NORTHERN

MARCH 2018

GRDC GROWNOTES™

GRDC GRAINS RESEARCH & DEVELOPMENT CORPORATION

TRITICALE

SECTION 13

STORAGE

GRDC'S STORED GRAIN INFORMATION HUB | HOW TO STORE GRAIN ON-FARM | STORED GRAIN PESTS | AERATION DURING STORAGE | GRAIN PROTECTANTS FOR STORAGE

Storage

Key messages

- Long-term on-farm storage of triticale will be a problem unless the storage facility is sealed silos.
- Triticale grain is softer than wheat and barley grain. Soft grain is more prone to attack from weevils and other grain storage insects.
- Maintain grain at under 10% moisture content to minimise insect infestation.
- Fumigation during to storage in sealed silos effectively reduces the risk of insect damage when storing triticale.
- Storing grain at levels less than 12% moisture content does not eliminate the need for treating it with insecticide, although it does avoid spoilage from mould and fungus growth.
- It is recommended to use a protectant when storing triticale after harvest. Aeration is also recommended.
- The moisture content and the temperature of the grain at harvest determine the safe storage period. Drying and cooling of freshly harvested, moist, warm grain is an important operation before it goes for processing or storage.

Drying and storing triticale is similar to the process for wheat or rye. However, more care must be taken, especially for long-term storage, since triticale has a softer kernel and is extremely sensitive to grain-insect infestations, far more so than wheat, and more so than barley (Photo 1). [1]

Photo 1: *Warehouse beetle found in stored cereal grain.*

Source: DAFWA

Triticale should be stored in a dry, well-ventilated area to reduce the likelihood of damage from moisture. The preferred harvest moisture content (MC) to reduce damage due to heating caused by moulding is 12% or less. [2] However, the lower the MC the better. Storing grain at less than 12% does not eliminate the need for treating it with insecticide; however, it does avoid spoilage from mould and fungus growth. [3]

1 DAFWA (2016) Insect pests of stored grain. DAFWA, https://www.agric.wa.gov.au/pest-insects/insect-pests-stored-grain

2 M Mergoum, H Gómez-Macpherson (eds) (2004) Triticale improvement and production. FAO Plant Production and Protection Paper No. 179. Food and Agriculture Organisation, http://www.fao.org/docrep/009/y5553e/y5553e00.htm

3 Waratah Seed Company (2010) Triticale: planting guide. Waratah Seed Company, http://www.porkcrc.com.au/1A-102_Triticale_Guide_Final_Fact_Sheets.pdf

It is recommended to use a protectant and aeration when storing triticale after harvest. [4] When storing, it is critical to pay attention to:

- truck, auger, silo or storage bin hygiene
- grain temperature
- grain moisture content
- grain insecticide treatment
- regular monitoring

Seek professional advice about storing triticale to reduce the risk of insect infestation and, subsequently, significant grain losses.

Triticale may also support fungal development. Some triticales show high levels of enzymatic activity, even in the absence of visual sprouting or spike wetting. In sprouted grain, this may promote fungal development during storage, or may have deleterious effects on the food-processing characteristics of grain. [5]

13.1 GRDC's Stored Grain Information Hub

Following the work already done through the Grain Storage Extension Project, the GRDC funded another three years of work, allowing grain storage extension support to continue to 2018.

The project provides an online facility, the Stored Grain Information Hub, to equip growers with the skills and knowledge to carry out the best management of on-farm grain storage. Apart from the resources on the dedicated website, more information on the grain storage extension project and to arrange for a workshop in your area, you can contact a member of the team:

- National hotline, 1800 933 845 (1800 weevil)
- Queensland and northern NSW, Philip Burrill, philip.burrill@daff.qld.gov.au
- Southern NSW, Victoria, SA and Tasmania, Peter Botta, pbotta@bigpond.com
- WA, Ben White, ben@storedgrain.com.au
- Project coordinator, Chris Warrick, info@storedgrain.com.au

MORE INFORMATION

Stored grain information hub

13.2 How to store grain on-farm

On-farm grain storage is a significant investment. Many farms have older storage facilities that cannot be sealed for grain fumigation purposes, but replacing them with sealable silos may not be economically viable.

Growers might only plan to store grain on the farm for a short time, but markets can change, requiring grain to be stored for longer than anticipated, so investing in gas-tight sealable structures means you can treat pests reliably and safely, and remain open to a range of markets.

Growers should approach storage as they would purchasing machinery. They spend a lot of time researching a header purchase to make sure it is fit for their purpose; in the same way, because grain storage can also be a significant investment, and even a permanent one, it pays to do thorough research and develop a storage plan that adds value to your enterprise into the future.

Agronomist's tip: Decide what you want to achieve with storage, critique existing infrastructure and be prepared for future changes. A good storage plan can remove a lot of stress at harvest: growers need a system that works so they capture a better return in their system. [6]

4 Waratah Seed Company (2010) Triticale: planting guide. Waratah Seed Company, http://www.porkcrc.com.au/1A-102_Triticale_Guide_Final_Fact_Sheets.pdf

5 M Mergoum, H Gómez-Macpherson (eds) (2004) Triticale improvement and production. FAO Plant Production and Protection Paper No. 179. Food and Agriculture Organisation, http://www.fao.org/docrep/009/y5553e/y5553e00.htm

6 GRDC (2015) Extension tailored for regional challenges. Ground Cover. Issue 119. GRDC, https://grdc.com.au/Media-Centre/Ground-Cover-Supplements/Ground-Cover-Issue-119--Grain-storage/Extension-tailored-for-regional-challenges

A mixed-storage strategy could be the solution. The strategy is to purchase a small number of sealable silos and to use them to batch-fumigate grain prior to sale. This works because grain silos in the Northern Region are aeration cooled for most of the time, and only sealed for the purpose of fumigation.

There are several reason why growers might consider storing grain on the farm including:

- improving harvest logistics
- taking advantage of higher grain prices some time after harvest
- supplying a local market (e.g. feedlot, dairy)
- avoiding high freight costs at peak time
- adding value by cleaning, drying or blending grain
- retaining planting seed

In most cases, for on-farm storage to be economical it needs to deliver on more than one of these benefits. There are advantages and disadvantages with each of the four main storage systems: sealed silos, unsealed silos, storage bags, and storage sheds (Table 1). Under very favourable circumstances, grain-storage facilities can pay for themselves within a few years, but it is also possible for an investment in on-farm storage to remain unprofitable. A grain storage cost–benefit analysis template is very useful tool in the decision-making process to test the viability of grain storage on your farm. [7]

Table 1: *Advantages and disadvantages of grain storage options.*

Storage type	Advantages	Disadvantages
Gas-tight, sealable silo	Gas-tight, sealable status allows phosphine and controlled atmospheres to control insects Easily aerated with fans Fabricated on-site, or off-site and transported Capacity from 15 t to 3,000 t 25 years or more of service life Simple in-loading and out-loading Easily administered hygiene (cone-based silos particularly) Can be used multiple times in a season	Requires foundation to be constructed Relatively high initial investment required Seals must be maintained regularly Access requires safety equipment and infrastructure Requires and annual test to check gas-tight sealing
Unsealed silo	Easily aerated with fans 7–10% cheaper than sealed silos Capacity from 15 t to 3,000 t Up to 25 year service life Can be used multiple times in a season	Requires foundation to be constructed Silo cannot be used for fumigation Insect control limited to protectants in eastern states and Dryacide® in WA Access requires safety equipment and infrastructure

7 GRDC (2015) Grain storage strategies in the northern region. GRDC, https://grdc.com.au/Media-Centre/Hot-Topics/Grain-storage-strategies-in-the-northern-region

Storage type	Advantages	Disadvantages
Grain-storage bags	Low initial cost Can be laid on a prepared pad in the paddock Provide harvest logistics support Can provide segregation options Are ground operated	Requires purchase or lease of loader and unloader Increased risk of damage to grain beyond short-term storage (typically three months) Limited insect control options, with fumigation possible only under specific protocols Requires regular inspection and maintenance, which need to be budgeted for Aeration of grain bags currently limited to research trials only Must be fenced off Prone to attack by mice, birds, foxes, etc. Limited wet-weather access if stored in paddock Need to dispose of bag after use Single-use only
Grain-storage sheds	Can be used for dual purposes 30 years or more of service life Low cost per stored tonne	Aeration systems require specific design Risk of contamination from dual purpose use Difficult to seal for fumigation Vermin control is difficult Limited insect control options without sealing Difficult to unload

Source: Kondinin Group

13.2.1 Silos

As triticale is very prone to damage from insects during storage due to its soft kernel, the grain should be stored at less than 10% MC, preferably in sealed silos (Photo 2).[8] Treat the grain as it enters the silo and then check regularly (every 2–3 months) for reinfestation.

