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AK Jain
Department of Plant Pathology, JNKVV, College of Agriculture, Rewa, Madhya, Pradesh, India

Corresponding Author:
AK Jain
Department of Plant Pathology, JNKVV, College of Agriculture, Rewa, Madhya, Pradesh, India

Seed borne mycoflora of finger millet and their management: A review

AK Jain

Abstract
Fungi harboring finger millet (*Eleusine coracana* L. Gaertn.) seeds are potentially toxic to plant and indirectly to human health. Seed borne pathogens retarded the market value of the grains and deteriorate the nutritional quality. In the present review, attempts are made to compile the available information on mycoflora associated with the finger millet seeds, their role in disease development, phyto-pathological effects, toxic substances produced by them and their management by various methods. Eighty seven fungal species belonging to 38 genera have been reported in different cultivars of finger millet. *Alternaria alternata, Aspergillus flavus, A. niger, Drechslera nodulosum, D. tetramera, Fusarium equiseti, F. moniliforme, F. semitectum, Pyricularia grisea, Curvularia lunata, C. pallascence* and *Phoma* sp. were found predominantly associated with the seeds and reported to cause seed rot, seedling blight and leaf spots in finger millet. Deleterious effects of mycoflora on seed viability and seedling growth parameters were also reported. Phytotoxic compounds produced by *Bipolaris bicolor* (Cochlioquinone A, Cochlioquinone B, Stemphone and Isocochlioquinone), *Pyricularia grisea* (Pyrichalasin H), *Aspergillus* species (Aflatoxins, Petulin, Terreic acid and Sterigmocystin), *Fusarium* species (Zearalenone, Fusarinone-X, Deoxynivalenol, Nivalenol, Diacetoxyscripenole, Neosolanil and HT-2 toxins) and *Penicillium griseofulvum* (Cyclopiazonic acid) were found to inhibit or suppress the seed germination, shoot/root elongation and seedling vigour. Seed treatment with botanicals viz. Dhatura, Neem, Aloe vera, Garlic, Tulsi, Ardusi, Piper leaf extracts and seed biopriming with *Trichoderma viride, T. harzianum, T.faciculatum, Pseudomonas fluorescens* and *Bacillus subtilis* were reported to minimize the seed associated mycoflora in finger millet and enhance the seed quality parameters. A number of systemic and non-systemic fungicides were reported to control the seed borne mycoflora in finger millet.

Keywords: Finger millet, seed borne mycoflora, phyto-pathological effects, toxic substances, management

Introduction
Finger millet (*Eleusine coracana* L. Gaertn.) popularly known as *Ragi* or *Madua* is a nutritionally as well as medicinally rich small millet crop and grown in many parts of the country under diverse ecological conditions as sole or intercrop. Finger millet was domesticated in Ethiopia and Western Uganda around 5000 BC then reached India by 3000 BC. The inflorescence of the crop are resembles with the fingers of human hand, hence commonly known as finger millet. In India, the crop is cultivated in an area of 0.988 m ha with annual production of 1.587 mt and productivity of 1607 kg ha^{-1}. Karnataka (0.651 m ha), Uttarakhand (0.105 m ha), Maharashtra (0.078 m ha), Tamil Nadu (0.055 m ha), Andhra Pradesh and Odisha (0.027 m ha) are major finger millet growing states in the country (2019-2020). Finger millet is rich in calcium, proteins, iron, fiber and other minerals. The seed is a vital unit for sustainable agricultural production and play major role in the dissemination of pathogenic and non-pathogenic microorganisms. Fungi are the key seed borne micro flora found associated with the seed externally or internally and reported to cause seed deterioration in storage resulting retarding effect in seed germination and other seed quality parameters. Nutritional quality of the grains was also affected badly and some seed borne fungi were reported to produce toxic substances that are hazardous to plant, animal and human health. The air spora and myco-phyllo flora of finger millet was studied by Shankara and shetty (1989) [53] at vegetative, flowering, soft dough, hard dough and harvest of the crop. They reported that both the air and myco phyllo flora increased from vegetative to hard dough stage, but decreased markedly at harvest due to incessant rain except *Drechslera nodulosa* and *Fusarium oxysporum*. Further, blast and blight infected leaves harbored more number of fungi compared to healthy leaves. Besides fungal pathogens, few other pathogens like Indian peanut clump virus (IPCV) was found seed transmitted in finger millet (Reddy *et al.* 1998) [52].

