SOUTHERN
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GRDC GROWNOTES™

GRDC™ GRAINS RESEARCH & DEVELOPMENT CORPORATION

FIELD PEA

SECTION 12

STORAGE

KEY POINTS | STORING PULSES | CONDITION OF THE SEED AT HARVEST | HANDLING FIELD PEA | GRAIN CLEANING | ON-FARM STORAGE | GRAIN QUALITY IN STORAGE | MOISTURE CONTENT AND TEMPERATURE | COOLING AND DRYING PULSES | PREVENTING MOISTURE MIGRATION | GRAIN BAGS FOR PULSE STORAGE | GRAIN STORAGE: GET THE ECONOMICS RIGHT | INSECT PESTS IN STORAGE | FARM AND GRAIN HYGIENE | FUMIGATION IN SEALED SILOS | ALTERNATIVE FUMIGANTS FOR PULSES | SEALING SILOS

Storage

Key points

- **Field pea is prone to mechanical damage. Use efficient and a minimal number of handling stages.**
- **Harvest field pea at 13–14% moisture content to minimise damage during handling, but do not store at moisture contents above 12% without aeration cooling or aeration drying.**
- **Cone silos are ideal for storing field pea. For storage longer than 3 months ensure silo has aeration cooling and gas-tight sealing for fumigation.**
- **Store grain at low temperature and low moisture for maximum storage time.**
- **Good hygiene and low temperatures through aeration cooling are important for protection against pests.**
- **Fumigation options are limited for pulses. Successful fumigation requires a gas-tight, sealable silo.**

12.1 Storing pulses

The successful storage of pulses requires a balance between ideal harvest conditions and ideal storage conditions. Harvesting at 14% moisture content 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]

Test quality and physiological age are two principal components of chickpea, field 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 that 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, 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.

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 downgrading stored field pea. The Australian Pulse Standards stipulate standards for heat-damaged, bin-burnt, mouldy, caked or insect-infested field pea, and breaching of any of these can result in the discounting or rejection of product.[3]

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 colour and minimise the darkening of seed, any grain stored >12% moisture content will require cooling and/or drying.

Growers should avoid even short to medium storage of weather-damaged grain.[4]

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.[5]

1 P Burrill, P Botta, C Newman, B White, C Warrick (2014) Storing pulses. Fact Sheet. GRDC, updated July 2014, www.grdc.com.au/GRDC-FS-GrainStorage-StoringPulses

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 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

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

5 P Burrill (2013) Grain storage: future pest-control options and storage systems 2013–14. GRDC Update Papers. GRDC, https://grdc.com.au/resources-and-publications/grdc-update-papers/tab-content/grdc-update-papers/2013/07/grain-storage-future-pest-control-options-and-storage-systems-2013-2014

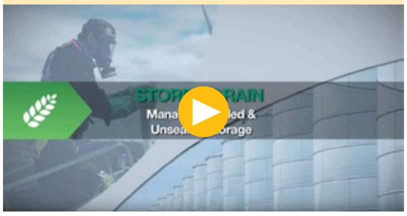
FEEDBACK

VIDEO

Watch GCTV Stored Grain: Storing Pulses
https://youtu.be/CeWA-OdhhSk

VIDEO

Watch Stored Grain: Managing Sealed and Unsealed Storage
https://youtu.be/Tls0S-7DwxA



MORE INFORMATION

Stored Grain information hub
http://storedgrain.com.au/

12.1.1 How to store product on-farm

Key points

- Combining good hygiene with 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]

Summary

Harvesting pulses at 13–14% moisture content preserves grain quality and reduces mechanical damage. However, pulses should not be stored at moisture contents above 12%. To successfully store pulses:

- Avoid mechanical damage to pulse seeds to maintain market quality and seed viability and to ensure they are less attractive to insect pests.
- Pulses above 12% moisture content can be held safely with aeration cooling for up to 3 months.
- Pulses above 12% moisture content will require aeration drying to maintain quality over 3 or more months.
- Prevent pests with careful hygiene and aeration cooling.
- Control pests with fumigation in gas-tight, sealable storage.[7]

Regular monitoring is required to ensure grain quality in storage is maintained. Check monthly, taking samples from the bottom and, if safe, from the top. Monitor:

- insect pests;
- grain temperature;
- grain moisture content; and
- grain quality and germination.[8]

12.2 Handling field pea

Field pea are prone to mechanical damage, particularly during rough handling. This especially applies to:

- overly dry grain (<10% moisture content); and
- crops that have been exposed to weather damage prior to harvest.

The use of tubulators or belt conveyors can reduce damage compared to conventional spiral augers.

Grain can be handled up to six times before delivery to receival points, so it is important that growers:

- Minimise the number of handling stages wherever possible.
- Use efficient handling techniques that minimise damage.

6 P Burrill (2013) Grain storage: future pest-control options and storage systems 2013–14. 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

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

8 GRDC (2013) Grain storage pest control guide. Grain storage fact sheet, Northern and Southern Regions. GRDC, June 2013, http://www.grdc.com.au/GRDC-FS-GrainStoragePestControl

If using augers:

- operate slow and full;
- use large diameter augers;
- the flight pitch should be greater than the auger diameter;
- length of the auger should be no longer than is necessary – the shorter the better;
- keep auger incline as low as practical;
- check flight casing clearance – optimal clearance is typically 50% of grain size to minimise grain becoming wedged between the auger spiral and the casing, causing cracking; and
- auger drives should be at the discharge end, and not on the intake.

12.3 Grain cleaning

Re-cleaning field pea after harvest is sometimes necessary. Cereals can be cleaned from most other pulses, but not field pea because of their similar size. Cleaning of cereals out of field pea must occur with herbicides in the paddock well before the cereals produce any grain.

Vetch and tare seeds are difficult to remove by cleaning from field pea grain. If the paddock has a potential vetch or tare problem a suitable-sized field pea variety should be chosen to assist with grading.

Screens or paddles can be damaged beyond repair if the grain jams in rotary screens. Fitting the screens with a spacer will provide additional clearance and so avoid the problem.

Milk thistle buds can be difficult to separate if they contaminate the sample because they are similar in size and weight to peas. However, if desiccated or given time to dry, the buds disintegrate when put through an auger and can be easily separated.

Dirt and most small weed seeds can be separated in rotary screens, however the dirt will increase component wear.[9]

Photo 1: *Grain cleaning to remove vetch and tare seeds.*

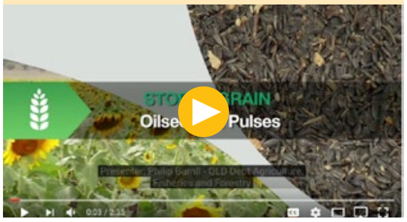
Photo: M Raynes, formerly Pulse Australia (2016). Southern/western field pea best management practices training course, module 8-2016. Pulse Australia Limited image 8.35

9 Pulse Australia (2016) Southern/western field pea best management practices training course, module 8-2016, Draft. Pulse Australia Limited

FEEDBACK

VIDEO

Watch GCTV Stored Grain: Oilseeds and Pulse Storage
https://youtu.be/JvzfJ2Xo6Sg



12.4 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.[10]

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:

- Maintain thorough hygiene in storages and equipment.
- Keep grain in storage cool and dry.

