


Grain Drying & Management


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 University of Missouri Extension

Materials primarily developed by:
 Charles Ellis, Natural Resource Engineer
 University of Missouri Extension – Lincoln County




Successful Storage

- Proper storage moisture
- Insect control
- Cool the grain
- Grain quality

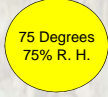


What Happens When We Dry Grain?

- Heat from the air moving through the grain is used to evaporate moisture from the grain resulting in:
 - Increased water held in the air as vapor
 - Lower air temperatures leaving the grain




Psychrometrics

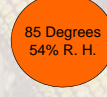


75 Degrees
75% R. H.

Equilibrium Corn
Moisture 15.2%


Heat






85 Degrees
54% R. H.

Equilibrium Corn
Moisture 11.4%




Proper Storage Moisture

Corn	
Sold by spring	15.5%
Stored one year	14.0%
Soybeans	
Sold by spring	13.0%
Stored one year	12.0%
Wheat	13.5%



Storage Time for Corn

Grain Temp. °F	15%	16%	18%	20%
35		670	265	112
40	870	500	200	85
45	650	385	150	64
50	490	290	115	48
55	360	215	86	36
60	270	165	65	28
65	200	125	49	21
70	152	93	37	16
75	112	70	28	12
80	84	53	17	9



Storage Time for Beans

Grain Temp. °F	14%	16%	18%
40	230	140	75
45	175	95	40
50	134	65	23
55	100	40	15
60	76	27	11
65	55	19	9
70	41	14	6
75	32	11	4
80	25	8	2

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Temp. Data for Lamar, MO

Month	Avg. Max	Avg. Min	Avg.	Avg. R. H.	
				a.m.	p.m.
Jan.	43	23	33	78	58
Feb.	49	27	38	80	56
March	58	34	46	79	52
April	69	44	57	79	50
May	76	54	65	85	55
June	85	63	74	86	55
July	90	68	79	87	53
Aug.	90	66	78	88	50
Sept.	82	57	70	87	52
Oct.	71	46	59	82	50
Nov.	58	36	47	80	54
Dec.	46	26	36	79	59

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Computing Equilibrium Moisture Content

- Need to know:
 - Species of grain (corn, beans, wheat, etc.)
 - Air temperature, °F
 - Air relative humidity, %
 - Current grain moisture, % wet basis
 - Target grain moisture, % wet basis

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Equilibrium Moisture of Corn

Air Temp. (°F)	Air Relative Humidity					
	30%	40%	50%	60%	70%	80%
40	9.3	11.0	12.7	14.5	16.4	18.7
50	8.8	10.5	12.2	13.9	15.7	17.9
60	8.5	10.1	11.7	13.3	15.1	17.2
70	8.1	9.7	11.2	12.8	14.5	16.6
80	7.8	9.3	10.8	12.4	14.0	16.0
90	7.6	9.0	10.5	12.0	13.6	15.5
100	7.3	8.7	10.1	11.6	13.2	15.1

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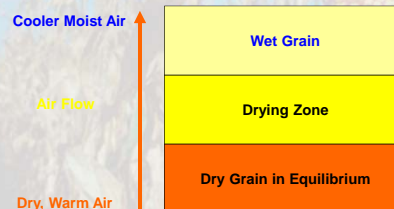
Recommended Airflow for Drying Corn

Min. Airflow, CFM/bu.	Corn harvested on or after					
	Sep. 1	Sep. 15	Oct. 1	Oct. 15	Nov. 1	Nov. 15
	Maximum moisture content, %					
1.0	19	19.5	20	21	22	20
1.25	19	20	20.5	21.5	22.5	20.5
1.5	19.5	20	21	22	23.5	21.5
2.0	20	21	22	23	24.5	21.5
3.0	21	22	23.5	24.5	25.5	22

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Reference: <http://extension.missouri.edu/p/G1305>

In-Bin Drying



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Fan Operation


During drying, turn on fans and leave them on



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15.5% Corn is:


- 47.3 lbs. of dry matter
- 8.7 lbs. of water



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20% Corn is:


- 47.32 lbs. of dry matter
- 11.83 lbs. of water



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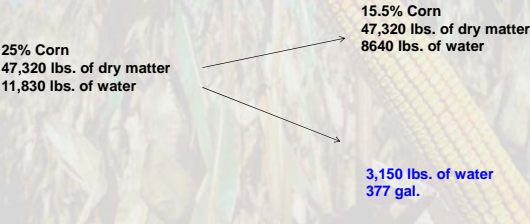
25% Corn is:

- 47.32 lbs. of dry matter
- 15.77 lbs. of water



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Drying 1000 bu. of 20% Corn



20% Corn
47,320 lbs. of dry matter
11,830 lbs. of water

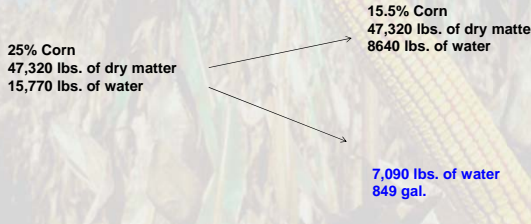
15.5% Corn
47,320 lbs. of dry matter
8,640 lbs. of water

3,150 lbs. of water
377 gal.



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Drying 1000 bu. of 25% Corn



25% Corn
47,320 lbs. of dry matter
15,770 lbs. of water

15.5% Corn
47,320 lbs. of dry matter
8,640 lbs. of water

7,090 lbs. of water
849 gal.



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Cubic Ft. of Air Required to Dry to 15.5% M.C.

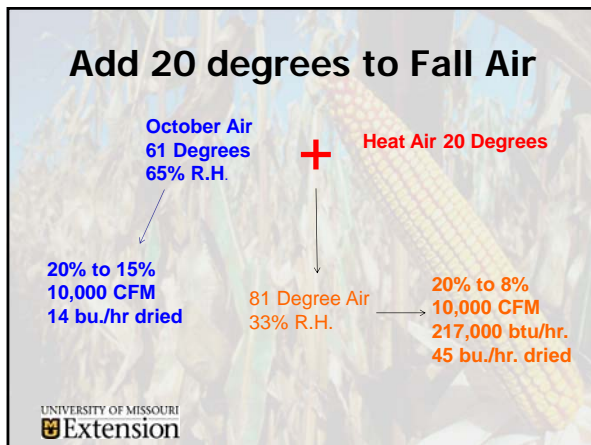
Month	Temp. °F	R.H. %	20% M.C.	25% M.C.
Sept.	71	68	36,800	68,000
Oct.	61	65	38,500	70,900
Nov.	46	68	62,700	103,600
Dec.	36	72	111,000	154,300

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Cubic Ft. of Air Required to Dry to 18% M.C.

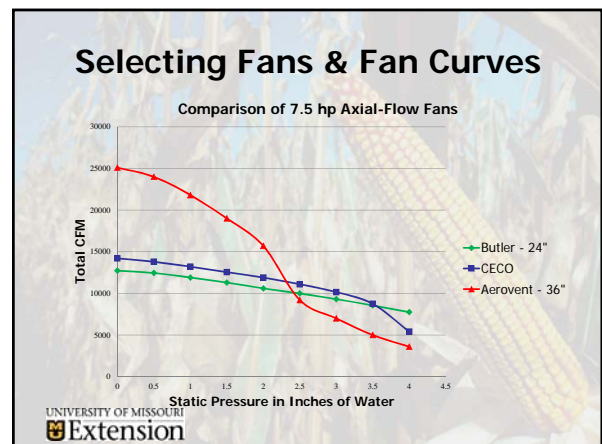
Month	Temp. °F	R.H. %	20% M.C.	25% M.C.
Sept.	71	68	16,000	51,000
Oct.	61	65	16,800	53,400
Nov.	46	68	27,900	78,300
Dec.	36	72	50,000	116,800