One bacterium *Acidovorax avanae* pv *avanae* was also found associated with the seeds of finger millet (Mudingotto *et al.* 2002) [29]. Mousa *et al.* (2015) [28] concluded that the finger millet is an ancient, disease-tolerant crop and possess a novel source of endophytic anti-fungal natural products. In the present review, attempt have been made to compile the status of seed borne mycoflora, toxic substances produces by them, their transmission in disease development, phytopathological effects on the host plant and their management in finger millet.

Seed borne mycoflora

About 87 species of fungi belonging to 38 genera (Table 1) have been identified on finger millet seeds so far. However, their severity depends on the time of sampling, location and varieties. Maximum eleven species of *Aspergillus* namely *Aspergillus flavus A. niger*, *A. rubber*, *A. terreus*, *A. clavatus*, *A. nidulans*, *A. fumigatus*, *A. ochraceous*, *A. candidus*, *A. flaviceps* and *A. chevalieri*, eleven species of *Drechslera* namely *D. graminea*, *D. nodulosum*, *D. oryzae*, *D. tetramera*, *D. rostrata*, *D. maydis*, *D. australiensis*, *D.helodes*, *D. hawailensis*, *D. setariae* and *D. plurisepta*, ten species of *Penicillium* namely *P. chrysogenum*, *P. lapidosum*, *P. implicatum*, *P. oxalicum*, *P. cyclopium*, *P. citrinum*, *P. islandicum*, *P. funiculosum*, *P. variable*, *P. griseofulvum* and seven species of *Fusarium* viz. *F. equiseti*, *F. moniliforme*, *F. semitectum*, *F. oxysporum*, *F. roseum*, *F. solani* and *F. dimerum* were found associated with finger millet seeds. Four species of *Chaetomium* namely *C. globosum*, *C. robustom*, *C. indicum*, *C. funiculum*, three species of *Cladosporium* namely *C. cladosporiodes*, *C. herbarum*, *C. oxysporum*, three species of *Pyricularia* viz. *P. oryzae*, *P. grisea and P. setariae* were other important seed borne fungi. Two species of *Curvularia* viz. *C. lunata*, *C. pallascence*, two species of *Epicocum* viz. *E. nigram*, *E. perpurascens*, three species of *Mucor* viz. *M. fraglis*, *M. hiemlis*, *M. varians*, two species of *Nigrospora* viz. *N. sphaerica*, *N. oryzae*, three species of *Rhizopus* viz. *R. nigricans*, *R. stolonifer* and *R. nodosus* were found associated with finger millet seeds. Other important mycoflora associated with finger millet seeds were *Alternaria alternata*, *Absidia ramosa*, *Botryodiplodia theobromae*, *Botrytis cineria*, *Cercospora* sp., *Excerohilum halodes*, *Humicola* sp., *Helminthosporium leucostylum*, *Cephalosporium* sp, *Monilia* sp., *Memnoniella echinata*, *Mortierella* sp., *Macrophomina phaseolina*, *Phoma* sp., *Melampsora* sp., *Rhizoctonia solani*, *Stachybotrys altra*, *Sordaria* sp. *Stemphylium* sp, *Pithomyces maydicus*, *Syncephalastrum recemosum*, *Torula graminis*, *Trichothecium roseum*, *Trichoderma viride*, white sterile mycelium, *Phycomyces* sp. and *yeasts*. Predominant fungi associated with seeds were *Drechslera nodulosum*, *Curvularia lunata*, *Fusarium moniliforme*, *F. semitectum*, *Pyricularia grisea*, *Aspergillus flavus*, *A. niger*, *Drechslera rostrata* and *Phoma* species. Kumar (2010) [21] found four fungi namely *Aspergillus niger*, *Penicillium citrinum*, *Fusarium sp. and Alternaria alternata* were dominant on seeds of four finger millet genotypes. Most of the mycoflora were reported surface seed borne, but *Fusarium* sp., *Bipolaris nodulosa* and *Pyricularia grisea* were found internally seed borne. The internally seed borne inoculum were not deep seated but rather were predominantly found around the hilum (Grewal and Pall, 1965 [10], Adipala, 1992) [3]. Inter-varietal differences among nine varieties of *Eleusine coracana* in the distribution and composition of the grain microflora were observed by Srinivasa *et al.* (1972) [56].

