in both the seed coat and endosperm, with slightly lower diversity observed in the embryo axis. *Aspergillus niger* was dominant in the seed coat, while *Rhizopus oryzae* and *Macrophomina phaseolina* were notably absent from the embryo axis. Carbendazim treatment showed effective results to minimize the disease, while Topsin M, Aliette, and Acrobat had intermediate effects compared to untreated controls. Neem extract was the most effective, followed by Datura, Nazboo, and Khabar. Carbendazim consistently had the most positive impact on plant height and weight. The untreated, uninoculated control exhibited the highest plant growth, emphasizing the negative impact of fungal inoculation. Neem extract consistently had the most positive impact on plant height and weight among plant extracts. The untreated, uninoculated control consistently had the highest values, indicating the absence of fungal inoculation positively influenced plant growth. Neem extract proved to be a promising alternative for managing seedborne fungi.

Keywords: management, maiz, seed-borne fungi

INTRODUCTION

Maize is the important staple cereal crops, that contribute and fulfill up to 50-60% of regular human energy requirements. Maize is originated in Mexico about 7000 years ago from natural wild grass (Batasubhanshini et al., 2015). Maize has remained a major source of income for the poor farmers of many countries. The demand for this crop is increasing with time due to its multiple uses as food, oil, and silage for human beings and animals. Maize, commonly known as corn, is indeed a nutritious and versatile grain that provides a variety of essential nutrients that have an efficient role in supporting physical functions which are: Carbohydrates, dietary fiber, plant-based protein, magnesium, phosphorus, potassium, zinc, copper, manganese, vitamin B3 (Niacin), vitamin B5 (Pantothenic Acid). Corn also contains thiamine (B1), pyridoxine (B6), and folate (B9) (Figure 1) (Shah et al., 2016), which are important for various metabolic processes, including energy production and the synthesis of DNA and red blood cells (Kumar & Jhariya 2013).

The United States has consistently been the largest producer of corn (maize) in the world, accounting for a significant percentage of global production (30.18%). China is another major producer of corn, with a substantial share of global production (23.99%) followed by Brazil (11.86%) while India has been increasing its corn production over the years and is among the top corn-producing countries in Asia (3.12%) as indicated in (Figure. 2 as given below) (Shahbandeh, 2023). Maize is processed for food and industrial products such as starch, oil, sweeteners, beverages, glue, fuel, ethanol, and industrial alcohol. It is also estimated that the demand for maize will be doubled in developing countries by 2050 (Ranum et al., 2014).

About 47 diseases have been reported in maize crops and 25 more diseases during the last few years are believed to be a major threat to maize production

(Ominski et al., 1994). under favorable conditions, fungal pathogens contribute about 50-80% of maize grain loss during the storage period. Major associated fungi are *Aspergillus*, *Penicillium*, *Fusarium*, and *Xerophytic* species, some of which can produce toxins having serious implications on human as well as animal health (Orsi et al., 2000)

