Food Science and Quality Management
ISSN 2224-6088 (Paper) ISSN 2225-0557 (Online)
Vol.81, 2018

Seed Borne Fungi; Food Spoilage, Negative Impact and Their Management: A Review

Jabir Amza
Department of Plant Science, Assosa University, P .O. Box 18, Assosa, Ethiopia

Abstract
Seed is among the most key input for improving crop production and productivity. Increasing the quality of seeds can increase the yield potential of the crop by significant folds. In recent years seed has become an international commodity used to exchange germplasm around the world. Seed is, however, also an efficient means of introducing plant pathogens into a new area as well as providing a means of their survival from one cropping season to another. Seed borne mycroflora are significant destroyers of food stuffs and grains during storage rendering them unfit for human consumption by retarding their nutritive value and often by producing mycotoxins. Seed-borne pathogens have been involved in seed rots during germination and seedling mortality leading to poor crop stand reduction in plant growth and productivity of crops. The seed-borne pathogens associated with seeds externally or internally may cause seed abortion, seed rot, seed necrosis, reduction or elimination of germination capacity, as well as seedling damage resulting in development of disease at later stages of plant growth by systemic or local infection. Infected seeds play considerable role in the establishment of economically important plant diseases in the field resulting in heavy reduction of crop yields. This paper presents the negative impact of seed borne fungi and their implication in food safety. It also discusses the detection mechanism and implies some management strategies that are implemented to reduce the loss due to seed borne fungi.
Keywords: Disease, food safety, Mycotoxins, Pathogens, Seed,

1. Introduction

Seed is the most important input for crop production. Many plant pathogens are seed borne, which can cause enormous crop losses. Recent increases in the production and sale of organic seed has heightened the scrutiny of organic seed quality and in particular brought attention to concerns of seed-borne disease contamination. Seed-borne diseases are pathogens such as bacteria, fungus, or viruses, which live on the surface or interior of seed and have the potential to spread disease to the subsequent crop. Of these fungal contamination is the most important (Colley, 2009).

Fungi contamination probably affects the quality in both direct and indirect manner. Direct effects upon grain quality may be due to the growth and ramification of the fungus throughout the kernel and the production of metabolites which may alter grain composition or metabolism, or render it unfit for human or animal consumption. Indirect effects relate to reductions in yield that are associated with contamination. Infected seed play considerable role in establishment of economical important plant disease in the field resulting in heavy reduction of crop yield. Infected seed also have lower seed quality leading to reduce market value poor germination and field establishment (Akranuchat, *et al.,* 2007).

The losses caused by seed fungi may occur during seed development, storage, or germination. Damage results from loss of seed viability or from seedling infection following germination. In general, Seed-harvesting practices such as letting the seed fall on nets or the ground before harvesting seem to increase the incidence of seed-borne fungi. Cone-processing procedures that result in high moisture and temperature conditions in the cone often increase seed fungi. Handling seeds during extraction can also attacked. Produce conditions favoring the development of seed fungi, in addition to damaging seed, which lets the fungus penetrate the seed. Fungi can also build up in storage if temperatures and seed moisture are not properly maintained. Cool, wet conditions at the time of seeding in the nursery seem to enhance these fungi and their subsequent damage (Mehrotra and Aggarwel, 2003).

Conventional seeds are often treated or coated with chemical fungicides to kill pathogens, a practice not allowed in organic production. Organic seed companies must instead practice careful monitoring and management of seed crops to prevent disease and utilize organically approved treatments to clean infected seed. It is always prudent to seek high-quality seed and work with a reputable company. However, seed-borne diseases are not ubiquitous in all crops, and high concern should be placed primarily on specific diseases known to be seed-borne that pose a risk in specific growing region. The use of organic seed does not pose any higher risk than conventional seed if high-quality seed is used (Colley, 2009).

The risk of seed-borne disease infection varies widely by crop, disease, and location. Many diseases will only become a problem if grown in a region or environment conducive to the disease. Commonly diseases present on seed may also be soil-borne or air-borne and the ultimate fate of the crop may be as dependent on the variety resistance and crop management practices a son the presence of seed-borne inoculums (Colley, 2009).

Even though Seed-borne fungi can be managed using physical, biological methods and chemical treatment practices, it is important to start with high-quality, clean seed (Waller, 2002). This paper presents the negative impact of seed borne fungi and their implication in food safety. It also discusses the detection mechanism and implies some management strategies that are implemented to reduce the loss due to seed borne fungi

2. Occurrence of seed-borne fungi

Fungi are the dominant microorganisms in grain storages. Traditionally fungi associated with grain are classified in to two categories; field fungi those fungi invading grain before harvest and storage fungi field which develop on grain after harvest under storage condition. A storage and field fungus is not taxonomically justified and is based on moisture requirement of the fungi (Amare *et al*., 1995).

