Regular checks reduce moisture risk in stored grain

Condensation is often observed on the inside of metal grain storage bins or on the surface of the grain bulk, causing significant moisture damage to grain. CSIRO researchers have investigated the reasons why condensation and moisture damage occur in grain storage bins and how growers can manage the problem.

by **Len Caddick,**
CSIRO

To maintain grain quality, growers are urged to regularly sample the surface of grain bulks to check for insects, rising moisture levels and possible mould damage.

CSIRO research shows the two main causes of moisture damage on the surface of grain bulks are condensation in the headspace (inside the roof of metal storage bins) and moisture migration within the grain bulk.

These processes can combine to increase the problem and if left unchecked, significant moisture damage and moulding will occur at the grain surface.

Temperature variations in grain

The main cause of moisture movement in stored grain is temperature gradients.

Grain is a good insulator and heat loss at the edges of a grain bulk during the cooler months occurs at a much faster rate than the well-insulated inner core. This results in temperature gradients in undisturbed, unaerated bulks.

Cold air has a higher density than warm air, with air density decreasing as temperature increases. In the absence of any other effect, cold air will fall and displace warmer, less dense air.

As grain near the silo wall cools, warmer air in central parts of the bulk is ‘pumped’ by this cold dense air leading to the formation of air currents which circulate in loops from the cooler outer areas up through the warmer inner core (see Figure 1).

The cold air warms as it is gradually forced up through the central core of the bulk and takes up moisture.

At a glance

- CSIRO research shows the main causes of moisture damage in grain storage bins are condensation inside the bin roof and moisture movement in the grain bulk.
- Moisture damage can be caused by a range of factors including moisture migration via natural air currents, harvest condensation on cold surfaces and insect infestation.
- Regularly sample stored grain to check for insects, increased moisture levels and mould damage.

CSIRO Stored Grain Research Laboratory

Cooling grain in storage bins using aeration will maintain uniform temperature and moisture levels throughout the bulk and help reduce the risk of moisture damage (as pictured) in stored grain.

The warm, moisture-laden air then starts to cool as it approaches the grain surface, its capacity to hold moisture is reduced and moisture condenses at the cool grain surface and the cycle continues. This is referred to as moisture migration.

Grain spoilage is often the result of moisture accumulation. Damage can be significant when convection currents become well established and the grain is held undisturbed in storage for long periods.

Moisture movement

The behaviour of air currents in grain bulks is complex.

A key influence is the peak or ridge present in grain stored in bins. This acts as a chimney effectively channelling warm moist air, leading to moisture accumulation in the ridge or peak area.

Mould and insect spoilage in this area is often associated with moisture migration.

The rate that natural convection currents establish is also influenced by bulk density. Grain type, seed size and the amount of fine screenings present influence bulk density.

Natural convection currents appear to establish at a faster rate where clean grain of low bulk density is held in well-sealed storage bins.

For example, there have been numerous reports from growers of significant moisture damage where large-seeded pulses were stored in sealed farm bins.

Grain stored at higher moisture contents is at higher risk of moisture damage mainly because it is stored closer to the threshold, which will allow moulds to develop.

Higher grain moisture content also means more moisture can be evaporated into the air current and carried to other parts of the bulk.

Natural convection occurs just as readily in dry grain but moisture aggregation at the surface takes longer to reach a level where spoilage occurs.

The influence sealed storage has on moisture movement has been hotly debated. Sealed bins prevent air in the headspace of storage bins being mixed with external air. This can allow moisture migration and accumulation to progress with minimal interference.

But the increased level of grain spoilage risk in sealed bins due to moisture movement and condensation is difficult to quantify.

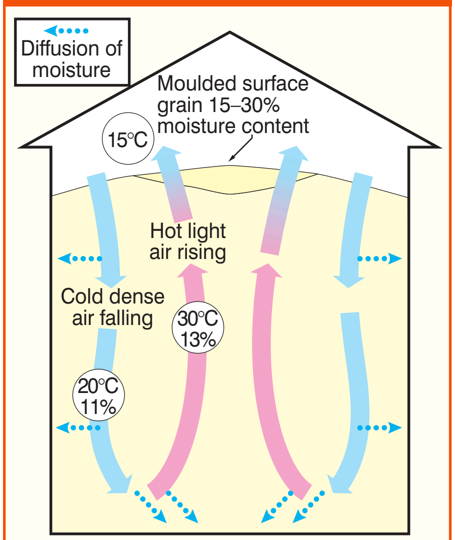
Condensation after harvest

Condensation in the headspace of storage bins immediately after harvest can result in moisture damage at the grain surface.

Grain temperatures at harvest can be more than 30 degrees Celsius.

Warm moist air moves into the headspace of the silo following inloading. When the surface of the bin structure has cooled due to daily changes in ambient temperature, condensation occurs. This is referred to as night ‘top silo cooling’ or ‘silo sweating’.