Association of mycoflora was low in red grained cultivars as compared to white grained cultivars (Reddy and Luke, 1978) [49]. Dutta and Jha (1983) [8] found more association of *Curvularia lunata* with black non-germinated finger millet seeds. Shankara and Shetty (1989) [53] studied the fungal association with finger millet seeds and reported that black discoloured seeds showed the presence of *Pyricularia grisea*, while *Drechslera* species infected seeds showed brown discolouration. Kumar *et al.* (2000) [22] determine the fungi from 400 finger millet seed samples collected from different areas in Bihar. *Cochliobolus nodulosus* was found in all the samples followed by *Curvularia* sp., *Alternaria* sp., *Pyricularia* sp., *Fusarium* sp. and *Mucor* sp. Pre-treated seeds contained less number of fungi than those not treated with mercuric chloride. David (2009) [7] detected *Pyricularia grisea*, *Bipolaris nodulosa* and *B. setariae* in finger millet seed samples. The level of seed infection ranged from 10 to 50% and *P. grisea* was more prevalent in finger millet seed samples. Emayavaramban and Ramabadran (1986) [9] reported that increased storage temperature, storage period and relative humidity markedly influenced the change in fungal population. Jain *et al.* (1997) [14] constructed three dimensional ordination and grouped the seed borne mycoflora into different clusters on the basis of importance value index (IVI). *Fusarium moniliformae*, *F. semitectum*, *Curvularia lunata*, *Drechslera nodulosa* and *Phoma* sp. were grouped in separate cluster exhibiting higher IVI (23.3) and average association (11.3%) in finger millet. Shobha Rani and Dorcas (2016) [55] recorded white sterile, brown sterile and black sterile mycelium associated with sterilized seeds of finger millet variety CO 10 (5.25 to 6.24%) and CO 13 (1.19%).

Table 1: Seed borne mycoflora of finger millet

S. No.	Genus	Species	Reference
1	*Alternaria*	*A. alternata*	Nema and Khare, 1978 [30], Pandey, 1982 [36], Pall and Khare, 1983 [32], Reddy, 1983 [50], Pandey, 1986 [37], Pall and Lakhani, 1991 [34],Ghodke *et al.* 2000 [12], Penugonda *et al.* 2007 [40]
2	*Aspergillus*	*A. flavus*	Kato *et al.* 1977 [17],Pandey, 1982 [36], Reddy, 1983 [50], Emayavaramban and Ramabadran, 1986 [9],Pandey, 1986 [37], Gupta and Prasad, 1988 [11], Kannan *et al.* 2001 [15], Penugonda *et al.* 2007 [40]
		A. niger	Kato *et al.* 1977 [17], Pandey, 1982 [36], Reddy, 1983 [50], Pandey, 1986 [37], Gupta and Prasad, 1988 [11], Ghodke *et al.*2000 [12], Kannan *et al.* 2001 [15], Penugonda *et al.* 2007 [40]
		A. rubber, A. terreus	Pandey, 1982 [36], Penugonda *et al.* 2007 [40]
		A. clavatus	Reddy, 1983 [50], Pandey, 1986 [37],
		A. nidulans	Reddy, 1983 [50], Penugonda *et al.* 2007 [40]
		A. fumigatus, A. candidus, A.	Pandey, 1986 [37]