2.1 Field fungi

Most species of field fungi that invade the developing grain seed are facilitative parasite. The fungi in this group can be divided in to three sub groups. This includes specialized pathogen that invade developing or mature grain and which may not cause visible damage. The second groups are unspecialized highly pathogenic fungi that invade developing grain. And finally those unspecialized saprobic fungi that invade moist mature grain. Common species of field fungi colonizing cereal grain include *Clasporium cladosporioides, Alternaria alternaria, Verticillium*
*lecanii, Epicoccum purpurascens, Fusarium species; Helmintho sporium, Penicillium species and Aspergillus flavous*are found (Amare *et al*., 1995).

2.2 Storage fungi

After the grain are lifted the field fungi do not seem to survive the drying process and a second group of fungi the storage fungi those species of saprophytic and weekly parasitic fungi which proliferate at lower seed moisture levels become dominant during the drying, picking, and storage. The principal storage fungus belongs to the *Genera Aspergillus, Penicillium, Rhizopus, Sclerotium* and *Fusarium* (Mashilla, 2004). The ability of storage fungi to germinate, grow and sporulate in stored grain is dependent on the availability of water in the substrate, temperature and the inter-granular gas composition. These factors may interact to have a profound influence on the initiation of spoilage of stored grain by fungi. An understanding of the ecological determinants of mould growth may help to develop improved and safer methods of grain storage
(Magan, and Lacey, 1988).

3. Loss potential of seed-borne fungi

It is difficult to predict damage from seed-borne fungi. The most common fungi are saprophytic or even beneficial because they compete with other potentially pathogenic species. Some, however, are consistently associated with reduced germination rates and vigor. In general, fungi that are present within seed are more damaging than those that merely contaminate the outer seed coat. *Trichothecium,* for example, can reduce germination of Douglas-fir seed lots by 20 percent.
*Caloscypha*is still more damaging; this fungus penetrates and kills seeds before germination. It can spread during cool, moist storage and even after sowing. A large number of pathogenic fungi, cause annual 9.4% yield losses worldwide. Fungi affect the quality of grain through increase in fatty acid, reduction in germination, mustiness and finally spoilage of grain. The importance of fungi is also due to production of toxins that causes health hazard in human and animals (Niaz and Sdawar, 2009).

4. Food spoilage by seed-borne fungi

It has already been noted that fungi play a major role in recycling organic material. The fungi which make our bread and jam go moldy are only recycling organic matter, even though in this case, we would prefer that it didn't happen. Fungal damage can be responsible for large losses of stored food, particularly food which contains any moisture. Dry grains can usually be stored successfully, but the minute they become damp, moulds are likely to render them inedible. This is obviously a problem where large quantities of food are being produced seasonally and then require storage until they are needed (Schnürer *et al*., 1999).

Invasion of food grain by fungi generally leads to losses in grain weight and viability, discoloration, heating mustiness, taints and general deterioration in grain quality in addition to this fungi such as *Claviceps purpurea* changes food grain in to mold causing complete loss. Fungal growth leads to spoilage of food and animal feeds and to formation of mycotoxins and potentially allergenic spores. Fungi produce volatile compounds, during both primary and secondary metabolism, which can be used for detection and identification. Fungal volatiles from mainly *Aspergillus, Fusarium,* and *Penicillium* are the most important (Schnürer, *et al*., 1999).

Fungal spoilage forms an increasing economic problem in the food industry. The fungal spoilage of ingredients of food manufacture is an economic problem, often causes product loss and may constitute a health

hazard. Growth of commonly occurring filamentous fungi in foods may result in production of toxins known as mycotoxins, which can cause a variety of ill effects in humans, from allergic responses to immune-suppression and cancer (Table 1).The most important mycotoxins are aflatoxins, ochratoxin A, fumonisins, tnchothecenes and zearalenone (Pitt, 2000).

Long-term effects of low levels of mycotoxin ingestion are also varied. The prime chronic effect of many mycotoxins is the induction of cancer, especially of the liver. Some toxins affect DNA replication, and hence can produce mutagenic or teratogenic effects. The symptoms of mycotoxicoses are almost as diverse as the chemical structures of the compounds themselves

Table 1. Summary of mycotoxins that are agricultural importance on a worldwide scale

Mycotoxins	**Producing fungi**	**Reported biological effect**	**Occurrence**
Aflatoxin	*Aspergillus flavous* *Aspergillus parasiticus*	Hepatoxin , hepacarrcenogenic , teratogenic, immunosupression, death	Corn, cotton seed, peanuts, sorghum, cassava, rice, soybean, oats, beans, barely, green coffee bean,
Ochratoxin	*Aspergillus ocrhraceous* *Penicillum viridicatum*	Nephrotoxin,teratogenic, carsinogenic, immunotoxin	Barely, corn, oats,rye, wheat, rice, bean, pea, mixed feeds
Trichothecence	*Fusarium spp.* *Stachybotrysatra*	Vomiting, feed refusal, emesis, reduced weight grain, necrosis of Gl tract, immuniotoxicity,	Corn, wheat, barley, mixed feeds
Zearalenone	*Fusarium graminearum* *Fusarium saporotrichoides*	Hyperestrogersim, infertility, abortion, carcinogenic, immunosuppressive	Corn, wheat, mold hay
Fumonisense	*Fusarium monliform* *Fusarium proliferatum* *Fusarium napiforme* *Fusarium nygami*	Equine leukoencephalomalacia, hepato-carcinogenic, esophageal cancer	Grains mainly maize and maize products
Ergot alkaloid	*Claviceps purpurea* *Claviceps paspali*	Convulsions, vasoconstriction, necrosis of extremities	Rey, cereal grain
Sterigmatystin	*Aspergillus versicolor* *Aspergillus nidulans*	Hepatotoxin, hepato-carcinogenic	Wheat, barley, rice, green coffee bean

