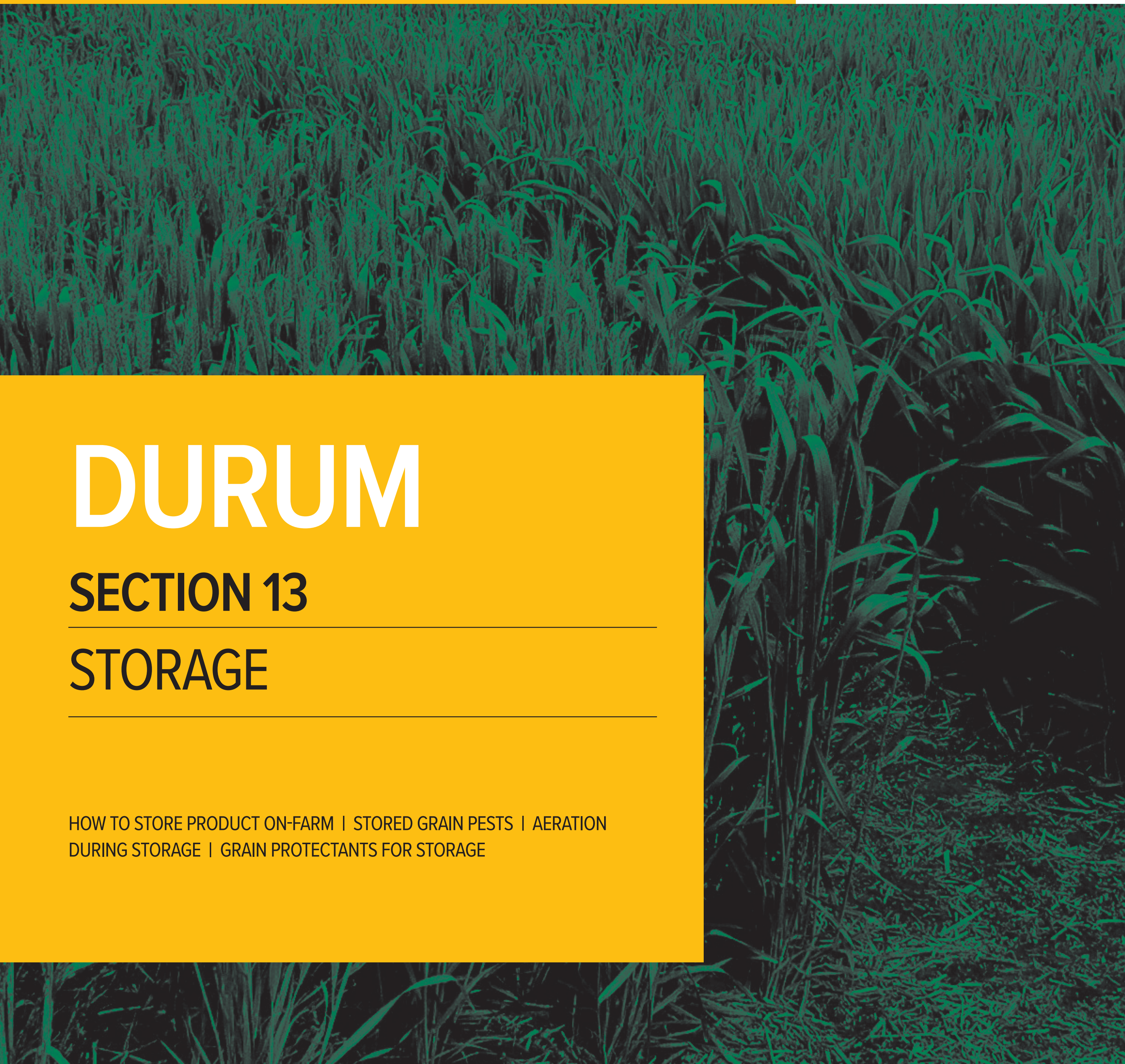
SOUTHERN
AUGUST 2017

GRDC GROWNOTES™

GRDC
GRAINS RESEARCH & DEVELOPMENT CORPORATION



DURUM

SECTION 13

STORAGE

HOW TO STORE PRODUCT ON-FARM | STORED GRAIN PESTS | AERATION DURING STORAGE | GRAIN PROTECTANTS FOR STORAGE

Storage

Key messages:

- Effective grain hygiene and aeration cooling can overcome 85% of pest problems.
- Monitor stored grain monthly for moisture, temperature and pests.
- Most markets want clean grain, free from insects and chemical residues. Check with potential buyers before treating with chemicals.
- Clean grain handling and storage equipment and dispose of or treat old, infested grain.
- Aeration cooling reduces insect breeding activity, but does not eliminate storage pests. Treatment may still be required, especially in the warmer period of the year.
- Fumigating with phosphine is only fully effective in pressure-tested storage that is gas-tight.

13.1 How to store product on-farm

Growers in the southern region are investing in on-farm storage for a range of reasons. In the eastern states, on-farm storage gives growers options into domestic and export markets, while in South Australia—where the majority of grain goes to bulk handlers—growers tend to set up storage to improve harvest management.

Growers might only plan to store grain on-farm for a short time, but markets can change, so investing in gas-tight sealable structures means you can treat pests reliably and safely and leave your business open to a range of markets.