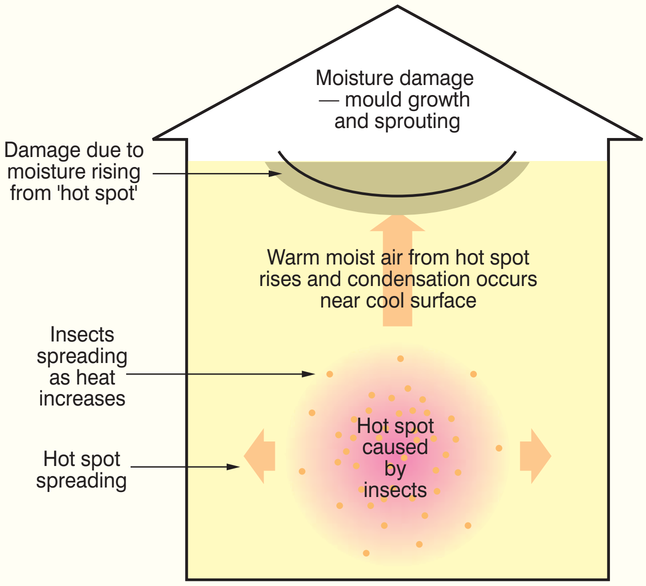
FIGURE 1 Air movement in grain



Note: Natural convection currents are formed by displacement of hot air by dense cold air.

Source: CSIRO Stored Grain Research Laboratory.

FIGURE 2 Insect infestations can cause 'hot spots' to form in grain stores



Note: Moisture carried by warm air rises and condenses on cool grain at the bulk surface.

Source: CSIRO Stored Grain Research Laboratory.

Headspace condensation is most likely to occur during the initial weeks after harvest.

Moisture transfer by diffusion

Moisture moves between grains by diffusion in response to temperature and moisture differences. Diffusion gradually evens out the grain moisture in a storage bin.

The variation in grain moisture content at harvest is generally higher than the variation obtained at out-turn following 3–9 months storage.

Evening out of grain moisture can be beneficial for some seed types, particularly pulses such as chickpeas and field peas where uniform seed size and moisture content is important to achieve high processing efficiency.

Aeration can be used to even out grain moisture and disrupt the formation of natural convection currents in bulk grain.

Biological influences

Moisture produced through biological factors such as insect and mould activity and grain respiration can result in damage and moulding at the bulk surface.

In Australia, grain is generally harvested at moisture levels well below that required for the growth of typical storage fungi.

Similarly, grain respiration occurs slowly in dry grain. But insects can breed in grain as dry as nine per cent moisture content when temperatures are favourable.

The peak area of a stored bulk is particularly prone to moisture aggregation and insects are often detected in this area due to more favourable moisture levels.

Regularly sample the surface of a grain bulk to check for insects, rising moisture levels and possible mould damage.

Avoid entry into a bin, instead use a probe or sampling cup attached to a cable. Never enter a bin containing fumigated grain.

Insects produce heat and moisture during their development and an infestation that develops below the grain surface can form a 'hot spot' in a grain bulk (see Figure 2).

The localised temperature increase and moisture within the developing hot spot provides favourable conditions for rapid insect and mould development, adding further heat and moisture.

The heat generated often raises grain temperatures well above 40°C, forcing insects to move away from the core of the hot spot. The warm, moisture-laden air formed within the hot spot rises to the bulk surface and moisture condenses on cooler grain or the bin structure.

Significant condensation and moisture damage due to biological influences will not occur in well-managed grain stores.

Where insect infestation does occur, early detection and treatment will avoid the problems associated with hot-spots.

Cooling using aeration

Moisture moves from areas of high temperature to cooler parts of the grain bulk through the formation of natural convection currents.

Aeration disrupts the formation of temperature gradients in a bulk by cooling and maintaining the grain at a uniform temperature. Aeration also can be used to even out grain moisture in a bin.

Grain aeration is the pumping of ambient air through a static grain bulk using a fan and a suitable arrangement of perforated ducts and exhaust vents to allow efficient distribution and airflow through the grain bulk.

Where cooling alone is required, an airflow rate of up to 2.5 litres per second per tonne (L/s) is adequate.

Aeration-cooling aims to establish and maintain uniform temperature and moisture levels in the grain and to keep the temperature as low as possible.

If the main objective of aeration is to prevent moisture migration and even out temperature, a smaller capacity aeration-maintenance system which delivers airflow rates less than 1.0L/s is suitable.

Aeration-cooling also slows insect development and maintains quality of the commodity during long-term storage.

Grain temperatures less than 20°C curb the development of insect pests and at or less than 15°C insect development ceases or takes place slowly.

But low temperatures are difficult to achieve during summer so aeration needs to be used in an integrated insect control approach.

Grain storage at lower temperatures is the best way of maintaining grain quality, particularly for preserving germination in malting barley and canola oil quality.

White painted bins

Heat-reflective white-painted bins reduce heating by sunlight and enhance passive cooling.

The temperature difference at the edges of a grain bulk near the walls and upper surface can be up to 5°C lower in painted bins.

Insulating the outer layers of grain from radiant heating improves the efficiency of aeration-cooling.

Reducing the fluctuations in grain temperature at the edges of a grain bulk between day and night also reduces the effect of night 'top silo cooling' which causes condensation of water from air and wetting of the grain peak.

Turning grain in unaerated silos

In bins without aeration, turning grain during storage will even out temperature and moisture contents, disrupting the formation of convection currents. The formation of hot spots is also reduced as insects are dispersed through the bulk.

Grain drawn from the bottom hopper of a bin is initially taken from the central core and the bulk surface in a funnel flow pattern.

Warm grain removed from the core of the bulk is mixed with cool grain from the surface and then placed back onto the top where further passive cooling occurs. Regular turning of this portion of a grain bulk (about one-third of a bin's capacity) can be an effective method of temperature management.

For more information contact Len Caddick, CSIRO Stored Grain Research Laboratory, by email on Len.Caddick@csiro.au, phone (02) 6246 4214 or fax (02) 6246 4202 or visit the web site at http://sgrl.csiro.au.