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.[11]

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-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.[12]

10 GRDC. (2015) Grain storage. Extension tailored for regional challenges. Ground Cover™ issue 119, http://www.grdc.com.au/rv/gcs118

11 P Burrill (2013) Grain storage: future pest-control options and storage systems 2013–14. 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

12 GRDC. (2015) Grain storage strategies in the northern region. https://grdc.com.au/archive/key-issues/grain-storage-strategies-in-the-northern-region

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 tonnes up to 3000 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
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 3 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, B White (2012) Planning for efficiency and quality, A Grains Industry Guide. GRDC, http://storedgrain.com.au/wp-content/uploads/2013/07/GRDC-GS-FACILITIES-Booklet-2013_Final.pdf

The following videos show some of the benefits of on-farm storage:

- Video On-farm storage in the SA Mallee, with Corey Blacksell, https://youtu.be/fFKJYylp0hk
- Video On-farm storage in SA, Linden Price, https://youtu.be/V9pSYmh_cO0
- Video Over the Fence: On-farm storage pays in wet harvest, May 2011, https://youtu.be/ejywX-WytTs
- Video Over the Fence: storage delivers harvest flexibility and profit, https://youtu.be/UWr7CTMxVMg

FEEDBACK

12.4.1 Silos

Silos are ideal for storing pulses, particularly those with a cone base as there is less likely to be grain damage at out-loading (Photo 1). When storing for longer than 3 months only use storage that is suitable for aeration cooling and gas-tight for fumigation. Ideally an aeration controller should be used to optimise aeration efficiency and cooling of the grain.

Photo 2: *On-farm storage silo.*

Photo: GRDC

It is especially important with pulses to always fill and empty silos from the centre holes because they have a high bulk density. Loading or out-loading off-centre puts uneven weight on the structure and may cause it to collapse.

The approximate weight of grain stored in a cubic metre of silo is shown in Table 2. The actual figures can vary as much as 6–7% in wheat and barley and 15% in oats. In pulses the variation is likely to be less (3–4%) and will vary with the grain size, variety and season.

Table 2: Calculating silo capacities.

Grain	Cubic metres	Kilograms	3-bushel bags
Lentil	1	800	9.2
Chickpea	1	750	9.2
Faba bean	1	750	9.2
Broad bean	1	645	9.2
Field pea	1	750	9.2
Lupin	1	750	9.2
Vetch	1	750	9.2
Wheat	1	750	9.2
Barley	1	625	9.2
Oat	1	500	9.2

Source: Grain Legume Handbook (update 2008) https://grdc.com.au/grainlegumehandbook

Calculating silo capacity

Calculating the volume of a cylinder

Volume = area of base (diameter squared x 0.7854) x height

Calculating the volume of a cone

Volume = 1/3 (area of base x height)

12.4.2 Safety around grain storage

Watch GCTV Stored Grain: Stay Safe Around Grain Storage.

VIDEO

Watch GCTV Stored Grain: Stay Safe Around Grain Storage, https://youtu.be/CM2mgmo3jWU

12.5 Grain quality in storage

Grain quality is at its highest when first loaded into storage but can steadily deteriorate if the storage environment is not well managed. A combination of good farm hygiene, storage choice and aeration cooling are important for maintaining grain quality and overcoming many problems with pests associated with storage.

Quality in storage can be reduced by:

- weather damage prior to harvest;
- moisture;
- heat; and
- pests, including insects, mould and fungi.

Growers should avoid even short to medium storage of weather-damaged grain. Seed that has weathered prior to harvest will deteriorate a lot quicker in storage, even if stored under ideal conditions.

Field pea will darken in storage, although not as dramatically as faba bean or desi chickpea. Rate of seed coat darkening (deterioration in grain colour) will be accelerated by:

- high seed moisture content.; high temperatures;
- high relative humidity;
- condition of the seed at harvest; and
- sunlight.[13]

MORE INFORMATION

GRDC Fact Sheet: Storing pulses, https://grdc.com.au/Resources/Factsheets/2014/07/Grain-Storage-Fact-Sheet-Storing-Pulses

13 Pulse Australia (2016) Southern/western field pea best management practices training course, module 8-2016, Draft. Pulse Australia Limited

12.6 Moisture content and temperature

Typical harvest temperatures of 25°C–35°C and grain at a moisture content greater than 13–14% can provide the ideal conditions for mould and insect growth (Figure 1 and Table 3). High-moisture grain will generate additional heat when in confined storage, such as a silo, further encouraging mould and insect growth. Without aeration grain can maintain its warm harvest temperature for a long time.[14]

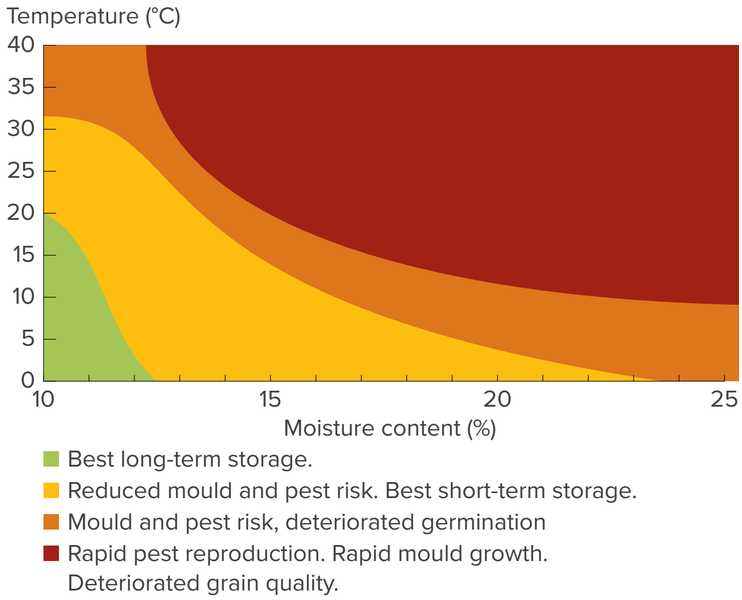


Figure 1: *Effects of temperature and moisture on stored grain.*

Source: CSIRO Ecosystems Sciences, Stored Grain Project (2013) Dealing with high-moisture grain, Grain storage fact sheet, GRDC, June 2013, https://grdc.com.au/GRDC-FS-HighMoistureGrain

Table 3: The effect of grain temperature and moisture on stored grain insect and mould development.

