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GRDC GROWNOTES™

GRDC
GRAINS RESEARCH & DEVELOPMENT CORPORATION

CHICKPEA

SECTION 13

STORAGE

HOW TO STORE PRODUCT ON-FARM | STORED GRAIN PESTS | MONITORING STORED CHICKPEAS | GRAIN PROTECTANTS FOR STORAGE

Storage

Key messages

- Pulses stored above 12% moisture content (MC) require aeration cooling to maintain quality. The recommended air-flow rate for cooling grain is 2–3 litres of air per second per tonne of grain in the storage.
- Unlike cereal grains, pulses cannot be treated with protectants to prevent insect infestations. Therefore, meticulous hygiene and aeration cooling to manage storage temperature and moisture are crucial to preventing insect damage and moulds from downgrading stored chickpeas.
- Fumigation is the only option available to control pests in stored pulses. This requires a gas-tight, sealable storage.
- Avoiding mechanical damage to pulse seeds will maintain market quality and seed viability, and will make them less attractive to insect pests.
- It is important that growers minimise the number of handling operations wherever possible and use efficient handling techniques that minimise damage, for example belt conveyors rather than spiral augers.

The successful storage of pulses requires a balance between ideal harvest conditions and ideal storage conditions. Harvesting at 14% MC captures grain quality and reduces mechanical damage to the seed, but it also requires careful management of seeds in aerated silos to avoid deterioration during storage. [1]

Testa quality and physiological age are two principle components of chickpea, pea, lentil and faba bean seed quality. Both are affected by harvest and storage practices. Both also influence germination (although they are not the only factors) as well as other measures of seed quality which affect the ability of seeds to produce seedlings which can emerge and establish. [2]

Many of the quality characteristics of the grain from these crops are in the appearance, size and physical integrity of the seed. Mechanical seed damage, discolouration, disease, insect damage (Photo 1), split seeds or small seeds will lead to a downgrade in quality and market value. Buyers prefer large, consistently sized seed free of chemical residues for easy processing and marketing to consumers.

Photo 1: *Insect (cowpea weevil) damage on seeds of two 'kabuli' and three 'desi' chickpeas (from left to right). Photo: F. Erler* et al *99 (2009)*[3]

Unlike cereal grains, pulses cannot be treated with protectants to prevent insect infestations. Therefore, meticulous hygiene and aeration cooling to manage storage temperature and moisture are crucial to prevent insect damage and moulds from

1 P Burrill, P Botta, C Newman, B White, C Warrick (2014) Storing pulses. Fact sheet. Updated July 2014, https://grdc.com.au/Resources/Factsheets/2014/07/Grain-Storage-Fact-Sheet-Storing-Pulses

2 RH Ellis, PK Agrawal, EE Roos (1988) Harvesting and storage factors that affect seed quality in pea, lentil, faba bean and chickpea. In World Crops: Cool Season Food Legumes. Springer Netherlands, Dordrecht. 303–329.

3 Erler, F., Ceylan, F., Erdemir, T., & Toker, C. (2009). Preliminary results on evaluation of chickpea, *Cicer arietinum*, genotypes for resistance to the pulse beetle, Callosobruchus maculatus. Journal of Insect Science, 9(1), 58.

VIDEOS

1. GCTV Stored grain: Storing pulses.

downgrading stored chickpeas. The Australian Pulse Standards stipulate standards for heat-damaged, bin-burnt, mouldy, caked or insect-infested chickpeas, and breaching of any of these can result in the discounting or rejection of product. [4] The effective management of stored chickpeas can eliminate all these risks. Growers contemplating medium–long-term storage (6–12 months) need to be aware that chickpeas continue to age, so that quality will deteriorate over time. Desi chickpeas will darken considerably in storage, with the rate of seed-coat darkening being accelerated by:

- high seed moisture content (MC)
- high temperatures
- high relative humidity

Condition of the seed at harvest

- Seed subject to field weathering before harvest will deteriorate a lot quicker in storage, even when stored at acceptable temperature and relative humidity.
- Conditions of high relative humidity and high temperatures result in rapid deterioration in grain colour.
- To maintain yellow colour and minimise the darkening of seed, any grain stored >12% MC will require cooling and/or drying.
- Growers should avoid even short–medium storage of weather-damaged grain. [5]

Gaining a better understanding of the insect pests themselves, and fighting them using the right combination of management choices and equipment gives growers the upper hand. In a deregulated market there is a large range of domestic and export selling options. Growers strengthen their position when their storage facilities allow flexibility with grain handling and timing of sales.

As a bonus, many of the strategies used to minimise pest problems also significantly improve storage conditions for maintaining grain quality.

13.1 How to store product on-farm

Key points

- Combining good hygiene, well-managed aeration cooling and regular grain inspections provide the best foundation for successful grain storage.
- Findings of recent ecological research, which involved trapping flying storage pests across grain-growing regions, reinforced the value of cleaning up grain residues in storages and equipment.
- New, easy-to-use functions in automatic aeration controllers provide improved reliability of achieving good results from aeration cooling.
- Recirculation and ground-level applications have a role to play in effective, safe fumigation. [6]

13.1.1 Handling and storage of chickpea seed

Planting-seed selection

Special attention should be given to the harvest, handling and storage of planting seed retained on the farm. Seed should be:

- Sourced from the cleanest paddocks, where Ascochyta blight was not detected.
- Harvested at minimum of 13–14% MC to minimise mechanical damage to the seed.

4 Pulse Australia (2011) Australian Pulse Standards, 2011/2012 Season. Pulse Australia, http://www.graintrade.org.au/sites/default/files/file/Commodity Standards/Pulse Standards 201112.pdf

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

6 P Burrill (2013) Grain storage: future pest-control options and storage systems 2013–2014. GRDC Update Papers. GRDC, https://grdc.com.au/Research-and-Development/GRDC-Update-Papers/2013/07/Grain-Storage-Future-pest-control-options-and-storage-systems-2013-2014

- If heat dried, at temperatures below 40°C.
- Stored at approximately 13% MC.
- Kept at a grain temperature of below 30°C (Table 2).
- Graded to remove split, damaged and small seeds.

Handling

Grain may have been handled (augured) up to six times by the time it is delivered to receival points or is planted. It is important that growers minimise the number of handling operations, and use efficient handling techniques to minimise damage; e.g. using belt conveyors rather than spiral augers.

If using augers:

- Operate slowly and full.
- Use large-diameter augers.
- Length of the auger should be no longer than is necessary.
- Keep auger incline low.
- Check flight casing clearance—optimal clearance is typically 50% of grain size to minimise the grain being wedged between the auger spiral and the casing.

Seed longevity in storage

Growers contemplating medium- to long-term storage (6–12 months) need to be aware that chickpea seed continues to age, and that quality deteriorates over time (Table 1). Desi chickpea will darken considerably, and seed germination capacity and vigour will decline in storage, with the rate being accelerated by:

- high seed-moisture content
- high temperatures
- high relative humidity
- condition (weathering) of the seed at harvest.