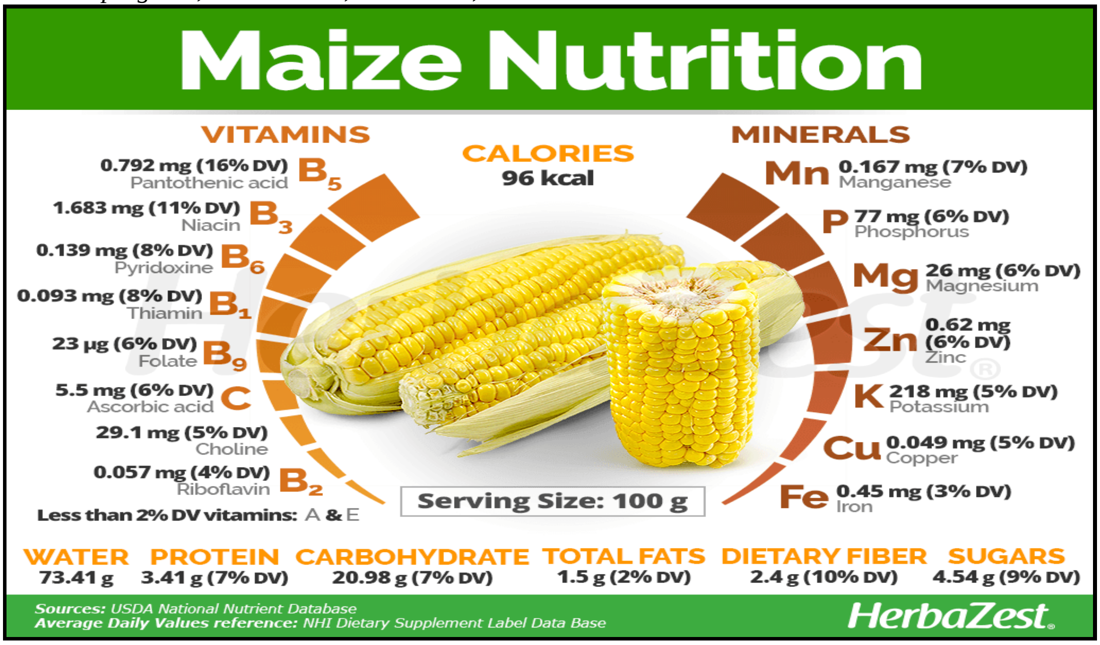


Figure. 1. Nutritional value of maize

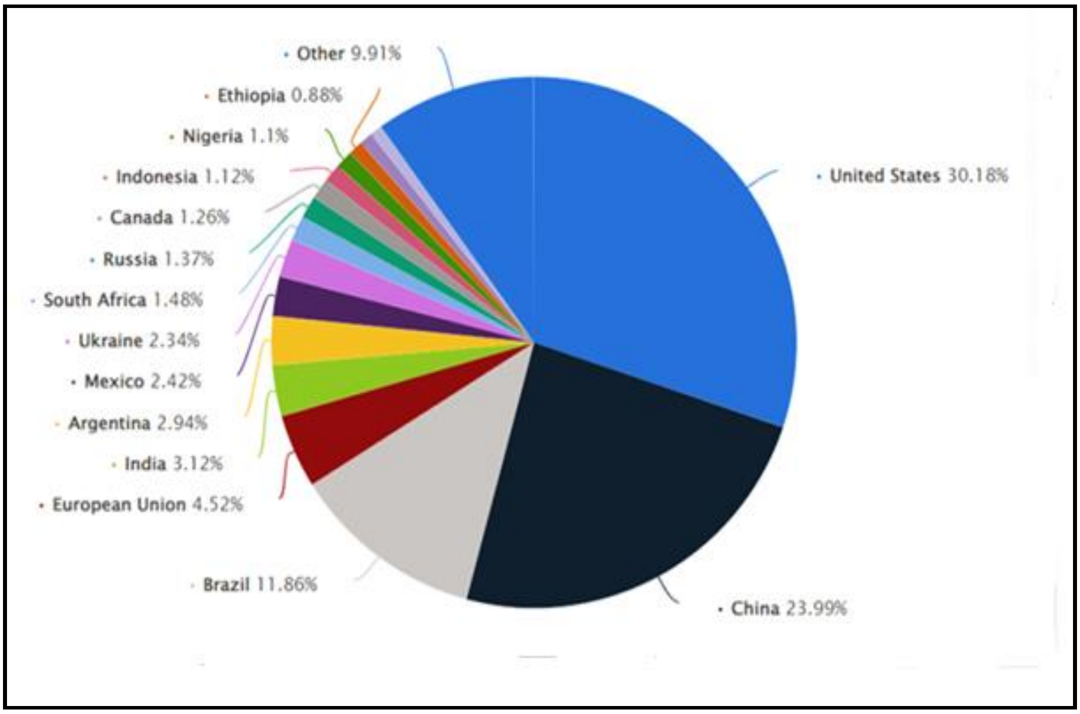


Figure 2. Distribution of global corn production share worldwide by country, 2022/2023

Seed-borne fungal pathogens are a significant concern in agriculture, as they can have detrimental effects on the growth and productivity of crop plants. Some of the specific impacts of these pathogens on crop plants, including maize, are seed necrosis, seed abortion, rotting of seeds, reduction or elimination of germination, seedling damage, and systemic or local infection, These effects highlight the importance of managing and preventing seed-borne fungal pathogens to ensure healthy and productive crop plants (Hussain et al., 2013). The presence of fungal pathogens in grain crops, including maize, can lead to contamination of the grains both before and after harvesting. This contamination can have several negative consequences, and certain fungal pathogens are particularly problematic due to their ability to produce mycotoxins. The main related issues are contamination, mycotoxins, deterioration of grain quality, poor germination capacity, and reduced vigor, these plants may be more susceptible to various stress factors and diseases. Various fungal species are known to produce mycotoxins, and some of these have been detected in maize such as *Aspergillus*, *Fusarium*, *Penicillium*, and *Rhizopus*. These fungi can produce mycotoxins that pose a significant threat to the quality and safety of maize crops and their products. Effective management strategies, including proper storage and handling practices, as well as disease control measures, are essential to mitigate mycotoxin contamination in maize and ensure the safety of both human and animal consumption (CIMMYT, 2004).