		ochraceous, A. flaviceps, A. chevalieri	
3	*Drechslera*	*D. graminea*	Nema and Khare, 1978 [30]
		D. nodulosum (Bipolaris nodulosus)	Oblisami and Srinivasa, 1973 [31], Ranganathaiah, 1976 [47], Ranganathaiah and Mathur, 1978 [48], Nema and Khare, 1978 [30], Dutta and Jha, 1983 [8], Pall and Khare, 1983 [32], Reddy, 1983 [50], Gupta and Prasad, 1988 [11], Pall and Lakhani, 1991 [34], Pattnaik *et al.* 1994 [39], Kumar *et al.* 2000 [22], David (2009) [7]
		D. oryzae	Nema and Khare, 1978 [30], Emayavaramban and Ramabadran, 1986 [9]
		D. tetramera	Nema and Khare, 1978 [30], Pall and Khare, 1983 [32], Reddy, 1983 [50], Pall and Lakhani, 1991 [34], Ghodke *et al.* 2000 [12],
		D. rostrata	Pandey, 1982 [36], Pandey, 1986 [37]
		D. maydis	Ghodke *et al.*2000 [12]
		D. australiensis, D. hawailensis	Pandey, 1982 [36]
		D.helodes	Pandey, 1982 [36], Penugonda *et al.* 2007 [40]
		D. plurisepta	Khetrapal *et al.* 1984 [20]
		D. setariae (Bipolaris setariae)	David (2009) [7]
4	*Penicillium*	*P. chrysogenum*	Pandey,1982 [36]
		P. lapidosum, P. citrinum, P. implicatum, P. oxalicum, P. cyclopium, P. islandicum	Pandey,1986 [37]
		P. funiculosum, P. variable, P. griseofulvum	Shobha Rani and Dorcas, 2016 [55]
5	*Fusarium*	*F. equiseti*	Nema and Khare, 1978 [30], Pall and Khare, 1983 [32], Pall and Lakhani, 1991 [34]
		F. moniliforme	Nema and Khare, 1978 [30], Pall and Khare, 1983 [32], Gupta and Prasad, 1988 [11], Pall and Lakhani, 1991 [34], Ghodke *et al.* 2000 [12], Penugonda *et al.* 2007 [40]
		F. semitectum	Nema and Khare, 1978 [30], Pall and Khare, 1983 [32], Pandey, 1986 [37], Gupta and Prasad, 1988 [11], Pall and Lakhani, 1991 [34]
		F. oxysporum	Pandey, 1982 [36], Pall and Lakhani, 1991, Penugonda *et al.* 2007 [40]
		F. roseum	Gupta and Prasad, 1988 [11]
		F. solani	Pall and Khare, 1983 [32], Pall and Lakhani, 1991 [34]
		F. dimerum	Shobha Rani and Dorcas, 2016 [55]
6	*Chaetomium*	*C. globosum, C. robustom, C. indicum, C. funiculum*	Reddy, 1983 [50]
7	*Cladosporium*	*C. cladosporiodes*	Pandey, 1982 [36], Pandey, 1986 [37]
		C. herbarum	Pandey, 1982 [36], Reddy, 1983 [50]
		C. oxysporum	Ghodke *et al.*2000 [12]
8	*Pyricularia*	*P. oryzae*	Nema and Khare, 1978 [30], Reddy, 1983 [50]
		P. grisea	Ranganathaiah, 1976 [47], Ranganathaiah and Mathur, 1978 [48], Pall and Khare, 1983 [32], Shetty *et al.* 1985 [54], Gupta and Prasad, 1988 [11], Adipala, 1992 [3], Pandey *et al.* 1994 [38], Ghodke *et al.* 2000 [12], David (2009) [7]
		P. setariae	Pall, 1988 [33]
9	*Curvularia*	*C. lunata*	Nema and Khare, 1978 [30], Pandey, 1982 [36], Dutta and Jha, 1983 [8], Pall and Khare, 1983 [32], Reddy, 1983 [50], Pandey, 1986 [37], Gupta and Prasad, 1988 [11], Pall and Lakhani, 1991 [34], Ghodke *et al.* 2000 [12]
		C. pallascence	Nema and Khare, 1978 [30], Pandey, 1982 [36], Pall and Khare, 1983 [32], Pall and Lakhani, 1991 [34]
10	*Epicocum*	*E. nigram*	Nema and Khare, 1978 [30]
		E. perpurascens	Pandey, 1986 [37]
11	*Mucor*	*M. fraglis*	Pandey, 1982 [36], Bhattacharjee *et al.* 1995 [6]
		M. hiemlis	Pandey, 1986 [37]
		M. varians	Shobha Rani and Dorcas, 2016 [55]
12	*Nigrospora*	*N. sphaerica*	Pandey, 1982 [36],Ghodke *et al.*2000 [12]
		N. oryzae	Reddy, 1983 [50], Pandey, 1986 [37]
13	*Rhizopus*	*R. nigricans*	Pandey, 1986 [37],
		R. nodosus	Shobha Rani and Dorcas, 2016 [55]
		R. stolonifer	Pandey, 1982 [36], Reddy, 1983 [50]
14	*Absidia*	*A. ramosa*	Pandey, 1986 [37]
15	*Botryodiplodia*	*B. theobromae*	Nema and Khare, 1978 [30], Pall and Khare, 1983 [32], Gupta and Prasad, 1988 [11], Pall and Lakhani, 1991 [34]
16	*Botrytis*	*B. cineria*	Nema and Khare, 1978 [30], Pall and Khare, 1983 [32], Pall and Lakhani, 1991 [34]
17	*Cercospora*	*Cercospora* sp.	Pall and Khare, 1983 [32], Pall and Lakhani, 1991 [34]
18	*Excerohilum*	*E. halodes*	Ghodke *et al.*2000 [12]
19	*Humicola*	*Humicola* sp.	Oblisamy and Srinivasa, 1973 [31]