Source: Pestka and Casale (1990)

Some compounds may elicit few symptoms until death results, while others may produce severe effects including skin necrosis, leucopoenia and immune-suppression. Doses producing chronic disease are usually far below those responsible for acute effects, and so long-term effects such as cancer or tum our induction are undetected at the time of ingestion and, indeed, may remain so until disease is quite advanced. Many of the toxigenic fungi are ubiquitous and, in some cases, apparently have a strong ecological link with human food supplies. The natural fungal flora existing in conjunction with food production is dominated by three genera: *Aspergillus, Fusarium* and *Pentcillium. Fusarium* species are destructive pathogens on cereal crops and other commodities, and produce mycotoxins before, or immediately after, harvest. Certain species of *Aspergillus* and *Penicillium* are also plant pathogens or commensals, but these genera are more commonly associated with commodities and foods during drying and storage (Pitt, 2000).

To effectively combat fungal food spoilage, a mechanistic understanding of tolerance for, and adaptation to, the preservation method used is crucial. In order to prevent to delay microbiological spoilage of foods, different physical methods are applied. Example: heating (pasteurization and sterilization), cooling (cold or frozen storage), vacuum packing, canning and irradiation. In some instances the organic quality of a food suffers greatly by physical mode of processing. While in certain areas these methods not technologically or economically feasible; in these cases chemical preservation often can be important (Smith and Brul, 2005).

5. Negative impact of seed-borne fungi

Seed are known to be colonized by varied type of fungi among which many are plant pathogen .the fungus may affect the seed by causing seed abortion, shrunken seed, reduce seed size, cause seed rot, sclerotization or stromatization of seed, seed necrosis , seed discoloration, reduction or complete loss of germablity and some physiological changes (Mehrotra and Aggarwel, 2003).

5.1 Reduction or complete loss of viability

Fungal infection in seed tissue reduces the germination, viability, longevity and vigor of seed. Storage fungi are one of the major factors responsible for the loss of seed viability. Storage fungi such as *Aspergillus candidus, A. flavous, A. fumigatus, A. glaucus* group*, A. niger, A. ocraceous, A. parasiticus and Penicillium species* can

damage the seed germ and decrease germination in short time under favorable condition (Table 2).

It was observed that seed-borne fungi *Mucor racemosus* and *Rhizopus nigricans* caused significant reduction in germination and seedling growth of watermelon (Anjorin and Mohammed, 2009). According to Mehrotra and Aggarwel (2003) wheat infected with *Tilletia indica* had very little effect on viability irrespective of the age of the seed. While the germination of infected seeds appeared to be depend up on the wheat cultivars and the seeds. Infected seed had a lower survival rate in storage compared with healthy seed of the same seed lots. Reduction in percentage seed germination of soybean seeds was observed in seeds soaked in filtrates of *Phomopsis phaseoli* and also Soybean seeds soaked in cultures filtrates of *Fusarium solani*, *F. oxysporum*, *Aspergillus flavus*, *A. niger*, *Alternaria tenuis* and *A. alternate* for 24 hours showed reduction in percentage seed germination (Haikal, 2008).

Table 2. Reduction of seed germablity by seed-borne fungi

Moisture contents	Temperature(^{o}C)	Timestored	Inoculation	Germination (%)
15.6	20-25	6 weeks	No fungi	95
			Aspergillus restricus	5
16.2	25	2 month	No fungi	90
			Aspergillus candidus	25
			Aspergillus amesterodami	38
			Aspergillus restricus	40
17.1	25	1 month	No fungi	93
			Aspergillus candidus	20
			Aspergillus ruber	32
			Aspergillus restricus	34

Source: Papavizas and Christensen (1960)

Damage to seed may be due to diffusible toxic substance such as peptic enzymes, protease, lipases and toxins released by storage fungi can result in change in the percentage chemical component and lower the potential nutritive value of the grain. Mashilla (2004) reported significant variation in organic matter and soluble carbohydrate content of sorghum seed stored in corrugated iron bins and underground pits without and with different lignin. According to Papaviz as and Christensen (1960) as cited in (Mengistu and Amare, 1996) seed-borne fungi can affect germination of wheat significantly.

