2000

G1408 Grain Molds and Mycotoxins in Corn

Jim Stack
University of Nebraska at Lincoln

NebGuide

Published by Cooperative Extension, Institute of Agriculture and Natural Resources,
University of Nebraska-Lincoln

G00-1408-A

Grain Molds and Mycotoxins in Corn

Jim Stack, Extension Research Plant Pathologist

Storage molds of corn occur in Nebraska annually, potentially lowering grain quality. Mycotoxin contamination of corn occurs periodically, potentially affecting human and animal health. Learn how to identify the different types and their effects.

In Nebraska, grain molds occur every year to varying degrees on field corn, seed corn, white corn, and other specialty corn hybrids. Most grain mold pathogens become associated with the kernel in the field; however, under certain conditions of temperature, relative humidity, and grain moisture, these molds can grow within the colonized kernel and even spread to adjacent kernels during transport and storage. Several issues are associated with grain molds in corn including lowered grain quality, effects on human health, and effects on animal health and reproduction. Most grain mold pathogens have the potential to lower grain quality by affecting feed efficiency or grain processing characteristics. Human health concerns include allergenicity and hypersensitivity associated with the inhalation of mold spores in grain storage facilities and acute or chronic disease associated with infection by some species of grain mold fungi. In addition, some grain mold pathogens produce compounds (mycotoxins) that can be toxic to farm animals, wildlife, or humans. The presence of mold, however, does not indicate contamination of the grain with mycotoxins. Only certain strains of certain fungal (mold) species have the potential to produce these potentially harmful compounds. Grain mold pathogens are also capable of causing disease in other parts of the plant. *Fusarium graminearum* and *Fusarium verticillioides* (formerly named *F. moniliforme*) cause stalk rots, grain molds, and are capable of producing different classes of mycotoxins within colonized kernels. Recent evidence suggests that the mycotoxins are produced during infection of the plant and although not essential, may play a role in disease development.

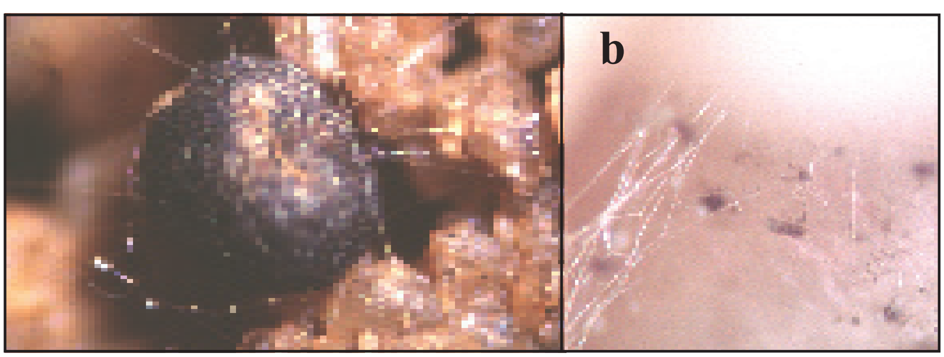

Figure 1. Filamentous growth habit of fungi. These filaments, called hyphae, allow the pathogen to colonize grain and to grow through soil (a). A network of hyphae is called a mycelium. Mycelial development (b) in grain piles can result in cementing of the kernels together into columns.

Grain Mold Pathogens

Molds are fungi that grow by producing long filaments called hyphae *(Figure 1)*. In general, hyphae are important to the survival and dispersal of fungi. Hyphal growth allows the fungus to colonize a food source (e.g., a corn kernel) as well as to grow from one food source to another; e.g., from root to root through soil or from one kernel to an adjacent kernel in a pile of stored grain *(Figure 1)*. A network of hyphae is referred to as mycelium. This hyphal network is responsible for "cementing" kernels together in grain piles resulting in columns of grain that cannot be separated. Grain mold fungi also produce spores (conidia) capable of aerial dispersal in the field as well as within a grain storage bin *(Figure 2)*. It is usually masses of spores that give the mold a characteristic color. Spores are dispersed passively by wind and rain. Insects can serve as vectors of these fungi usually by transporting the spores on the surface of their bodies; this is particularly important within grain storage bins. Managing grain storage insects can reduce contamination by grain molds and mycotoxins. Most species of grain mold fungi are well adapted to the conditions of grain production and postharvest handling and storage. They can survive long periods in storage facilities making sanitation of the facility an important part of a grain mold management plan.