20	*Helminthosporium*	*H. leucostylum*	Gupta and Prasad, 1988 [11]
21	*Cephalosporium*	*Cephalosporium* sp.	Pandey, 1982 [36]
22	*Monilia*	*Monilia* sp.	Pandey, 1982 [36]
23	*Memnoniella*	*M. echinata*	Pandey, 1982 [36]
24	*Mortierella*	*Mortierella* sp.	Pandey, 1982 [36]
25	*Macrophomina*	*M. phaseolina*	Nema and Khare, 1978 [30],Pall and Khare, 1983 [32], Pall and Lakhani, 1991 [34]
26	*Phoma*	*Phoma* sp.	Nema and Khare, 1978 [30], Reddy, 1983 [50], Pall, 1988 [33], Pall and Lakhani, 1991 [34], Ghodke *et al.*2000 [12]
27	*Melampsora*	*Melampsora* sp.	Reddy, 1983 [50]
28	*Rhizoctonia*	*R. solani*	Reddy, 1983 [50]
29	*Stachybotrys*	*S. altra*	Reddy, 1983 [50]
30	*Sordaria*	*Sordaria* sp.	Reddy, 1983 [50]
31	*Stemphylium*	*Stemphylium* sp.	Nema and Khare, 1978 [30], Ghodke *et al.*2000 [12]
32	*Pithomyces*	*P. maydicus*	Pandey, 1986 [37]
33	*Syncephalastrum*	*S.recemosum*	Pandey, 1986 [37]
34	*Torula*	*T. graminis*	Pandey, 1986 [37]
35	*Trichothecium*	*T. roseum*	Nema and Khare, 1978 [30]
36	*Trichoderma*	*T. viride*	Kato *et al.* 1977 [17], Reddy, 1983 [50]
37	*Phycomyces*	*Phycomyces* sp.	Shobha Rani and Dorcas, 2016 [55]
38	Yeasts	Yeasts	Shobha Rani and Dorcas, 2016 [55]

Toxic substances

Ansari and Shrivastava (1991) [2] reported that *Aspergillus flavus* produces aflatoxin, which inhibit the seed germination and reduced the root growth, but stimulate the shoot growth in finger millet. Miyagawa *et al.* (1994) [27] obtained four phytotoxic compounds namely Cochlioquinone A, Cochlioquinone B, Stemphone and Isocochlioquinone from a culture of *Bipolaris bicolor* E 1-1. These compounds were found to inhibit the root growth of finger millet. Kumar *et al.* (2006) [23] reported that *Pyricularia grisea* produces Pyrichalasin H, a phytotoxic metabolite, which was found to inhibit the seed germination and seedling growth in finger millet. Penugonda *et al.* (2010) [41] concluded that variety of fungi harbouring finger millet seeds is potentially toxigenic and not only hazardous directly to man but also may be responsible for diseases of poultry and livestock. Many species of *Aspergillus* elaborated aflatoxins, petulin, terreic acid and sterigmocystin, while species of *Fusarium* elaborated zearalenone, fusarinone-X, deoxynivalenol, nivalenol, diacetoxyscripenole, neosolanil and HT-2 toxins. *Penicillium griseofulvum* elaborated cyclopiazonic acid. Fungal metabolites of *Aspergillus flavus, Fusarium moniliforme and F. oxysporum* was found to suppress the 100% seed germination and shoot/root elongation of finger millet, where as fungal metabolite of *Aspergillus carbonarious* inhibit the 50% seed germination as well as significant reduction in shoot/root elongation (Khairnar *et al.* 2011) [18]. The reduction or complete inhibition in seed germination, shoot root elongation and suppression of seedling vigour might be due to the presence of some inhibitory substances in the fungal culture filtrates and the secretion of some phytotoxic ingredients. Penugonda *et al.* (2015) [42] reported significant seed germination inhibition and seedling growth due to Fusarium species which varied with the species and age of the culture. Culture filtrate of *F. moniliforme, F. proliferatum, F. chlamydosporum, F. aethiopicum, F. heterosporum* and *F. sporotrichoides* were comparatively more toxic. It may be due to their secondary metabolites including mycotoxins.