Growers always need pure, healthy, and quality seeds with high germination and maximum production of maize. Keeping in view the importance and potential of the maize crop in the country and the globe and possible pathogenic threats to the crop

MATERIAL AND METHODS

The research work was carried out in the Department of Plant Pathology, Sindh Agriculture University, Tandojam. Pakistan

Collection of Seeds: Four seed of maize variety such as: Neelam, Shahanshah Akbar, and Local were collected from the market of Tandojam and Hyderabad for isolation of seed-borne fungi associated with maize seeds. (Figure.3)

Isolation of seed-borne fungi from maize varieties: Two samples (100 seeds /sample) of each maize variety were randomly selected. Each sample was dipped in 0.01% mercuric chloride for 2-3 min. and washed in two changes of double distilled water for 3-4 min. each to eliminate the saprophytic organisms present on surface of seeds. Seed samples were tested for the occurrence of different fungi in the seeds by using the standard blotter paper method and agar plate method (ISTA, 2014). Five seeds per plate were placed and there were three replications. Observation was recorded regularly to check the growth of fungi associated with maize seeds. The various fungal cultures were identified using key given by Barnett (2006) and through available literature on the internet.

The incidence percent of each fungus with the seed was recorded by using the following formula:

$$\text{Frequency (\%)} = \frac{\text{No of seeds colonized in each plate by a particular species}}{\text{Total no of colonies in each plate}} \times 100$$

Effect of seed-borne fungi on seed germination of maize varieties: Healthy and infected (symptomatic) seeds of maize varieties were separated from the seed lot. Total 100 seeds of each type of all varieties were selected. Five seeds were placed in each Petri plate containing three layers of moistened blotter paper. All plates were incubated at room temperature and observations were taken regularly on seed germination from healthy and infected seeds of different maize varieties.

$$\text{Germination (\%)} = \frac{\text{Number of seeds germinated}}{\text{Total no of seeds in each plate/pot}} \times 100$$

Location of fungi in the seed components: Seeds of local maize variety were soaked in water for 24 hrs, and then seeds were dissected carefully into different parts i.e., pericarp, embryo axis, and cotyledon. Each part was surface sterilized in 0.01/% mercuric chloride and placed on petri dishes containing sterilized PDA medium. The petri dishes were incubated at room temperature for 7 days and then examined for infection under a stereoscopic microscope.

Effect of different plant extracts on plant growth of maize

Preparation of stock solutions: Fresh and healthy plant part i.e., leaves of neem, nazbo, datura, and khabar were collected from the premises of Sindh Agriculture University, Tandojam. These were washed thoroughly under tap water, dried on blotting paper, and grinded to make a powder form. The powder of various plant materials was soaked in distilled water for 24 hrs to prepare 10ml/l, 20ml/l and 30ml/l concentrations and stored at room temperature. Later solutions were passed through muslin cloth and filtered through Whatman filter paper

.

Table 1 Different plant species used against seed-borne fungi of maize

S. No.	Local Name	Botanical Name	Family	Parts used
1.	Neem	*Azadirachta indica*	Meliaceae	Leaves
2.	Nazboo	*Ocimum basilicum*	Lamiaceae	Leaves
3.	Datura	*Datura stramonium*	Solanaceae	Leaves
4.	Khabar	*Salvadora persica*	Salvadoraceae	Leaves

The experiment was carried out in earthen pots (9 inch dia.); all pots were thoroughly washed, dried then sprayed with spirit to avoid any saprophytic contamination. The aqueous extracts of different plant species given in Table 1 were prepared by a method discussed above and were used as treatment with the following doses: D1 = 10ml, D2 = 20ml, D3 = 30ml per pot containing sterilized soil. Whereas, untreated, inoculated (C1) and untreated, uninoculated (C2) pots served as control. The pots were arranged in a randomized complete block design with three replications. One Petri dish fully covered with a growth of isolated fungi was added per pot and left for seven days to let the fungus establish before adding respective doses of plant extracts. Then all doses were thoroughly mixed with sterilized soil. Ten seeds of uniform size of Neelam maize variety per pot were sown and watered regularly. After 45 days of sowing, mortality percentage and growth parameters shoot and root were recorded.

Effect of plant extract on plant growth parameters of maize: A hundred seeds from Neelam were taken and soaked in 10% aqueous leaf extracts of selected plants for 2 hours, while seeds soaked in sterile distilled water served as the control. The treated and control seeds were then air-dried. Subsequently, these dried seeds were plated on blotter paper, incubated for seven days at room temperature. Moreover, the percentage of seed germination, as well as the lengths of roots and shoots were recorded.