5.2 Physiological effect on the seeds

Seed borne and storage fungi produce a large number of metabolites that are toxic to the seed. Aflatoxin produced by *Aspergillus flavous* group are known to reduce elongation, inhabit chlorophyll synthesis, inhabit various enzymes and degranulate the endoplasmic reticulum. The toxin produced by the field fungus *Alternaria alternaria* on cotton seed, a cyclic tetra peptide, that cause irreversible chlorosis in germinating seedling. Change in protein content, amino acid and sugar content of seed due to fungal infection and reduce vigor have been reported. Seed borne fungal metabolites may affect seed metabolism at the cellular level. Aflatoxin and other secondary mycotoxin affect the seed viability, germination and vigor which ultimately affect the seed yield (Mehrotra and Aggarwel, 2003).

5.3 Seed discoloration

Seed discoloration is an important disorder which indicates the presence of pathogenic fungi in sowing seed. Commercially discolored seed are of poor quality. The extent of discoloration depends on the seed mycroflora, environmental factor and host cultivar physiology. Coating of fungal mycila and sporulating structure many saprophytic fungi often develop seed discoloration. The discolored seed showed deoxynevalinin, diacetoxyirpenol, HT-2 and T-2 mycotoxin was observed in the seed coasts (Mehrotra and Aggarwel, 2003).

5.4 Seed rot

Many seed borne fungi produce seed rot. In sorghum, *Fusarium moniliforme*, in paddy *Drechslera oriza, Trichochoconiellap wickii* and *Fusarium species*. In maize *Diplodia maydis*, *Botryodiplodia theobromae*, in Perl millet, *Curvuliaria penniseti, Drechslera setaria, Fusarium moniliforme, Phoma exigua* cause seed rot. Species of *Aspergillus* and *Penicillium* are important storage fungi which develop on seed during storage and cause seed rot in the sown crop. Seed deterioration: reduction in seed quality which starts from physiological maturity continuous until the seed until dead (Khore and Bhale, 2007).

5.5 Sunken seed and reduced seed size

Fungal infection cause both quantitative and qualitative damage to the seed, as well as reduce the size and weight of the seed. Fungal infection often substantially reduces the size and weight of seed. Small seed of wheat show a

higher infection percentage of *Ustilago segetum var. tritici*than larger seeded. According to Rout, *et al*. (1983) the wheat seed collected from *Alternaria triticina* infected plant were small and shriveled and based on 1000 grain weight, showed 46 to75% reduction to weight over the collected or unaffected plant. Sherman and Bhowmik, (1987) studies various aspect of ground nut seed discoloration due to *Macrophoma phaseoli* infection. Infected pod were brown to black, smaller in size and numerous scelorotia could be seen on the surface of the shell. Low yield results primarily due to the formation of under sized pod and kernels, at latter being most shriveled.

5.6 Sclerotisantion and stromatization

Here, seed are transformed in to stromata or scleorotia as in the case of false smut of paddy and ergot of sorghum. Normally the disease cause little loss in yield, but under favorable condition heavy losses have been reported. Ergot severity in sorghum depends mostly up on weather condition at flowering. If they are cool, highly humid and cloudy during the anthesis period the spread of the disease is rapid and damage is sever (Mehrotra and Aggarwel, 2003).

5.7 Seed abortion

Seed abortions due to fungi that occur during anthesis are kernel smut (*Neovossia horrida*) and false smut of paddy, kernel smut of wheat and ear cockle of wheat. The diseased seed of kernel smut of paddy when examined show minuet black pustules or streaks bursting the glumes. Normally only part of the seed is affected. In false smut of rice (*Ustilagino ideaviren*) the fungus transforms the individual seed of the panicle into greenish spore balls with a velvety appearance. The moderately infected seeds look dark green while heavily infected grains are completely transformed in to pseudomorphus (Mehrotra and Aggarwel, 2003).

5.8 Cause disease to the next crop

The sowing of contaminated seed or infected seed for crop production can reduce germination and seedling vigor, and affect the yield by transmitting pathogen from seed to plant (Table 3). The most adverse effect of seed borne fungi is contamination of previously disease free area. Primary infection foci are followed by secondary pathogen dissemination, leading to monocyclic or polycyclic diseases.

The risk of seed borne fungi inoculums giving rice to disease problems in growing crops depend on many factors from the initiation of infection in the developing plant to epidemic development in the growing crop depend on a range of environmental factors affecting these process. Although seed borne fungi can provide initial inoculums for the development of epidemic, may survive and are dispersed by other means (Waller, 2002).