Growers should approach storage as they would approach purchasing machinery:

- Growers spend a lot of time researching a header purchase to make sure it is fit-for-purpose. Grain storage can also be a significant investment, and a permanent one, so it pays to have a plan that adds value to your enterprise into the future.
- Agronomists tip: Decide what you want to achieve with storage, critique any 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. [1]

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

A mixed storage strategy is a possible solution. The strategy is to purchase a small number of sealable silos and to use them to batch fumigate grain prior to sale.

There are several reasons why growers might consider storing grain on-farm, including:

- improving harvest logistics;
- taking advantage of higher grain prices some time after harvest;
- supplying a local market (e.g. feedlot, dairy etc.);
- avoiding high freight costs at peak time'
- value adding through cleaning, drying or blending grain;
- retaining planting seed; and
- potentially other site-specific benefits.

In most cases, for on-farm storage to be economical it will need to deliver on more than one of these benefits (Table 1). Under very favourable circumstances, grain

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

storage facilities can pay for themselves within a few years, but it is also possible for an investment in on-farm storage to be very unprofitable. The grain storage cost-benefit analysis template is very useful step in the decision making process to test the viability of grain storage on your farm. [2]

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 atmosphere options to control insects • Easily aerated with fans • Fabricated on-site or off-site and transported • Capacity from 15 t up to 3000 t • Up to 25 years-plus service life • Simple in-loading and out-loading • Easily administered hygiene (cone base particularly) • Can be used multiple times in a season	• Requires foundation to be constructed • Relatively high initial investment required • Seals must be regularly maintained • Access requires safety equipment and infrastructure • Requires an annual test to check gas-tight sealing
Non-sealed silo	• Easily aerated • 7–10% cheaper than sealed silos • Capacity from 15 t up to 3000 t • Up to 25 years-plus service life • Can be used multiple times in a season	• Requires foundation to be constructed • Silo cannot be used for fumigation—see phosphine label • Insect control options limited to protectants in eastern states and dryacide in Western Australia • Access requires safety equipment and infrastructure

2 GRDC (2015) Grain storage strategies in the northern region, 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 all ground operated • Can accommodate high yielding seasons	• Requires purchase or lease of loader and unloader • Increased risk of damage beyond short term storage (typically three months) • Limited insect control options; fumigation only possible under specific protocols • Requires regular inspection and maintenance which needs to be budgeted for • Aeration of grain in 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 year-plus 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

13.1.1 Storing durum

Storage conditions determine the safe storage period for any grain. Up until 2011 there were no safe storage guidelines for durum wheat, despite the fact that it is more susceptible to spoilage than other wheat classes. A study conducted at the University of Manitoba, Canada, in 2011 studied the rates of deterioration of durum wheat samples at various moisture contents and temperatures to develop guidelines. Samples with 15, 16, 17, 18, 19 and 20% initial moisture content (wet basis [wb]) were stored at 10, 20, 30 and 40°C for 12 weeks. Key findings included:

- There was no quality loss of durum wheat when stored at low moisture (<15% wb) and low temperatures (<20°C).
- High moisture (>16% wb) grains should be dried in a week to prevent deterioration.
- Fungal growth increased with an increase in moisture content, storage temperature and time.
- Time available for corrective actions decreased with increased moisture content and temperature. [3]

Utilise this On-farm storage checklist to optimise grain storage potential.

MORE INFORMATION

Benefits flow from on-farm storage in the Mallee.

GRDC Retaining seed factsheet.

VIDEOS

WATCH: Over the Fence: On-farm storage pays in wet harvest.

3 U Nithya, V Chelladurai, DS Jayas, NDG White (2011). Safe storage guidelines for durum wheat. Journal of Stored Products Research, 47(4), 328–333, http://dx.doi.org/10.1016/j.jspr.2011.05.005.

13.1.2 Silos

To minimise insect attack, the grain should be stored at less than 10% moisture, preferably in sealed silos (Photo 1). Treat the grain as it enters the silo and then check regularly (2–3 months) for reinfestation by grain insects.

Photo 1: *When using on-farm silos it is important to pressure test all silos, even those that are labeled as "sealed".*

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 grain storage bags and are depreciated over a longer time frame than the machinery required for the grain bags. In a silo grain storage system as stored tonnage increases the capital cost of storage increases.

Potential 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 and the opportunity to segregate and blend grain.

Potential disadvantages of using sealed grain silos as a method for grain storage include the initial capital outlay, the outlay required to meet occupational health and safety requirements, the additional on-farm handling required and the additional site maintenance requirements. [4]

Pressure testing

- A silo sold as a "sealed silo" 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 AS2628 on the invoice as a means of legal reference to the quality of the silo being paid for.
- Pressure test sealed silos upon erection, annually and before fumigating with 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 sealed 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.

4 J Francis (2006) An analysis of grain storage bags, sealed grain silos and warehousing for storing grain, https://grdc.com.au/uploads/documents/Final%20report%20Grain%20Storage%20Bags%2021%20Jul%20061.pdf

MORE INFORMATION

GRDC Pressure testing sealable silos factsheet

GRDC Silo buyer's guide

VIDEOS

WATCH: Pressure testing sealed silos.

Even if a silo is sold as "sealed" it is not sealed until it is proven gas-tight with a pressure test.

The term "sealed" has been used loosely during the past and in fact some silos may not have been gas-tight from the day they were constructed.