The most striking external symptom of grain mold is the presence of the mold itself. The degree of growth on the kernels and the appearance of the mold (e.g., color and density) varies with the species of mold, the quality of the grain being colonized, and the prevailing environmental conditions *(Figure 3)*. Incidence (the proportion of ears with mold) and severity (the proportion of infected kernels on an ear) of disease depends on many factors.

Aspergillus species tend to be more prevalent when

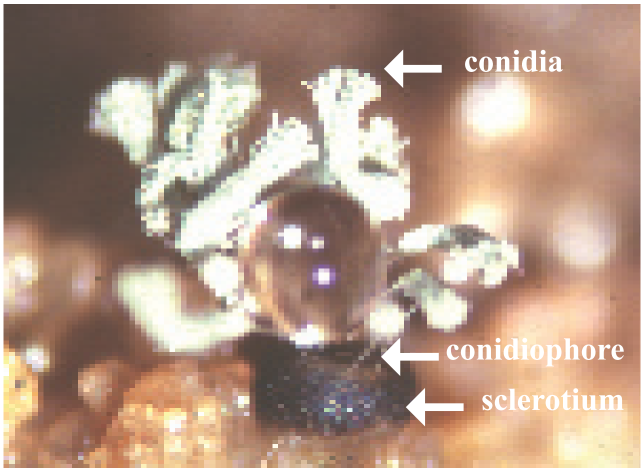

Figure 2. Conidia production by the grain mold fungus *Aspergillus flavus*. Most grain mold fungi produce spores that are dispersed by wind, rain, or insects.

there is drought during the latter half of the growing season. *Fusarium verticillioides* is associated with a high proportion of corn kernels under most growing conditions but *Fusarium* ear and grain mold develops more often when cool wet weather during silking is followed by hot dry weather. *Gibberella* grain mold is more prevalent in hybrids with tight husks. Unlike *F. verticillioides*, *F. graminearum* is rarely seed-borne.

Common Grain Molds in Nebraska

Many species of fungi cause molding in grain. Most grain mold fungi are relatively non-specific; they colonize several species of plants and utilize different types of organic matter as an energy source. Most of these fungi become associated with the grain in the field although they may only become visible during storage, and then only if environmental conditions are favorable (e.g., moderate temperature and high relative humidity). *Fusarium*, *Gibberella*, *Diplodia*, *Penicillium*, *Aspergillus*, and *Cladosporium* are among the prevalent grain mold pathogens in Nebraska. These species are widespread across the corn belt and can be found throughout Nebraska every year. They all survive in field residue. *Fusarium* spp. and *Diplodia* are the same pathogens that cause stalk rot diseases during the growing season. (See NebGuide G99-1385, *Common Stalk Rot Diseases of Corn.*)

Fusarium Grain Mold

Fusarium grain mold is probably the most common grain mold pathogen in Nebraska. It is caused by three seed-borne species of *Fusarium*: *F. verticillioides*, *F. proliferatum*, and *F. subglutinans*. The role of seed-borne inoculum to the development of grain mold is uncertain. Disease symptoms and severity vary with hybrid genetics and environmental conditions. Moldy kernels may be clumped at the tip of the ear or randomly dispersed across the entire ear. Infected kernels may be pink or show a white starburst pattern radiating from the top of the kernel.

Gibberella Grain Mold

Gibberella grain mold is also common in Nebraska. It is caused by the fungus *Gibberella zeae*; the asexual stage of the pathogen is *Fusarium graminearum*. Unlike *F. verticillioides*, *F. graminearum* is rarely seed-borne. Disease symptoms and severity vary with hybrid genetics and environmental conditions. Infected kernels are usually clumped at the tip of the ear and the mold is reddish in color.

Diplodia Grain Mold

Diplodia grain mold is common throughout the corn belt, usually occurring weeks after silking. It is caused by the pathogen *Stenocarpella maydis* (*Diplodia maydis*) which can be seed-borne. Like the *Fusarium* spp. that cause grain mold, *Diplodia* survives on corn residue. Consequently, the incidence of *Diplodia* has increased in recent years as a result of the increased practice of reduced tillage. Although less common than *Fusarium*, *Diplodia* grain mold was widespread in Nebraska in 1999. Infected kernels may show no external symptoms or be brown with small brown-to-black reproductive structures at the base of the kernels.