MORE INFORMATION

Benefits flow from on-farm storage

Prepare on-farm storage early to protect your harvest

Investment in on-farm storage and the grain supply chain

Grain storage: invest today for the system of tomorrow

8 Stored Grain Information Hub (2014) Pressure testing sealable silos. GRDC, http://storedgrain.com.au/pressure-testing/

Photo 2: *Sealable silos help growers protect triticale from insect attack, but for silos to remain effective, they must be maintained and regularly pressure-tested.*

Source: GRDC

Sealed silos offer a more permanent grain storage option than grain storage bags. Depending on the amount of storage required, they will have a higher initial capital cost than bags, and can be depreciated over a longer time frame than the machinery required for the grain bags. With a silo system, as stored tonnage increases, the capital cost of storage increases.

The advantages of using sealed grain silos as a method for grain storage include improved harvest management, reduced harvest stress, reduced harvest-freight requirements, minimal insecticide exposure for the grower and farm workers, and the opportunity to segregate and blend grain.

The disadvantages include the initial capital outlay, the outlay required to meet occupational health and safety (OH&S) requirements, the additional handling required on the farm, and the additional site-maintenance requirements. [9]

Pressure testing

- A silo sold as a sealable unit needs to be pressure tested to be sure it's gas-tight.
- It is strongly recommended that growers ask the manufacturer or reseller to quote the Standards Australia number AS2628 on the invoice as a means of legal reference to the quality of the silo being paid for.
- Pressure-test sealable silos upon erection, annually, and before fumigating, by conducting a five-minute half-life pressure test.
- Maintenance is the key to ensuring a silo purchased as sealable can be sealed and gas-tight.

A silo is only truly sealable if it passes a five-minute half-life pressure test according to the Australian Standard AS2628. Often silos are sold as sealed but are not gas-tight—rendering them unsuitable for fumigation.

There is no compulsory manufacturing standard for sealed silos in Australia. Although a voluntary industry standard was adopted in 2010, it remains in the buyer's own interests to test silos before purchase.

Even if a silo is sold as sealable it is not until it is proven to be gas-tight using a pressure test. The term 'sealed' has been used loosely in the past, and some silos

9 J Francis (2006) An analysis of grain storage bags, sealed grain silos and warehousing for storing grain. Holmes Sackett and Associates

MORE INFORMATION

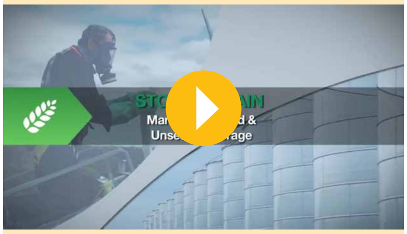
Stored Grain Information Hub, Pressure testing sealable silos

GRDC, Silo buyer's guide

VIDEOS

WATCH: GCTV2: Pressure testing sealed silos

WATCH: Stored grain: Managing sealed and unsealed storage



WATCH: GCTV2: National standards for sealed silos

may not have been gas-tight from the day they were constructed. However, even a silo that was gas-tight to the standard on construction will deteriorate over time, so it needs annual maintenance to remain gas-tight.

Why test the pressure?

In order to kill grain pests at all stages of their life cycle (egg, larvae, pupae, adult), phosphine gas concentrations need to reach and remain at 300 parts per million (ppm) for seven days, or 200 ppm for 10 days.

The importance of a gas-tight silo

National agricultural surveys have revealed that around 85% of growers have used phosphine at least once during the previous five years, and that ~37% of growers use phosphine every year. A Grains Research and Development Corporation survey during 2010 revealed that only 36% of growers using phosphine applied it correctly, i.e. in a gas-tight, sealed silo (Figure 1).

Research shows that fumigating in a storage that does not meet the industry standard does not achieve a high enough concentration of fumigant for a long enough period to kill pests at all life-cycle stages (Figure 2). For effective phosphine fumigation, a minimum gas concentration of 300 ppm for seven days, or 200 ppm for 10 days, is required. Fumigation trials in silos with small leaks demonstrated that phosphine levels are as low as 3 ppm close to the leaks. In the rest of the silo gas levels are also too low. [10]

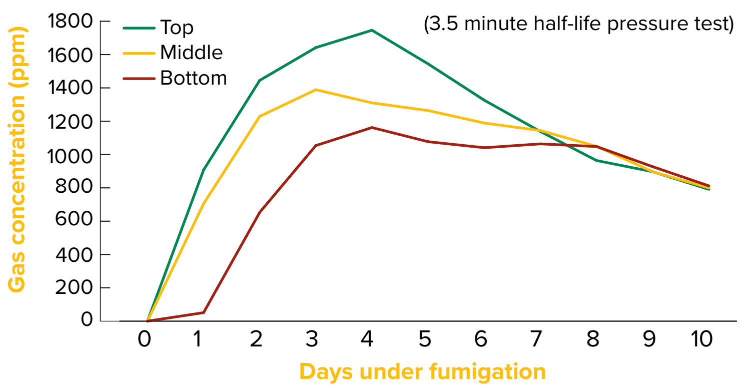


Figure 1: *Gas concentration in gas-tight silo.*

Source: GRDC

10 P Botta, P Burrill, C Newman (2010) Pressure testing sealable silos. Factsheet. GRDC, http://storedgrain.com.au/pressure-testing/

MORE INFORMATION

Fumigating with phosphine, other fumigants and controlled atmospheres

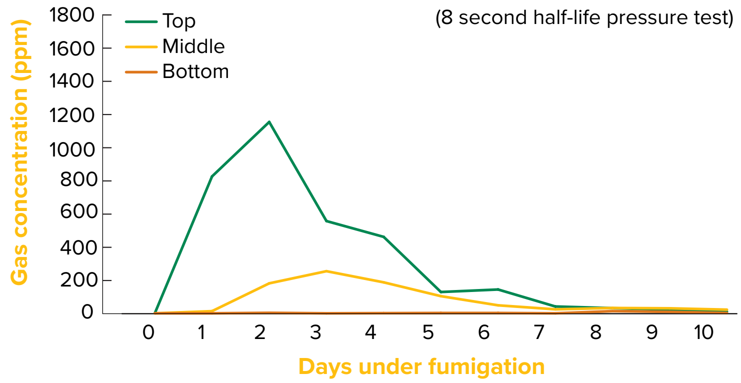


Figure 2: *Gas concentration in non-gas-tight silo.*

Source: GRDC

It is recommended to pressure-test silos that are sealable once a year to check for damaged seals on openings.

13.2.2 Grain bags

Grain-storage bags are a relatively new technology, and offer a low-cost alternative to silos for the temporary storage of grain on the farm. They are made of a multilayer polyethylene material similar to that used for silage fodder. Bags typically store 200–220 t of cereal grain, and are filled and emptied using specialised machinery (Photo 3). [11] The bags are sealed after filling, producing a relatively airtight environment which, under favourable storage conditions, protects grain from insect damage without the use of insecticides.

The potential advantages of using grain-storage bags include the low capital set-up costs, improved harvest management, less harvest stress, reduced harvest-freight requirements, minimal cost for OH&S requirements, reduced grain-insecticide requirements, and the opportunity to segregate and blend grain.