Seed that has been weathered before harvest will deteriorate quicker in storage, even when stored under acceptable conditions of temperature and relative humidity. To maintain colour and minimise darkening of seed, any grain stored above 12% moisture will require cooling. [7]

Table 1: *Effect of moisture content and temperature on storage life of chickpea.*

Storage moisture (%)	Storage temperature (°C)	Longevity of seed (days)
12	20 30 40	>2000 500-650 110-130
15	20 30 40	700-850 180-210 30-50

Note: Most planting seed will need to be stored for a period of 180 days or more.

Source: Pulse Australia

Moisture and temperature

Research has shown that harvesting pulses at higher moisture content (up to 14%) reduces field mould, mechanical damage to the seed, and splitting, and preserves seed viability. The challenge is to maintain this quality during storage, when there is an increased risk of deterioration at these moisture levels. As a result, pulses stored above 12% MC require aeration cooling to maintain quality.

7 B O'Mara, S Belfield, G Cumming (n.d.) Chickpea harvest and seed storage. Pulse Australia, http://www.pulseaus.com.au/storage/app/media/crops/2007_Chickpea-Harvest-Storage.pdf

Grain Trade Australia (GTA) sets a maximum moisture limit of 14% for most pulses, but bulk handlers may have receival requirements as low as 12%. [8] As a general rule of thumb, the higher the moisture content, the lower the temperature required to maintain seed quality (Table 2). [9]

Table 2: *Maximum recommended storage period.*

Moisture content (%)	Grain temperature (°C) 20	30
14	3 months	N/A
13	9 months	3 months
12	>9 months	9 months

Source: GRDC

Green pods and grains increase the risk of mould developing during storage—even at a lower moisture content. Aeration cooling will help prevent mould and hot spots by creating uniform conditions throughout the grain bulk. [10]

Weathering damage hinders storage

Pulses exposed to weathering before harvest deteriorate more quickly in storage. Chickpeas stored for the medium to long term (6–12 months) continue to age and lose quality (Table 1). Growers can minimise the effects of seed darkening, declining germination capacity and reduced seed vigour by:

- Lowering moisture content and temperature.
- Harvesting before weather damages the grain. [11]

13.1.2 On-farm storage

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 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. [12]

The two most common of the serious threats to grain quality in Australia's storages are insect pest infestations and grain moisture problems causing the growth of mould or fungus. Key initial strategies include:

VIDEOS

2. GCTV: Stored grain: Oilseeds and pulse storage

8 Storing pulses. Stored Grain Information Hub. GRDC, www.grdc.com.au/GRDC-FS-GrainStorage-StoringPulses

9 B O'Mara, S Belfield, G Cumming (n.d.) Chickpea harvest and seed storage. Pulse Australia, http://www.pulseaus.com.au/storage/app/media/crops/2007_Chickpea-Harvest-Storage.pdf

10 Storing pulses. Stored Grain Information Hub. GRDC, http://storedgrain.com.au/storing-pulses/

11 GRDC Stored Grain Hub. Storing pulses. http://storedgrain.com.au/storing-pulses/

12 GRDC. (2015). Ground cover issue 119—Grain storage. Extension tailored for regional challenges. https://grdc.com.au/resources-and-publications/groundcover/ground-cover-issue-119-nov-dec-2015?f.Region%7Csregion=West&query=!allitems&meta_aissueno_not=%22Ground%20Cover%20supplements%22&personal=false&form=listing&collection=grdc-multi&profile=groundcover&meta_aissueno_not=GroundCover%E2%84%A2&meta_aissueno_not=%22Ground+Cover+supplements%22&matrix_origin=groundcover_details&meta_aissueno=119&fmo=on&start_rank=11

- Thorough hygiene maintained in storages and equipment.
- Keeping grain cool and dry grain in storage.

Attention paid to the three areas listed below will provide reliable grain quality:

- Good storage and equipment hygiene reduces early pest infestations and grain-contamination problems. Sieve and inspect grain in storages monthly.
- High-moisture grain in storage—have the right equipment and management strategies in place to deal promptly with any growth of mould or fungus. Monitor regularly.
- Cool grain temperature—use aeration to achieve cool, uniform temperature in storages in the first few weeks after harvest. Monitor to maintain these conditions. [13]

In most cases, for on-farm storage to be economical it will need to deliver on more than one of these benefits (Table 3). 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 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. [14]

Table 3: *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 tonnes up to 3,000 tonnes Up to 25 year plus service life Simple in-loading and out-loading Easily administered hygiene (cone base particularly) Can be used multiple times in-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 with fans 7–10% cheaper than sealed silos Capacity from 15 tonnes up to 3,000 tonnes Up to 25 year plus service life Can be used multiple times in-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 WA Access requires safety equipment and infrastructure

13 P Burrill (2013) Grain storage: future pest-control options and storage systems 2013–2014. GRDC Update Papers. GRDC, https://grdc.com.au/Research-and-Development/GRDC-Update-Papers/2013/07/Grain-Storage-Future-pest-control-options-and-storage-systems-2013-2014

14 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 a paddock Provide harvest logistics support Can provide segregation options Are all ground operated Can accommodate high-yielding seasons Grain is untreated for wider market access.	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 need 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 and bird control is difficult Limited insect control options without sealing Difficult to unload

Source: Kondinin Group

Established strategies

There is an increasing number of growers who are reaping rewards by placing extra emphasis on the management of their grain-storage facilities. It is the combination of practices listed below that provides the real strength to successful storage.

Key strategies include:

- High standard of hygiene for storages and grain-handling equipment—minimising insect-pest breeding sites.
- Monthly checks of grain in storage, including those of planting seed—sieving for insects and checking quality.
- Aeration—aeration fans fitted to storages, and operated by an automatic controller.
- Grain temperatures—checked and maintaining 20–23°C in summer and less than 15°C in winter.
- Fumigations, when required, are carried out in sealable silos. The silos are pressure-tested at least once a year.
- Storage record keeping—a simple system is used to record details such as grain variety, moisture content, any treatments given, inspection dates, and information on insects found and grain temperature.

MORE INFORMATION

[Benefits flow from on-farm storage in the Mallee.](#)

[Grain storage facilities: Planning for efficiency and quality.](#)

VIDEOS

3. [Over the Fence: On-farm storage pays in wet harvest](#)

New products and equipment

Aeration using automatic controllers

Reliability good results with aeration cooling are significantly increased with the use of automatic controllers to turn on silo fans when the best ambient temperature and humidity conditions are available. There are new functions in automatic aeration controllers. Some of the options available include:

- The ability to have fans automatically step through the three important stages of aeration cooling—continuous, purge, and protected.
- The ability to exclude very humid air (>85% RH) in all three of these stages.
- The ability to cater for fans with air-flow rates higher than the standard 2–3 litres per second per tonne (L/s/t).

These functions provide another good reason to stop using the less-reliable methods of trying to remember to manually switch fans on and off, or using power-point timers.

High–flow rotary grain cleaner

One of benefits of having storages on the farm is the ability to segregate different quality grades of grain at harvest time. For farmers who only just miss being given a premium grade due to a few extra percent screenings in wheat, or who face downgrades in pulses due to splits or weed seed contamination, grading is an option that can quickly add value.

Storage safety is also improved by grading out impurities and fines from oilseeds when filling silos.

The rotary grader has multiple screen tubes designed for flow rates that will keep up with most harvesting operations. A range of screen sizes and slot designs suit most grading requirements.