6. Detection of Seed-Borne Fungi

Seed fungi are found on and in the seed coat and in the gametophyte and embryo. With some exceptions, such as molds, these fungi cannot be detected by examining the outside of seeds. Some internal seed fungi can be detected by the visible presence of mycelium when the seed is cut open. However, the only accurate way to assess the incidence of seed fungi is to place samples of the seeds on appropriate culture media. After incubation, fungi can be detected by the presence of fruiting bodies or mycelium on the surface of the seed and the growth medium. Because of the large number of fungi that infect seed, a specialist is usually needed to identify them (Walcott, 2003). Method for the detection fungal pathogen associated with seed includes:

6.1. Direct Inspection

This could involve direct examination of seed or seed washings. With the former, generally dry seeds are examined; for instance, seed samples may be examined dry for the presence of ergots, other sclerotia and smut balls without or with a stereomicroscope. Also, the sample may be immersed in water or another liquid to make fungal fruiting bodies, for example pycnidia, or symptoms more visible or to encourage the liberation of spores. After immersion, the seeds are examined by means of a stereomicroscope. It is the simplest method to detect seed borne disease (Rao *et al*., 2006).

6.2. Incubation Tests

6.6.2. Incubation Tests: Agar Plate

Incubation methods allow the detection of viable fungus material even at the preliminary phase of development of the fungus. This is done generally by placing seeds onto sterile agar media (potato dextrose or malt agars are most commonly used) to encourage the growth of seed borne fungi. Agar plate is the most common method used for identification of seed borne fungi. It may be employed to quantitatively determine the fungal load such as CFU/gm of seed (dilution plate methods) or to qualitatively determine the species composition (direct plate method). The most common way to estimate quantity of fungal tissue in kernels is the dilution plate method. There are two variations of this method: the pour plate method which is used more frequently, and the spread

plate method which is preferred at low sample contamination. On the other hand, the direct plating method is one of the best methods to determine the composition of the grain fungi as to genera and species. In this method whole kernels are placed on the surface of the culture medium after having the kernels surface disinfected. The direct plating technique can be recommended as a very effective procedure for determining internal colonization of kernels by fungi and consequently is a very useful tool for evaluating the quality of bulk grain (Trojanowska, 1991).

6.2.2. Incubation tests: blotter tests/seedling symptom tests

In seed health testing for seed-borne fungal pathogens the blotter test is no doubt one of the most important methods available (Limonard, 1966). Blotter tests are similar to germination tests in that seeds are placed on moistened layers of blotter paper and incubated under conditions that promote fungal growth. The seed may then be allowed to germinate and fungal seed-borne infections may manifest themselves by any pertinent signs or symptoms. The manifestations of the pathogen are influenced by the environmental conditions during incubation. The blotter test gives an indication of the infection of the seed, as shown by the presence of mycelium and fruiting bodies, and, in some tests, infection of the germinated seedlings as demonstrated by symptoms on the young plants. In some tests seeds are incubated during which they are allowed to germinate and symptoms are observed (e.g. dark spots on the cotyledons of bean seeds infected by the anthracnose pathogen). In other tests the germination of seeds is deliberately suppressed to allow seed-borne infection to develop (e.g. to allow the pycnidia of seedborne *Phoma lingam* to develop on *Brassica* seeds, the herbicide 2,4 –D is applied before incubation, allowing greater numbers of seeds to be tested) (Limonard, 1966).

6.3. Examination of the embryo

Staining methods are used for seed borne pathogens which cannot be detected by direct inspection or incubation methods. The standard method used in seed health testing is that of staining of barley embryos for the presence of loose smut (*Ustilago segetum* var. *tritici*) mycelium.

6.4. Molecular Methods

6.4.1. Immunoassays

The methods are based on the immunological principle that foreign molecules injected into the bloodstream of mammals stimulate the immune system of those mammals to produce specific antibodies, which will recognize and bind to the antigens. Such antibodies recognize many chemical sites, referred to as epitopes, on target antigens; these are polyclonal antibodies. Immunoassays utilizing antisera produced against purified pathogens or extracts of pathogens have been effective in the detection of bacteria and particularly fungi.

6.4.2. Nucleic acid assays

The application of molecular nucleic acid tests in practical methods for the detection of seed borne organisms has not been fully exploited. The versatile nature of molecular methods has resulted in their use to supplement or replace established morphological, biochemical and serological techniques. Their introduction has been favored in part, by their relatively quick development and validation time as opposed to serological and biochemical assays that take longer to implement. Once developed and validated, molecular assays can provide simple, quick, high-throughput diagnosis that is relatively cheap and easy to transfer to other laboratories. Initially, non-amplification assays were used, but the need for pure cultures and poor repeatability did not make them suitable for routine diagnosis. Development of *in-vitro* amplification by PCR is leading to specific, sensitive, robust assays for both pure cultures and, more importantly, for the detection and identification of organisms directly from seed and plant material. Nucleic acid-based methods tend to be relatively expensive to apply (Rao *et al*., 2006).

Nucleic acid hybridization assays (called southern and northern blotting), in which DNA or RNA is transferred from an electrophoresis gel onto a membrane and then the nucleic acids are detected with a labeled probe, can also be used. The nucleic acid spot hybridization (NASH) technique, in which a labelled DNA pathogen hybridizes directly to the pathogen DNA immobilized on a nylon membrane, can also be used without going through the PCR stage (Rao *et al*., 2006).