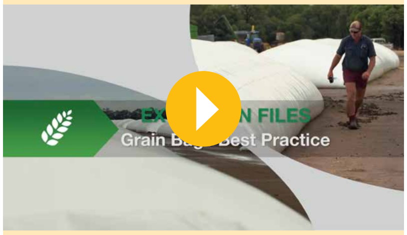
The potential disadvantages include the need to dispose of used bags, and the relatively short period of storage (~6–8 months) before bags begin to deteriorate and management becomes necessary to ensure bag integrity. Grain bags can also be prone to animal attacks from birds, foxes and pigs. Another potential disadvantage of this system, when compared to permanent structures, is that once the storage period is complete there is no asset value in the storage system other than the bagging machinery. [12]

11 T Meersman (2014) More farmers seeking storage are turning to grain bags. 4 October. Star Tribune, http://www.startribune.com/more-farmers-seeking-storage-are-turning-to-grain-bags/278072461/

12 J Francis (2006) An analysis of grain storage bags, sealed grain silos and warehousing for storing grain. Holmes Sackett and Associates

VIDEOS

WATCH: GCTV extension files: Grain bags—best practice



WATCH: GCTV extension files: Grain bags—a grower's perspective

WATCH: GCTV2: Grain silo hygiene

Photo 3: *A 100 m bag can be filled in 30 minutes when there is a constant supply of grain.*

Source: Star Tribune

13.2.3 Hygiene

The first grain harvested is often the grain at the greatest risk of early insect infestation, due to contamination by pests that have been inadvertently harboured in machinery and equipment since the previous harvest. One on-farm test found more than 1,000 lesser grain borers in the first 40 L of wheat that passed through the harvester.

This shows how important it is to remove grain residues from empty storages and grain-handling equipment, including harvesters, field bins, augers and silos to ensure an uncontaminated start for new-season grain.

Clean equipment by blowing or hosing out residues and dust, and then consider a structural treatment. Bury, use or burn any grain left in hoppers and bags from the grain-storage site so it doesn't provide a habitat for pests during the off-season. Always thoroughly clean trucks, augers and storages prior to storing triticale. Dust and grain from previous years' grain should all be completely removed to avoid rapid infestation with stored-grain insects. [13]

13.2.4 Monitoring stored grain

Check the grain regularly during storage for signs of insect activity, and be prepared to deal with an infestation if it occurs. [14] When monitoring grain temperature and moisture content, take note of the following:

- Pests and grain moulds thrive in warm, moist conditions. Monitor grain moisture content and temperature to prevent storage problems.
- Use a grain-temperature probe to check storage conditions and aeration performance (Photo 4).
- When checking grain, smell the air at the top of storages for signs of high grain moisture or mould problems.
- Check germination and vigour of planting seed in storage.
- Aeration fans can be used to cool and dry grain to reduce problems of the storage environment.

13 Waratah Seed Company (2010) Triticale: planting guide. Waratah Seed Company, http://www.porkcrc.com.au/1A-102_Triticale_Guide_Final_Fact_Sheets.pdf

14 Waratah Seed Company (2010) Triticale: planting guide. Waratah Seed Company, http://www.porkcrc.com.au/1A-102_Triticale_Guide_Final_Fact_Sheets.pdf

It is vital to monitor grain moisture content to prevent pests and grain moulds from thriving. [15]

Photo 4: *Use a digital probe to monitor moisture and temperature from both the top and the bottom of silos, if safe to do so.*

Source: Plant Health Australia

13.2.5 Grain storage: get the economics right

As growers continue to expand their on-farm grain storage, the question of economic viability gains in significance. There are many examples of growers investing in on-farm grain storage and paying for it in one or two years because they struck the market at the right time, but are these examples enough to justify greater expansion of on-farm grain storage for most farmers?

The grain-storage extension team conducts approximately 100 grower workshops every year Australia wide, and it's evident from these that no two growers use on-farm storage in the exact same way: like many other economic comparisons in farming, the viability of grain storage is different for each grower. Depending on the business's operating style, the location, the resources, and the most limiting factor to increase profit, grain storage may—or may not—be the next best investment. For this reason, everyone needs to do a simple cost–benefit analysis of their own operation.

Comparing on-farm storages

To make a sound financial decision, growers need to make two comparisons. The first is to compare the expected returns from using storage with expected returns from other farm-business investments and decisions, such as more land, a chaser bin, a wider boomspray, a second truck, or paying off debt. The other comparison is to determine if they can store grain on the farm cheaper than paying a bulk handler to store it.

Calculating the costs and benefits of on-farm storage will give the grower a return on investment (ROI) figure, which can be compared with other investment choices and the total cost of storage with bulk handlers.

Cheapest form of storage

The key to a useful cost–benefit analysis is identifying which financial benefits to plan for, and costing an appropriate storage to suit that plan. People often ask, 'What's the cheapest form of storage?' The answer is the storage that suits the planned benefits. Short-term storage for harvest logistics or freight advantages can be suited to grain bags or bunkers. If flexibility is required for longer-term storage, gas-tight, sealable silos with aeration cooling allow quality control and insect control.

15 Plant Health Australia (2015) Monitoring stored grain on farm. Plant Health Australia, http://www.planthealthaustralia.com.au/wp-content/uploads/2018/03/Monitoring-stored-grain-on-farm-2018.pdf

Benefits

To compare the benefits and costs in the same form, work everything out on the basis of dollars per tonne. On the benefit side, the majority of growers will require multiple financial gains for storing grain to make money out of it. These might include harvest logistics or timeliness, market premiums, freight savings or cleaning, blending, or drying grain to add value.

Costs

The costs of grain storage can be broken down into fixed and variable. The fixed costs are those that don't change from year to year and have to be covered over the life of the storage. Examples are depreciation and the opportunity or interest cost on the capital. The variable costs are all those that vary with the amount of grain stored and the length of time it's stored for. Interestingly, the costs of good hygiene, aeration cooling and monitoring are relatively low compared to the potential impact they can have on maintaining grain at a high quality. One of the most significant variable costs, and one that is often overlooked, is the opportunity cost of the stored grain; i.e. the cost of having grain in storage rather than having the money in the bank paying off an overdraft or a term loan.

The result

While it's difficult to put a precise dollar value on each of the potential benefits and costs, a calculated estimate will determine if it's worth a more thorough investigation. If a grower compares the investment of on-farm grain storage to other investments and the result is similar, then they can revisit the numbers and work on increasing their accuracy. If the return is not even in the ball park, the grower has potentially avoided a costly mistake. On the contrary, if after checking the numbers the return is favourable, they can proceed with the investment confidently.

Summary

Unlike a machinery purchase, grain storage is a long-term investment that cannot be easily changed or sold. Based on what the grain-storage extension team is seeing around Australia, those growers who take a planned approach to on-farm grain storage and do it well are being rewarded for it. Grain buyers are seeking out growers who have a well-designed storage system that can deliver insect-free, quality grain without delay.

Table 2 can be used to figure out the likely economic result of on-farm grain storage for an individual business. Each column can be used to compare storage options, including type of storage, length of time held or paying a bulk handler. [16]

16 C Warrick (2016) Grain storage: get the economics right. GRDC Update Paper. GRDC, https://grdc.com.au/Research-and-Development/GRDC-Update-Papers/2016/09/Grain-storage-get-the-economics-right

Table 2: *Cost–benefit template for grain storage.*

Financial gains from storage		Example $/t	Your $/t
Harvest logistics, timeliness	Grain price x reduction in value after damage % x probability of damage %	$16.00	
Marketing	Post-harvest grain price–harvest grain price		
Freight	Peak rate $/t–post harvest rate $/t	$20.00	
Cleaning to improve grade	Clean grain price–original grain price–cleaning costs–shrinkage		
Blending to lift average grade	Blended price–((low grade price x %mix) + (high grade price x %mix))		
Total benefits	Sum of benefits	$36.20	
Capital cost	Infrastructure cost/storage capacity	$155.00	
Fixed costs			
Annualised depreciation cost	Capital cost $/t ÷ expected life storage (e.g. 25, for 25 years)	$6.20	
Opportunity cost on capital	Capital cost $/t x opportunity or interest rate e.g. 8% / 2	$6.20	
Total fixed costs	Sum of fixed costs	$12.40	
Variable costs			
Storage hygiene	(Labour rate $/h x time to clean hours ÷ storage capacity) + structural treatment	$0.23	
Aeration cooling	Indicatively $0.23 for the first 8 days, then $0.18 per month/t	$0.91	
Repairs and maintenance	Estimate e.g. capital cost $/t x 1%	$1.51	
Inload/outload time and fuel	Labour rate $/h/60 minutes ÷ auger rate t/m x 3	$0.88	
Time to monitor and manage	Labour rate $/h x total time to manage hours ÷ storage capacity	$0.24	
Opportunity cost of stored grain	Grain price x opportunity interest rate e.g. 8% / 12 x number of months stored	$7.20	
Insect treatment cost	Treatment cost $/t x number of treatments	$0.35	
Cost of bags or bunker trap	Price of bag ÷ bag capacity tonne		
Total variable costs	Sum of variable costs	$11.32	
Total cost of storage	Total fixed costs + total variable costs	$23.72	
Profit/Loss on storage	Total benefits–total costs of storage	$12.48	
Return on investment	Profit or loss/capital cost x 100	8.1%	