13.1.3 Silos

Well-designed and properly operated on-farm storage provides the best insurance that a grower can have to maintain the quality of chickpeas to be out-turned. Storages must be used in conjunction with sound management practices, which include monthly sieving for insects, regular grain-quality inspections, and ensuring that aeration cooling equipment is operating as required. [15]

Silos are the ideal storage option for pulses, especially if they are cone-based for easy out-loading with minimal seed damage (Photo 2). Because chickpeas are susceptible to splitting at the ideal storage moisture content of ≤12%, cone-based rather than flat-based silos are recommended for easy out-loading with minimal seed damage. For anything more than short-term storage (three months) aeration cooling and gas-tight sealable storage suitable for fumigation are essential features for best-practice quality control.

Always fill and empty silos from the centre holes. This is especially important with pulses because most have a high bulk density. Loading or out-loading off-centre will put uneven weight on the structure and may cause it to collapse. Avoid storing lentils in silos with horizontally corrugated walls, as the grain can run out from the bottom first and cause the collapse of the silo as, in bulk, the grain will slide down the silo walls rather than from the centre.

15 P Burrill, P Botta, C Newman, B White, C Warrick (2014) Storing pulses. Fact sheet. Updated July 2014, https://grdc.com.au/Resources/Factsheets/2014/07/Grain-Storage-Fact-Sheet-Storing-Pulses

Photo 2: *Sealable, aerated silos fitted with thermosiphons to assist with gas distribution during fumigation.*

Source: GRDC

Paint the outside of the silo with white paint. This reduces storage temperature by as much as 4–5 °C and can double the safe storage life of grains. Aerate silos with dry, ambient air. In addition to reducing storage temperatures, aeration is also effective in reducing moisture of seed harvested at high moisture content if flow rates are sufficient. Growers should avoid even short–medium storage of weather-damaged grain. [16]

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. [17]

16 DAF Queensland (2012) Chickpea: harvesting and storage. DAF Qld, https://www.daf.qld.gov.au/plants/field-crops-and-pastures/broadacre-field-crops/chickpeas/harvesting-and-storage

17 Francis J. (2006). An analysis of grain storage bags, sealed grain silos and warehousing for storing grain.

Pressure testing

At industry level, it is within growers' best interests to house grain in aerated, sealable storages to help curtail the rise of insect resistance to phosphine. Resistance has come about because of the prevalence of silos that are poorly sealed, or even unsealed, during fumigation. [18]

- 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.

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 seven days or 200ppm for 10 days.

The importance of a gas-tight silo

Growers should pressure-test sealable silos once a year to check for damaged seals on openings. Storages must be able to be sealed properly to ensure high phosphine gas concentrations are held long enough to give an effective fumigation. At an industry level, it is in growers' best interests to only fumigate in gas-tight sealable storages to help stem the rise of insect resistance to phosphine. This resistance has come about because of the prevalence of storages that are poorly sealed or unsealed during fumigation. [19]

Research shows that fumigating in a storage that is not gas-tight does not achieve a sufficient concentration of fumigant for long enough to kill pests at all life cycle stages. For effective phosphine fumigation, a minimum gas concentration of 300 parts per million (ppm) for 7 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. [20]

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.

MORE INFORMATION

GRDC Pressure testing sealable silos factsheet.

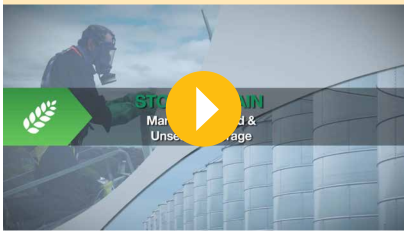
GRDC Silo buyer's guide

VIDEOS

4. Pressure testing sealed silos.

VIDEOS

5. Stored grain: Managing sealed and unsealed storage.



18 C Warrick (2012) Fumigating with phosphine, other fumigants and controlled atmospheres. Reprinted August 2012. GRDC, https://grdc.com.au/__data/assets/pdf_file/0025/206791/fumigating-with-phosphine.pdf.pdf

19 C Warrick (2011) Fumigating with phosphine, other fumigants and controlled atmospheres: Do it right—do it once: A Grains Industry Guide. GRDC Stored Grain Project, January 2011 (reprinted June 2013), https://grdc.com.au/__data/assets/pdf_file/0025/206791/fumigating-with-phosphine.pdf.pdf

20 P Botta, P Burrill, C Newman (2010) Pressure testing sealable silos. GRDC Grain Storage Fact Sheet, September 2010 Revised July 2014, http://storedgrain.com.au/wp-content/uploads/2014/09/GSFS-3_PressureTest-July14.pdf

13.1.4 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 grain and are filled and emptied using specialised machinery (Photo 3). 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. [21]

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

Source: StarTribune.

Risks with chickpeas

Chickpeas can be stored successfully in silo bags of up to three months, but it is a less desirable option than silo storage. Marketers have rejected pulse grain because of moulds, taints and odours from storage in grain bags. Such taints and odours are not acceptable in pulse markets. [22]

Black discoloration of chickpeas due to moisture ingress into the base of grain bags has also occurred, causing serious losses in storage.

13.1.5 Grain storage—get the economics right

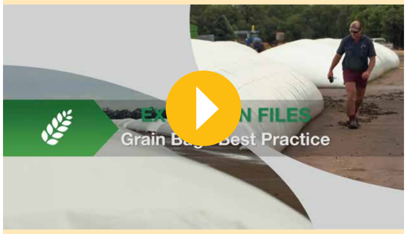
As growers continue to expand their on-farm grain storage, the question of economic viability gains significance. There are many examples of growers investing in on-farm grain storage and paying for it in one or two years because they struck the market at

MORE INFORMATION

Fumigating in a silo bag with phosphine?

VIDEOS

6. Grain bags best practice.



7. Extension Files: Grain bags—a grower's perspective.

21 Francis J. (2006). An analysis of grain storage bags, sealed grain silos and warehousing for storing grain.

22 W Hawthorne, A Meldrum, G Cumming (2010) Grain bags for pulse storage—use care. Australian Pulse Bulletin 2010 No. 3, http://www.pulseaus.com.au/storage/app/media/crops/2010_APB-Pulse-grain-bag-storage.pdf

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's 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'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 quality. One of the most significant variable cost, 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's difficult to put an exact dollar value on each of the potential benefits and costs, a calculated estimate will determine if it's 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've 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 are seeing around Australia, the growers who are taking a planned approach to on-farm grain storage and doing 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 4 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. [23]

Table 4: *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 eg 25yrs	$6.20
Opportunity cost on capital	Capital cost $/t x opportunity or interest rate eg 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	
Total variable costs	Sum of variable costs	$11.32

MORE INFORMATION

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

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

23 Warrick C. (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

VIDEOS

8. On-farm storage in the SA Mallee with Corey Blacksell.

9. On-farm storage in SA—Linden Price.

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

11. Stay safe around grain storage

Financial gains from storage		Example $/t
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

Insects are not considered to be a major problem in stored chickpea. The exceptions appear to be where chickpeas have higher levels of splits and damaged seed, or are loaded into storages containing residues of cereal grains that are already infested with pests, or both. Then chickpeas may harbour several insects, including:

- rust-red flour beetle (*Tribolium castaneum*)
- lesser grain borer (*Rhyzopertha dominica*)
- saw-toothed grain beetle (*Oryzaephilus surinamensis*)

Where a prior infestation exists in storage facilities, pests can spread and develop in chickpeas. The most common pulse pests are the cowpea weevil and pea weevil (Note that pea weevil is a pest of field peas and infection occurs in the field. It is not a stored grain pest as such although adults can emerge from peas in storage) which can also survive and breed at slower rates in chickpeas. The cowpea weevil has a short life span of 10–12 days while the pea weevil only breeds one generation per year. [24] Hygiene is the most cost-effective method of managing bruchid problems. Growers need to thoroughly clean all residues of other pulses from headers, planting equipment, shed floors, augers and empty trucks and storages after each harvest, and whenever pulse seeds are handled on the farm. [25]

If weather damage before harvest or header settings have led to chickpeas containing higher levels of split grain and trash, they are more prone to infestation by pests such as the rust-red flower beetle. Pre-storage grading to remove splits or extra storage monitoring is required.

Chickpea gradings are attractive to storage pests. Gradings can act as a breeding site, causing infestations to spread to the storage complex. Use or remove gradings from the area as soon as possible.

Good hygiene by ensuring that all handling equipment and storages are clean before handling chickpea should prevent infestations from developing. If insects are found in stored chickpeas, the only registered treatment option are controlled atmospheres (CO_2, N_2) or phosphine fumigation. [26]

The high numbers of storage pests that can fly away from on-farm sources of infested grain in spring and summer looking for newly harvested clean grain to infest (Figure 1) demonstrates the value of regularly maintaining hygiene and inspecting grain.

24 Storing pulses. Stored Grain Information Hub. GRDC, http://storedgrain.com.au/storing-pulses/

25 DAF Queensland (2012) Chickpea: harvesting and storage. DAF Qld, https://www.daf.qld.gov.au/plants/field-crops-and-pastures/broadacre-field-crops/chickpeas/harvesting-and-storage

26 Pulse Australia. Chickpea harvest and seed storage. http://www.pulseaus.com.au/storage/app/media/crops/2007_Chickpea-Harvest-Storage.pdf

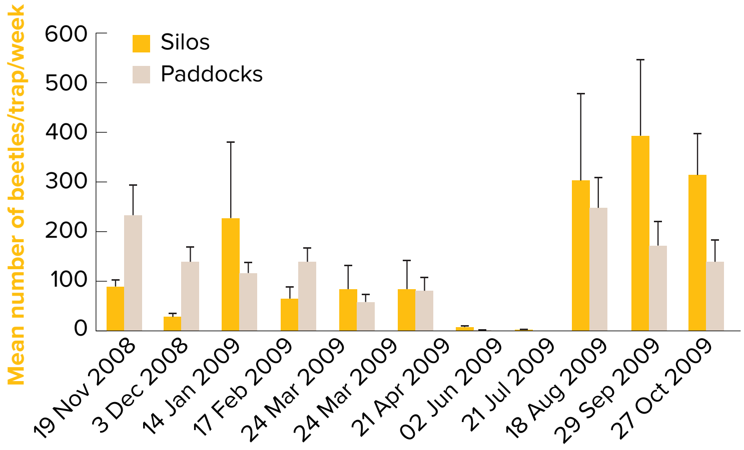


Figure 1: *Numbers of lesser grain borers trapped in warm and cooler months at farm silos and 1 km away in the paddocks.*

Source: GRDC

No insecticide sprays are currently registered for use on chickpea grain. Markets are particularly sensitive to insecticide residues, so the detection of any residues on chickpeas could result in the loss of a market, not just the rejection of a contaminated delivery. This is so whether the insecticide residue is from a storage application or from harvesting sooner than witholding periods (whp) allow.

For structural treatments of silos, use an inert dust such as diatomaceous earth (DE) after a thorough cleaning of all old grain residues. Wash out the silo with a pressure hose, then leave it open to dry is also recommended, particularly if an insect infestation occurred in the last grain stored in it. [27]

The aeration of pulses stored in silos is the key non-chemical tool used to minimise the risk of insect infestations and spoiling through heat and/or moisture damage (Figure 1). Pulses stored above 12% MC require aeration cooling to maintain quality. Australian pulse trading standards are set at a maximum moisture limit of 14% for chickpeas, and most other pulses [28], but bulk handlers may have receival requirements as low as 12%. As a general rule of thumb, the higher the moisture content, the lower the temperature required to maintain seed quality.

Aeration of chickpeas as soon as they go into the silo will provide uniform moisture conditions in the grain bulk, and quickly lower grain temperatures, which will minimise the effects of seed darkening, declining germination capacity and seed vigour.

13.2.1 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 in order to survive and reproduce.
- 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, and avoid using with pulses and oil seeds.

27 Pulse Australia (2013) Northern Chickpea—Best Management Practices Training course Manual 2013. Pulse Australia.

28 Pulse Australia (2016) Australian Pulse Standards 2016–2017. Pulse Australia, http://www.pulseaus.com.au/storage/app/media/markets/20160801_Pulse-Standards.pdf

VIDEOS

12. GCTV2: Grain silo hygiene

The first line of defence against grain pests occurs before the pulses are put into storage—in meticulous grain hygiene. Because pest control options are limited, it's critical to remove pests from the storage site before harvest. The key to control is to ensure that all handling equipment and storages are cleaned of old grain residues before they are used to handle chickpeas. Effective hygiene plus aeration cooling can overcome 75% of pest problems in on-farm storage.

A bag of infested grain can produce more than one million insects during a year, and these can walk and fly to other grain storages where they will start new infestations.

Cleaning silos and storages thoroughly and removing spilt and leftover grain removes the feed source and harbour for insect pests.

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 (Photo 4). 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. [29]

Successful grain hygiene involves cleaning all areas where grain gets trapped in storages and equipment. Grain pests can survive in a tiny amount of grain, so any fresh parcel of grain passing through machinery, storage or equipment can easily become infested.

Photo 4: *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

29 Hygiene and structural treatments for grain storage. Fact sheet. Stored Grain Information Hub. GRDC, http://storedgrain.com.au/hygiene-structural-treatments/

When to clean

Straight after harvest is the best time to clean grain handling equipment and storages, before they have time to become infested with pests. A trial carried out at the start of a harvest in Queensland revealed more than 1,000 lesser grain borers in the first 40 L of grain through a harvester, which had been considered reasonably clean at the end of the previous season. Discarding the first few bags of grain at the start of the harvest is a good idea.

Studies have revealed that insects are least mobile during the colder months of the year. Cleaning around silos from July–August can reduce insect numbers before they become mobile.

How to clean

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

- sweeping
- vacuuming
- compressed air
- blow guns or vacuum guns
- pressure washers
- fire-fighting hoses

Using a broom or jets of 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 5). Choose a warm, dry day to wash storages and equipment so they dry out quickly and do not get rusty. 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 left-over 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 5: *Clean silos, including the silo wall, with air and/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 DE as a structural treatment. (See Section 13.2.6 Structural treatments for chickpea storage for more information.)