However, even a silo that was gas-tight to the Australian Standard on construction will deteriorate over time, so needs annual maintenance to remain gas-tight.

Why do I need to do a pressure test?

In order to kill grain pests at all stages of their life cycle (egg, larvae, pupae, adult) phosphine gas concentration levels need to reach and remain at 300 parts per million (ppm) for 7 days or 200 ppm for 10 days.

The importance of a gas-tight silo

The Kondinin Group 2009 National Agricultural survey revealed that 85% of respondents had used phosphine at least once during the previous 5 years, and of those users, 37% used phosphine every year for the past five years. A Grains Research and Development Corporation survey during 2010 revealed that only 36% of growers using phosphine applied it correctly, in a gas-tight, sealed silo (Figure 1). Research shows that fumigating in a storage that does not meet the industry standard "silo pressure test" 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 of 300 ppm gas concentration for seven days or 200 ppm for ten days is required. Fumigation trials in silos with small leaks demonstrated that phosphine levels are as low as 3 ppm close to the leaks. The rest of the silo also suffers from reduced gas levels. [5]

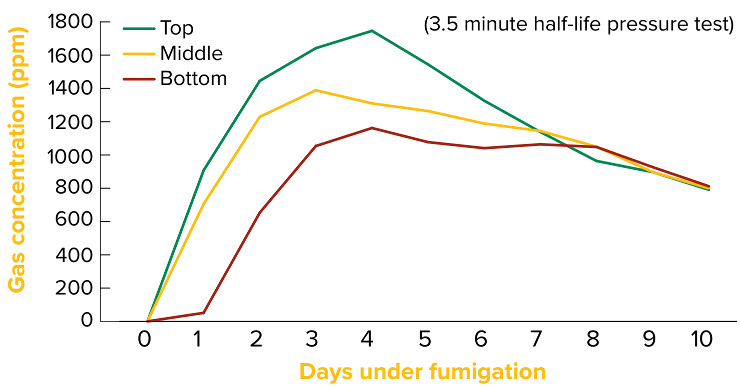


Figure 1: *Gas concentration in gas-tight silo.*

Source: GRDC

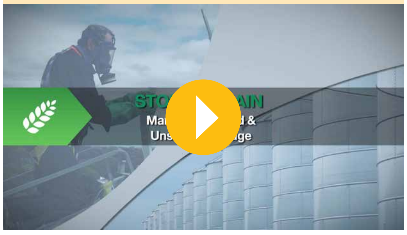
5 P Botta, P Burrill, C Newman (2010) Pressure testing sealable silos. GRDC Fact Sheet, September 2010, https://www.grdc.com.au/~/media/0218DA4A22264A31B6202718043758DE.pdf

MORE INFORMATION

[Fumigating with phosphine, other fumigants and controlled atmospheres](#)

VIDEOS

WATCH: Stored grain: Managing sealed and unsealed storage



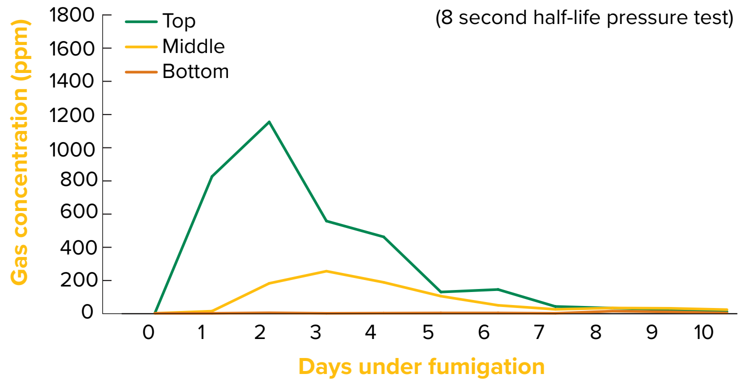


Figure 2: *Gas concentration in non-gas-tight silo.*

Source: GRDC

It is recommended to pressure test silos that are sealable once a year to check for damaged seals on openings. Storages must be able to be sealed properly to ensure effective fumigation.

There is no compulsory manufacturing standard for sealed silos in Australia. A voluntary industry standard was adopted in 2010. Watch this GRDC Ground Cover TV clip to find out more.

13.1.3 Grain bags

Grain storage bags are relatively new technology offering a low cost alternative for temporary storage of grain to permanent grain storage structures on-farm such as silos. Grain storage bags are made of multilayer polyethylene material, similar to that used in silage fodder systems. Bags typically store between 200 and 220 tonnes of wheat and are filled and emptied using specialised machinery (Photo 2). 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.

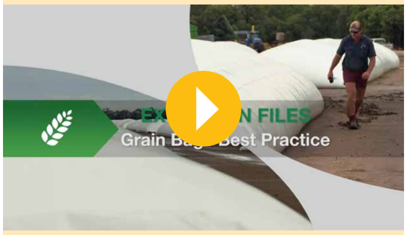
Potential advantages of using grain storage bags as a method for grain storage include the low capital set up costs, improved harvest management, less harvest stress, reduced harvest freight requirements, minimal cost in occupational health and safety (OH&S) requirements, reduced grain insecticide requirements and the opportunity to segregate and blend grain.