Temperature (°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 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: Kodinin Group, GRDC (2013) Grain storage pest control guide. Grain storage fact sheet, Northern and Southern Regions, GRDC, June 2013, https://grdc.com.au/GRDC-FS-GrainStoragePestControl

Moisture

Pulses harvested at 14% moisture or higher must be dried before going into storage to preserve seed germination and viability. As a general rule, every 1% rise in moisture content above 11% will reduce the storage life of pulse seed by one-third (see Table 3). Any pulse stored above 12% moisture content will require aeration cooling to maintain quality.

14 C Warrick and C Nicholls (2013) Aerating stored grain: Cooling or drying for quality control. A Grains Industry Guide. GRDC, http://storedgrain.com.au/aerating-stored-grain/

Temperatures

High temperatures in storage will cause deterioration in grain viability. Temperatures of stored pulse grain should not exceed an average of 25°C and preferably the average temperature should be below 20°C. In general, each 4°C rise in average stored temperature will halve the storage life of the grain. See Table 4 and Figure 2.

Table 4: Maximum recommended storage periods by temperature and moisture.

Grain moisture (%)	Grain temperature (°C)	
	20°C	30°C
14	3 months	n/a
13	9 months	3 months
12	> 9 months	9 months

Source: CSIRO Stored Grains Research Laboratory, Pulse Australia (2016). Southern/western field pea best management practices training course, module 8-2016. Pulse Australia Limited Table 8.14

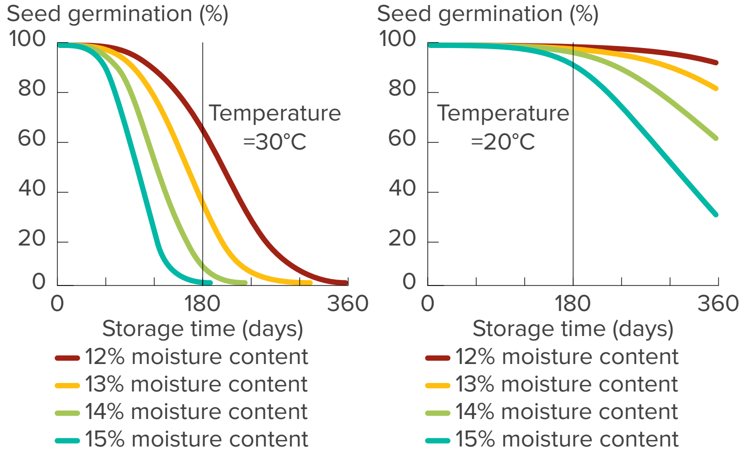


Figure 2: *Generalised graph of storage temperature* and moisture effect on seed vigour.*

* The left graph shows effects of moisture content on wheat germination when stored at 30°C. Right graph is when stored at 20°C.

Source: CSIRO Stored Grain Research Laboratory, Pulse Australia (2016). Southern/western field pea best management practices training course, module 8-2016. Pulse Australia Limited Figure 8.3 Used in Lentil Section 13 Fig 2

Fumigate using sealable, gas-tight silos immediately after filling to stop any insects present from creating moisture. Maintain the grain at low temperatures and moisture content for the maximum storage time.

12.7 Cooling and drying pulses

Grain aeration systems are generally designed to carry out either a drying or a cooling function, but not both.

Knowing whether grain needs to be dried or cooled can be discovered by following these simple rules:

- Grain that is dry enough to meet specifications for sale can be cooled, without drying, to slow insect development and maintain quality during storage.
- Grain of moderate moisture will require aeration drying to reduce the moisture content to maintain quality during storage.
- If aeration drying is not available immediately, moderately moist grain (up to 14% maximum) can be cooled for a short period to slow mould and insect development, then dried when the right equipment is available.
- After drying to the required moisture content, cool the grain to maintain quality.

- High-moisture grain (>14% for pulses) will require immediate moisture reduction before cooling for maintenance.[15]

Grain that is over the safe storage moisture content of 12.5% can be dealt with by:

- Blending with low-moisture grain, then aerating. Blending can be used for grain up to 13.5% moisture content. Blending is less suitable for pulses because the additional handling can damage the seed.
- Aeration cooling – grain up to 15% moisture content can be held short-term until drying equipment is available.
- Aeration drying – large volumes of air are pumped through the grain gradually reducing moisture. Additional heating can be used.
- Continuous flow drying – grain is transferred through the dryer, which pumps a high volume of heated air through the continual grain flow. This is a highly efficient way to dry large volumes of grain.
- Batch drying 10–20 tonnes of grain at a time with a high volume of pre-heated air, usually using a transportable trailer.[16]

One practical way of reducing temperatures is to paint the silo white as dark coloured silos will absorb more heat (Photo 3).

Grain in large silos (>75 t) will remain cooler as grain is a poor conductor of heat and day/night temperature fluctuations rarely reach 15 cm beyond the silo wall. Small silos (<20 t) and field bins will have larger temperature fluctuations and can cause deterioration in grain quality.[17]

Photo 3: *Silos painted white to reduce temperature.*

Photo: GRDC

15 C Warrick and C Nicholls (2013) Aerating stored grain: Cooling or drying for quality control. A Grains Industry Guide. GRDC, http://storedgrain.com.au/aerating-stored-grain/

16 Stored Grain Project (2013) Dealing with high-moisture grain, Grain storage Fact Sheet. GRDC, June 2013, https://grdc.com.au/GRDC-FS-HighMoistureGrain

17 Pulse Australia (2016) Southern Faba & Broad Bean - Best Management Practices Training Course, Module 8-2016. Pulse Australia Limited

VIDEO

Watch GCTV2: Grain Storage Cooling Aeration, https://youtu.be/qb3WAXZOl1g

12.7.1 Aeration cooling

Cooler temperatures of grain in storage have several advantages:

- seed viability (germination and vigour) is maintained longer;
- moist grain can be safely stored for a short time before blending or drying;
- moisture migration is reduced;
- insect breeding cycles are slowed (or ceased in some instances) and 'hot spots' are prevented;
- mould growth is reduced; and
- darkening of the seed coat is slower.

Aeration cooling is a vital tool when storing pulses. It allows for longer-term storage of low-moisture grain by creating cool, uniform conditions. These conditions maintain seed quality, protect seed viability, and reduce mould and insect development. Aeration cooling also allows grain to be harvested earlier, and at higher moisture levels, capturing grain quality and reducing mechanical seed damage.

Aerated silos are fitted with fans that push air through the grain, to cool the grain, and equalise the moisture and temperature throughout the silo (Photo 4). With an aeration system, a waterproof vent on the top of the silo allows the air to escape as it is forced from the base of the silo. This vent needs to be replaced with a sealed lid or a capped venting tube during fumigation.

Photo 4: *Silo fitted with aeration fan for cooling.*

Photo: Evan Collis Photography

It is important to know the capacity of an existing aeration system. Aeration cooling can be achieved with airflow rates of 2–3 L/second per tonne delivered from fans driven by 0.37 kilowatt (0.5 horsepower) electric motor for silos of around 100-tonne capacity.