Tip: A concrete slab underneath silos makes cleaning much easier (Photo 6).

Photo 6: *Concrete slab under silo makes cleaning up spilled grain much easier.*

Source: Stored Grain Information Hub

13.2.2 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 the relative humidity of the ambient air exceeds 85%.
- Automatic grain-aeration controllers that select optimum fan running times provide the most reliable results.

Not all growers are convinced that the aeration of grain is worthwhile, or a valuable asset for their storage system in this region, and have been reluctant to install aeration fans in their storages. However, a well-managed aeration system typically reduces grain temperatures by at least 10°C (Figure 2). This has a significant impact on reducing insect-pest problems and in maintaining grain quality.

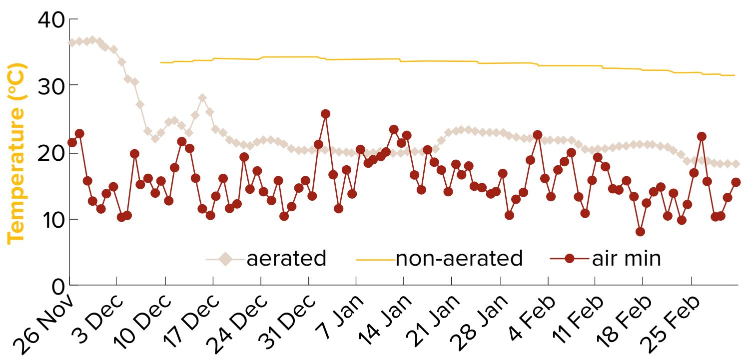


Figure 2: *Comparison of grain temperatures in aerated and non-aerated silos.*

Source: GRDC

Aeration cooling:

- Creates uniform conditions throughout the grain bulk.
- Prevents moisture migration.
- Maintains seed viability (germination and vigour).
- Reduces mould growth.
- Lengthens (and in some instances stops) insect reproduction cycles.
- Slows seed-coat darkening and quality loss.

Grain temperatures below 15°C stop the breeding cycle for all common storage pests. During summer, achieving grain temperature close to 20°C is also valuable, as it either stops or significantly slows insect population increases.

Fungal growth in grain in storage is kept in check with appropriate grain-moisture. Keeping grain at lower temperatures also assists to some extent in reducing fungal growth.

While adult insects can still survive at low temperatures, most of the young of storage pests stop developing at temperatures below 18–20°C (Table 5). At cool temperatures (20–23°C) 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. [30]

Table 5: *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

With the support of an aeration controller, aeration can rapidly reduce stored grain temperatures to a level that helps maintain grain quality and inhibit insect development.

The recommended airflow rate for cooling grain is 2–3 litres of air per second per tonne (L/s/t) of grain in the storage.

Grain is an effective insulator because, like housing insulation, it holds many tiny pockets of air within a stack. Without aeration it will maintain its warm harvest temperature for a long time. Aeration cooling allows for longer-term storage of low-moisture grain by creating desirable conditions for the grain and undesirable conditions for mould and pests. Unlike aeration drying, aeration cooling can be achieved with air-flow rates of as little as 2–3 (L/s/t) of grain, from fans driven by a 0.37 kilowatt (0.5 horsepower) electric motor for silos of around 100 t capacity.

30 Aeration cooling for pest control. Stored Grain Information Hub. GRDC, http://storedgrain.com.au/aeration-cooling/; Keeping aeration under control (2010) Farming Ahead. No. 208, March 2010. Kondinin Group, http://storedgrain.com.au/wp-content/uploads/2013/06/Kondinin-Group-Report-Aeration-Controllers-Reduced.pdf

MORE INFORMATION

Aeration cooling for pest control.

High-moisture grain can also be safely held for a short time with aeration cooling before it is blended or dried. Run fans continuously to prevent self-heating and quality damage. [31]

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 17–24°C from November to March.

Before replicating these results on the farm, growers need to:

- 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.

Air movement within the stack

The grain at the top of the stack is the hottest, as heat rises through the grain and the top grain is exposed to the head space in the silo (Figure 3).

As the air in the head space heats and cools each day, it creates ideal conditions for condensation to form. If this happens, the grain on the top of the stack will get wet.

Be aware that aeration drying requires specifically designed equipment and the process is much slower than aeration cooling or hot-air drying.

31 P Burrill, P Botta, C Newman, B White, C Warrick (2014) Storing pulses. Fact sheet. Updated July 2014, https://grdc.com.au/Resources/Factsheets/2014/07/Grain-Storage-Fact-Sheet-Storing-Pulses.

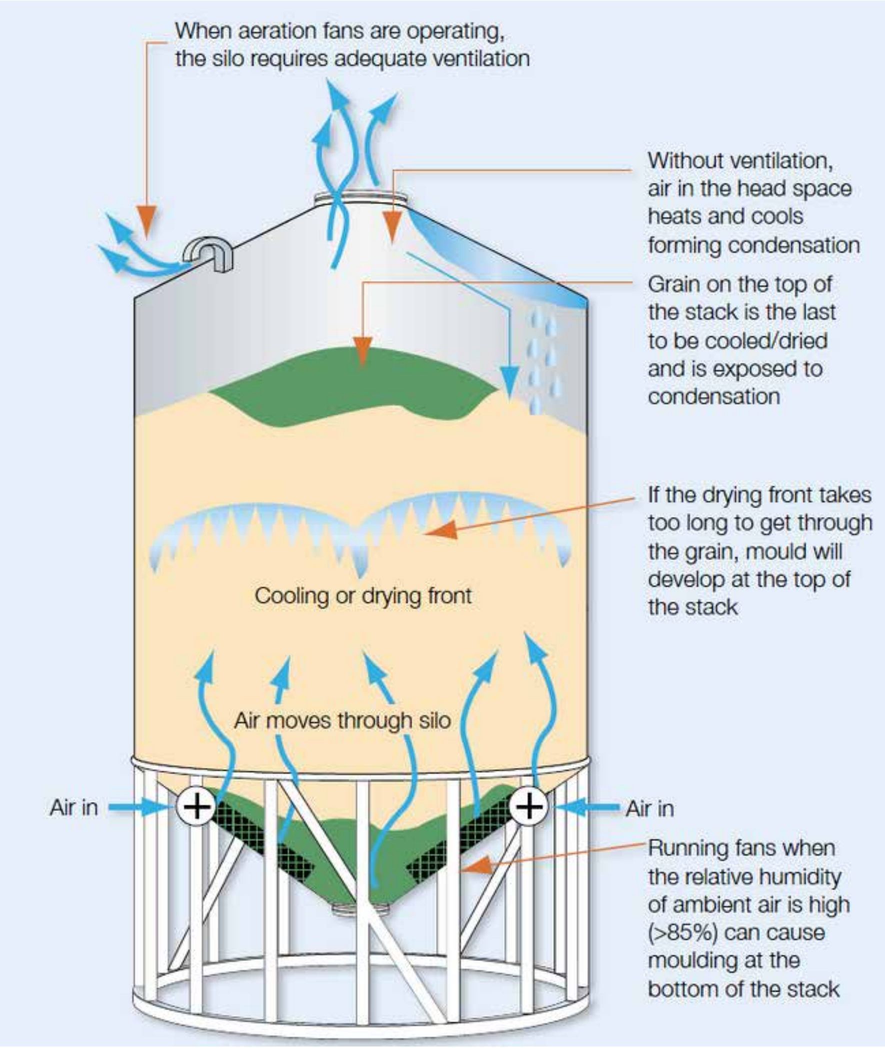


Figure 3: *Air movement within an aerated silo.*

Source: Stored Grain Information Hub

The cooling process

Operating an aeration fan for cooling requires a planned control program, which is best done with an automatic aeration controller. But even without a controller, growers need to aim for the same run time, following the same process.