Potential disadvantages of using grain storage bags as a method for grain storage include the requirement for disposal of used bags, the period of storage before bag deterioration and the management necessary to ensure bag integrity. 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. [6]

6 J Francis (2006) An analysis of grain storage bags, sealed grain silos and warehousing for storing grain, https://grdc.com.au/uploads/documents/Final%20report%20Grain%20Storage%20Bags%2021%20Jul%20061.pdf

VIDEOS

WATCH: Grain bags best practice.



WATCH: Extension Files: Grain bags—a grower's perspective

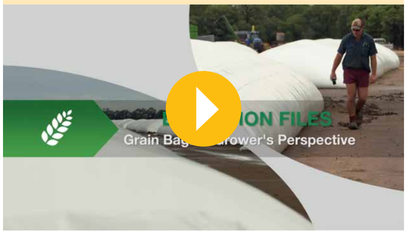


Photo 2: *A 100 m bag can be filled in 30 minutes with a constant supply of grain.*

Source: StarTribune

13.1.4 Monitoring stored grain

Monitoring grain temperature and moisture content:

- 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 3).
- When checking grain, smell 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 storage environment problems.

It is vital to monitor grain moisture content to prevent pests and grain moulds from thriving. [7]

Photo 3: *Monitor moisture and temperature using a digital probe from both the top and the bottom of silos, if safe to do so.*

Source: Plant Health Australia

7 Plant Health Australia (2015) Monitoring stored grain on farm, http://www.planthealthaustralia.com.au/wp-content/uploads/2015/11/Monitoring-stored-grain-on-farm.pdf

13.1.5 Grain storage—get the economics right

As growers continue to expand their on-farm grain storage, the question of economic viability gains 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?

The grain storage extension team conduct approximately 100 grower workshops every year, Australia wide, and it is evident that no two growers use on-farm storage in the exact same way. Like many 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 for their own operation.

Comparing on-farm grain storage

To make a sound financial decision, we need to compare the expected returns from grain storage versus expected returns from other farm business investments—such as more land, a chaser bin, a wider boomspray, a second truck or paying off debt. The other comparison is to determine if we can store grain on-farm cheaper than paying a bulk handler to store it for us.

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

Benefits

To compare the benefits and costs in the same form, work everything out on a 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 is 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 quality. One of the most significant variable costs, and one that is often overlooked, is the opportunity cost of the stored grain. That is 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 is difficult to put an exact dollar value on each of the potential benefits and costs, a calculated estimate will determine if it is worth a more thorough investigation. If we compare the investment of on-farm grain storage to other investments and the result is similar, then we can revisit the numbers and work on increasing their accuracy. If the return is not even in the ball park, we have potentially avoided a costly mistake. On the contrary, if after checking our numbers the return is favourable, we 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, the growers who are taking a planned approach to on-farm grain storage and doing it well are being rewarded. Grain buyers are seeking out growers who have a well-designed storage system that can deliver insect free, quality grain without delay.

Table 2 is a tool that can be used to figure out the likely economic result of on-farm grain storage for each individual business. Each column can be used to compare various storage options including type of storage, length of time held or paying a bulk handler. [8]

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

Financial gains from storage		Example $/t
Harvest logistics/ timeliness	Grain price x reduction in value after damage % x probability of damage %	$16
Marketing	Post harvest grain price - harvest grain price	
Freight	Peak rate $/t - post harvest rate $/t	$20
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
Fixed costs		
Annualised depreciation cost	Capital cost $/t / expected life storage e.g. 25 yrs	$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 $/hr x time to clean hrs / storage capacity) + structural treatment	$0.23
Aeration cooling	Indicatively 23c for the first 8 days then 18c 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 $/hr / 60 minutes / auger rate t/m x 3	$0.88
Time to monitor and manage	Labour rate $/hr x total time to manage hrs / storage capacity	$0.24
Opportunity cost of stored grain	Grain price x opportunity interest rate e.g. 8% / 12 x No. months stored	$7.20
Insect treatment cost	Treatment cost $/t x No. of treatments	$0.35
Cost of bags or bunker trap	Price of bag / bag capacity tonne	

MORE INFORMATION

GRDC Economics of on-farm grain storage, cost benefit analysis

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

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

Financial gains from storage		Example $/t
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

13.2 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.

Prevention is better than cure

The combination of meticulous grain hygiene plus 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. [9]

Common species

The most common insect pests of stored cereal grains in Australia are (Figure 3):

- 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.)*.
- Sawtooth Grain Beetle *(Oryzaephilus spp.)*.
- Flat Grain Beetle *(Cryptolestes spp.)*.
- Indian Meal Moth *(Plodia interpunctella)*.
- Angoumois Grain Moth *(Sitotroga cerealella)*.

Another dozen or so beetles, psocids (booklice) and mites are sometimes present as pests in stored cereal grain.