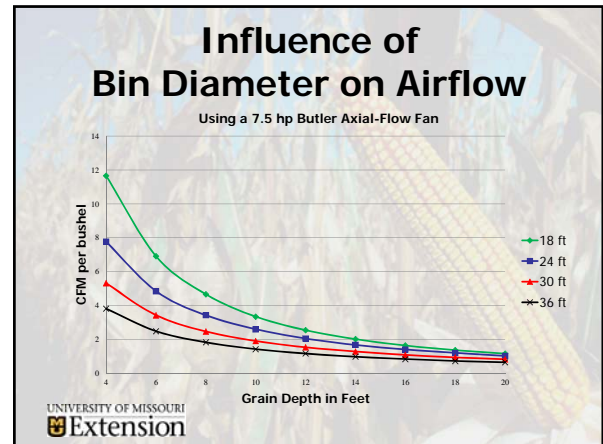
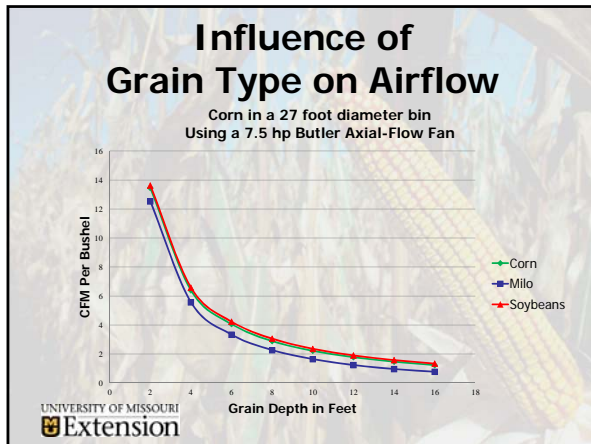
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- ### Airflow Through Grain
- When air is forced through grain, it encounters resistance, which is pressure drop
 - Pressure drop is the result of friction in the grain mass
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- ### Airflow Through Grain Cont.
- Pressure drop is dependent on:
 - Properties of the drying air
 - Airflow rate
 - Characteristics of the grain
 - Amount of void space
 - Broken kernels and fines
 - Grain depth
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Cool Grain in the Fall

- Cool to 35-40°F
- Don't freeze grain
- Once cooling front starts, cool the entire mass of grain

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Warm Grain in the Spring

- Warm grain in spring to 55-65°F to minimize moisture migration

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Level Grain

- Peaks will cause lower air movement and complicate drying and management

Natural filling angle for most dry grains

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Uneven Grain Temperatures in Storage Bin

- More stored grain goes out of condition because temperatures are not controlled than for any other reason

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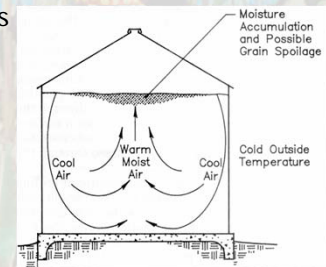
Uneven Grain Temperatures

- Grain is a poor thermal conductor
 - Corn has an R-value of 1 per inch
 - For an 18 foot diameter bin, the distance from the center to the wall is 108" or an R-value of 108
 - Suggestions for our home walls is R-19!
- The larger the bin, the longer it takes for the center of the grain mass to respond to outdoor temperature changes

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Convection Currents

- Center of grain is warm – edges are cool
- Causes moisture migration



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The Answer - Aeration

- Aeration is the most effective way to control grain temperature
- Insects - dormant below 50°F - die below 32°F
- Mold growth nearly zero below 40°F
- Aeration also controls moisture content and moisture migration
- Aeration is for temperature control – not drying
 - Try to maintain < 20°F difference between average outdoor temperature and grain temperature

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How Cool is Cool Enough?

- For Missouri, grain should be cooled to 35-40°F for winter storage
 - Do not freeze!! This can cause additional problems
- For Missouri, grain should be warmed to 55-65°F for summer storage
 - If the temperature exceeds this, aerate only on cool nights in order to maintain uniform temperatures throughout the bin

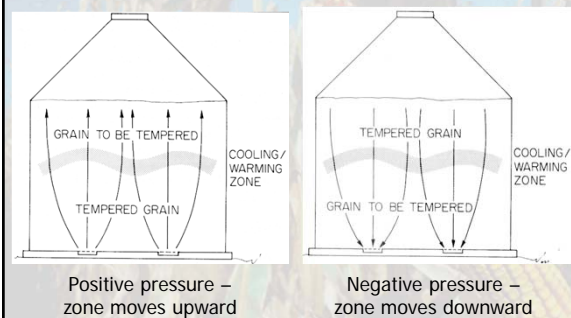
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Aeration Procedures

- Provide 1 square foot of vent space for each 1000 CFM of air the fan moves
- Airflow direction is not critical
- Type of fan is not critical – will only affect time fan will run
- Change grain temperature in steps
- Do NOT stop fans until the cycle is complete – a cycle is when the front moves all the way through the grain mass

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Airflow Direction



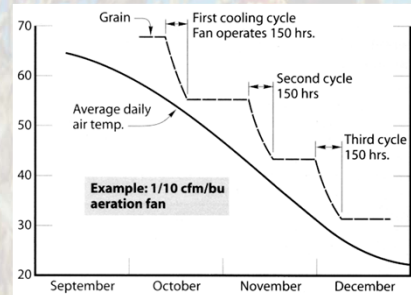
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Aerate in Steps