Source: GRDC

MORE INFORMATION

Stored Grain Information Hub, Economics of on-farm grain storage, cost benefit analysis

Economics of on-farm grain storage: a grains industry guide

VIDEOS

WATCH: Over the Fence: On-farm storage delivers harvest flexibility and profit

WATCH: GCTV: Stay safe around grain storage

13.3 Stored grain pests

Key points:

- Effective grain hygiene and aeration cooling can overcome 85% of pest problems.
- When fumigation is needed it must be carried out in pressure-tested, sealed silos.
- Monitor stored grain monthly for moisture, temperature and pests.

13.3.1 Insecticide treatment

There are three options for insecticide treatment:

- Chemical protectant—applied directly to the grain, it is used to treat uninfested grain, and protects grain for three to nine months, depending on the product.
- Fumigation—only done in a sealed silo; the fumigant is put in a tray or sachet, and put in the head-space of silo so as to prevent physical contact with the grain; it is residue-free; and it minimises insect resistance to chemicals.
- Aeration cooling—is a residue-free means of lowering the temperature of grain to reduce possible insect infestation.

Prevention is better than cure

The combination of meticulous grain hygiene and well-managed aeration cooling generally overcomes 85% of storage pest problems. For grain storage, three key factors provide significant gains for both grain storage pest control and grain quality: hygiene, aeration cooling, and correct fumigation. [17]

13.3.2 Common species

The most common insect pests of stored cereal grains in Australia are

- weevils *(Sitophilus spp.)*—rice weevil is the most common weevil in cereals in Australia
- lesser grain borer *(Rhyzopertha dominica)*
- rust-red flour beetle *(Tribolium spp.)*
- saw-toothed grain beetle *(Oryzaephilus spp.)*
- flat grain beetle *(Cryptolestes spp.)*
- Indian meal moth *(Plodia interpunctella)*
- angoumois grain moth *(Sitotroga cerealella)*

The most common ones are quite distinct from each other, and should be fairly readily identifiable (Figure 3): [18] Another dozen or so beetles, psocids (booklice) and mites are sometimes present as pests in stored cereal grain as well.

17 Stored Grain Information Hub (2016) Northern and Southern Regions grain storage pest control guide. GRDC, http://storedgrain.com.au/pest-control-guide-ns/

18 Stored Grain Information Hub (2013) Northern and southern regions stored grain pests: identification. GRDC, http://storedgrain.com.au/stored-grain-pests-id-ns/

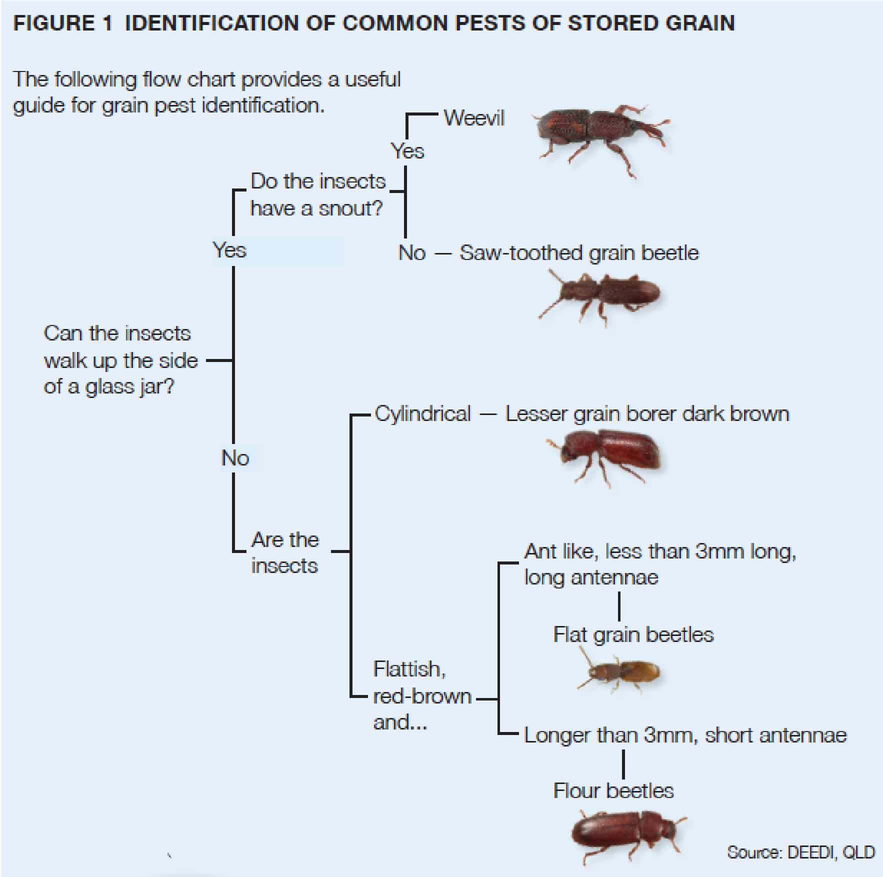


Figure 3: *Identification of common pests of stored grain.*

Source: Stored Grain Information Hub

Why identify insect pests of stored grain pests?

Most insect-control methods for stored grain work against all species, so it is not necessary to identify the storage pests to make decisions about most control methods. But if you intend to spray grain with insecticides you may need to know which species are present if:

- A previous application has failed and you want to know whether resistance was the reason—if more than one species survived, resistance is unlikely to be the cause.
- You intend using a residual protectant to treat infested grain—pyrimiphos-methyl, fenitrothion and chlorpyrifos-methyl are ineffective against the lesser grain borer, and pyrimiphos-methyl and fenitrothion are generally ineffective against the saw-toothed grain beetle.
- You intend to use dichlorvos to treat infested grain—if the lesser grain borer is present you need to apply the higher dose rate, which increases the withholding period (WHP) before grain can be marketed from 7 days to 28 days.

13.3.3 Monitoring grain for pests

Damage by grain pests often goes unnoticed until the grain is removed from the storage. Regular monitoring will help to ensure that grain quality is maintained.

- Sample each grain storage at least monthly. During warmer periods of the year fortnightly sampling is recommended.

MORE INFORMATION

Stored grain pests: identification

MORE INFORMATION

[Stored grain pests: the back pocket guide]

[Monitoring stored grain on farm]

VIDEOS

WATCH: GCTV2: Grain storage insect ID

- Take samples from the top and bottom of grain stores and sieve using 2 mm mesh onto a white tray to separate any insects (Photo 5). [19]
- Hold the tray in the sunlight for 10–20 seconds to trigger movement in any insects, making them easier to see. Use a magnifying glass to identify pests.
- Also use grain probes or pitfall traps to check for insects. Traps are kept in the grain while it is being stored and are often able to detect the start of an infestation.
- Push the probe or trap into the grain surface and pull up for inspection fortnightly or monthly. Place 1–2 traps in the top of a silo or several traps in a grain shed.
- Be sure to check grain three weeks before sale to allow time for treatment if required. [20]

Photo 5: *A 2 mm mesh sieve will separate insects from grain.*

Source: Plant Health Australia

13.3.4 Hygiene

Key points:

- Effective grain hygiene requires the complete removal of all waste grain from storages and equipment.
- Be meticulous with grain hygiene: pests only need a small amount of grain for survival.

A bag of infested grain can produce more than one million insects in a year—and these million can walk and fly to other grain storages where they will start new infestations. Therefore, meticulous grain hygiene is important. It involves removing any grain that can harbour pests and allow them to breed. It also includes regular inspection of seed and stockfeed grain so any pest infestations can be controlled before pests spread.