Effect of different fungicides on plant growth of maize: A pot experiment was conducted to evaluate the efficacy of commercial fungicides namely: viz. Acrobat, Topsin-M, Carbendazim, and Aliette as soil drench against seed-borne fungi associated with maize seeds. The doses applied were 2, 3, and 4 g L^{-1}. Each fungicide @ 10ml per pot was drenched in the pot containing sterilized and infested soil. Untreated inoculated and untreated uninoculated pots were kept as control. Sowing of seed, inoculation of the fungus, experiment design, observation of data was same as described above. (Figure-6)

Effect of fungicides on plant growth parameters of maize: A hundred seeds from Neelam variety were taken and dipped in fungicide solution for 2 hours, while seeds soaked in sterile distilled water served as the control. The treated and control seeds were then air-dried. Subsequently, these dried seeds were plated on blotter paper, incubated for seven days at room temperature. Moreover, the percentage of seed germination, as well as the lengths of roots and shoots were recorded.

All the data were statistically analyzed by using the 'student edition of Statistix, version1.0' computer software for analysis of variance and LSD at 5% to compare the differences among treatment means.

RESULTS

The present study was carried out to record the frequency of seed-borne fungi and their effect on seed germination of maize varieties, location of fungi in maize seed and management with different fungicides and plant extracts.

Incidence of various seed-borne fungi associated with maize varieties: Six different fungi i.e., *Fusarium oxysporum*, *Aspergillus niger*, *Penicillium* spp., *Curvularia lunata*, *Rhizopus oryzae*, and *Macrophomina phaseolina* were isolated from seeds of maize varieties. Among all isolated fungi, *Aspergillus niger* was isolated as the predominant fungus (28.50-63.50%), followed by *Penicillium* spp. (22.50-49.50%), *Fusarium oxysporum* (15.00-37.50%), *Curvularia lunata* (10.50-15.00%), *Rhizopus oryzae* (6.50-7.50%) and *Macrophomina phaseolina* (3.50-4.50%) respectively (Table 2 & Figure 4).

Effect of seed-borne fungi on seed germination of maize varieties: The results regarding germination percentage of healthy and infected seeds of maize variety grown on moistened blotter paper showed that germination was reduced in infected seeds. Maximum seed germination (90%) was observed in healthy seeds of Neelam followed by Shahanshah (87.5%) varieties whereas; minimum germination (49%) was seen in infected seeds of Local variety (Table 3& Figure-5).

Location of seed-borne fungi in seed component of maize: Table 4 indicates the frequency of different fungi associated with different parts of maize seeds. All six fungi were present in both the seed coat and endosperm. In the embryo axis, only four fungi were observed, suggesting a slightly lower diversity of fungi in this part compared to the seed coat and endosperm. *Aspergillus niger* was the dominant fungus in the seed coat followed by *Penicillium* spp, and *Fusarium. Curvularia*, *Rhizopus*, and *Macrophomina phaseolina* were found in the seed coat but were less prevalent. The endosperm also exhibited the presence of all six fungi, with varying frequencies. *Rhizopus* and *Macrophomina phaseolina* were notably absent in the embryo axis, indicating that these fungi were not detected in this specific part of the maize seed.

(Figure. 3) (A) Healthy and infected seeds of Akbar and Local variety
(B) Healthy and infected seeds of Shahanshah and Neelam variety

Table 2. Frequency of seed borne fungi associated with maize varieties

Variety	Seed-borne fungi	Number of infected seeds/200	Percentage
Neelam	*Aspergillus niger*	57	28.5
	Penicillium spp.	45	22.5
	Fusarium oxysporum	30	15
	Curvularia lunata	21	10.5
	Rhizopus oryzae	*	
	Macrophomina phaseolina	*	
Shahanshah	*Aspergillus niger*	98	49
	Penicillium spp.	57	28.5
	Fusarium oxysporum	41	20.5
	Curvularia lunata	30	15
	Rhizopus oryzae	13	6.5
	Macrophomina phaseolina	*	
Akbar	*Aspergillus niger*	115	57.5
	Penicillium spp.	75	37.5
	Fusarium oxysporum	45	22.5
	Curvularia lunata	28	14
	Rhizopus oryzae	13	6.5
	Macrophomina phaseolina	7	3.5
Local	*Aspergillus niger*	127	63.5
	Penicillium spp.	99	49.5
	Fusarium oxysporum	75	37.5
	Curvularia lunata	30	15
	Rhizopus oryzae	15	7.5
	Macrophomina phaseolina	9	4.5