- Aerate when you fill the bin
- Aerate each time there is a 10-15°F change in the *average* outside temperature
- Do not shut the fan off until the cycle is complete
- 3 cycles is generally adequate for cooling
 - 75°F to 60°F
 - 60°F to 45°F
 - 45°F to 30°F

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Example of Step Cooling



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Airflow Rates & Cycle Times

- Cycle time depends on the airflow
- Airflow is expressed in CFM/bu
- Airflow rate is a function of
 - Fan design
 - Backpressure
 - Air delivery system
 - Type of grain
 - Depth of grain
- Performance data should be provided with your fan

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Cycle Times

- Estimating Cycle times
 - Take airflow in CFM/bu from fan data
 - Divide 15 by that number
- Example:
Airflow rate of 0.25 CFM/bu

$$15/0.25 = 60 \text{ hours to cool the grain}$$

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How do you know the cycle is complete?

- The best way to find the cooling front is to measure the temperature at various depths.
- Measure the top layer of grain for a positive pressure system or the exhaust air of a negative pressure system until an abrupt change in the temperature occurs.
- *A cooling front pushed only partway through the grain can cause condensation in the cooling zone.*

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Additional Tips

- Soybeans are hygroscopic
 - Will rapidly absorb moisture from the air
- Close doors and cover bin fans when not in use
- Level the grain – fronts will not push through the cone
- If there is a rapid warm up in the spring, you may need to warm the grain

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Other Useful Information & Equilibrium Moisture Content

- Horizon Point through AgEBB
agebb.missouri.edu/horizonpoint
- is a custom weather analysis system for farmers. It provides farmers with the opportunity to have site specific weather reports sent directly to their e-mail address.



Other Useful Information & Equilibrium Moisture Content

- Part of the Horizon Point report

Time	Temperature			Relative Humidity		
	Corn EMC		Soybean EMC			
	12/6/2006	12/7/2006	12/8/2006			
12:00 AM	-	23°F 87%	17°F 70%	20.4%	18.0%	14.3%
3:00 AM	-	20°F 70%	14°F 70%	19.0%	16.0%	14.3%
6:00 AM	-	18°F 68%	13°F 74%	17.5%	13.8%	15.2%
9:00 AM	37°F 40%	17°F 67%	10°F 70%	15.6%	13.6%	11.1%
12:00 PM	40°F 39%	22°F 54%	30°F 56%	14.3%	11.3%	11.1%
3:00 PM	41°F 35%	23°F 40%	30°F 43%	13.0%	10.2%	8.7%



The "Big Two"

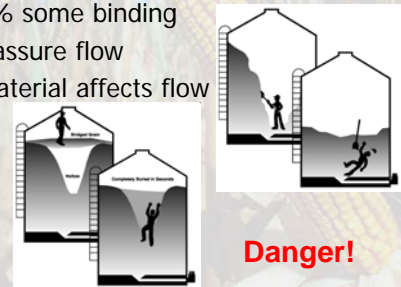
- Grain not checked often enough during storage
- Uneven grain temperatures in storage bin



Corn Flowability



- 28% moisture freezes together
- 24% - 25% some binding
- <24% to assure flow
- Foreign material affects flow



Causes of Grain Storage Problems

- Grain too wet
- Grain too warm
- Too much foreign material and fines
- Storage facilities not cleaned before filling
- Grain not checked often enough during storage
- Uneven grain temperatures in storage bin



Grain Too Warm & Too Wet

- The primary agents of grain deterioration are **molds** and **insects**
 - Molds need moist grains
 - Insects need warm grain – 60 - 100°F



Fusarium Grain Mold



Granary Weevil



Storage Facilities Not Clean

- Clean facilities reduce insect problems
 - Old grain residue is often the source of insect infestation in new crops
 - Can contain insect adults, larvae or eggs
- Sweep or Vacuum floors and walls
- If you have had a prior problem in that bin, consider using an insecticide to pretreat the bin
- Cleaning will have little effect on mold development



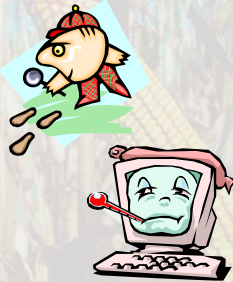
Too Much Foreign Material & Fines

- Cracked and broken grain less resistant to mold and insects
- Foreign material often has a higher moisture content and is thus more susceptible to mold
- Largest problem is fines tend to concentrate in one area and have a higher resistance to airflow making them difficult to cool or dry – they can develop into hotspots