Where to clean

Removing an environment for pests to live and breed in is the basis of grain hygiene, and encompasses all grain-handling equipment and storages. Grain pests live in dark, sheltered areas and breed best in warm conditions. Common places to find them are:

- empty silos and grain storages
- aeration ducts, augers and conveyers
- harvesters, field bins and chaser bins
- leftover bags or loose grain in grain trucks
- spilt grain around grain storages

19 Plant Health Australia (2015) Monitoring stored grain on farm. Plant Health Australia, http://www.planthealthaustralia.com.au/wp-content/uploads/2018/03/Monitoring-stored-grain-on-farm-2018.pdf

20 Plant Health Australia (2015) Monitoring stored grain on farm. Plant Health Australia, http://www.planthealthaustralia.com.au/wp-content/uploads/2018/03/Monitoring-stored-grain-on-farm-2018.pdf

- equipment and rubbish around storages
- seed grain
- stockfeed grain

Successful grain hygiene involves cleaning all areas where grain gets trapped in storages and equipment (Photo 6). [21] Grain pests can survive in a tiny amount of grain, so any parcel of fresh grain in a machine or storage can become infested.

Photo 6: *Grain left in trucks is an ideal place for grain pests to breed. Keep trucks, field bins and chaser bins clean.*

Source: Stored Grain Information Hub

When to clean

Straight after harvest is the best time to clean grain-handling equipment and storages, before they become infested with pests. One trial revealed more than 1,000 lesser grain borers in the first 40 L of grain through a harvester at the start of harvest; the harvester had been considered to be reasonably clean at the end of the previous season. Discarding the first few bags of grain at the start of the next harvest is a good idea to help keep grain pest-free. Other studies have showed that insects are least mobile during the colder months of the year, so cleaning around silos in July–August can reduce insect numbers before they become mobile.

How to clean

The better the cleaning job, the less the chance of pests being harboured. The best tools to get rid of all grain residues are a combination of:

- brooms
- vacuum cleaners
- compressed air
- blow–vacuum guns
- pressure washers
- fire-fighting hoses

Using a broom or compressed air gets rid of most grain residues (Photo 7) [22], and a follow-up wash-down removes grain and dust left in crevices and hard-to-reach spots. Choose a warm, dry day to wash storages and equipment so it dries out quickly and doesn't rust. When inspecting empty storages, look for ways to make the structures easier to keep clean. Seal or fill any cracks and crevices to prevent grain lodging and

21 Stored Grain Information Hub (2013) Hygiene and structural treatments for grain storage. Factsheet. GRDC, http://storedgrain.com.au/hygiene-structural-treatments/

22 Stored Grain Information Hub (2013) Hygiene and structural treatments for grain storage. Factsheet. GRDC, http://storedgrain.com.au/hygiene-structural-treatments/

insects harbouring. Bags of leftover grain lying around storages and in sheds create a perfect harbour and breeding ground for storage pests. After collecting spilt grain and residues, dispose of them well away from any grain storage areas.

Photo 7: *Clean silos, including the silo wall, with air or water to provide a residue-free surface to apply structural treatments.*

Source: Stored Grain Information Hub

The process of cleaning on-farm storages and handling equipment should start with the physical removal, blowing and/or hosing out of all residues. Once the structure is clean and dry, consider the application of diatomaceous earth (DE) as a structural treatment. See Section 1.2.4 Structural treatments for more information.

A concrete slab underneath silos makes cleaning much easier (Photo 8).

Photo 8: *A concrete slab under silo makes cleaning up spilled grain much easier.*

Source: Stored Grain Information Hub

VIDEOS

WATCH: GCTV2: Grain silo hygiene

13.3.5 Aeration cooling for pest control

While adult insects can still survive at low temperatures, most juveniles stop developing at temperatures below 18–20°C (see Table 3). [23] At temperatures below 15°C the common rice weevil stops developing.

23 Stored Grain Information Hub (2014) Aeration cooling for pest control. Revised. GRDC, http://storedgrain.com.au/aeration-cooling/

MORE INFORMATION

Aeration cooling for pest control

Hygiene and structural treatments for grain storages

At low temperatures insect pest life cycles (egg, larvae, pupae and adult) are lengthened from the typical four weeks at warm temperatures (30–35°C) to 12–17 weeks at cooler temperatures (20–23°C).

Table 3: *The effect of grain temperature on the development of insects and mould.*

Grain temp (°C)	Insect and mould development	Grain moisture content (%)
40–55	Seed damage occurs, reducing viability	–
30–40	Mould and insects are prolific	>18
25–30	Mould and insects are active	13–18
20–25	Mould development is limited	10–13
18–20	Young insects stop developing	9
<15	Most insects stop reproducing, mould stops developing	<8

Source: Kondinin Group

For more information, see Section 13.4.2 Aeration cooling below

13.3.6 Structural treatments

Key points:

- Structural treatments such as diatomaceous earth (DE) can be used on storages and equipment to protect against grain pests.
- Check delivery requirements before using chemical treatments.

Growers who use chemicals as structural treatments run the risk of exceeding the maximum residue limit (MRL) and so this is not recommended. These chemicals do not list storage as a registered use on their labels or their MRLs. If you are storing pulses, or intend to in the future, be aware that MRLs are either extremely low or nil.

A better product to use is diatomaceous earth (DE), sometimes called inert dust. It is an amorphous silica commercially known as Dryacide® and acts by absorbing the insect's cuticle (protective waxy exterior), causing death by desiccation. Using DE as a structural treatment is possible, but the storage and equipment must be washed and dried before using for pulses. This will ensure the DE doesn't discolour the grain surface. If applied correctly, i.e. with complete coverage in a dry environment, DE can provide up to 12 months of protection for storages and equipment.

If unsure, check with the grain buyer before using any product that will come in contact with the stored grain. [24]

13.3.7 Application

Inert dust requires a moving airstream to direct it onto the surface being treated; alternatively, it can be mixed into a slurry with water and sprayed onto surface. Read and follow label directions. Throwing dust into silos by hand will not achieve an even coverage, and so will not be effective. For very small grain silos and bins, a hand-operated duster, such as a bellows duster, is suitable. Larger silos and storages require a powered duster, e.g. a Venturi duster such as the Blovac BV-22 gun (Photo 9), operated by compressed air or a fan. If compressed air is available, it is the most economical and suitable option for use on the farm.

24 Stored Grain Information Hub (2014) Storing pulses. Factsheet. Revised. GRDC, http://storedgrain.com.au/storing-pulses/

Photo 9: *A blower–vacuum gun such as the Venturi gun is the best applicator for inert dusts. Aim for an event coat of diatomaceous earth across the roof, walls and base.*

Photo: C. Warrick, Proadvice

The application rate is calculated at 2 g/m^2 of surface area treated. Although DE is inert, breathing in excessive amounts of it is not ideal, so use a disposable dust mask and goggles during application. Apply DE at the recommended rates (Table 4).