9 GRDC Stored Grain Information Hub. Northern and Southern Regions Grain Storage Pest control guide, http://storedgrain.com.au/pest-control-guide-ns/

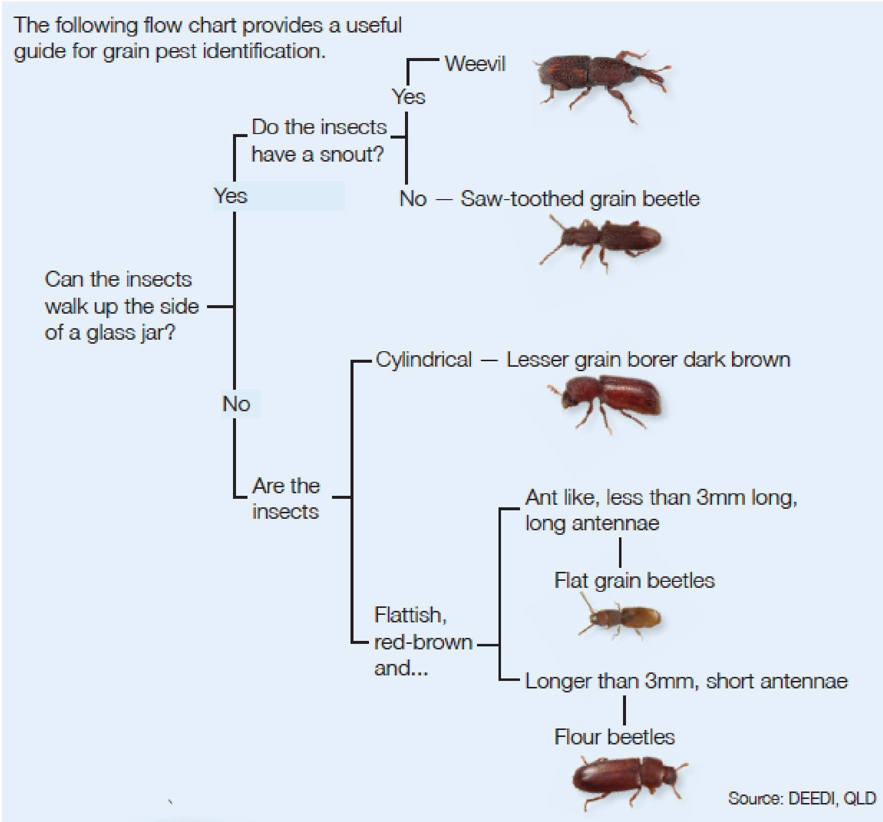


Figure 3: *Identification of common pests of stored grain.*

Source: GRDC

Why identify stored insect grain pests?

Most insect control methods for stored grain work against all species. So you don't need to identify the storage pests to make decisions about most control methods. But if you intend spraying 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 to use a residual protectant to treat infested grain—pyrimiphos-methyl, fenitrothion and chlorpyrifos-methyl are ineffective against lesser grain borer, and pyrimiphos-methyl and fenitrothion are generally ineffective against sawtoothed grain beetle.
- You intend to use dichlorvos to treat infested grain—if lesser grain borer is present you need to apply the higher dose rate. This then increases the withholding period before grain can be marketed from 7–28 days.

13.2.1 Monitoring grain for pests

Damage by grain insect pests often goes unnoticed until the grain is removed from 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.
- 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 4).
- Hold tray in the sunlight for 10–20 seconds to trigger movement of any insects, making them easier to see. Use a magnifying glass to identify pests.

MORE INFORMATION

Stored grain pests identification

MORE INFORMATION

GRDC Stored grain pests: the back pocket guide

Monitoring stored grain on-farm.

VIDEOS

WATCH: GCTV2: Grain Storage Insect ID

- Grain probes or pitfall traps should also be used to check for insects. These traps are left in the grain during storage and are often able to detect the start of an infestation.
- Push probe/trap into the grain surface and pull up for inspection fortnightly/monthly. Place 1–2 traps in the top of a silo or several traps in a grain shed.
- Be sure to check grain 3 weeks prior to sale to allow time for treatment if required. [10]

Photo 4: *A 2 mm mesh sieve will separate insects from grain.*

Source: Plant Health Australia

13.2.2 Hygiene

Key points

- Effective grain hygiene requires 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 during a year, which can walk and fly to other grain storages where they will start new infestations. Meticulous grain hygiene involves removing any grain that can harbour pests and allow them to breed. It also includes regular inspection of seed and stockfeed grain so that 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, which includes all grain handling equipment and storages. Grain pests live in dark, sheltered areas and breed best in warm conditions.

Common places where pests are found include:

- Empty silos and grain storages.
- Aeration ducts, augers and conveyers.
- Harvesters, field bins and chaser bins.
- Left-over bags of grain trucks.
- Spilt grain around grain storages.
- Equipment and rubbish around storages.
- Seed grain.
- Stockfeed grain.

10 Plant Health Australia (2015) Monitoring stored grain on-farm, http://www.planthealthaustralia.com.au/wp-content/uploads/2015/11/Monitoring-stored-grain-on-farm.pdf

Successful grain hygiene involves cleaning all areas where grain gets trapped in storages and equipment (Photo 5). Grain pests can survive in a tiny amount of grain, so any parcel of fresh grain through the machine or storage becomes infested.

Photo 5: *Grain left in trucks is an ideal place for grain pests to breed. Keep trucks, field bins and chaser bins clean.*

Source: GRDC

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 litres of grain through a harvester at the start of harvest, which was considered reasonably clean at the end of the previous season. Discarding the first few bags of grain at the start of the next harvest is also a good idea. Further studies revealed insects are least mobile during the colder months of the year. Cleaning around silos in July–August can reduce insect numbers before they become mobile.