Table 3 Germination percentage of healthy and infected seeds of maize varieties

Variety	Type of seed	Number of seeds germinated/200	Percentage
Neelam	Healthy	180	90.00
	Infected	118	59.00
Shahanshah	Healthy	175	87.50
	Infected	115	57.50
Akbar	Healthy	170	85.00
	Infected	108	54.00
Local	Healthy	165	82.50
	Infected	98	49.00

Table 4. Location of seed-borne fungi in seed component of maize

Fungi	Infection percentage		
	Seed coat	Cotyledon	Embryonic axis
Aspergillus niger	36.00	19.00	5.00
Penicillium spp.	31.00	13.00	4.00
Fusarium oxysporum	23.00	12.00	3.00
Curvularia lunata	13.00	5.00	1.75
Rhizopus oryzae	8.00	3.00	0.00
Macrophomina phaseolina	3.00	1.50	0.00

Effect of different fungicides on plant growth of maize: Carbendazim treatment consistently outperformed other fungicides and the control in terms of germination percentage, shoot length, and root length. Topsin M, Aliette, and Acrobat showed intermediate results, with varying degrees of impact on germination and plant growth. The control treatment had the lowest values for all three parameters, indicating the negative impact of seed-borne fungi in the absence of fungicide treatment (Table 5 and **Figure 6**).

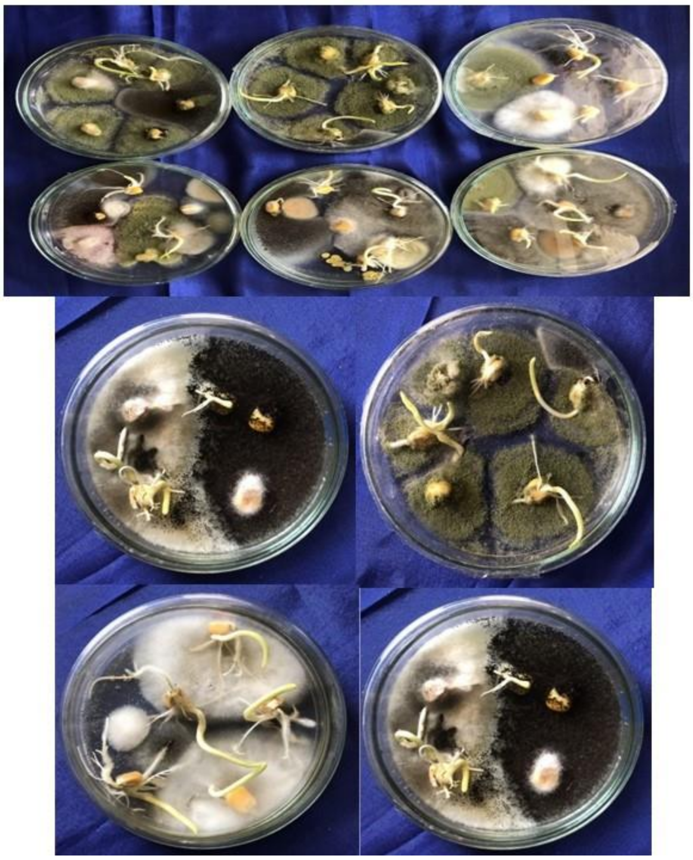


Figure 4. Different fungi isolated from the seed of maize varieties

Figure 5. Impact of seed-borne fungi on seed germination of maize varieties

Effect of seed-borne fungi and seed treatment with different plant extracts: Neem extract appears to be the most effective among the tested plant extracts, leading to higher germination percentages and superior shoot and root lengths. Datura, Nazboo, and Khabar showed intermediate results, with varying degrees of impact on germination and plant growth. The control treatment, without plant extract application, resulted in the lowest values across all parameters (Table 7).

Effect of different fungicides on plant growth of maize: The (Table 7) provides information on the effect of different fungicides on the growth of maize plants sown in inoculated soil. Among the fungicide treatments, Carbendazim consistently had the most positive impact on both plant length and weight. Topsin M and Aliette showed intermediate effects, while Acrobat had slightly lower effects. The untreated, inoculated control (C1) had the lowest plant length and weights, indicating the negative impact of fungal inoculation. The untreated, uninoculated control (C2) consistently had the highest values for both plant length and weight, indicating that the absence of fungal inoculation positively influenced plant growth.(Table 6).

Effect of different plant extracts on plant growth of maize: Among the plant extracts, Neem consistently had the most positive impact on both plant length and weight at all three doses. Datura and Nazboo showed intermediate effects, while Khabar had slightly lower effects. The untreated, inoculated control (C1) consistently had the lowest values, emphasizing the negative impact of fungal inoculation on plant growth. The untreated, uninoculated control (C2) consistently had the highest values for both plant length and weight, indicating that the absence of fungal inoculation positively influenced plant growth (Table.8 and (Table 7).