Silo application

Apply inert dust in silos, starting at the top (if safe), by coating the inside of the roof then working your way down the silo walls, finishing by pointing the stream at the bottom of the silo. If silos are fitted with aeration systems, distribute the inert dust into the ducting, taking care not to get it into the motor, where it could cause damage. [25]

Table 4: *DE application guide.*

Storage capacity (t)	Dust quantity (kg)
20	0.12
56	0.25
112	0.42
224	0.60
450	1.00
900	1.70
1800	2.60

13.3.8 Fumigation

There are a number of chemical options for the control of grain pests in stored cereals (Table 5). [26]

VIDEOS

WATCH: GCTV7: Applying diatomaceous earth demonstration

MORE INFORMATION

Hygiene and structural treatment for grain storages

25 Pulse Australia (2013) Northern Chickpea—Best Management Practices Training Course Manual 2013. Pulse Australia.

26 Stored Grain Information Hub (2016) Northern and southern regions grain storage pest control guide. Factsheet. Revised. GRDC, http://storedgrain.com.au/pest-control-guide-ns/

Table 5: *Resistance and efficacy guide for stored grain insects.*

Treatment and example product	WHP	Lesser grain borer	Rust-red flour beetle	Rice weevil	Saw-toothed grain beetle	Flat grain beetle	Psocids (booklice)	Structural treatments
Grain disinfestants—used on infested grain to control full life cycle (adults, eggs, larvae, pupae)								
Phosphine (Fumitoxin®)[1,3] when used in gas-tight, sealable stores	2	Effective control	Effective control	Effective control	Effective control	High-level resistance	Effective control	
Sulfuryl fluoride (ProFume®)[10]	1	Effective control	Effective control	Effective control	Effective control	Effective control		
Grain protectants—applied postharvest. Poor adult control if applied to infested grain								
Pirimiphos-methyl (Actellic 900®)	nil[2]		Effective control	Effective control	Resistance widespread	Effective control		Resistant species likely to survive
Fenitrothion (Fenitrothion 1000®)[4, 7]	1–90		Effective control	Effective control	Resistance widespread			Resistant species likely to survive
Chlorpyrifos-methyl (Reldan Grain Protector®)[5]	Nil[2]	Resistance widespread	Effective control	Effective control	Resistance widespread			Resistant species likely to survive
'Combined products' (Reldan Plus IGR Grain Protector)	Nil[2]	Resistance widespread	Effective control	Effective control	Effective control			Resistant species likely to survive
Deltamethrin (K-Obiol®)[10]	Nil[2]	Effective control	Effective control	Resistance widespread	Effective control	Effective control		
Spinosad and Chlorpyrifos-methyl (eg Conserve On-Form™)[9]		Effective control	Effective control	Effective control	Effective control	Effective control		
Diatomaceous earth, amorphous silica—effective internal structural treatment for storages and equipment. Specific-use grain treatments								
Diatomaceous earth, amorphous silica (Dryacide®)[8]	Nil[2]	Effective control	Effective control	Effective control	Effective control			Effective control

Not registered for this pest
High-level resistance in flat grain beetle has been identified, send insects for testing if fumigation failures occur
Resistant species likely to survive this structural treatment for storage and equipment
Resistance widespread (unlikely to be effective)
Effective control

1 Unlikely to be effective in unsealed sites, causing resistance, see label for definitions
2 When used as directed on label
3 Total of (exposure + ventilation + withholding) = 10 to 27 days
4 Nufarm label only
5 Stored grains except malting barley and rice/ stored lupins registration for Victoria only/ not on stored maize destined for export
6 When applied as directed, do not move treated grain for 24 hours
7 Periods of 6–9 months storage including mixture in adulticide (e.g. Fenitrothion at label rate
8 Do not use on stored maize destined for export, or on grain delivered to bulk-handling authorities
9 Dichlorvos 500 g/L registration only
10 Restricted to licensed fumigators or approved users
11 Restriced to use under permit 14075 only. Unlikely to be practical for use on farm

Source: Registration information courtesy of Pestgenie, APVMA and InfoPest (DEEDI) websites

Before applying, check with your grain buyers and bulk handlers and read labels carefully.

Source: GRDC

Fumigation with phosphine is a common component of many integrated pest-control strategies (Photo 10).

Taking fumigation shortcuts may kill enough adult insects in grain so it passes delivery standards, but the repercussions of such practices are detrimental to the grains industry: poor fumigation techniques fail to kill pests at all stages of the life cycle, so while some adults may die, grain will soon be reinfested again as soon as larvae and eggs develop. What's worse, every time fumigation is carried out poorly, insects with some resistance survive, making the chemical less effective in the future.

VIDEOS

WATCH: GCTV Stored grain: Fumigation recirculation

WATCH: GCTV Stored grain: Phosphine dose rates

Photo 10: *Phosphine is widely accepted as having no residue concerns.*

Photo: DAF Qld

It is important to use phosphine as directed. While there is some resistance to phosphine, it is widely accepted as having no residue concerns for use in grains or pulses. The grain industry has adopted a voluntary strategy to manage the build-up of phosphine resistance in pests: its core recommendations are to limit the number of conventional phosphine fumigations on undisturbed grain to three per year, and to employ a break strategy. [27]

Phosphine application

For effective phosphine fumigation, a minimum of 300 ppm gas concentration for seven days or 200 ppm for 10 days is required.

Achieve effective fumigation by placing phosphine at the correct rates (as directed on the label) onto a tray and hanging it in the top of a pressure-tested, sealed silo, or into a ground-level application system if the silo is fitted with recirculation.

After fumigation, ventilate grain for a minimum of one day with aeration fans running, or for five days if no fans are fitted.

After ventilation, a minimum withholding (WHP) period of two days is required before grain can be used for human consumption or stockfeed.

The total time needed for fumigating is 10–17 days.

As a general rule, only keep a silo sealed while carrying out the fumigation (e.g. one to two weeks). After fumigation has been completed, return to aeration cooling to hold the stored grain at a suitable temperature level.

Handle with care

Phosphine is a highly toxic gas with potentially fatal consequences if handled incorrectly. As a minimum requirement, the label directs users to wear cotton overalls buttoned at the neck and wrist, eye protection, elbow-length PVC gloves, and a breathing respirator with a combined dust and gas cartridge.

27 P Collins (2009) Strategy to manage resistance to phosphine in the Australian grain industry, Cooperative Research Centre for National Plant Biosecurity, http://www.graintrade.org.au/sites/default/files/file/NWPGP/Phosphine%20Resistance%20Strategy.pdf

MORE INFORMATION

GRDC, Grain fumigation guide

Fumigating with phosphine, other fumigants and controlled atmospheres

DAF Queensland, Fumigation to control insects in stored grain

Where to apply

Arrange the tablets where as much surface area as possible is exposed to air, so the gas can disperse freely throughout the grain stack. Spread phosphine tablets evenly across trays before hanging them in the head space or placing them level on the grain surface inside a gas-tight, sealed silo. Hang bag chains in the head space or roll out flat on the top of the grain so air can freely pass around them as the gas dissipates. Bottom-application facilities must have a passive or active air circulation system to carry the phosphine gas out of the confined space as it evolves. Without air movement, if left in a confined space, phosphine can reach explosive levels.

Non-chemical treatment options

Two non-chemical treatment options are:

- Carbon dioxide—treatment involves displacing the oxygen inside a gas-tight silo with CO_2, which creates an atmosphere toxic to grain pests. To achieve a complete kill of all the main grain pests at all life stages, CO_2 must be retained at a minimum concentration of 35% for 15 days.
- Nitrogen—grain stored under N_2 provides insect control and quality preservation with the advantages of also being safe to use and environmentally acceptable. The main operating cost is the capital cost of equipment and electricity. N_2 also produces no residues, so grains can be traded at any time (compared with chemical fumigants, which have withholding periods). Insect control with N_2 entails using pressure-swinging adsorption (PSA) technology to modify the atmosphere inside the grain storage to remove everything except N_2, thereby starving pests of oxygen. [28]

13.3.9 Maximum residue limits (MRLs)

Key points:

- Grain samples are tested for pesticide residues in Australia and when export shipments leave the port to ensure they are within maximum residue limits (MRLs).
- A single violation of an importing country's MRL can lead to punitive measures on all Australian grain exported to that country and undermine Australian grains' reputation internationally.
- Consequences may include costs awarded against the exporter and/or grower. If repeated violations are detected with the same chemical, that chemical may be banned.
- It is essential that growers ensure both pre-harvest and post-harvest chemical applications adhere to the Australian Grain Industry Code of Practice.
- Use only registered products and observe all label recommendations including label rates and withholding periods.
- Trucks or augers that have been used to transport treated seed or fertiliser can be a source of contamination. Pay particular attention to storage and transport hygiene.
- Silos that have held treated fertiliser or pickled grain will have dust remnants that require particular attention. These silos either need to be cleaned or designated as non-food-grade storage.
- Compliance with Australian MRLs does not guarantee the grain will meet an importing country's MRL (which may be nil).
- Know the destination of your grain. When signing contracts, check the importing countries' MRLs to determine what pesticides are permitted on that crop.