Correctly controlled aeration should aim to reduce grain temperature to 20°C or lower. Controlling aeration cooling is a three-stage process: continual, rapid and then maintenance. Cooling achieved during storage depends on both the moisture content of the grain, and the humidity and temperature of the incoming air.

An understanding of the effects of relative humidity and temperature when aerating stored grain is important. Automatic aeration controllers that select optimum fan run times provide the most reliable results and are deemed best for convenience.[18]

MORE INFORMATION

GRDC Booklet: *Aerating stored grain: cooling or drying for quality control*, www.grdc.com.au/GRDC-Booklet-AeratingStoredGrain

GRDC Fact Sheet: Performance testing aeration systems, https://grdc.com.au/Resources/Factsheets/2012/08/Grain-Storage-Performance-testing-aeration-systems

18 Pulse Australia (2016) Southern Faba & Broad Bean - Best Management Practices Training Course, Module 8-2016, Pulse Australia Limited

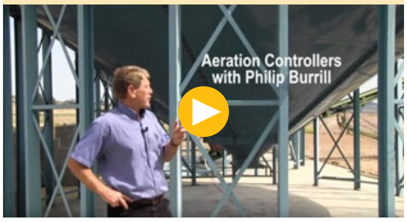
FEEDBACK

VIDEO

Watch GCTV5: Aeration Drying – getting it right, https://youtu.be/vzMHzyHCWuw

VIDEO

Watch 10: Grain Storage with Philip Burrill – Using Aeration Controllers, https://youtu.be/vxoBO71rTDg



MORE INFORMATION

GRDC Gain Storage Fact Sheet: Storing Pulses, https://grdc.com.au/GRDC-FS-GrainStorage-StoringPulses

GRDC Grain Storage Fact Sheet: Grain Storage Pest Control Guide, https://grdc.com.au/GRDC-FS-GrainStoragePestControl

GRDC Grain Storage Fact Sheet: Dealing with High-Moisture Grain, https://grdc.com.au/GRDC-FS-HighMoistureGrain

GRDC *Aerating stored grain: Cooling or Drying for Quality Control, A Grains Industry Guide*, http://storedgrain.com.au/wp-content/uploads/2016/10/GRDC-Aeration-Book-2016_R2.pdf

12.7.2 Aeration drying

If high moisture content (>14%) pulses are to be stored for longer than 3 months they require drying or blending to maintain seed quality. Aeration drying is the preferred method as it has a lower risk of cracking or damaging pulses than using hot-air dryers.

Careful selection of conditions using dry ambient air (using an automated controller) can remove moisture from the stored grain over a period of weeks.

Unlike aeration cooling, drying requires higher air flow rates of at least 15–25 L/sec/tonne of grain (Photo 5).[19] Aeration drying is a slow process that also relies on high air-flow rates, well-designed ducting for even air flow, exhaust vents in the silo roof, and warm, dry weather conditions.[20]

Photo 5: *Aeration drying requires air-flow rates of 15–25 L/sec/tonne of grain.*

Photo: GRDC

Supplementary heating can be used to aid the drying process by removing moisture more effectively than cold air and by reducing the relative humidity of the air.

Once drying is complete all grain needs to be cooled, regardless of whether supplementary heat was used.[21] Storage pests stop breeding at temperatures below 15°C (Table 3). Aim for less than 23°C in summer and less than 15°C in winter.[22]

12.7.3 Heated air drying

Continuous-flow or batch dryers provide reliable drying, although they can reduce quality if run at too high a temperature. Check the specifications or talk to the manufacturer about safe conditions for drying pulses.

19 Stored Grain Project (2014) Storing pulses. Grain storage Fact Sheet, GRDC, July 2014, https://grdc.com.au/GRDC-FS-GrainStorage-StoringPulses

20 Stored Grain Project (2013) Dealing with high-moisture grain, Grain storage Fact Sheet. GRDC, June 2013, https://grdc.com.au/GRDC-FS-HighMoistureGrain

21 C Warrick and C Nicholls (2013) Aerating stored grain: Cooling or drying for quality control. A Grains Industry Guide. GRDC, http://storedgrain.com.au/aerating-stored-grain/

22 GRDC (2013) Grain storage pest control guide. Grain storage Fact Sheet, Northern and Southern Regions, GRDC, June 2013, https://grdc.com.au/GRDC-FS-GrainStoragePestControl

12.8 Preventing moisture migration

Grain stored in sealable, gas-tight silos must be of sufficiently low moisture content to prevent moisture migration. Use an aerated, sealable, gas-tight silo with adequate ventilation fitted. Sealable, gas-tight/aerated silos should only be sealed for fumigation and then aerated once the fumigation is completed.

Do not load grain with excess moisture (>12%) into a sealable, gas-tight store where there is no escape of moisture. In a sealable, gas-tight silo moisture can migrate to condense in upper grain layers. This top area of the grain is at high risk from mould and insect colonisation.

Moisture sources include grain, insects, any green material, immature seeds, condensation and leaks.

Grain

Grain and seed are living and release moisture as they respire. This moisture moves upwards by convection currents created by the temperature difference between the grain in the centre of the silo and the walls, which can be either warmer or cooler.

Insects

Insects or mites in the grain respire and release moisture and heat into air spaces. If grain is stored at less than 14% moisture and is free of insects the increase in moisture content in the upper layers of the grain will be insignificant. If grain is stored above 14% moisture content there may be enough moisture in the upper grain layers to cause mould. Moisture builds up quicker and to higher levels from insect respiration than from grain respiration alone. There is no moisture migration in an aerated silo as the entire stack is normally cooled to an even temperature (20°C or less).

Condensation

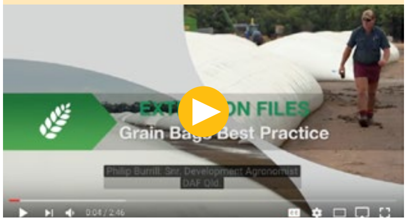
Moisture carried into the silo headspace can condense on a cold roof and fall back as free water. This can cause a circle of mould or germinated grain against the silo wall. Moist grain can also contain greater numbers of insects.

Leaks

Water entering through structural damage will increase grain moisture content to a level where mould and insect growth can occur.

VIDEO

Watch GCTV Extension Files: Grain Bags – best practice, https://youtu.be/Ab-A2Il6b1Q



12.9 Grain bags for pulse storage

Harvest bags (also known as 'silo bags' or 'sausage bags') are a polymer-membrane-based storage system providing a cost-competitive option to grain growers (Photo 6). There are, however, industry concerns over grain spoilage, contamination, insect control and out-turned processing quality with their use for pulses.[23]

Grain bag capacity varies with bag size, which ranges from from 40–90 metres long, and from 100 to 300 tonnes, depending on the type of grain and how much the bag is stretched during filling.

Grain bags are best used for short-term, high-volume grains storage to assist with harvest logistics. Their success as a storage option is dependent on site planning and preparation, best management practices and frequent monitoring for repairs and patching of holes.