Check Grain Regularly

- Run fans
- Smell air
- Check temperatures
- Record temperatures



Grain Not Checked Often Enough

- Grain in storage should be checked
 - Weekly in fall and spring due to rapid temperature changes
 - Every 2-3 weeks in cold weather
 - Every 1-2 weeks in warm weather
- Small problems can quickly turn into large, expensive problems
- Mold and insects grow under similar conditions – producing heat and moisture which can make the situation worse



Checking Your Grain

- **SAFETY first!!**
 - Keep shields in place
 - Beware of ice/moisture on ladders
 - Install safety cages on ladders
 - Beware of power lines
 - Use a respirator if entering a bin – mold spores can cause lung problems
 - Beware of crusted grain – use a safety harness
 - Follow the “buddy system” if possible



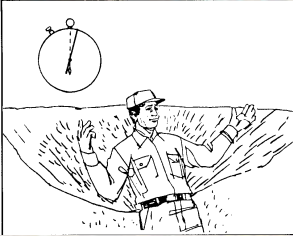
Safety in Grain Handling

- Many accidents occur in handling grain
- Hazards:
 - Suffocation
 - Carbon dioxide
 - Health hazards
 - Hazardous equipment



Suffocation Hazard

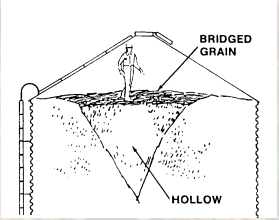
- Flowing grain can suffocate you in a matter of seconds



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Crusty Grain

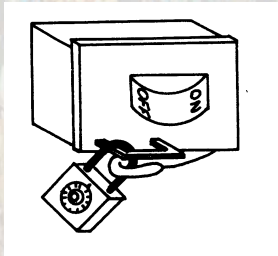
- Crusty grain on the surface with a void underneath will cause suffocation



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Electrical Lockouts

- Electrical lockouts can prevent someone from turning on an auger while you are inside a bin



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Checking Your Grain

- Check for changes in grain condition
 - Temperature
 - Moisture
 - General condition
- Run fan and smell the exhaust for a musty or sour smell
- Check roof condition – does frost melt off one bin faster than another?
- Look for insects
- Keep records of the conditions – compare them!!

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Checking Your Grain Moisture


- Pull multiple samples from various locations and depths –
 - Minimum is one from the center and one from the edge both approx. 3 feet from the surface
- Let samples warm to room temperature in sealed container or Ziploc bag BEFORE measuring

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Moisture Meter Error

- Calibrated for 15% corn – error on high moistures
- Adjust for temperature
 - Not accurate <40°F
- Electronic meters more sensitive to outside of kernel
 - Moisture variation after rapid drying
- Meters affected by condensation

- Measure moisture content
- Place sample in sealed container for several hours (6-12 hrs)
- Warm to 70°F
- Recheck moisture



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Extension Service

Checking Your Grain Temp.

- Check in several locations
- Check at several depths
 - Use a probe with a thermometer attached or pull samples to the surface and measure
 - Record the temperatures
- Allows you to identify
 - Cooling front
 - Heating caused by insect or mold activity



Checking Temperatures

- How??

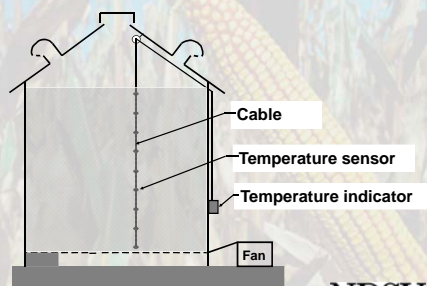


Can be attached to a 3/8" diameter rod

\$20.80 <http://www.enasco.com/product/C12108N>



Senses only grain near cable



Checking Grain

- How??