The initial aim is to get maximum airflow through the grain bulk as soon as it enters storage, to stop it from sweating and heating.

When first loading grain into storage, run the aeration fans continuously from the time the grain covers the aeration ducts and for the next 1–3 days, until the cooling front reaches the top of the storage.

However, do not operate the aeration fans on continuous mode if the ambient relative humidity is higher than 85 per cent for extended periods of time, as this will wet the grain.

After the aeration fans have been running continuously for 2–3 days to flush out any warm, humid air, reduce the running time to 9–12 hours per day during the coolest part of the day, for the next seven days.

The goal is to quickly reduce the grain temperature from the mid-30s (°C) down to the low 20s (°C). An initial reduction in grain temperature of 10°C ensures grain is less prone to damage and insect attack, while further cooling becomes a more precise task. During this final stage, automated aeration controllers generally run fans during the coolest periods of the day, for an average of 100 hours per month.

Grain temperature is gradually reduced as low as possible and then maintained throughout the storage period.

Achieving reliable results with aeration cooling

Tips for producing the best results using aeration:

- Fan operations—replace manual switching or timers with automatic controllers to provide reliable, consistent cool grain temperatures. Buy them from a trustworthy supplier.
- Maintenance—manually test individual silo fans to check there are no electrical faults. For auto-controllers, check that the temperature and humidity sensor is clean. Also compare its readings with a reliable hand-held thermometer and RH (relative humidity) reader.
- Fan operations—ensure fans are stepped through the three important stages of aeration cooling. The most recent auto-controller models (e.g. Grainsafe-5000) automate this procedure over the first two weeks of storage.
- Fan performance—during 2011–2012 an Australian research group developed a simple, accurate method for testing the air-flow performance of aeration fans while they are operating. The recommended air-flow rate for cooling grain is 2–3 L/s/t of grain in the storage. Field tests on farm storages have shown that some fans do not deliver these rates. [32]

The risks of getting it wrong

Once in maintenance mode, running aeration fans on timers that are preset to run at the same time each day will not ensure the selection of the most appropriate air to maintain grain quality. The biggest risk with running aeration fans without a controller is forgetting to turn them off, or not being available to, if the relative humidity exceeds 85%.

Operating fans for extended periods of a few hours or days during humid conditions can increase grain moisture and cause moulding. Aeration controllers are designed to automatically select the best time to run aeration fans. Fans on these systems only run when the conditions will benefit the stored grain. [33]

Weevil development ceases at temperatures below 20°C. This is a strong incentive for aeration cooling, especially if gas-tight storage is not available. [34]

Installation and management tips

When retrofitting an aeration system, avoid splitting airflow from one fan to more than one storage. Each storage will provide a different amount of back-pressure on the fan, resulting in uneven airflow and inefficient or even ineffective cooling.

If buying an aeration controller be aware that most controllers need to be installed by an electrician.

The preferred mounting location for aeration controllers is outside where the sensors can get ambient condition readings but are sheltered from the direct elements of the weather. To avoid the chance of a dust explosion, do not install aeration controllers in a confined space.

Ensure your electrician installs wiring that is properly insulated and protected from potentially damaging equipment, such as augers.

MORE INFORMATION

GRDC Performance testing aeration systems Fact sheet.

MORE INFORMATION

Aeration cooling for pest control.

VIDEOS

13. GCTV2: Grain storage cooling aeration.

32 P Burrill (2013) Grain storage: future pest-control options and storage systems 2013–2014. GRDC Update Papers. GRDC, https://grdc.com.au/Research-and-Development/GRDC-Update-Papers/2013/07/Grain-Storage-Future-pest-control-options-and-storage-systems-2013-2014

33 Aeration cooling for pest control. Stored Grain Information Hub. GRDC, http://storedgrain.com.au/aeration-cooling/

34 Storing pulses. Stored Grain Information Hub. GRDC, www.grdc.com.au/GRDC-FS-GrainStorage-StoringPulses

Monitoring is a must

Aeration controllers reduce the amount of time operators need to physically monitor grain storages and turn fans on and off, but units and storage facilities still need to be checked regularly (Photo 7).

Photo 7: *Temperature check: monitor the effectiveness of the cooling process by checking grain temperature with a probe or a thermometer taped to a rod.*

Source: Stored Grain Information Hub

Most controllers have hour meters fitted, so run times can be checked to ensure they are within range of the expected total average hours per month.

Check fans to ensure they are connected and operating correctly.

The smell of the air leaving the storage is one of the most reliable indicators of whether the system is working. The exhaust air should change from a humid, warm smell to a fresh smell after the initial cooling front has passed through the grain.

Animals can damage power leads and automatic controller sensors and fan blades, or bearings can fail, so check these components regularly.

Check for suction in and feel for air-flow out of the storage vents when the fans are running.

Keeping grain at the right moisture and temperature levels will reduce the likelihood of insect infestations, but stored grain still needs to be sampled regularly and monitored for any changes. If possible, safely check the moisture and temperature of the grain at the bottom and top of the stack. [35]

13.2.3 Aeration drying

Ambient air can also be used to dry grain. Here, air is pumped through the grain bulk at high flow rates and at a temperature and humidity that will remove water from the grain (Table 6). [36]

Pulses stored for longer than three months at high moisture content (>14%) will require drying or blending to maintain seed quality. Aeration drying has a lower risk of cracking and damaging pulses, which occurs more readily with hot-air dryers. Unlike aeration cooling, drying requires high airflow rates of at least 15–25 L/s/t and careful management.

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:

35 Aeration cooling for pest control. Stored Grain Information Hub. GRDC, http://storedgrain.com.au/aeration-cooling/

36 GRDC (2004) How aeration works. Grains Research Update Advice. GRDC, http://storedgrain.com.au/how-aeration-works-grdc-update/

- 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.

Management strategies

If ambient air conditions are such that grain will dry, fans should be turned on and left on. When conditions are such that grain is no longer drying, turn the fans off, and only turn them back on when air conditions will again allow grain to dry. The moisture content that grain will dry to is determined by the average condition of the air used. If the average condition of air used is too dry, grain below the drying front will be over-dried. To calculate if air of a certain quality will dry grain, training in calculating the equilibrium moisture content is needed. The data presented in Table 6 provides a rough guide. It should be noted that different types of grain have slightly different equilibrium grain moistures.

Table 6: *Approximate moisture content of grain resulting from aeration with air at various temperatures and humidity (equilibrium grain moisture content).*

Temp °C	Relative humidity (%)				
	30	40	50	60	70
15	9.8	11	12.1	13.4	15
25	9	10.3	11.4	12.8	14
35	8.5	9.7	10.7	12.0	13.5

Source: GRDC.