How to clean

The better the cleaning job, the less chance of pests harbouring. The best ways to get rid of all grain residues use a combination of:

- Sweeping
- Vacuuming
- Compressed air
- Blow/vacuum guns
- Pressure washers
- Fire-fighting hoses

Using a broom or compressed air gets rid of most grain residues, and a follow-up wash-down removes grain and dust left in crevices and hard-to-reach spots (Photo 6). Choose a warm, dry day to wash storages and equipment so that it dries out quickly, to prevent rusting. 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 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 6: *Clean silos, including the silo wall, with air or water to provide a residue-free surface to apply structural treatments.*

Source: GRDC

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 DE as a structural treatment. See Section 13.2.4 Structural treatments for more information.

A concrete slab underneath silos makes cleaning much easier (Photo 7).

Agronomist's view

Photo 7: *A concrete slab underneath silos makes cleaning up spilled grain much easier.*

Source: GRDC

VIDEOS

WATCH: Grain Silo Hygiene.

13.2.3 Aeration cooling for pest control

While adult insects can still survive at low temperatures, most young storage pests stop developing at temperatures below 18–20°C (see Table 3).

At temperatures below 15°C the common rice weevil stops developing.

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 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 in GRDC

For more information, see Section 13.3.2 Aeration cooling below

MORE INFORMATION

GRDC fact sheet, Aeration cooling for pest control

13.2.4 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.

Using diatomaceous earth (DE) as a structural treatment is possible. Diatomaceous earth is an amorphous silica commercially known as Dryacide® that acts by absorbing the insect's cuticle or protective waxy exterior, causing death by desiccation. If applied correctly 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. [11]

MORE INFORMATION

Hygiene and structural treatments for grain storages.

Application

Inert dust requires a moving air stream to direct it onto the surface being treated; alternatively, it can be mixed into a slurry with water and sprayed onto the surface. See label directions. Throwing dust into silos by hand will not achieve an even coverage, 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 operated by compressed air or a fan. If compressed air is available, it is the most economical and suitable option for on-farm use, connected to a venturi duster such as the Blovac BV-22 gun (Photo 8).

11 GRDC Stored Grain information hub. Storing Pulses, http://storedgrain.com.au/wp-content/uploads/2014/09/GSFS-8_Storing-Pulses-July14.pdf

Photo 8: *A blow/vac or air venture 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 surface area treated. Although inert, breathing in excessive amounts of dust is not ideal, so use a disposable dust mask and goggles during application (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 (Table 4). If silos are fitted with aeration systems, distribute the inert dust into the ducting without getting it into the motor, where it could cause damage. [12]

Table 4: *Inert dust (diatomaceous earth) 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
1,800	2.60

Source: GRDC

13.2.5 Fumigation

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

MORE INFORMATION

GRDC Grain Storage Fact Sheet: Hygiene and Structural Treatment for Grain Storages.

VIDEOS

WATCH: Applying diatomaceous earth dust.

12 Pulse Australia (2013) Northern chickpea best management practices training course manual—2013. Pulse Australia Limited.

Table 5: *Resistance and efficacy guide for stored grain insects. Before applying, check with your grain buyers/bulk handlers and read labels carefully.*

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							
Sulfuryl fluoride (ProFume®)[10]	1							
Grain protectants—applied postharvest. Poor adult control if applied to infested grain								
Pirimiphos-methyl (Actellic 900®)	nil[2]							
Fenitrothion (Fenitrothion 1000®)[4, 7]	1–90							
Chlorpyrifos-methyl (Reldan Grain Protector®)[5]	Nil[2]							
'Combined products' (Reldan Plus IGR Grain Protector)	Nil[2]							
Deltamethrin (K-Obiol®)[10]	Nil[2]							
Spinosad and Chlorpyrifos-methyl (eg Conserve On-Form™)[9]								
Diatomaceous earth, amorphous silica—effective internal structural treatment for storages and equipment. Specific-use grain treatments								
Diatomaceous earth, amorphous silica (Dryacide®)[8]	Nil[2]							

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

Source: http://storedgrain.com.au/pest-control-guide-ns/

Fumigation with phosphine is a common component of many integrated pest control strategies (Photo 9).

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 life cycle stages, so while some adults may die, grain will soon be reinfested again as soon as larvae and eggs develop.

What's worse, every time a poor fumigation is carried out, 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 9: *Phosphine is widely accepted as having no residue issues.*

Photo: QDAFF

While phosphine has some resistance issues, it is widely accepted as having no residue issues for grain. 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. [13]

Phosphine application

For effective phosphine fumigation, a minimum of 300 parts per million (ppm) gas concentration 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. The rest of the silo also suffers from reduced gas levels.

Achieve effective fumigation by placing the correct phosphine 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 five days if no fans are fitted.

A minimum withholding period of two days is required after ventilation before grain can be used for human consumption or stock feed.

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

As a general rule, only keep a silo sealed while carrying out the fumigation (for example, 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 the use of cotton overalls buttoned at the neck and wrist, eye protection, elbow-length PVC gloves and a breathing respirator with combined dust and gas cartridge.

13 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

Grain fumigation—a guide

Fumigating with phosphine, other fumigants and controlled atmospheres: Do it right—do it once. A Grains Industry Guide

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, phosphine can reach explosive levels if left to evolve in a confined space.