Penicillium Grain Mold

Penicillium grain mold is probably the second most common grain mold pathogen in Nebraska. It may be caused by several species of *Penicillium*, including *P. oxalicum* and *P. chrysogenum*. Which species is the most prevalent in Nebraska is unknown. *Penicillium* species are well adapted to survival in many types of storage facility. Kernel infection can occur in the field or in storage. Symptoms range from external mold development to internal discoloration ("Blue Eye") of the embryo. Symptoms caused by *Penicillium* are easy to confuse with those caused by *Aspergillus glaucus*.

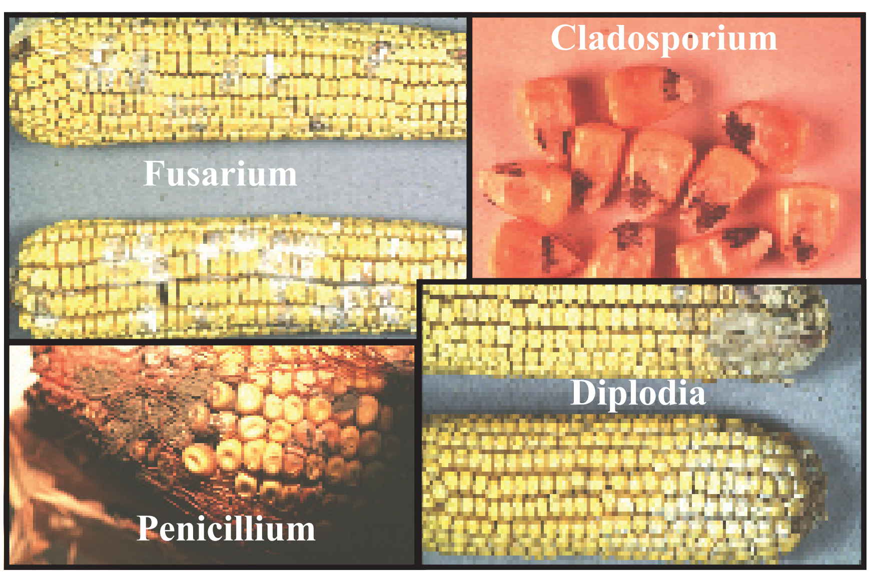

Figure 3. *Fusarium*, *Cladosporium*, *Pennicillium*, and *Diplodia* are among the most common grain mold spsecies in Nebraska.

Aspergillus Grain Mold

Aspergillus grain mold is probably the least common grain mold pathogen in Nebraska. At least three species of *Aspergillus* can cause grain mold in corn, including *A. flavus*, *A. parasiticus*, and *A. glaucus*. Like *Penicillium* species, *Aspergillus* species are very well adapted to survival in many types of storage facility. Infection of kernels can occur in the

field or in storage. Also like *Penicillium*, symptoms range from mold development on the surface of kernels to internal discoloration ("Blue Eye") of the embryo.

Mycotoxins

Most fungi produce a class of chemical compounds called secondary metabolites. These compounds have a wide range of biological activities including antibiotic (antibacterial and antifungal), acute and chronic toxicities (plant, animal, and humans), and hormone and growth regulation (plants and animals). There is much speculation but little direct evidence for a specific role of secondary metabolites in the growth and reproduction of the organisms that produce them. Most mycotoxins are secondary metabolites. Several species of fungi that colonize corn produce mycotoxins, however not all isolates of a toxigenic species produce mycotoxins and isolates capable of producing a mycotoxin do not always synthesize the toxin. Clearly, synthesis and excretion of the toxin is not required for reproduction and survival of the organism. There are several chemical classes of mycotoxins, each with a unique chemistry. Generally, the chemical class of mycotoxin is specific to a genus of fungus; i.e., usually only one genus of fungus produces a given class of mycotoxin. Only two species of *Aspergillus* produce aflatoxins and only a few species of *Fusarium* produce the class of mycotoxins known as fumonisins; however, species of two genera, *Penicillium* and *Aspergillus*, may produce the mycotoxin ochratoxin.