Table. 5. Effect of fungicide on plant growth parameters of maize

Fungicide	Germination (%)	Shoot length (cm)	Root Length (cm)
Carbendazim	81.00	6.00a	5.10a
Topsin M	78.00	5.20ab	4.30b
Aliette	74.00	4.80bc	4.80c
Acrobat	73.00	4.10c	3.30d
Control	71.00	2.90d	2.10e
LSD (P=0.05)	--	0.891	0.382

Note: The alphabetical letters showing the same homogenous groups in column are not significant with each other.

Table. 6 Effect of plant extract on plant growth parameters of maize

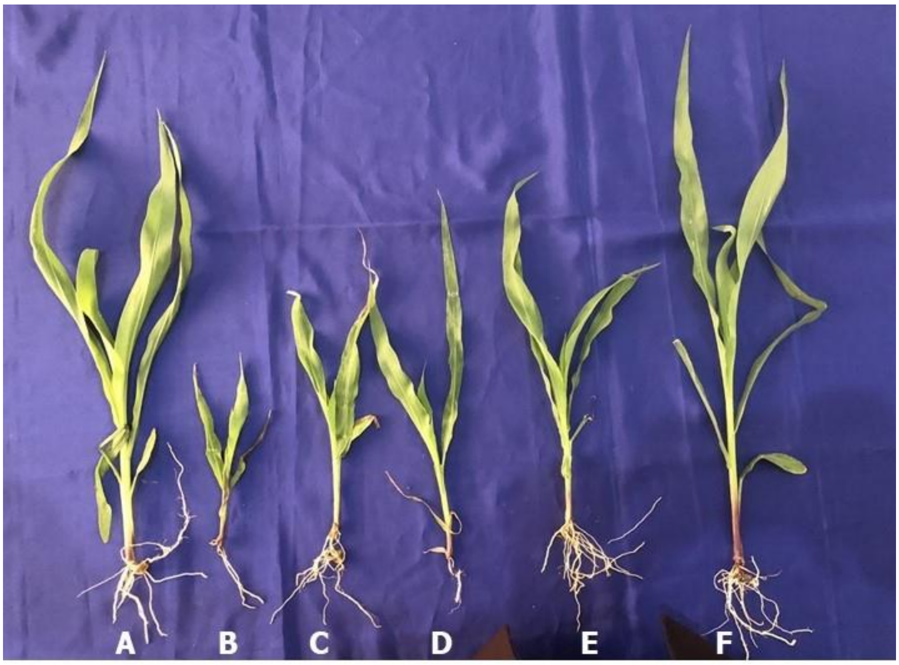
Local Name	Botanical Name	Germination (%)	Shoot length(cm)	Root length(cm)
Neem	*Azadirachta indica*	78.00	5.50a	4.80a
Datura	*Ocimum basilicum*	74.00	4.90b	3.80b
Nazboo	*Datura stramonium*	73.00	4.30bc	3.50b
Khabar	*Salvadora persica*	72.00	3.90c	3.00c
Control		71.00	2.90d	2.10d
LSD (P=0.05)		--	0.504	0.304

Note: The alphabetical letters showing the same homogenous groups in column are not significant with each other.

Table 7. Effect of fungicides on plant growth of maize sown in inoculated soil

Treatments	Plant length (cm)			Plant weight (g)		
	D1(10ml)	D2(20ml)	D3(30ml)	D1 (10ml)	D2(20ml)	D3(30ml)
Carbendazim	42.00d	44.00c	46.00b	25.00d	26.20c	27.50b
Topsin M	40.00ef	42.00d	44.00c	22.67fg	24.00e	25.10d
Aliette	37.00h	39.00fg	41.00de	21.00h	22.00g	23.10f
Acrobat	36.50h	38.50g	39.50fg	18.10k	19.00j	20.00i
C1	20.67i	-	-	11.30l	-	-
C2	50.00a	-		33.00a	-	-
LSD (P =0.05)	1.1775	-	-	0.7162	-	-

C1 = Control (untreated, inoculated), C2 = Control (untreated, uninoculated)
Note: The alphabetical letters showing the same homogenous groups in column are not significant with each other.