By observing several precautions, growers can ensure that grain coming off their farm is compliant with the maximum pesticide residue limits that apply to Australian exports. Violations of maximum residue limits (MRLs) affect the marketability of

28 C Warrick (2012) Fumigating with phosphine, other fumigants and controlled atmospheres. GRDC, http://storedgrain.com.au/fumigating-with-phosphine-and-ca/

MORE INFORMATION

Managing MRLs factsheet

Australian grain exports, and consequences may include costs being imposed on exporters and/or growers.

It is essential that both pre-harvest and post-harvest chemical applications adhere to the Australian Grain Industry Code of Practice, only registered products are used and all label recommendations, including rates and withholding periods, must be observed. Other key points include:

- Trucks or augers that have been used to transport treated seed or fertiliser can be a source of contamination–pay particular attention to storage and transport hygiene;
- Silos that have held treated fertiliser or pickled grain will have dust remnants–these silos either need to be cleaned or designated as non-food grade storage;
- Know the destination of your grain. When signing contracts, check the importing countries' MRLs to determine what pesticides are permitted on a particular crop. [29]

13.4 Aeration during storage

13.4.1 Dealing with moist grain

Key points:

- Deal with high-moisture grain promptly.
- Monitoring grain moisture and temperature daily will enable early detection of mould and insects.
- Aeration drying requires airflow rates in excess of 15 litres per second per tonne (L/s/t).
- Dedicated-batch or continuous-flow dryers are a more reliable way to dry grain than aeration drying in less-than-ideal ambient conditions.

Aeration is recommended when storing triticale. In a Queensland trial, wheat at 16.5% MC and a temperature of 28°C was put into a silo with no aeration. Within hours, the grain temperature reached 39°C, and within two days reached 46°C, providing ideal conditions for mould growth and grain damage (Figure 4). [30] Grain that is over the standard safe storage moisture content of 12.5% can be dealt with by:

- Blending—mixing high-moisture grain with low-moisture grain, then aerating.
- Aeration cooling—for a short time holding grain of moderate moisture, up to 15% MC, under aeration cooling until drying equipment is available.
- Aeration drying—forcing large volumes of air to push a drying front through the grain in storage to slowly remove moisture. Supplementary heating can be added.
- Continuous-flow drying—transferring grain through a dryer, which uses a high volume of heated air to pass through the continual flow of grain.
- Batch drying—using a transportable trailer to dry 10–20 tonnes of grain at a time with a high volume of heated air, which passes through the grain and out perforated walls.

29 GRDC. (2014). Managing maximum residue limits in export grain - Factsheet. https://grdc.com.au/GRDC-FS-ManagingMRLs

30 Stored Grain Information Hub (2013) Dealing with high-moisture grain. Factsheet. GRDC, http://storedgrain.com.au/dealing-with-high-moisture-grain/

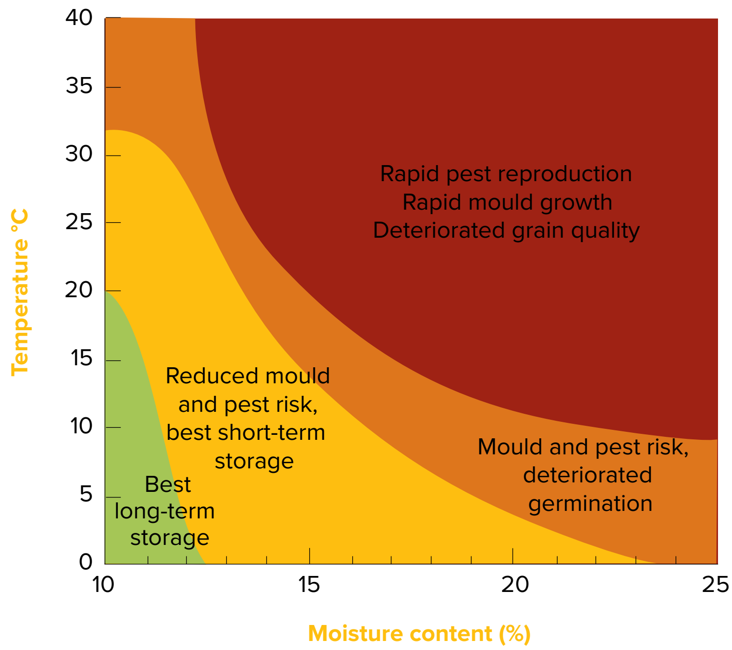


Figure 4: *Effects of temperature and moisture on stored grain.*

Source: GRDC

13.4.2 Aeration cooling

Key points:

- Grain temperatures below 20°C significantly reduce mould and insect development.
- Reducing grain temperature with aeration cooling protects seed viability.
- Controlling aeration cooling is a three-stage process: continual, rapid, and maintenance.
- Stop aeration if ambient, relative humidity exceeds 85%.
- Automatic grain aeration controllers that select optimum fan running times give the most reliable results.

Aeration cooling can be used to reduce the risk of mould and insect development for a month or two until drying equipment is available to dry grain down to a safe level for long-term storage or delivery. In most circumstances, grain can be stored at up to 14–15% MC safely with aeration cooling fans running continuously and delivering at least 2–3 L/s/t. It is important to keep fans running for the entire period, stopping them only if the ambient relative humidity is above 85% for more than about 12 hours, to avoid wetting the grain further. [31]

Blending

Blending is the practice of mixing slightly over-moist grain with lower-moisture grain to achieve an average moisture content below the ideal 12.5% MC. It is successful with grain with MC up to 13.5%, and can be an inexpensive way of dealing with wet grain, providing the infrastructure is available. Aeration cooling does allow blending in layers but if aeration cooling is not available, blending must be evenly distributed (Figure 5). [32]

31 Waratah Seed Company (2010) Triticale: planting guide. Waratah Seed Company, http://www.porkcrc.com.au/1A-102_Triticale_Guide_Final_Fact_Sheets.pdf

32 Stored Grain Information Hub (2013) Dealing with high moisture grain. Factsheet. GRDC, http://storedgrain.com.au/dealing-with-high-moisture-grain/

VIDEOS

WATCH: GCTV2: Grain storage cooling aeration

MORE INFORMATION

GRDC, Aerating stored grain

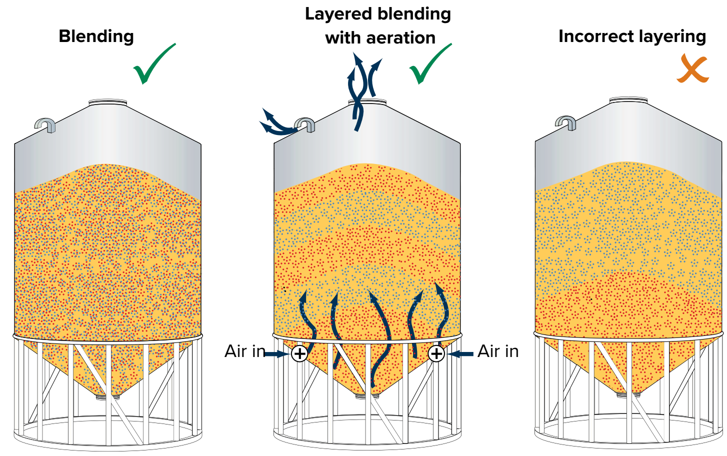


Figure 5: *Diagram demonstrating the correct practices for blending.*

Source: GRDC

Seed viability

Research trials have revealed that cereal grain stored at 12% MC for six months at 30–35°C (unaerated grain temperature) will have reduced seedling vigour and a lower rate of germination.

13.4.3 Aeration drying

Aeration drying relies on a high air volume and is usually done in a purpose-built drying silo or a partly filled silo with high-capacity aeration fans. Aeration drying is a slow process and relies on four factors:

- High airflow rates.
- Well-designed ducting for even airflow through the grain.
- Exhaust vents in the silo roof.
- Warm, dry weather.

It is important to seek reliable advice on equipment requirements and correct management of fan running times, otherwise there is a high risk of damaging the grain and reducing its quality.

High airflow for drying

Unlike aeration cooling, aeration drying requires high airflow, in excess of 15 L/s/t, to move drying fronts quickly through the whole grain profile and depth, and carry moisture out of the grain bulk. As air passes through the grain, it collects moisture from the grain, and forms a drying front. If airflow is too low, the drying front will take too long to reach the top of the grain stack, an occurrence that is often referred to as a 'stalled drying front'. Providing the storage has sufficient aeration ducting, a drying front can pass through a shallow stack of grain much faster than a deep stack of grain. As air will take the path of least resistance, make sure the grain is spread to an even depth to ensure even and adequate drying.