Table 3. Some important seed-borne fungal disease and their control

Crop	Disease	Pathogen	Control measurement
Wheat	Loose smut	*Ustilago segetum*	Hot water treatment, solar energy heat treatment and chemical treatment with vitavax or bentlate
	Foot rot	*Helmintosporium satiium*	Seed treatment with organmercurial compound such as Agrosan-GN
	Leaf blight	*Alternaria triticina*	Normal mercurial seed dressing, pre-socking in water for 4 hour followed by 10 miniut deep in hot water at 50 0C.
	kernel bunt	*Neovssia indica*	Seed treatment with Thiram, Zineb, Belate andBavistin
Barley	Coverd smut	*Ustilago hordi*	Treatment of the seed with organo mercurialcompound
	Loose smut	*Ustilago nuda*	Hot water treatment, solar energy heat treatment and chemical treatment with Vitavax or Bentlate
	Strip disease	*Helmintosporium gramineum*	Treatment of the seed with organo mercurial dusts.
	Foot rot and seedling blight	*Helmintosporium sativia*	Seed treatment with organo mercurial compound such as Agrosan-G
Paddy	Foot rot	*Fusarium moniliforme*	Treatment of the seed with organo mercurial Compound
	Brown leaf spot	*Helmintosporium orzae*	Treatment of the seed with organo mercurial Compound
Pea	Downy mildew	*Peronspora pisi*	Seed treatment at 50 0C
Oat	Covered smut	*Ustilago kolleria*	Seed treatment with organo mercurial compound such as Agrosan-GN
Groundnut	Pre emergency blight	*Aspergillus niger*	Seed treatment with Thiram and Capitan ororgano mercurial

Source: Mehrotra, and Aggarwel (2003).

7. MANAGEMENT OF SEED-BORNE FUNGI

7.1 Quarantine

The best way to control diseases is to exclude them from the area of sphere in which the host plants are being known. This method of exclusion enforced through certain legal measures is commonly known as quarantine. Quarantines are promulgated by governments or group of governments prohibit, restrict and limit the entry of new pests with plants, plant products ,soil, culture of living organism and means of conveyance. Hence, having good quarantine system enable us to control the occurrence of seed-borne fungi from abroad to the area where it does not exist before.

7.2 Cultural management of seed-borne fungi

One of the most important factors in avoiding disease in seed crops is producing in regions with minimal disease pressure. Careful field management in seed production can significantly mitigate seed-borne diseases in seed crops. Many of the same practices that prevent disease infield crops are used to prevent disease in seed crops. Disease promoting conditions are avoided by not using overhead irrigation under moist conditions, using drip irrigation, and cutting water to allow seed crops to dry before harvesting. Spacing plants adequately and orienting rows with the prevailing winds aids in increasing air flow an important factor in minimizing disease. Rotating crops is important to avoid disease build-up in the soil. Of course, starting with clean, disease-free seed for planting stock is also crucial. Additionally, seed growers must use care in harvesting and cleaning seed to avoid post-harvest infection (Colley, 2009).

Since Initial infestation by storage fungi might occurs in the field. From the field it is carried over to the storage where can rapidly build up. Thus, pre-harvest cultural methods and storage management can be effective in the control of fungi affecting stored grain. Field isolation, prompt harvesting, selection of uninfected grain, proper drying before storage, storage hygiene are important cultural practices for management of seed borne fungi (Mashilla, 2004).

7.3 Physical management of seed-borne fungi

Physical control methods include the use of heat and hot water treatments to eradicate deep-seated infection from

seed. A temperature of about 50 ^{o}C is commonly used. The success of the methods depends on even heat distribution thought the seed lot and requires careful monitoring to ensure this without exposing some seed to excess time-temperature regimes that will lead to loss of viability (Waller, 2002).

7.3.1 Hot water treatment

Hot water treatment is the most important method in the management as well as eradication of seed-borne pathogen including seed borne fungi. It was reported that seed treatment with hot water at 52°c was effective against *Bipolaris sorokiniana* which cause leaf blight wheat(*Triticum aestivum*) as a result of the water treatment the germination of wheat was increased(Panna, 2009). Hot water treatment of carrot seeds at 44, 49 and 54°C generally improved germination of infected seeds and reduced the incidence of *Alternaria dauci*. Treatments at 54°Cfor 20 minutes eradicated *A. dauci* without adversely affecting germination, emergence or yield. .

7.3.2 Radio-Frequency Heat Treatment

Radio frequency heat treatment is an alternative way with high potential to control seed-borne fungi such as, *Aspergillus flavus, Alternaria* sp., *Penicillium* sp. and *Rhizopus* sp. The thermal energy of radio frequency is transported into the material by an alternating electromagnetic field and heat can only be generated where dielectric loss occurs. This leads to the so-called "*internal heating*" become new alternative technology which help about eliminate seed-borne fungi and maintain seed quality (Akranuchat *et al., 2007*).