Automated controllers simplify the process of selecting air that is suitable for drying. If air conditions are such that drying will not occur, supplemental heating can be used to raise the air inlet temperature a few degrees. This greatly increases the potential of that air for drying, but care should be taken not to over dry. If supplementary heating is unavailable and the available air will not dry the grain, a short-term holding measure may be to change strategy and cool the grain, with the intent of maintaining its quality, until better quality air for drying is available. The grain is placed at risk of mould development if air conditions do not improve in the short term; and this risk is far greater if air of suitable quality to cool grain is also unavailable.

The best air for drying is often from midday to dusk, but this varies from region to region. There are 50 locations around Australia where the drying potential of air has been monitored and recorded over many years. This data can provide information on the frequency of air suitable to dry grain from varying moisture contents and will assist in determining if supplemental heating is likely to be needed. It also gives insight as to the time of the day when the best air quality for cooling or drying is likely to occur. [37]

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.

37 GRDC (2004) How aeration works. Grains Research Update Advice. GRDC, http://storedgrain.com.au/how-aeration-works-grdc-update/

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 8). 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.

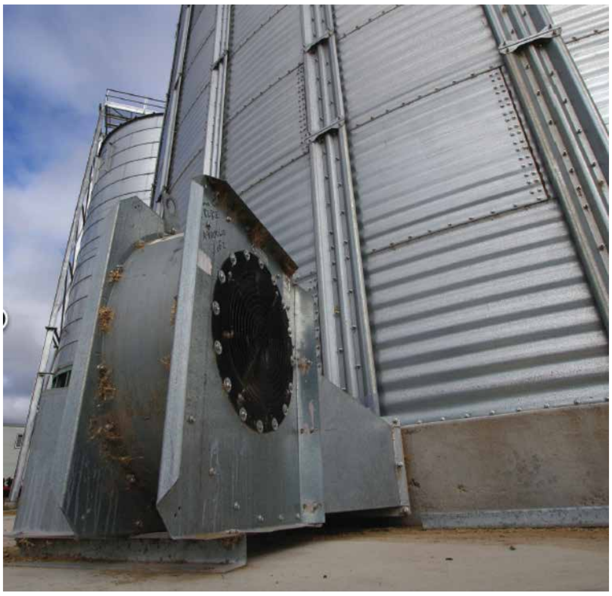


Photo 8: *Aeration drying requires careful management, high airflow rates, well designed ducting, exhaust vents and warm, dry weather conditions.*

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. For example, Table 7 shows that grain at 25°C and 14% moisture content has an equilibrium point of the air around it at 70% relative humidity. In order to dry this grain 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.

Phase two of drying

By monitoring the temperature and moisture content of the grain in storage and referring to an equilibrium moisture table, 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 7: *Equilibrium moisture content for wheat. NOTE: values may be different for other grains.*

Relative humidity (%)	Temperature 15	Temperature 25	Temperature 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. [38]

13.2.4 Cooling or drying: making a choice

It can be difficult to know whether grain needs to be dried or cooled, but there are some simple rules of thumb to help you decide. For longer-term storage grain must be lowered to the correct moisture content. Grain that is dry enough to meet the specifications for sale can be cooled, without drying, to slow insect development and maintain quality. Grain of moderate moisture can be either cooled for short periods to slow mould and insect development, or dried providing the right equipment and conditions are available. After drying to the required moisture content, grain can be cooled to maintain quality. High-moisture grain (for example, 16% or more for wheat) will require immediate moisture reduction before cooling for maintenance. [39]

13.2.5 Aeration controllers

Aeration controllers manage both aeration drying, cooling and maintenance functions in up to ten separate storages (Photo 9). The unit it takes into account the moisture content and temperature of grain at loading, 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 combine the ability to control all three functions, but automatically selects the correct type of aeration strategy to obtain the desired grain moisture and temperature. [40]

MORE INFORMATION

Dealing with high moisture grain.

VIDEOS

14. Aeration drying – getting it right.

MORE INFORMATION

Aerating stored grain: cooling or drying for quality control.

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

39 Aeration cooling for pest control. Stored Grain Information Hub. GRDC, http://storedgrain.com.au/aeration-cooling/

40 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

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 during November through to March.

Before replicating similar results on farm, growers need to:

- 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 9: *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.

13.2.6 Structural treatments for chickpea storage

Chemical sprays are not registered for pulses in any state in Australia. While there is a maximum residue limit (MRL) for dichlorvos on lentils, the product is only registered for use on cereal grains.

Chemicals used for structural treatments do not list the specific use before storing pulses on their labels, and MRLs in pulses for those products are either extremely low or nil. Using chemicals even as structural treatments risks exceeding the MRL, so is not recommended.

One possibility of a structural treatment is using diatomaceous earth (DE), an amorphous silica that is sold commercially as Dryacide®. It acts by absorbing the insect's cuticle or protective waxy exterior, causing death by desiccation. Before applying DE for use with pulses, wash and dry the storage and all equipment to be used in the application to remove any residues left from previous years. This will ensure the DE doesn't discolour the grain surface. If applied correctly, with complete coverage in a dry environment, DE can provide up to 12 months of protection for storages and equipment. [41]

If unsure, check with the grain buyer before using any product that will come into contact with the stored grain.

MORE INFORMATION

Performance testing aeration systems.

VIDEOS

15. Aeration controllers with Philip Burrill.

41 Storing pulses. Stored Grain Information Hub. GRDC, http://storedgrain.com.au/storing-pulses/

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. Follow the 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 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; connect it to a Venturi duster (e.g. Blovac BV-22 gun) (Photo 10).

Photo 10: *A blower/vacuum or Venturi gun are the best applicators 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 the 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 (Table 8).

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 without getting it into the motor, where it could cause damage. [42]

Table 8: *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

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

MORE INFORMATION

Hygiene and structural treatments for grain storages Fact sheet.

VIDEOS

16. Applying diatomaceous earth demonstration

13.2.7 Fumigation

The only control options against stored pests are phosphine, an alternative fumigant, or a controlled atmosphere.

Protectant insecticide sprays, as commonly used to protect cereal grains against insect infestations, cannot be used with pulses. Phosphine is the only fumigant currently registered for use in pulses (Photo 11), and successful fumigation requires a storage that can be sealed gas-tight.

Photo 11: *Phosphine is widely accepted as having no residue issues.*

Photo: DAF Qld

There is some resistance to phosphine, 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. Phosphine is widely accepted as causing no residue problems. [43]

Phosphine application

You achieve effective fumigation by placing phosphine tablets at the rate directed on the label onto a tray and hanging the tray in the top of a pressure-tested, sealed silo, or into a ground-level application system if the silo is fitted with recirculation. Keep the silo sealed for 7–10 days: seven days if the grain temperature is above 25°C, and 10 days if it is 15–25°C. Do not fumigate if the temperature inside the silo is less than 15°C as insects will not be active and the phosphine will therefore be ineffective. After the waiting period, open the top lid of the silo and 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 required for fumigating ranges from 10–17 days. Read label directions.