Ducting for drying

The way to avoid hot spots is with adequate ducting to deliver an evenly distributed flow of air through the entire grain stack (as can be seen on the silo sides in Photo 11).[33] A flat-bottomed silo with a full floor aeration plenum is ideal providing it can deliver

33 Stored Grain Information Hub (2013) Dealing with high moisture grain. Factsheet. GRDC, http://storedgrain.com.au/dealing-with-high-moisture-grain/

air at at least 15 L/s/t. The silo may only be able to be part filled, which in many cases is better than trying to dry grain in a cone-bottomed silo with insufficient ducting.

Photo 11: *Aeration drying requires careful management, high airflow rates, well designed ducting, exhaust vents and warm, dry weather.*

Source: GRDC

Venting for drying

Adequate ventilation maximises airflow and allows moisture to escape rather than forming condensation on the underside of the roof and wetting the grain at the top of the stack. The amount of moisture that has to escape with the exhaust air is 10 L for every 1% MC removed per tonne of grain.

Weather conditions for drying

For moisture transfer to occur and drying to succeed, the external air, which is harnessed for pushing through the grain, must have a lower relative humidity than the grain's equilibrium moisture content. For example, grain at 25°C and 14% MC has an equilibrium point of the air around it at 70% relative humidity: in order to make this grain drier, the aeration drying fans would need to be turned on when the ambient air was below 70% relative humidity (Table 6). [34]

Phase one of drying

Aeration drying fans can be turned on as soon as the aeration ducting is covered with grain, and left running continuously until the air coming out of the top of the storage has a clean, fresh smell. The only time drying fans are to be turned off during this phase is if ambient air exceeds 85% relative humidity for more than a few hours.

34 Stored Grain Information Hub (2013) Dealing with high moisture grain. Factsheet. GRDC, http://storedgrain.com.au/dealing-with-high-moisture-grain/

Phase two of drying

By monitoring the temperature and moisture content of the grain in storage and referring to an equilibrium moisture table, such as Table 6, a suitable relative humidity trigger point can be set. As the grain dries, the equilibrium point will fall, so the relative humidity trigger point will need to be reduced to dry down the grain further. Reducing the relative humidity trigger point slowly during phase two of the drying process will help keep the difference in grain moisture from the bottom to the top of the stack to a minimum, by ensuring the fans get adequate run time to push each drying front right through the grain stack.

Table 6: *Equilibrium moisture content for wheat.*

Relative humidity (%)	Temperature		
	15	25	35
30	9.8	9.0	8.5
40	11.0	10.3	9.7
50	12.1	11.4	10.7
60	13.4	12.8	12.0
70	15.0	14.0	13.5

Grain moisture content %)

Note: values may be different for triticale grain.

Source: GRDC

VIDEOS

WATCH: GCTV5: Aeration drying—getting it right

MORE INFORMATION

Dealing with high moisture grain

Supplementary heating

Heat can be added to aeration drying in proportion to the airflow rate. Higher airflow rates allow more heat to be added as it will push each drying front through the storage quick enough to avoid overheating the grain close to the aeration ducting. As a general guide, inlet air shouldn't exceed 35°C.

Cooling after drying

Regardless of whether supplementary heat is added to the aeration drying process, the grain should be cooled immediately after it has been dried. Cool to the desired level. [35]

13.4.4 Aeration controllers

Aeration controllers can manage both aeration drying and cooling, as well as maintenance functions, in up to 10 separate storages (Photo 12). [36] The unit takes into account the moisture content and temperature of grain at loading and the desired grain condition after time in storage, and automatically selects the correct type of aeration needed to obtain the desired grain moisture and temperature. [37]

Research has shown that, with the support of an aeration controller, aeration can rapidly reduce stored grain temperatures to a level that helps maintain grain quality and inhibits insect development. During trials, where grain was harvested at 30°C and 15.5% MC, grain temperatures rose to 40°C within hours of being put into storage. An aeration controller was used to rapidly cool grain to 20°C and then hold the grain between 17°C and 24°C from November to March.

Before replicating similar results on their farm, growers need to:

- Know the capacity of their existing aeration system.
- Determine whether grain requires drying before cooling can be carried out.

35 Stored Grain Information Hub (2013) Dealing with high moisture grain. Factsheet. GRDC, http://storedgrain.com.au/dealing-with-high-moisture-grain/

36 Stored Grain Information Hub (2014) Aeration cooling for pest control. Factsheet. Revised. GRDC, http://storedgrain.com.au/aeration-cooling/

37 GRDC (2007) New generation in aeration controller. Ground Cover. Issue 57. GRDC, https://grdc.com.au/Media-Centre/Ground-Cover-Supplements/Ground-Cover-Issue-57-Grain-Storage-Supplement/New-generation-aeration-controller

- Understand the effects of relative humidity and temperature when aerating stored grain.
- Determine the target conditions for the stored grain.

Photo 12: *Automatic aeration controllers are the most effective way to cool grain and are designed to manage many storages from a central control unit.*

Source: GRDC

VIDEOS

WATCH: Grain storage with Philip Burrill: using aeration coolers

13.5 Grain protectants for storage

It is recommended that a protectant be used when storing triticale, given the softness of the grain. [38] The widespread resistance of the lesser grain borer (*Rhyzopertha dominica)* to grain protectants is decreasing with the availability of products based on deltamethrin (e.g. K-Obiol® EC Combi) and spinosad (e.g. Conserve™ On-Farm).

K-Obiol® EC Combi

K-Obiol® EC Combi is a synergised grain protectant for use on cereal grains, malting barley and sorghum. [39] It is not suitable for oil seeds or pulses. It can be used in any type of storage, sealed or unsealed. It is suitable for use by grain growers and grain accumulators. Like all protectants, it is a liquid and must be evenly applied as a dilution to the grain as it is fed into the storage. It is for use on un-infested grain and is not recommended for eradicating insect pests when they have infested grain.

The active constituent is deltamethrin. Piperonyl butoxide is added as a synergist, i.e. to increase the effectiveness of the deltamethrin. As K-Obiol® EC Combi is based on deltamethrin, there are none of the insect-resistance problems that growers have with other protectants at this stage.

Because protectants are residual, grain end users may be concerned that the grain does not contain excessive levels of chemicals. This would generally only come about with incorrect treatment or double treatment as the grain moves along the supply chain. To protect the end user, and ultimately Australian grain growers, a product stewardship program has been developed to help ensure correct use of the product, including minimising the development of insect resistance and increasing the usable life of the chemical. [40]

38 Waratah Seed Company (2010) Triticale: planting guide. Waratah Seed Company, http://www.porkcrc.com.au/1A-102_Triticale_Guide_Final_Fact_Sheets.pdf

39 Bayer (n.d.) K-Obiol. Bayer, https://www.environmentalscience.bayer.com.au/K-Obiol/About%20K-Obiol

40 GRDC Stored Grain Information Hub. K-Obiol Combi. GRDC, http://storedgrain.com.au/k-obiol-combi/

Conserve™ On-farm

Conserve™ On-Farm is a Dow AgroSciences grain protectant that has three active ingredients that control most major insect pests of stored grain, including the resistant lesser grain borer (LGB). [41] It provides six to nine months of control and has no WHP. MRLs have been established with key trading partners, and there are no meat residue bioaccumulation problems.

MORE INFORMATION

Grain protectants prevent pests

Conserve™ On-Farm is a combination of two parts that are mixed together for application. Using Part A and Part B together is very important in order to successfully control the complete spectrum of insects. They comprise:

- Part A—1 x 5 L of chlorpyrifos-methyl and S-methoprene, which controls all stored grain insect pests other than the LGB
- Part B—2 x 1 L of spinosad, which is very effective on the LGB, including resistant strains, but has little to no effect on other key species. [42]

41 Dow AgroSciences (n.d.) Conserve. Dow AgroSciences, http://www.conserveonfarm.com.au/en

42 GRDC Stored Grain Information Hub. Conserve. GRDC, http://storedgrain.com.au/conserve-farm/