Time to kill

To control pests at all life stages and prevent insect resistance, phosphine gas concentration needs to reach 300 ppm for seven days (when grain is above 25°C) or 200 ppm for 10 days (between 15–25°C). Insect activity is slower in cooler grain temperatures so require longer exposer to the gas to receive a lethal dose. [14]

Non-chemical treatment options include:

- Carbon dioxide: Treatment with CO_2 involves displacing the oxygen inside a gas-tight silo with CO_2, which creates a toxic atmosphere 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 without chemicals. It is safe to use and environmentally acceptable, and the main operating cost is the capital cost of equipment and electricity. It also produces no residues, so grains can be traded at any time, unlike chemical fumigants that have withholding periods. Insect control with N_2 involves a process using pressure swinging adsorption (PSA) technology, modifying the atmosphere within the grain storage to remove everything except N_2, starving the pests of oxygen. [15]

13.3 Aeration during storage

13.3.1 Dealing with high moisture grain

Key points

- Deal with high-moisture grain promptly.
- Monitoring grain moisture and temperature regularly (daily) will enable early detection of mould and insect development.
- Aeration drying requires airflow rates in excess of 15 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.

A Department of Employment, Economic Development and Innovation (DEEDI) trial revealed that high-moisture grain generates heat when put into a confined storage, such as a silo.

Wheat at 16.5% moisture content at 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). 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 aerate.
- Aeration cooling: grain of moderate moisture, up to 15% moisture content, can be held for a short term under aeration cooling until drying equipment is available.

14 GRDC Stored Grain Information Hub. Grain Fumigation—A guide, http://storedgrain.com.au/fumigation-guide/

15 C Warrick (2012) Fumigating with phosphine, other fumigants and controlled atmospheres: Do It right—(2012) Fumigating with phosphine, other fumigants and controlled atmosphhttp://www.grdc.com.au/~/media/5EC5D830E7BF4976AD591D2C03797906.pdf

- Aeration drying” large volumes of air force a drying front through the grain in storage and slowly removes moisture. Supplementary heating can be added.
- Continuous flow drying: grain is transferred through a dryer, which uses a high volume of heated air to pass through the continual flow of grain.
- Batch drying: usually a transportable trailer drying 10–20 tonnes of grain at a time with a high volume of heated air, which passes through the grain and out perforated walls.

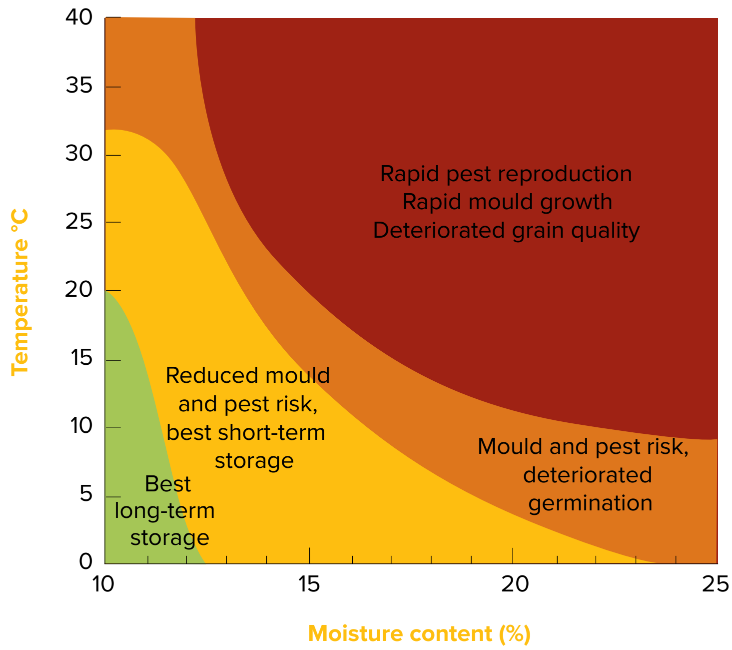


Figure 4: *Effects of Temperature and moisture on pest risk in stored grain.*

Source: CSIRO Ecosystems Sciences in GRDC

13.3.2 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 then maintenance.
- Stop aeration if ambient, relative humidity exceeds 85%.
- Automatic grain aeration controllers that select optimum fan run times provide 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 deliver. In most circumstances, grain can be stored at up to 14–15% moisture content safely with aeration cooling fans running continuously, delivering at least 2–3 L/s/t. It is important to keep fans running continuously for the entire period, only stopping them if the ambient relative humidity is above 85% for more than about 12 hours, to avoid wetting the grain further.

Blending

Blending is the principle of mixing slightly over-moist grain with lower-moisture grain to achieve an average moisture content below the ideal 12.5% moisture content. Successful for grain moisture content levels up to 13.5%, blending 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 (see Figure 5). [16]

MORE INFORMATION

GRDC Aerating Stored Grain—Industry Guide

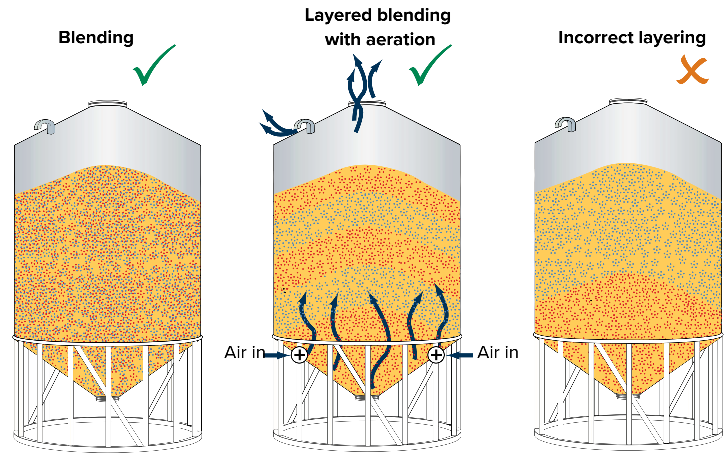


Figure 5: *Diagram demonstrating the correct practices for blending.*

Source: Kondinin Group, in GRDC

VIDEOS

WATCH: Grain Storage Cooling Aeration

Seed viability

Research trials reveal that wheat at 12% moisture content stored for six months at 30–35°C (unaerated grain temperature) will have reduced germination percentage and seedling vigour.