Location, transmission and disease development

Mitra (1931) [26] reported the seed borne nature of *Helminthosporium nodulosum* and *H. leucostylum* in finger millet. Hansford (1935) [13] reported that spores of *Pyricularia* are seed borne and diseased seeds could easily infect healthy seeds during threshing and transport. In Uganda, the contaminated seeds under these conditions are becoming a key source of primary inoculum. Grewal and Pall (1965) [10] reported that *Fusarium* sp. and *Bipolaris nodulosa* are both internally and surface seed borne. Pandey *et al.* (1994) [38] reported that *Bipolaris nodulosa* and *Pyricularia gisea* are present in the pericarp and endosperm but not in embryo. These fungi have ability to kill the young seedlings. Shetty *et al.* (1985) [54] reported that one diseased seed per 10000 seeds is sufficient to produce epiphytotics of blast disease under field conditions and suggested to adopt a zero tolerance limit in the seed certification programme. Seed to plant transmission of *Cochliobolus nodulosus* and *Phoma* sp. in finger millet was reported by Ghodke *et al.* (2000) [12]. Reddish brown spots are formed on the leaves developed from *C. nodulosus* infected seeds and cause seedling blight and leaf spots in finger millet. *Phoma* sp. produces necrotic spots on stem near ground level.

Phytopathological effects

Inhibition of seed germination and development of the root and shoot of 12 varieties of ragi by the culture filtrates of *Helminthosporium nodulosum* and *H. leucostylum* was recorded by Mishra and Singh (1969) [25]. Seed borne mycoflora drastically reduced the viability of finger millet seed (Oblisami and Srinivasa, 1973) [31]. Seed treatment with spore suspension of *Aspergillus terreus, A. niger* and *Curvularia* sp. was found most inhibitory on finger millet (Ashokan *et al.* 1979) [4]. Dutta and Jha (1983) [8] reported that *Drechslera nodulosa* causes seed rot, seedling rot in finger millet and is predominant in chotanagpur areas. Reddy (1983) [50] reported 3 to 51% reduction in seed viability due to seed borne mycoflora in different varieties of finger millet. He also found positive and significant correlation between numbers of fungi associated and total loss in viability during storage. Prasad and Shankar(1988) [44] recorded deleterious effect on seedling growth, reduced activities of nitrate reductase and increased oxygen uptake due to seed borne mycoflora in finger millet. Biochemical constituents namely chlorophyll, starch, total sugars, free amino acids and protein contents were also reduced in the seedlings. Prasad *et al.* (1988) [45] reported that *Aspergillus flavus* stimulates the activities of the pectic enzyme complex, amylase, invertase and protease, peroxidase, catalase, IAA oxidase, pyruvic, alpha-ketoglutaric

and succinic acids dehydrogenase and L-arginine and L-tryptophan deaminase and decarboxylase in seeds of finger millet. Pall (1992) [35] reported that incidence of blast causing pathogen (*Pyricularia setariae*) increased the protein content and decreased the starch as well as ash content in finger millet seeds. Adipala (1992) [3] reported that *Pyricularia grisea* affected seeds were not rotted but the plumules and radicals were either damaged on germination or failed to emerge. Furthermore, most of the fungal growth and damage was around the hilum. *Alternaria alternata* was highly destructive, causing 63.33 per cent inhibition in seed germination and 56.11 per cent inhibition in seedling vigor index (SVI) of genotype VL 149. Similarly, a great reduction in root and shoot elongation was recorded in all the genotypes tested with cultural filtrates of fungi (Kumar, 2010) [21].

Control

Physical control

Hot water treatment for 15 minutes at 50^0C largely controlled seed borne fungi of finger millet without reducing seed germination, but at 60^0C germination was greatly reduced (Reddy and Laxmi, 1982) [51].