Aeration cooling in not yet proven with grain bags and storing high-value legumes or canola is not recommended.[24]

23 JA Darby, LP Caddick (2007) Review of grain harvest bag technology under Australian conditions. CSIRO Entomology, Technical Report No. 105, https://publications.csiro.au/rpr/pub?list=BRO&pid=procite:d0d57771-ffbb-4ffd-8fd4-de675a9a0448

24 Stored Grain Project (2012) Successful storage in grain bags. Grain storage Fact Sheet, GRDC, March 2012, https://grdc.com.au/Resources/Factsheets/2012/03/Grain-Storage-Fact-Sheet-Successful-storage-in-grain-bags

Photo 6: *Silo bag.*

Photo: Rod Peterson © GRDC

In theory, grain in a correctly sealed bag will convert residual oxygen into carbon dioxide (hermetic conditions), which will asphyxiate insects and inhibit fungal growth. However, CSIRO research has shown that it is difficult to achieve these conditions, particularly with high grain temperatures and the relatively dry grain harvested in Australia. It is unlikely a bag will not have some holes, tears or punctures throughout the storage period, which will allow air to enter and compromise the hermetic environment.[25]

Storing pulses in grain bags is a bigger risk than storing other crops. Pulse grain has been rejected because of objectionable taints and odours resulting from improper storage in grain bags.

The risks of storing pulses in grain bags are:

- Pulse grain may not retain its quality, colour or freedom from odour, especially if the seal is breached or moisture ingress occurs.
- Contamination and moisture can enter bags from tears or where vermin and other pests create holes in the bag.
- Excessive grain moisture can result in condensation within the bag, causing localised areas of mould and an offensive, distinctive mouldy odour throughout. Marketers have rejected pulse grain because of objectionable moulds, taints and odours acquired through storage in grain bags. Such taints and odours are not acceptable in pulse markets, particularly human consumption end uses. Odour virtually cannot be removed once present.
- Grain moisture content is critical. Pulses, particularly the larger-seeded ones like faba bean or kabuli chickpea, have bigger airspaces between grains than cereals, so moisture can move more freely through them.
- Removing taints and odours in affected grain is often not possible, even with further aeration.
- An overall offensive, distinctive 'plastic' odour can occur, and it requires considerable periods of aeration to remove. There is nil tolerance of odours in receival standards.

VIDEO

Watch GCTV Extension Files: Grain Bags – a grower's perspective, https://youtu.be/cLRgjjdEr0U

25 JA Darby, LP Caddick (2007) Review of grain harvest bag technology under Australian conditions. CSIRO Entomology, Technical Report No. 105, https://publications.csiro.au/rpr/pub?list=BRO&pid=procite:d0d57771-ffbb-4ffd-8fd4-de675a9a0448

MORE INFORMATION

Pulse Australia: Grain Bags
http://pulseaus.com.au/growing-pulses/publications/grain-storage-bags

GRDC Fact Sheet: Successful storage in grain bags
https://grdc.com.au/Resources/Factsheets/2012/03/Grain-Storage-Fact-Sheet-Successful-storage-in-grain-bags

- Storage at harvest temperatures of more than 30°C favours high insect reproduction rates so hygiene and monitoring are vital. Achieving a low oxygen environment (hermetic conditions) under Australian conditions is difficult and should not be relied upon as the only source of storage insect control.[26]

12.10 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 1 or 2 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 exactly the 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 with 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 handler's.

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 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.

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26 Pulse Australia (2016) Grain bags for pulse storage. Pulse Australia website http://pulseaus.com.au/growing-pulses/publications/grain-storage-bags

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 5 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.[27]

Financial gains from storage		**Example $/t**
Harvest logostics/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 years	$6.20
Opportunity cost on capital	Capital cost $/t x opportunity or interest rate e.g. 8% / 2	$6.20
Total fixed costs	Sum of fixed costs	$12.40
Variable costs		
Storage hygiene	(Labour rate $/hr x time to clean hrs / storage capacity) + structural treatment	$0.23
Aeration cooling	Indicatively 23¢ for the first 8 days then 18¢ per month / t	$0.91
Repairs and maintenance	Estimate e.g. capital cost $/t x 1%	$1.51
Inload/outload time and fuel	Labour rate $/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
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 https://grdc.com.au/resources-and-publications/grdc-update-papers/tab-content/grdc-update-papers/2016/09/grain-storage-get-the-economics-right

27 Warrick C. (2016). GRDC Update Papers: Grain storage—get the economics right. https://grdc.com.au/resources-and-publications/grdc-update-papers/tab-content/grdc-update-papers/2016/09/grain-storage-get-the-economics-right

FEEDBACK

MORE INFORMATION

Booklet: *Stored grain pests identification: the Back Pocket Guide*, https://grdc.com.au/GRDC-BPG-StoredGrainPests

GRDC Fact Sheet: Stored Grain Pests Identification, https://grdc.com.au/GRDC-FS-StoredGrainPestID

12.11 Insect pests in storage

The most common pulse pests are the cowpea weevil (*Callosobruchus* spp.) and pea weevil (*Bruchus pisorum*). The cowpea weevil has a lifespan of 10–12 days, while the pea weevil only breeds one generation per year.[28]

The tolerance for live pests sold off-farm is nil. Growers need an integrated approach to pest control. Prevention is better than a cure. Grain hygiene and aeration cooling can overcome 85% of pest problems. Insect-control options are limited for pulses, making hygiene, aeration and regular monitoring essential.

Most insect development ceases at temperatures below 20°C (Table 3). Freshly harvested grain usually has a temperature of around 30°C, which is an ideal breeding temperature for many storage pests. Aeration fitted to stores will rapidly reduce grain temperatures, reducing insect breeding and aiding grain quality.[29]

Controlling pea weevil

Control programs for pea weevil are best carried out in the flowering crop. See Section 8.5 Pea weevil (*Bruchus pisorum*).

However, effective fumigation with phosphine will destroy all stages of insects, adults, eggs, larvae and pupae. Effective fumigation requires a sealable, gas-tight silo (see Section 12.13 Fumigation in sealed silos). Fumigation should be carried out as soon as the silo is filled to ensure the feeding stage (larvae) and the non-feeding (pupae and adult) are eliminated before further grain damage or weight loss occurs.

Early harvest and immediate fumigation will reduce the number of adults which could emerge from the peas to infest crops in the next growing season.[30]

12.12 Farm and grain hygiene

Pest control is best managed with an integrated whole-of-season approach. Options for control are limited at storage so remove pests from storage site before harvest.

VIDEO

Watch GCTV2: Grain silo hygiene, https://youtu.be/3VU7qJCoCwI

12.12.1 Grain silo hygiene

Where to clean

Clean silos and storages thoroughly. This includes cleaning up spillage and minimising places where insects can collect. Clean after harvest to prevent insect build-up during the year. Areas to clean include:

- empty silos and grain storages;
- augers and conveyers;
- harvesters;
- field and chaser bins;
- spilt grain around grain storages;
- leftover bags of grain (seed grain and stock grain); and
- equipment brought onto the farm from outside.