13.3.3 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 keys:

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

It is important to seek reliable advice on equipment requirements and correct management of fan run times, otherwise there is a high risk of damaging grain 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 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—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 out to an even depth.

16 GRDC Stored Grain Information Hub: Dealing with high moisture grain, http://storedgrain.com.au/dealing-with-high-moisture-grain/

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 (Photo 10). A flat-bottom silo with a full floor aeration plenum is ideal providing it can deliver at least 15 l/s/t of airflow. The silo may only be able to be part filled, which in many cases is better than trying to dry grain in a cone-bottom silo with insufficient ducting.

Photo 10: *Aeration drying requires careful management, high airflow rates, well designed ducting, exhaust vents and warm, dry weather conditions.*

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 on the top of the stack. The amount of moisture that has to escape with the exhaust air is 10 L for every one per cent moisture content removed per tonne of grain.

Weather conditions for drying

For moisture transfer to occur and drying to happen, air with a lower relative humidity than the grain's equilibrium moisture content must be used. In order to dry this wheat from its current state, the aeration drying fans would need to be turned on when the ambient air was below 70% relative humidity.

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 initial, continuous phase is if ambient air exceeds 85% relative humidity for more than a few hours.

MORE INFORMATION

Dealing with high moisture grain

VIDEOS

WATCH: Aeration drying—getting it right

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 is dried down the equilibrium point will also 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 %)

Source: GRDC

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 over heating the grain close to the aeration ducting. As a general guide, inlet air shouldn't exceed 35°C to avoid over heating grain closest to the aeration ducting.

Cooling after drying

Regardless of whether supplementary heat is added to the aeration drying process or not, the grain should be cooled immediately after it has been dried to the desired level. [17]

13.3.4 Aeration controllers

Aeration controllers manage both aeration drying, cooling and maintenance functions in up to ten separate storages (Photo 11). The unit takes into account the moisture content and temperature of grain at loading and the desired grain condition after time in storage, and selects air accordingly to achieve safe storage levels.

A single controller has had the ability to control the diverse functions of aeration: cooling, drying and maintenance. The controller can not only control all three functions, but also automatically selects the correct type of aeration strategy to obtain the desired grain moisture and temperature. [18]

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% moisture, 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 17–24°C from November through to March.

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

17 GRDC Stored Grain Information Hub: Dealing with high moisture grain, http://storedgrain.com.au/dealing-with-high-moisture-grain/

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

VIDEOS

WATCH: Aeration controllers with Philip Burrill

- Know the capacity of their existing aeration system.
- Determine whether grain requires drying before cooling can be carried out.
- Understand the effects of relative humidity and temperature when aerating stored grain.
- Determine the target conditions for the stored grain.

Photo 11: *Automatic aeration controllers are the most effective way to cool grain and are designed to manage many storages, from one central control unit.*

Source: GRDC

13.4 Grain protectants for storage

Lesser grain borer's (*Rhyzopertha dominica)* widespread resistance to grain protectants is coming to an end with the availability of deltamethrin (e.g. K-Obiol) and spinosad (e.g. Conserve On-Farm) products.

K-Obiol Combi

K-Obiol is a synergised grain protectant for use on cereal grains, malting barley and sorghum. 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 not suitable for oil seeds or pulses. 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; meaning it increases the effectiveness of the deltamethrin. As K-Obiol is based on deltamethrin there are none of the insect resistance problems being experienced with other protectants.

Because protectants are residual, there can be concern by grain users that the grain does not contain excessive levels. This may come about from incorrect treatment or double treatment as the grain moves along the supply chain. To protect the end user of the grain, and ultimately the Australian grain growers, a Product Stewardship program has been developed to ensure correct use of the product. The program will also ensure the product is used in a way that minimises the development of insect resistance and increases its usable life. [19]

19 GRDC Stored Grain information hub. K-Obiol Combi, http://storedgrain.com.au/k-obiol-combi/

Conserve On-farm

Conserve On-Farm is a grain protectant from DOW that has three active ingredients to control most major insect pests of stored grain, including the resistant lesser grain borer (LGB).

Conserve On-Farm provides six to nine months of control and has a nil withholding period (WHP).
Maximum residue limits (MRLs) have been established with key trading partners and there are no meat residue bioaccumulation issues.

Conserve On-Farm is a combination of two parts that are applied together.
Using Part A and Part B together is very important to get control of the complete spectrum of insects.

Part A: 1 x 5 L of chlorpyrifos-methyl and S-methoprene: controls all stored grain insect pests other than the resistant lesser grain borer (Rhyzopertha dominica)

Part B: 2 x 1 L of spinosad: is very effective on the lesser grain borer, including resistant strains, but has little to no activity on other key species. [20]

20 GRDC Stored Grain information hub. Conserve On-farm, http://storedgrain.com.au/conserve-farm/