Mycotoxins have a wide range of activities and target species *(Table I)*. Some mycotoxins have toxic activity in both animals and plants, while others are only toxic to one or a few species. Mycotoxins vary greatly in their toxic effects and their potency. Some mycotoxins are somewhat target specific affecting primarily one organ (e.g., liver, kidney). Others have broad spectrum activity affecting several organs and tissues. For some mycotoxins, a concentration of many parts-per-million is required to elicit a toxic effect, while for other mycotoxins a concentration as low as 1 part-per-billion will elicit a toxic effect. Most mycotoxins can act alone. Some also act synergistically with other toxins causing effects greater than either toxin acting alone at concentrations less than required for either toxin alone. This can make field diagnosis of mycotoxin contamination very difficult. It is not unusual for more than one species of grain mold pathogen to be present within a single storage bin and many grain mold pathogens can be active under the same environmental conditions providing for the opportunity to have more than one mycotoxin produced in a lot of contaminated grain.

The nature of the toxic effects caused by mycotoxins varies greatly. Some mycotoxins cause acute toxicities (i.e., immediate effect) where a certain organ (e.g., liver, kidney) loses complete or partial function; other mycotoxins cause chronic toxicities (i.e., long-term) resulting in symptoms such as weight loss and reproductive dysfunction. Still other mycotoxins impair the immune system predisposing the affected animal to a variety of infections or other ailments. For some mycotoxins damage is not permanent and affected animals can recover from ingestion if the contaminated feed is removed from the diet.

All handlers of stored grain should exercise caution when in a storage facility especially if a mold problem exists. In addition to the mycotoxin concerns described above, grain mold fungi can affect human health in several ways. Exposure to the spores of the grain mold fungi can lead to acute allergic responses (e.g., hypersensitive response leading to pneumonia) or chronic allergic responses (e.g., sinusitis, acquired sensitivity). Some species can act as opportunistic pathogens causing serious disease in people with impaired immune function (e.g., people on broad spectrum antibiotics, corticosteroids, or immune suppressants following a transplant). All personnel should wear dust masks to minimize exposure to grain mold fungi.

Grain Mold and Mycotoxin Management

Preharvest

Hybrids that are less susceptible to grain mold should be planted where available in areas with perennial grain mold and/or mycotoxin problems. Identifying the prevalent grain mold pathogens will be necessary prior to selecting the appropriate hybrids. After planting, the overall strategy for grain mold management is to minimize plant stress during and after silking. Common stresses associated with grain mold include: high moisture in mid-to-late season after a dry early season, moisture stress early in season and during grain fill, high leaf disease pressure, and insect damage.

Postharvest

All grain storage facilities should be monitored regularly to detect grain mold development. Grain molds rarely develop uniformly throughout a storage unit; development of hot spots is common. Monitoring requires a systematic sampling plan to account for the unique design characteristics of each storage facility.

Ensure Proper Storage Conditions

To minimize the potential for mold growth and mycotoxin production, grain moisture content should be reduced to less than 15 percent within 48 hours after the grain is harvested.

Table I. Toxigenic fungi, their metabolites and target effects.

Grain Mold Fungus	*Toxin Produced*	*Toxic Effects*	*Species Affected*
Aspergillus flavus	aflatoxin	acute toxicity (liver)	many
		liver cancer	human
		immune suppression	humans, animals
Aspergillus alutaceus	ochratoxin	acute toxicity (kidney)	swine, poultry
		cancer	human
Fusarium verticillioides	fumonisin	blind staggers	horse
		pulmonary edema	swine
		esophageal cancer	human
Fusarium graminearum	trichothecenes	acute toxicity	many (not ruminants)
		immune suppression	many
	vomitoxin	acute toxicity	many
	zearalenone	reproductive dysfunction	swine
Penicillium spp.	ochratoxin	acute toxicity (kidney) cancer	swine, poultry
			human

This may be difficult to achieve in many storage facilities, especially larger capacity elevators. A storage temperature of less than 40° F should be maintained. Good air circulation throughout the storage bin is important. Storage conditions optimal for maintaining grain quality will minimize mold development and mycotoxin contamination.

Table II. FDA tolerance levels for some mycotoxins.

Mycotoxin	*FDA Tolerance*	*Target*
aflatoxin	0.5 ppb (parts/billion)	milk
	20 ppb	dairy
	100 ppb	mature breeding cattle, swine, and poultry
	200 ppb	finishing swine
	300 ppb	finishing beef
fumonisin	5 ppm (parts/million)	horses
	10 ppm	swine
	50 ppm	cattle
vomitoxin	1 ppm	human
	5 ppm	swine
	10 ppm	cattle, chickens

Minimize Mechanical Damage

Harvest and postharvest grain handling should be designed to minimize mechanical damage. Although most mold pathogens can directly penetrate plant tissues, mechanical damage provides additional entry sites, facilitating infection and spread from kernel to kernel during shipping and storage.