If an insect infestation is found, destroy all grain residues to prevent re-infestation.

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.

28 Stored Grain Project (2014) Storing pulses. Grain storage Fact Sheet, GRDC, July 2014, https://grdc.com.au/GRDC-FS-GrainStorage-StoringPulses

29 GRDC (2013) Grain storage pest control guide. Grain storage Fact Sheet, Northern and Southern Regions, GRDC, June 2013, https://grdc.com.au/GRDC-FS-GrainStoragePestControl

30 J Lamb, A Podder (2008) Grain Legume Handbook for the Pulse Industry. Grain Legume Hand Book Committee, https://grdc.com.au/grainlegumehandbook

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

Photo 7: *Hygiene needs to be a priority when storing grain on-farm.*

Photo: 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 diatomaceous earth as a structural treatment.[31]

31 Stored Grain Project (2013) Hygiene and structural treatments for grain storage. Fact Sheet. Stored Grain Information Hub. GRDC, https://grdc.com.au/resources-and-publications/all-publications/factsheets/2013/06/grdc-fs-hygienestructuraltreatments

FEEDBACK

VIDEO

Watch GCTV7: Applying Diatomaceous Earth Demonstration, https://youtu.be/L-lyCgstkc0

MORE INFORMATION

GRDC Fact Sheet: Hygiene and structural treatments for grain storages, www.grdc.com.au/GRDC-FS-HygieneStructuralTreatments

12.12.2 Structural treatments for field pea storage

Using chemicals for structural treatment is not recommended. They do not list the specific use before storing pulses on their labels and Maximum Residue Levels (MRLs) are either extremely low or nil. There is a high risk of exceeding the MRL.

Diatomaceous earth (DE) as a structural treatment can be used to treat storages after cleaning. It is an amorphous silica that is sold commercially as Dryacide®. It acts by absorbing the insects' 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.

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).

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 6).

Table 6: 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: Stored Grain Project (2013) Hygiene and structural treatments for grain storage. Fact Sheet. Stored Grain Information Hub. GRDC, https://grdc.com.au/resources-and-publications/all-publications/factsheets/2013/06/grdc-fs-hygienestructuraltreatments

Silo application

Apply the DE dust from the top of the silo, otherwise open all outlets and apply via the ground access door. Moving the Blovac gun quickly, coat the roof, walls then base of the silo. Finish by closing all outlets, top and bottom, to capture the remaining suspended dust and keep moisture out of the silo.

If silos are fitted with aeration systems, distribute the DE dust into the ducting without getting it into the motor, where it could potentially cause damage.[32]

Check with grain buyers before using any product that will come into contact with the stored grain.[33]

32 Stored Grain Project (2013) Hygiene and structural treatments for grain storage. Fact Sheet. Stored Grain Information Hub. GRDC, www.grdc.com.au/GRDC-FS-HygieneStructuralTreatments

33 Stored Grain Project (2014) Storing pulses. Grain storage Fact Sheet, GRDC, July 2014, https://grdc.com.au/GRDC-FS-GrainStorage-StoringPulses

FEEDBACK

12.13 Fumigation in sealed silos

Hygiene, cleaning storages, treating for insects and managing quality are all part of the comprehensive management and responsibility of growers producing grain for food. With 40% of Australian grain growers storing their product on-farm, understanding how to use fumigants safely is a necessity.[34]

Aeration and phosphine fumigation are the main methods to control insects in pulses. Controlled atmosphere (inert gases such as carbon dioxide or nitrogen) may be an option. Other grain protectants are not registered for pulses.[35]

Successful fumigation requires a gas-tight, sealable silo. To be effective against all live insect stages, as well as insects with resistance, fumigants must be held in the silo at a given concentration for a certain period of time. This is only possible in gas-tight, sealable silos (Photo 8).

Photo 8: *Unsealed silos are both ineffective and dangerous for fumigants such as phosphine.*

Photo: Grain Legume Handbook (2008), Harvesting, module 9, Plate 122, https://grdc.com.au/resources-and-publications/all-publications/publications/2008/03/2008-grains-legume-handbook

12.13.1 Pressure testing sealed silos

According to the new Australian Standard AS2628, a silo is only truly sealed if it passes a 5-minute, half-life pressure test. A pressure-relief valve gives a quick means of checking the seal of the silo. During testing, oil levels in the pressure-relief valve must take a minimum of 5 minutes to fall from 25 mm to a 12.5 mm difference. Pressure testing of silos should be carried out:

- when a new silo is erected on-farm;
- when silo is full of grain and before fumigation; and
- as part of the annual maintenance routine.[36]

See Section 12.15.1 Testing silos for seal.

VIDEO

Watch GCTV2: Pressure Testing Sealed Silos, https://youtu.be/BHKUNjnnhIE

34 J Severs (2016) Grain storage is about food and safety. Ground Cover™, Issue 123, July-August 2016 https://grdc.com.au/Media-Centre/Ground-Cover/Ground-Cover-Issue-123-JulyAugust-2016/Grain-storage-is-about-food-and-safety

35 GRDC (2013) Grain storage pest control guide. Grain storage Fact Sheet, Northern and Southern Regions, GRDC, June 2013, https://grdc.com.au/GRDC-FS-GrainStoragePestControl

36 C Warrick and C Nicholls (2013) Fumigating with phosphine, other fumigants and controlled atmosphere. A Grains Industry Guide. GRDC, http://storedgrain.com.au/fumigating-with-phosphine-and-ca/

Photo 9: *Pressure-relief valve on a sealable, gas-tight silo gives a quick means of checking the seal of the silo.*

Photo: Grains Legume Handbook (2008), Harvesting, module 9, Plate 123, https://grdc.com.au/resources-and-publications/all-publications/publications/2008/03/2008-grains-legume-handbook

When not to fumigate

Not all silos can be sealed adequately to enable fumigation. An unsealed silo will not hold the fumigant for more than a few minutes, even using a high dosage rate. However, aeration can be added to all silos. Fitting aeration cooling will help immensely with insect control. Aeration coupled with excellent hygiene can overcome many potential insect problems in grain storage. Having at least one sealable, gas-tight silo as a 'hospital' bin enables the grower to correctly and effectively manage any insect infestations when detected.

It is illegal and highly dangerous to put phosphine into unsealed systems.

When to fumigate?