Thermal method using radio-frequency heat treatment makes it possible to eradicate seed-borne fungi which permits effective planting and creates no chemical residue. It leads to short processing times and help saving energy. The mechanism of rise in temperature is the dipoles molecular in the materials are induced to oscillation in the same way of the electromagnetic field for many times in one second which generated two situations; first is inter molecule friction and second is hysteresis. The results of these is the rise in temperature rapidly that the cause why these technology is use less time. The effectiveness of the radio-frequency heating treatment depends on the temperature and time of exposure (Pattaya *et al.,* 2005).

It was reported the effect of radio-frequency treatment on germination and infection rate of wheat seed and the results showed that radio frequency treatment led to a complete eradication of *Fusarium graminearum* in wheat seed while maintaining germination (Akranuchat *et al.,* 2007).

Using the radio-frequency heat treatment shows effective of control seed-borne fungus *Trichoconispad wickii* in rice seeds (Pattaya *et al.,* 2005).

7.4 Biological control of seed-borne fungal pathogens

Biological control of seed-borne fungi has been developed recently mainly using antagonists such as *Bacillus subtilis* and *Pseudomonas cepacia* and some products are available commercially (Waller, 2002). It was reported that Seed treatment with *Trichoderma viride* and *Chaetomium globosum* was effective method to control the seed-borne fungal pathogens of pigeonpea. *T. viride* was found to eliminate completely seed-borne infection of *Alternaria alternata*. *Phyllosticta cajani*, *Rhizoctonia bataticola, R. solani, Curvularialunata, Cladosporium cladosporioide s*(each causing foliar diseases), *Colletotrichum dematium, Alternaria* and *Trichothecium roseum*(each causing seed rot and seedling diseases) and reduced the colonies of *Aspergillus flavus, A. niger,Botrytis cineria, Fusarium moniliforme* and *F. semitectum* (each causing seed rot/and seedling diseases) with significant increase in seed germination and emergence, root length, shoot length and fresh weight of seedling over *Chaetomium* treated and untreated seed (control). *Chaetomium globosum* could only eliminate the infection of *C. cladosporioides* completely and reduce the colonies of the remaining pathogens (Kumar *et al.,* 2000).

7.5 Chemical treatment of seed

A wide range of fungicide especially those with systemic or eradicant properties have been applied to seed. Seed application of fungicide has many advantages: very small amount of active ingredient are required and these can be precisely targeted compared to the required and achieved by field application to grow crops. Not only can seed-borne fungi be controlled but protection can also be given to young plants against many pathogens (Waller, 2002)

The application of fungicides serves to controls the seed-borne diseases and also protects germinating seedlings from the seed-borne or soil-borne pathogens. Fungicide seed treatments protect seed viability and inhibit diseases like seed rot and seedling blight. Seed treatments protect the seed in two ways: by controlling fungi present either on the seed surface or carried internally in the seed; and by controlling fungi present in the soil, or on crop residue in the soil (Jeffers *et al*., 1982).

The most extensively used seed treatments fungicide are Captan, Thiram, Zineb and Mancozeb. These are contact fungicide and because they have a broad spectrum of fungicidal activities, their compatibility with insecticide is quite good. Carboxin, Beneomyl and Carbendozin remove systemic control of various seed borne smut infection. Carboxin is successfully utilized for the control of various seed borne smut infection. The degree of control with seed treatment depends on five factors: fungicide active ingredients, rate of application, seed- and

soil-borne fungal diseases present, environmental conditions, and quality of seed coverage (Mehrotra and Aggarwel, 2003).

8. Conclusion

Seed is the basic unit of production for the world's food crop. In recent years seed has become an international commodity used to exchange germplasm around the world. Seed is, however, also an efficient means of introducing plant pathogens into a new area as well as providing a means of their survival from one cropping season to another. The role of seed-borne fungi in the deterioration of seed is well established. They can affect color, odor, flavor and nutritional value as well as producing toxin metabolites known as mycotoxins. Since most fungi are occur during harvesting and after harvesting process judicious management should consider the following points harvesting at optimum crop maturity, avoiding harsh drying temperature, drying grains sufficiently before storage, use safe techniques in harvesting and threshing process and storing the grains in appropriate storage condition and keeping storage hygiene are important things to be consider. Generally, considering the yield losses caused by seed-borne fungi managing them in integrated manner enable to overcome the problem effectively.

References

Akranuchat P, P. Noimanee, N. Krittigamas, D.V. Horsten and S. Vearasilp. 2007. Control of seed borne fungi by radio frequency heat treatment as alternative seed treatment in barely (*Hordeum vulgare*). Conference on International Agricultural Research for Development. University of Gottingen, October 9-11.

Amare, A., Dawit, A. and Mengistu, W. 1995.Mycloflora, aflatoxin and resistance of ground nut for eastern Ethiopia. SINET. Ethiopia journal of science 18: 117-131.