Minimize Insect Damage

Like mechanical damage, insect feeding provides additional entry sites for mold pathogens, facilitating infection and spread from kernel to kernel during shipping and storage. Some insects also act as vectors of grain mold pathogens. An effective IPM-based insect management plan during the growing season as well as during postharvest shipping and storage of the grain can reduce mold and mycotoxin contamination.

Tolerant Hybrids

Although hybrids vary in susceptibility, no hybrids are completely resistant to grain molds. Hybrids with very tight husks are more susceptible to *Gibberella* ear mold. Less *Fusarium* grain mold and subsequent mycotoxin contamination has been reported in corn-borer resistant Bt-hybrids. This is presumably due to less feeding damage by the borer.

Sanitation

The grain mold pathogens are well adapted to survive for long periods within grain storage facilities. Storage bins should be cleaned thoroughly each season. The type and configuration of the storage facility will dictate the nature of the sanitation required. The objective is to remove old grain and residue that could provide a harborage for these fungi.

Chemical Management

Fungicides are not currently used in Nebraska to manage grain molds or mycotoxin contamination. There are no fungicidal fumigants labeled for use in grain storage facilities. Formulations of propionic acid are used in some storage facilities with varied success in reducing grain mold and mycotoxin contamination.

Table III. Key management steps to minimize grain mold and mycotoxin contamination.

1. Ensure proper storage conditions — grain moisture, temperature, relative humidity
2. Minimize mechanical damage — harvest and postharvest shipping and handling
3. Minimize insect damage — pre-harvest and postharvest storage
4. Plant tolerant hybrids — some tolerant hybrids available
5. Sanitation of storage facility — critical management practice
6. Chemical management — propionic acid, mineral oils
7. Assay moldy grain for mycotoxins — Toxicology Lab, Vet Diagnostic Center, UNL
8. Segregate, blend, or destroy contaminated grain — as per FDA regulations

Assay Moldy Grain

Prior to use, moldy grain should be analyzed for possible mycotoxin contamination. Depending on the intended market (e.g., food or feed, domestic or export) and the mycotoxin present, contaminated grain should be handled according to the specific recommendations for that toxin and the level of contamination. This may require segregating the grain for allowable uses. With some mycotoxins, blending with non-contaminated grain is permitted. In a few cases, the contaminated grain must be destroyed. Proper protocols should be used to sample and ship moldy grain for mycotoxin analysis.

For toxin analysis and the most recent regulations contact the Toxicology Laboratory, Veterinary Diagnostic Center, University of Nebraska, P.O. Box 830907, Lincoln, NE 68583-0907.

Unresolved Issues for Grain Molds and Mycotoxins

Several issues related to molds and mycotoxins remain unresolved: 1) the impact of mycotoxin ingestion on human health, 2) the importance of cropping practices (e.g., plant density and spacing, tillage, crop sequence) to the incidence and severity of grain mold, and 3) the identification of true grain mold resistance in hybrids.

Relevant Web Sites

Several Web sites provide additional information on grain molds and mycotoxin contamination of corn. Some of these sites include excellent images of grain mold symptoms and the pathogens that cause them.

Grain mold and mycotoxin sites:

http://vm.cfsan.fda.gov/~frf/iupac.html
http://www.btny.purdue.edu/NC129/
http://pasture.ecn.purdue.edu/~grainlab/
http://www.ces.ncsu.edu/drought/dro-29.html
http://www.aces.edu/department/grain/ANR767.htm
http://www.ianr.unl.edu/pubs/pesticides/g790.htm
http://www.ipm.iastate.edu/ipm/icm/1998/1-19-1998/btdiscon.html
http://www.scisoc.org/feature/Btcorn/Top.html

Weather sites:

http://hpccsun.unl.edu/
http://www.crh.noaa.gov/

File under: PLANT DISEASES
C-43, Field Crops
Issued August 2000, 5,000

Issued in furtherance of Cooperative Extension work, Acts of May 8 and June 30, 1914, in cooperation with the U.S. Department of Agriculture
Elbert C. Dickey, Interim Director of Cooperative Extension, University of Nebraska, Institute of Agriculture and Natural Resources.