Storages should be cleaned prior to filling with new grain (refer to Section 12.12.1 Grain silo hygiene). However, if there is reason to believe there are stored grain insects in a silo, fumigation should be carried out as soon as possible. This will ensure that all insect stages are eliminated before any grain damage or weight loss occurs. Early harvesting and immediate fumigation will reduce the number of insects in stored pulses.[37]

37 J Lamb, A Podder (2008) Grain Legume Handbook for the Pulse Industry. Grain Legume Hand Book Committee, https://grdc.com.au/grainlegumehandbook

12.13.2 Using phosphine

Phosphine is the only fumigant currently registered for use in pulses. It is illegal and highly dangerous to put phosphine into unsealed systems.[38]

Phosphine is the single most relied upon fumigant in the Australian grains industry. Continued misuse is leading to poor insect control and developing resistance (Figure 3). To kill grain pests at all stages of their life cycle (egg, larva, pupa, adult) the only option is to fumigate in a gas-tight, sealed silo. A GRDC survey in 2010 showed that only 36% of users applied phosphine correctly in a gas-tight, sealed silo.

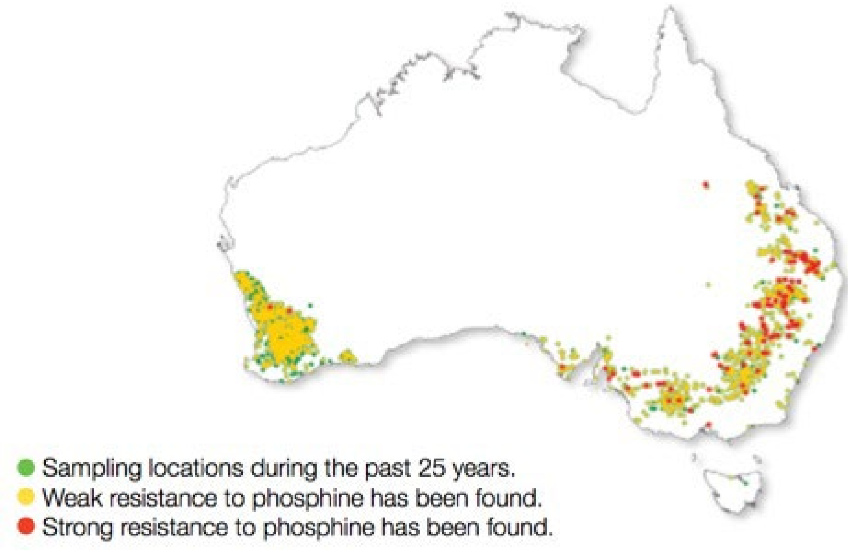

Figure 3: *Phosphine resistance in Australia.*

Source: DPIRD, Stored Grain Project (2014) Grain Fumigation - a Guide. Grain storage fact sheet, GRDC, January 2014, https://grdc.com.au/GRDC-FS-GrainFumigationGuide

Handling phosphine

Phosphine is a highly toxic substance (Schedule 7). To purchase and use phosphine a relevant chemical user registration must be held in the state (or territory) of operation.

Caution should always be used when dealing with phosphine gas as it is not only toxic but also highly explosive. Observe all ventilation and withholding periods for handling and grain use.

Gas respirators suitable for protection against phosphine must be worn. Always open containers of phosphine preparations in the open air. When opened, use the entire contents or dispose of excess chemical. Do not reseal leftover tablets as once they have been exposed to air they will begin to evolve into gas and may become explosive.

Face masks must fit properly for protection. This may be difficult for those with bearded faces, but is essential to avoid poisoning. Appropriate mask maintenance is also essential. For safety reasons, it is best not to work alone when applying phosphine tablets, or inside structures that have been fumigated.[39]

As a minimum requirement, the label directs the use of cotton overalls buttoned to the neck and wrist, eye protection, elbow-length PVC gloves and a breathing respirator with combined dust and gas cartridge. Operators should work in an open, well-ventilated area with the wind coming from the side.

38 Pulse Australia (2016) Southern/western field pea best management practices training course, module 8-2016, Draft. Pulse Australia Limited

39 Pulse Australia (2016) Southern Faba & Broad Bean - Best Management Practices Training Course, Module 8-2016, Pulse Australia Limited

Workers must not be exposed more than 4 times per day to more than 1 ppm for longer than 15 minutes, with at least 1 hour between each exposure. And workers must not be exposed to more than 0.3 ppm for more than 8 hours per day or 40 hours per week.

The odour threshold is 2 ppm, so once a worker can smell the phosphine they have already exceeded the safe exposure limit. Workers should wear a personal phosphine monitor that will sound an alarm if more than 0.3 ppm is detected.[40]

Warning signs must be clearly displayed when fumigation is in process (Figure 4). These should have details of when the fumigation commenced, the end date and information on ventilation. Entry into the silo is prohibited during both fumigation and ventilation. Signs should be placed at all storage access points during fumigation.[41]

Fumigation success

In order to kill grain pests at all stages of their life cycle (egg, larva, pupa, adult), including pests with strong resistance, phosphine gas levels for fumigation are:

- 300 parts per million (ppm) for 7 days when grain is above 25°C
- 200 ppm for 10 days when grain is between 15–25°C.

Do not use phosphine below 15°C as insects are hard to kill at low temperatures.

Fumigants take longer to distribute in storages with more than a few hundred tonnes capacity unless forced circulation is used.

Fumigation trials in silos with small leaks show that phosphine levels can be as low as 3 ppm close to the leaks, making it impossible to kill insects at all life stages. Poor fumigations may appear to have been successful when dead adults are observed; however, many of the eggs and pupae are likely to survive and will continue to infest the grain.

In addition, insects that survive are more likely to carry phosphine resistance genes, which has serious consequences for future insect control across the entire industry.[42]

Phosphine application and dosage rates

REFER TO LABEL INSTRUCTIONS.

Phosphine is slightly heavier than air and spreads rapidly. As grain does not absorb phosphine well, phosphine circulates through the stack effectively.

There are two forms of phosphine available for use on-farm: bag chains and tablets.

Bag chains are the safest form, and ensure there is no residue spilt onto the grain.

Tablets are the more traditional form and can be purchased in tins of 100.

Phosphine **blankets** are also available; however, these are designed for bulk storages of 600t or more.

The same amount of phosphine must be applied regardless of the amount of grain in the silo. When using fumigants, the volume of space determines the required amount of fumigant, not the grain in the storage.

The rate of application is the same for all crops:

- using a standard bag chain = 1 bag chain per 75m^3
- using tablets = 1.5 g/m^3 (equivalent to 3 tablets per 2 m^3).[43]

40 C Warrick and C Nicholls (2013) Fumigating with phosphine, other fumigants and controlled atmosphere. A Grains Industry Guide. GRDC, http://storedgrain.com.au/fumigating-with-phosphine-and-ca/

41 Pulse Australia (2016) Southern Faba & Broad Bean - Best Management Practices Training Course, Module 8-2016, Pulse Australia Limited

42 C Warrick and C Nicholls (2013) Fumigating with phosphine, other fumigants and controlled atmosphere. A Grains Industry Guide. GRDC, http://storedgrain.com.au/fumigating-with-phosphine-and-ca/

43 Pulse Australia (2016) Southern Faba & Broad Bean - Best Management Practices Training Course, Module 8-2016, Pulse Australia Limited

Table 7: Recommended rates of phosphine tablets (sealable, gas-tight silo only).