Biological control

Effectiveness of biocontrol agents has been reported to manage the seed borne mycoflora of finger millet by several workers. Leaf extract of *Datura alba* and *Cannabis sativa* was found effective to control the fungal population at 10, 20 and 40% concentration. Apart from controlling the seed mycoflora, higher seed germination was also recorded after the treatments (Pandey, 1982) [36]. Ahir *et al.* (2016) [1] reported that seed biopriming with *Trichoderma viride* recorded minimum association of seed mycoflora in finger millet seed with highest seed germination (89.00%) followed by *T. harzianum* (84.00%). Whereas, in *T. faciculatum*, *Pseudomonas fluorescens* and *Bacillus subtilis* recorded 82.00, 77.00 and 72.00 per cent seed germination, respectively. Maximum shoot length, root length and seedling vigour index were also recorded in *T. viride* treatment followed by *T. harzianum*, *T. faciculatum*, *B. subtilis* and *P. fluorescens* as compared to control. For the management of seed mycofloa in finger millet, seed treated with Dhatura leaf extracts recorded highest seed germination (82.00%) which was at par with Neem leaf extracts (78.00%). Whereas, in Aloe Vera leaf extracts, Garlic leaf extracts, Tulsi leaf extracts, Ardusi leaf extracts and Piper leaf extracts seed germination was recorded 77.00, 75.00, 72.00, 71.00, and 70.00 per cent, respectively. All the treatments showed larger shoot length, root length and seedling vigour index as compared to control.

Chemical control

Lucy Channamma and Delvi (1966) [24] studied the effect of seed treatment on the viability of seeds vis-a-vis seed borne fungi. Ashokan *et al.* (1981) [5] suggested that fungicidal treatment improves the seed germination and preserves the seed viability in finger millet. Systemic fungicides were more effective than non-systemic ones with higher concentration than lower one. Alkathene bags, alkathene lined gunny bags, alkathene tap bags and glass bottles proved better than cloth and gunny bags for storage of the finger millet seeds. Preservative ability of two mild acides viz. propionic acid and acetic acid in preventing the growth of associated fungi with stored ragi grains at high moisture content was studied by Pandey (1986) [37]. Acetic acid (3%) proved better than propionic acid for prevention and multiplication of all the mycoflora associated with the grains except *Aspergillus fumigatus*. Khanum *et al.* (2009) [19] reported that two of the newly synthesized compounds namely 2-azetidinonyl and 1,3,4-oxadiazoles showed promising effects in depleting the incidence of seed-borne pathogenic fungi of finger millet. The suppression of *Pyricularia grisea* and *Bipolaris setariae* resulted in enhanced seed germination and seedling growth. Effective fungicides for controlling the seed mycoflora associated with finger millet seeds are presented in table 2.

Table 2: Fungicides recommended for the control of seed borne mycoflora in finger millet

Fungicides	Reference
Agrosan GN	Grewal and Pall (1965) [10]
Chloropicrin	Oblisami and Srinivasa (1973) [31]
Panoctine Plus	Ranganathaiah (1976) [47]
Agrosan GN, Ceresan, Dithane M 45, Vitavax and Benlate	Ashokan *et al.* (1981) [5]
Dithane M 45, Captan, Ceresan dry and Difolatan	Pall and Khare (1983) [32]
Bavistin + Thiram	Dutta and Jha (1983) [8]
Ceresan and Captafol	Prasad and Basuchaudhary (1987) [43]
Captan, Thiram and Bavistin	Gupta and Prasad (1988) [11]
Dithan M 45 and Dithane Z 78	Kapkoti *et al.* (1989) [16]
Kitazin, Saprol, Captan, Cuman L and Hylinec	Rajashekar *et al.* (1989) [46]
Carbendazim + Iprodione and Carbendazim + TMTD (Thiram)	Ghodke *et al.* (2000) [12]
Carbendazim 12% + Mancozeb 63%	Ahir (2016) [1]
Mancozeb, Zineb, Bavistin	Shobha Rani and Dorcas (2016) [55]

Conclusion

The present review showed that there was a large variation in the diversity and severity of fungal flora associated with the seeds of finger millet. Presently 87 fungal species belonging to 38 genera were reported to be associated with the seeds of finger millet. Further research is needed to isolate, identify and characterize the pathogen associated with the seeds of finger millet collected from experimental field, market and store houses. Studies on seed to plant transmission and plant to seed transmission of the pathogen and their phytopathological effects is essential for preparing strategies for the effective management options. Biological options like biocontrol agents, plant products and other environment friendly strategies may be utilized to control the seed borne mycoflora for quality seed and grain production.

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