When using phosphine, it is important that gas concentrations are held at high levels for the full fumigation exposure time. Immature stages of the insects and resistant strains that are being found more frequently will be controlled by phosphine only in a sealed, gas-tight storage. Phosphine is toxic to people as well as insects, so do not

43 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

handle treated grain before the completion of the 7–10-day exposure period and the required airing period.

Fumigating in silo bags

In some situations, growers may find it difficult to gain access to a sealable, gas-tight silo in which to carry out effective fumigation of infested grain. Trials have shown that a silo bag can be used successfully for fumigation with phosphine when using the correct procedure.

Key steps:

- A gas-tight seal—inspect the silo bag and repair any minor holes.
- Correct phosphine tablet dose—apply in multiple grain spears evenly placed 7 m apart
- Allow a 14-day fumigation period.
- Vent the gas safely using a standard F650 aeration fan.

High concentrations of phosphine can be maintained for the required length of time to fumigate grain successfully in a silo bag. Fumigation trials on a standard 75-m-long bag containing ~230 t of grain were successful in controlling all life stages of the lesser grain borer.

When using phosphine in silo bags, remember that it is illegal to mix phosphine tablets with grain because of residue issues. Separate them by using perforated conduit to contain tablets and spent dust. The 1-m tubes can be speared horizontally into the silo bag and removed at the end of the fumigation. Trial results suggest that the spears should be no more than 7 m apart and fumigation should occur over 12–14 days. In previous trials when spears were spaced 12 m apart, the phosphine diffused through the grain too slowly. [44]

Fumigating in silos

The standard recommended practice for phosphine application has been to place tablets in trays in the sealed silo headspace. For small- and medium-sized silos (i.e. <150 t capacity) this is an effective method. The phosphine gas only takes approximately 24 hours to diffuse from the top to the bottom, through the 5–7 m depth of grain to the base of the silo.

For larger, taller silos (>150 tonnes), however, it can take two or more days for phosphine gas to reach the grain in the base of the silo. This can be a problem for a standard 7 or 10-day fumigation period, because any infested grain at the bottom does not get enough exposure to high gas concentrations to kill all stages of the insects.

The answer is recirculation. This is simply a system of adding plumbing to the silo to connect the silo base with the top of the silo to speed up the movement of gas through all grain in it. Recirculation should provide faster, more uniform gas distribution.

A number of silo manufactures now offer silos fitted with PVC tubes that run down the outside of silos from top to bottom. The complete system, including the silo itself, still needs to be well sealed so that it is gas-tight. Otherwise gas will leak out and the fumigation will fail to kill all the pests.

The two main systems are:

- Recirculation—has silo roof-to-base plumbing, with the addition of a small aeration fan that is used to force the phosphine gas around the silo. The critical time to have this operating is during the first 3–4 days, while tablets are liberating gas.
- Thermosiphon—has the same plumbing arrangement as the recirculation system, without the use of an electric fan. The heating and cooling of the silo head space

44 Silo bag fumigation (2012) Northern Update, Issue 66, Spring 2012. GRDC, http://www.icanrural.com.au/newsletters/NL66.pdf

and the black piping down side of the silo (passive heat exchange) is used to help generate air currents which distribute the phosphine gas.

A useful piece of equipment is a ground-level application box. To assist with safety and reduce the amount of time climbing silos to place tablets, phosphine tablets or bag chains can be placed in appropriate structures or containers on the ground at the base of the silo. These are often part of a recirculation system and connect to the internal aeration ducting.

Whatever system is used, it is very important to ensure it is designed so that it has ample space for tablets with free gas flow, to prevent the phosphine gas concentrations building up above the flammable limit, above 17,000 ppm, when it becomes explosive. Do not restrict gas movement with small containers for tablets or small-diameter pipe while gas is liberated in the first 3–4 days. Seek advice to ensure only safe designs are used. [45]

Non-chemical treatment options

Non-chemical treatments 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 also 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 leaves no residues, so grains can be traded at any time, unlike with chemical fumigants, which have withholding periods. Insect control with N_2 involves using pressure-swing adsorption (PSA) technology, and works by modifying the atmosphere inside the grain storage to remove everything except N_2, thereby starving the pests of oxygen. [46]

The carbon dioxide and nitrogen methods are sometimes referred to as a controlled atmosphere, because the composition of air in the silo is changed. They are more expensive than using phosphine, but they offer an alternative for resistant pest species.

MORE INFORMATION

Fumigating with phosphine, other fumigants and controlled atmospheres.

13.3 Monitoring stored chickpeas

Like cereal grains, chickpeas need to be delivered with nil live storage insects. [47] It is essential that any insect pests present in the on-farm storage are identified so that the best use of both chemical and non-chemical control measures can be exploited to control them.

Growers are advised to monitor all grain storages every two weeks during warmer periods of the year and at least monthly during cool periods (Photo 12). Use sieving and quality inspections to monitor stored pulses, and keep records of what you find. Use one of the GRDC publications on stored pest identification to help. Also record any fumigation action taken. If safe, visually check, smell and sample grain at the bottom and top of the stack regularly. [48] Having sample ports fitted in the side of the silos also enables temperature probe checks and grain sampling.

MORE INFORMATION

GRDC's Stored grain pest identification: The back pocket guide

45 P Burrill (2013) Grain storage: future pest-control options and storage systems 2013–2014. GRDC Update Papers. GRDC, https://grdc.com.au/Research-and-Development/GRDC-Update-Papers/2013/07/Grain-Storage-Future-pest-control-options-and-storage-systems-2013-2014

46 C Warrick (2011) Fumigating with phosphine, other fumigants and controlled atmospheres. GRDC, https://grdc.com.au/__data/assets/pdf_file/0025/206791/fumigating-with-phosphine.pdf.pdf

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

48 P Burrill, P Botta, C Newman (2010) Aeration cooling for pest control. Fact sheet. GRDC, http://storedgrain.com.au/aeration-cooling/

Photo 12: *Keep records of findings from monitoring insects in stored grain.*

Source: DAF Qld

Here are some basic points to follow when monitoring for insect pests in your pulses:

- Sample and sieve grain from the top and bottom of grain storages for early pest detection. Probe or pitfall traps placed into the top of the grain will often detect storage-pest insects before you can see them in your sieve, as the traps remain in the grain all the time.
- Holding an insect sieve in the sunlight will encourage insect movement, making pests easier to see. Sieve samples onto a white tray, again to make small insects easier to see. Sieves should be of 2 mm mesh and need to hold at least 0.5 L of grain.
- One way to help identify live grain pests is to place them into a glass container and hold them in sunlight to warm the grain and insects. This will encourage activity without overheating or killing them. Rice weevils, cowpea bruchids and saw-toothed grain beetles can walk up the walls of the glass easily, but flour beetles and lesser grain borers cannot. Look closely at the insects walking up the glass. Rice weevils have a curved snout, saw-toothed grain beetles do not; and cowpea bruchids have a globular, tear-shaped body. [49]

13.4 Grain protectants for storage

No protectants are registered for use on pulses and oilseeds.

49 GRDC (2011) Stored grain pests identification: The back pocket guide. GRDC, https://grdc.com.au/resources-and-publications/all-publications/publications/2016/09/grdc-bpg-storedgrainpests