A Carbendazim, B) control-1, C) Acrobat, D) Aliette, E) Topsin M, F) Control-2,

Figure 6. Effect of different fungicides on plant growth of maize varieties

Table 8. Effect of plant extracts on plant growth of maize sown in inoculated soil

Local Name	**Botanical Name**	**Plant length (cm)**			**Plant weight (g)**		
		D1(10 ml)	**D2 (20ml)**	**D3 (30ml)**	**D1 (10ml)**	**D2 (20ml)**	**D3(30ml)**
Neem	*Azadirachta indica*	37.33cd	38.69bc	40.00b	22.00d	23.00c	24.10b
Datura	*Ocimum basilicum*	35.00e	37.00d	38.67bc	21.00e	22.00d	23.00c
Nazboo	*Datura stramonium*	33.00f	34.00ef	35.33e	18.00g	18.90f	19.33f
Khabar	*Salvadora persica*	28.00h	29.00gh	30.00g	15.00i	15.60hi	16.10h
C1		20.67i	-	-	11.30j	-	-
C-2		50.00a	-	-	33.00a	-	-
LSD (P =0.05)		1.4130	-	-	0.6278	-	-

C1 = Control (untreated, inoculated), C2 = Control (untreated, uninoculated)

Note: The alphabetical letters showing the same homogenous groups in column are not significant with each other.

Neem B) control-1, C) Khabar, D) Nazboo, E) Datura, F) Control-2

Figure 7. Effect of plant extracts on plant growth of maize sown in inoculated soil

DISCUSSION

Numbers of various seedborne fungi associated with maize varieties: Six different fungi i.e., *Fusarium oxysporum*, *Aspergillus niger*, *Penicillium* spp., *Curvularia lunata*, *Rhizopus oryzae*, and *Macrophomina phaseolina* were isolated from seeds of maize varieties. Among all isolated fungi, *Aspergillus niger* was isolated as the predominant fungus (28.50-63.50%), followed by *Penicillium* sp. (22.50-49.50%), *Fusarium oxysporum* (15.00-37.50%), *Curvularia lunata* (10.50-15.00%), *Rhizopus oryzae* (6.50-7.50%) and *Macrophomina phaseolina* (3.50-4.50%) respectively. Hussain et al. (2013) reported that *Aspergillus, Fusarium, Penicillium,* and *Rhizopus* species were isolated from maize seeds. These pathogens are well known to affect the growth and production of crops. The main effect is necrosis of the seed, discoloration, rotting, and reduced seed germination. Ghosh et al. (2018) isolated *Alternaria* spp., *Curvularia* spp., *Fusarium* spp., *Helminthosporium* spp., *Penicillium* spp., *Monilinia* spp., *Aspergillus* spp., *Mucor* spp., and *Rhizopus* spp., were associated with the seeds of cereal crops. Castellari et al. (2010) isolated similar predominant genera of fungi: *Aspergillus*, *Penicillium*, and *Fusarium* from maize. *Aspergillus flavus*, *A. niger*, *Fusarium moniliformae*, *Alternaria alternata*, *Curvularia lunata*, *Bipolaris maydis*, and *Colletotrichum graminicola* were isolated from maize varieties. BML-06 variety appeared to be less infected compared to the other maize seed varieties tested (Sreenu et al., 2019). Fayza (2021) revealed the presence including *Fusarium*, *Aspergillus*, *Nigrospora*, *Macrophomina,* and *Penicillium* species in seeds old six maize cultivars.

Effect of seed-borne fungi on seed germination of maize varieties: The results regarding the germination percentage of healthy and infected seeds of maize variety grown on moistened blotter paper showed that germination was reduced in infected seeds. Maximum seed germination (90%) was observed in healthy seeds of Neelam followed by Shahanshah (87.5%) varieties whereas; minimum germination (49%) was seen in infected seeds of Local variety. Maize seed-borne fungi were responsible for poor grain quality, reduced seed germination, and reduced vigor of plants, this was reported by (Agrios, 2005). *Fusarium moniliforme* and *Aspergillus niger* had significant detrimental impacts on both seeds and seedlings of maize, indicating a potential threat to maize cultivation in the region (Hussain et al., 2013). Ghosh et al. (2018) reported that fungi associated with seeds of cereal crops are responsible for reduced viability, and changes in seed quality, unable to germinate properly seedling mortality. According to Niaz and Dawar (2009), fungal infections can reduce the germination rate of seeds. Infected seeds may fail to sprout, or they may exhibit delayed germination. This can lead to uneven crop emergence and reduced overall crop yield. Seed-borne fungi, whether present on or inside the seed of maize had adverse effects on seed viability, germination, emergence, plant growth vigor, and overall production and productivity (Mohmed et al., 2019).

Location of seed-borne fungi in seed component of maize: All six fungi were present in both the seed coat and endosperm. In the embryo axis, only four fungi were observed, suggesting a slightly lower diversity of fungi in this part compared to the seed coat and endosperm. *Aspergillus niger* was the dominant fungus in the seed coat followed by *Penicillium* spp. and *Fusarium*. *Curvularia*, *Rhizopus*, and *Macrophomina phaseolina* were found in the seed coat but were less prevalent. Tariq et al. (2006) also reported that seed coat had the highest number of fungi, followed by cotyledon and axis.