Probe as deep as 13-1/2 feet for samples

\$159.95 <http://www.enasco.com/product/C08661N>



Sampling Tips

- Sample once a month when:
 - grain temperature less than 50°F
 - Bins condition stable
- Sample twice a month when:
 - Problems detected
 - Grain mass not stabilized
- Small problems are early indicators
 - Insects
 - Moisture
 - High temperature
 - Smell
 - Temperature differences greater than 10°F



Stored Grain Fungi Management


- **Moisture** content – A moisture content below **13.5 percent** in starchy cereal seeds such as wheat, barley, rice, **corn and sorghum**
- **Temperature** - In the range of temperature **between 40-50 degrees F, storage fungi grow very slowly**
- below **12.5 percent** in **soybean** prevents invasion by storage fungi regardless of how long the grains are stored
- At 80-90 degrees F, they grow much more rapidly

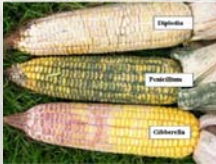


Stored Grain Fungi Management

- **Broken or cracked kernels** are more likely to be contaminated with storage fungi going into storage and more likely to be invaded once they are in storage than sound kernels. Foreign material may restrict air movement through the grain mass leading to temperature and moisture problems which may favor storage mold development.
- At risk is grain already invaded by storage fungi when it arrives at a given storage site- Grain invaded by storage fungi, even if not detected in ordinary inspection, is partly deteriorated and is a much poorer storage risk than grain free of storage fungi and otherwise sound.

Gibberella





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Management Practices to Minimize Damage from Stored Grain Fungi

1. Harvest as soon as the moisture content allows for minimum grain damage.
2. Adjust the harvesting equipment for minimum kernel or seed damage and maximum cleaning.
3. Clean all grain harvesting and handling equipment thoroughly before beginning to harvest. Clean bins or storage facilities thoroughly to remove dirt, dust and other foreign material, crop debris, chaff and grain debris.
4. Clean grain going into storage to remove light weight and broken kernels or seeds as well as foreign material and fines.
5. Moisture content is by far the most important factor affecting the growth of fungi in stored grain. After harvest grain should be dried to safe moisture contents as quickly as possible.
6. Aerate grain to safe and equalized temperatures through the grain mass.
7. Protect grain from insect and mite damage.
8. Check stored grain on a regular basis and aerate as needed to maintain low moisture and proper temperature.
9. High moisture corn can be protected from storage molds with propionic acid or other organic acids sold under various trade names. Grain treated with propionic acid can only be used for animal feed only.

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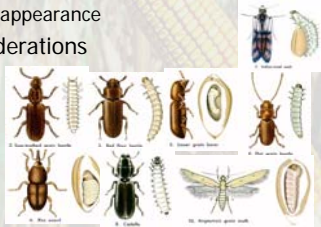
Storage Time & Need for Treatment

- If harvested grain (corn, soybeans) will only be stored until May or June the following year, may not need chemical strategies at all (of the listed above)
- Wheat is more susceptible to infestation due the time of year in which it's harvested and the temp
 - Insect populations are higher
 - Insects are actively reproducing
 - May not need treatment if you plan to store for only 1 month
- All long-term stored grains are at high risk for some level of insect infestation

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Insect Identification & Damage

- **Insects Attacking Stored Grain**
 - Identification is difficult because of small size of the insects
 - Many are similar in appearance
 - Management considerations may vary with the insect



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Preventing Insect Infestations

- Sources of infestations
 - Most originate from migration from outside to inside of the bin
 - Most problem insects have many food sources, but a bin full of grain is like going to Ponderosa
 - Other sources of infestations
 - Old grain
 - Spilled grain
 - Feeds, seeds, grain debris

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Preventing Insect Infestations

- Many infestations are carried over from bins not cleaned out completely, feed bins, or from grain debris under the bin
- Sanitation
 - ~2 weeks before introducing new grain, clean all old grain from the bin both inside and out
 - Sweep or vacuum, then discard or feed all grain still in wagons, augers, etc.

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Safety in Applying Structural & Residual **Protectants**


- Read all labels and follow instructions
- Use PPE recommended
- Check label for grains that can be treated
- Follow label rates to keep grain salable (within legal tolerances)



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In Missouri, the Poison Control Center is accessible 24 hours-a-day by calling:

1-800-222-1212



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Questions??

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Fax: 417-468-2086
E-mail: schultheisr@missouri.edu
Web: extension.missouri.edu/webster

Program Complaint Information
To file a program complaint you may contact any of the following:

University of Missouri

- MU Extension AA/EEO Office
109 F. Whitten Hall, Columbia, MO 65211
- MU Human Resources Office
130 Heinkel Bldg, Columbia, MO 65211

USDA

- Office of Civil Rights, Director
Room 326-W, Whitten Building
14th and Independence Ave., SW
Washington, DC 20250-9410

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