Anjorin, S.T. and M. Mohammed, 2009.Effects of seed-borne fungi on germination and seedling growth of water melon (*Citrullus lanatus*).*Journal of Agriculture and Social Science,* 5: 77–80

Colley, M. 2009. Field Report: Seed-Borne Disease and Organics.

Cordell C.E., R.L. Anderson, W.H. Hoffard, T.D. Landis, R.S. Smith and H.V. Toko. 1989.Forest Nursery Pests. USDA Forest Service, Agriculture Handbook No. 680, 184 pp.

Czyzewska, S. The effect of pathogenic seed-borne fungi on green pea (*pisum sativum*l.) Emergence

Gurjar, K. L., S. D Singh and P.Rawal.2009. Management of seed borne pathogens of okra with bio-agents.

Jeffers, D. L, Schmitthenner, A. F and Reichard, D. L. 1982. Seed-borne fungi, quality, and yield of soybeans treated with benomyl fungicide by various application methods. *Journal of Agronomy* .74:589-592.

Haikal, N. Z. 2008.Effect of filtrates of pathogenic fungi of soybean on seed germination and seedling parameters. Journal of Applied Sciences Research, 4(1): 48-52.

Khore, D. and M.S.Bhale. 2007. Seed technology. Jodhpur scientific publisher, India.

Kumar, P., A. Kumar and K. Kumar. 2000. Bio-control of seed-borne fungal pathogens of pigeon pea (Cajanus cajan (l.) millsp). C.S.Azad University of Agriculture and Technology, Kanpur, India.

Limonard T., 1966. A modified blotter test for seed health. Government seed testing station, Wageningen.

Mashilla, D. 2004. Grain storage methods and their effect on sorghum grain quality in Hararghe, Ethiopia. PhD Thesis. Swedish University of Agricultural Science. Uppsala, Sweden.

Masum, M. M, S. M. Islam and M. G. Fakir. 2008. Effect of seed treatment practices in controlling of seed-borne fungi in sorghum. http://www. academic journals.org/SRE

Magan, N. and J. Lacey. 1988. Ecological determinants of mould growth in stored grain *International Journal of Food Microbiology*, **7:**245-256

Mehrotra, R.S. and A.Aggarwel. 2003. Plant Pathology. 2nd ed. Tata, McGrew-Hill publishing company limited. New delhi.

Mengistu H and Amare A. 1996.Post harvest disease of food crops. Teaching material series, Alemaya University. Pp 99.

Niaz, I. and H.Sdawar. 2009. Detection of seed borne mycoflora in maize (*zea maize*).University of Karachi, karachi-75270, Pakistan.

Panna, R., F. M.Aminuzzaman, M. R. Islam, and M. H.Bhuyan. 2009. Evaluation of some physical seed treatments against *Bipolaris sorokiniana* associated with wheat seeds. *Int.j.Sustain. Crop prod.4 (6): 40-44.*

Pestka, J. J., and W. L. Casale. 1990. Naturally occurring fungal toxins. Adv. Environ. Sci. Technol. 23:613–638.

Pattaya, J., N. Krittigamas, W. Lücke and S. Vearasilp 2005.Using Radio Frequency Heat Treatment to Control Seed-borne *Trichoconis padwickii* in Rice Seed (*Oryza sativa* L.).Conference on International Agricultural Research for Development Stuttgart-Hohenheim, October 11-13.

Pitt, J.I. 2000. Toxigenic fungi and mycotoxins. *British medical bulletin,* 56: 184-192

Rout.J.G., S.M. Guldhe and P.D. Wangikar. 1983. Seed borne infection of *Alternaria alternari* in wheat and its control. Indian phytopathology, 36:274-277.

Rao, N.K, Hanson, J., Dulloo, M.E, Ghosh, K., Nowell, D. and Larinde, M., 2006. Manual of seed handling in

gene banks. Hand books for Gene banks No. 8. Biodiversity International, Rome, Italy

Smith, G.J and S. Brul. 2005. Stress tolerance in fungi-to kill spoilage yeast. *Current Opinion In Biotechnology*, 16: 225-230.

Schnürer, J., J. Olsson and T. Börjesson, 1999.Fungi volatile as indicator of food and feed spoilage. Fungal genetics and biology 27:209-217.

Sherman, R.C. and T.P Bhowmik. 1987. Effect of *Macrophoma phaseoli* infection on the Physio-chemical components of ground nut seed. J. phytopathology, 118: 181-186.

Trojanowska K., 1991. Evaluation of cereal grain quality using mycological methods. In: Chelkowski (editor), Cereal grain: Mycotoxins, fungi and quality in drying and storage. Elsevier, Amsterdam, pp, 185-215.

Walcott, R. R., 2003. Detection of Seed borne Pathogens. Hort technology 13(1): 40-47.

Waller, J.M. 2002.Seed health. CABI Bioscience UK center, Bakeham Lane, Egham, SurreyTW209TY,UK.