Effect of different fungicides on plant growth of maize: Carbendazim treatment consistently outperformed other fungicides and the control in terms of germination percentage, shoot length, and root length. Topsin M, Aliette, and Acrobat showed intermediate results, with varying degrees of impact on germination and plant growth. The control treatment had the lowest values for all three parameters, indicating the negative impact of seed-borne fungi in the absence of fungicide treatment. Sitara and Akhtar (2007) found Ridomyl Gold the most effective treatment against seed-borne mycoflora of maize and increased seed germination, followed by Aliette, Neem seed powder at various concentrations (0.1, 0.2, and 0.3%), Antracol, and Sodium hypochlorite. According to Walcott et al. (2007), infected seeds resulted in weakened germination, poor seedling vigor, and increased susceptibility to diseases. Seed treatment with fungicides and disease-resistant or tolerant crop varieties can eliminate pathogens.

Seed-borne fungi and seed treatment with different plant extracts: Neem extract appears to be the most effective among the tested plant extracts, leading to higher germination percentages and superior shoot and root lengths. Datura, Nazboo, and Khabar showed intermediate results, with varying degrees of impact on germination and plant growth. The control treatment, without plant extract application, resulted in the lowest values across all parameters. Sitara and Akhtar (2007) reported that neem seed powder at various concentrations (0.1, 0.2, and 0.3%) effectively controlled seed-borne mycoflora of maize and increased seed germination.

Effect of different fungicides on plant growth of maize: The table provides information on the effect of different fungicides on the growth of maize plants sown in inoculated soil. Among the fungicide treatments, Carbendazim consistently had the most positive impact on both plant length and weight. Topsin M and Aliette showed intermediate effects, while Acrobat had slightly lower effects. The untreated, inoculated control (C1) had the lowest plant length and weights, indicating the negative impact of fungal inoculation. The untreated, uninoculated control (C2) consistently had the highest values for both plant length and weight, indicating that the absence of fungal inoculation positively influenced plant growth. Maize seeds were treated with fungicides to reduce the seed-borne pathogens (Sharma et al., 2015). Ghosh et al. (2018) reported that Topspin, Mancozeb, and Dorsal significantly seed-borne fungi of maize and enhanced the plant health. Fungicides (triazoles, strobilurins, and pyrethroids) applied to maize seeds reduced the growth of *Fusarium*, *Aspergillus*, and *Penicillium*. Seed treatment also contributed to improved germination and seedling health (Sharma et al., 2015).

Effect of different plant extracts on plant growth of maize: Among the plant extracts, Neem consistently had the most positive impact on both plant length and weight at all three doses. Datura and Nazboo showed intermediate effects, while Khabar had slightly lower effects. The untreated, inoculated control (C1) consistently had the lowest values, emphasizing the negative impact of fungal inoculation on plant growth. The untreated, uninoculated control (C2) consistently had the highest values for both plant length and weight, indicating that the absence of fungal inoculation positively influenced plant growth. According to Koch and Roberts (2014), natural compounds derived from plants have pesticidal properties and can be used for seed treatments or as part of integrated pest management strategies. Debnath, et al. (2012) found neem and garlic extracts effective in controlling seedborne fungi of maize varieties. Similarly, Usman and Zakari (2018) and Ingle (2018) found *Azadirachta indica*, (Datura metal), *Vitex negundo*, *Cymbopogon citratus* (lemongrass), and *Vernonia amygdalina* (bitter leaf), most effective and inhibited the seed-borne fungi but also had positive effects on seed germination percentage, root length, and shoot length.

CONCLUSIONS

It was concluded that six seed-borne fungi in maize varieties were diagnosed among which, w *Aspergillus niger* being the predominant fungus. Infected seeds showed reduced germination percentages compared to healthy seeds, indicating the negative impact of seedborne fungi on maize germination. The highest germination was observed in the healthy seeds of Neelam and Shahanshah varieties. Carbendazim treatment consistently outperformed other fungicides, leading to higher germination percentages, shoot length, and root length, Among the tested plant extracts, Neem extract demonstrated the most positive impact on germination percentages and plant growth. the control without fungicide treatment had the lowest values for all parameters. Considering the effectiveness of Carbendazim in managing seedborne fungi, its use is recommended to enhance germination and overall plant growth. However, further research can explore sustainable and eco-friendly alternatives.

AUTHORS CONTRIBUTIONS

All Authors have equal contribution

CONFLICT OF INTEREST

All authors have no conflict **of interest**

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