Cubic metres	Bushels	Tonnes	Number of tablets
18	500	14	28
37	1,000	28	56
56	1,500	42	84
74	2,000	56	111
92	2,500	70	138

Source: Grain Legume Handbook (2008), https://grdc.com.au/resources-and-publications/all-publications/publications/2008/03/2008-grains-legume-handbook

Some silos may also be fitted with purpose-built facilities to apply phosphine from the ground. These must have a passive or active air circulation system. This is so the phosphine gas is carried out of the confined space as it evolves, otherwise an explosion can occur.[44]

Always read and follow label directions when using phosphine. Arrange tablets evenly across trays to expose as much surface area as possible to air so that the gas can disperse freely. Trays should be hung in the head space or placed on the grain surface. Bag chains can be hung in the head space or rolled out flat on top of the grain. Bottom application systems require air-circulation systems to carry the gas out of the confined space as phosphine can reach explosive levels if left to evolve in a confined space.

After fumigation ventilate silos to remove harmful gas residues. Remove tablet residues and bag chains and leave silos open for no less than 5 days, or no less than 1 day with aeration fans operating. A further 2-day withholding period is required before delivering or using for human or animal consumption.

Aeration fans fitted on gas-tight, sealed silos provide a number of benefits including a shorter ventilation period following fumigation.

Always read the Safety Data Sheet (SDS) for more information and the required personal protective equipment (PPE).[45]

Figure 4: *A phosphine warning sign must be clearly displayed.*

Source: Stored Grain, http://storedgrain.com.au/phosphine-warning-sign/

Timing

Minimum fumigation times following application of phosphine are:

- 7 days at grain temperatures above 25°C; and
- 10 days at grain temperatures 15–25°C.

The fumigation period varies from 7 to 20 days depending on temperature and product used. It is important to follow concentration and exposure instruction carefully, as overdosing may reduce the fumigants effectiveness.

44 J Lamb, A Podder (2008) Grain Legume Handbook for the Pulse Industry. Grain Legume Hand Book Committee, https://grdc.com.au/grainlegumehandbook

45 C Warrick and C Nicholls (2013) Fumigating with phosphine, other fumigants and controlled atmosphere. A Grains Industry Guide. GRDC, http://storedgrain.com.au/fumigating-with-phosphine-and-ca/

MORE INFORMATION

Booklet: *Fumigating with phosphine, other fumigants and controlled atmospheres*, http://storedgrain.com.au/fumigating-with-phosphine-and-ca/

GRDC Fact Sheet: Stay safe around grain storage, https://grdc.com.au/Resources/Factsheets/2011/11/Stay-safe-around-grain-storage

GroundCover™ article: Effective phosphine fumigation takes time, https://grdc.com.au/Media-Centre/Ground-Cover/Ground-Cover-Issue-119-Nov-Dec-2015/Effective-phosphine-fumigation-takes-time

Printable phosphine warning sign, http://storedgrain.com.au/phosphine-warning-sign/

Do not use phosphine when the grain temperature is below 15°C or when grain moisture is below 9%.

Ventilation after fumigation

If there is only natural air flow moving over the grain, a minimum period of 5 days' ventilation is required to allow the phosphine concentrations to drop to safe levels below 0.3 ppm time weighted average (twa).

The concentration of phosphine can be measured with a multigas detector pump, fitted with a Draeger testing tube for phosphine. This equipment can detect levels of phosphine as low as 0.01 ppm in the air.

The detector is available from Draeger Australia, 8 Acacia Place, Notting Hill, VIC 3168, telephone (03) 1800 647 484, https://www.draeger.com/en_aunz/Home

Disposal

Tablet residues and expended sachets should be swamped with dilute acid or soap water in open air until bubbling ceases and then buried at least 30 cm below the soil surface. The expended tablets should not be piled together as there is a risk they may catch fire.

First aid

If a person is exposed to phosphine gas, they should immediately be moved into the open air and given oxygen treatment if possible. Standard first aid emergency procedures (DRSABC) must be implemented. This may include some to all of the following:

- **Danger** – ensure area is safe
- **Response** – check for alertness
- **Send** for help – dial 000
- Clear **airway**
- Check for **breathing**
- Start **CPR**.

If a phosphine tablet is swallowed, vomiting should be induced as soon as possible. Milk, butter, oils (castor oil) or alcohol should not be consumed.

Accidents are always possible so an emergency plan should be prepared in advance. Ensure all personnel understand first aid treatment for phosphine poisoning. Standard first aid emergency procedures should be displayed as well as emergency phone numbers.[46]

12.14 Alternative fumigants for pulses

If phosphine resistance is suspected other options for fumigation of pulses are limited. These options are more expensive than phosphine and still require a gas-tight, sealable silo.

Controlled atmosphere (CA) options change the balance of natural atmospheric gases to produce a toxic atmosphere. They have the advantage of being non-chemical control options. These are:

- Carbon dioxide (CO_2) – displacing air in storage with a high enough concentration of CO_2 to be toxic to pests. A minimum concentration of 35% CO_2 must be maintained for 15 days.
- Nitrogen – this method is currently under research and not recommended for on-farm use

Other fumigants such as ProFume® and Vapormate® are not registered for pulses.[47]

46 J Lamb, A Podder (2008) Grain Legume Handbook for the Pulse Industry. Grain Legume Hand Book Committee, https://grdc.com.au/grainlegumehandbook

47 C Warrick and C Nicholls (2013) Fumigating with phosphine, other fumigants and controlled atmosphere. A Grains Industry Guide. GRDC, http://storedgrain.com.au/fumigating-with-phosphine-and-ca/

12.15 Sealing silos

The Australian Standard (AS 2628-2010) allows growers to refer to an industry benchmark when purchasing a gas-tight, sealable silo. This standard provides assurance that the silo will perform in the intended manner.

Growers may choose to retro-seal existing farm silos rather than buying new gas-tight silos. Always ensure any retro-sealed silos comply with Australian Standard AS 2628. It is illegal to put phosphine into unsealed systems, hence the importance of retro-sealing. It is important to note that not all silos can be made gas-tight.

Sealing a silo must be carried out with care and attention to achieve a successful outcome. A haphazard approach will be costly in terms of time required to locate and repair any leaks.

Silos that are inadequately sealed lose gas through small holes. This prevents the fumigant reaching and maintaining concentrations necessary for an effective insect kill (Photo 8).

Figures 5 and 6 show how gas is lost from inadequately sealed silos, due to the effects of wind and sun.

Information on sealing and testing silos, cited in this section, is sourced from the Grain Legume Handbook (2008) (https://grdc.com.au/resources-and-publications/all-publications/publications/2008/03/2008-grains-legume-handbook).

Techniques have been developed that allow farm silos to be sealed to gas-tightness for effective fumigation. Any retro-sealing work undertaken must meet the Australian standard and pass the standard pressure test.

Retro-sealing of silos is not usually recommended. It is recommended to aerate older silos and purchase new silos that have been constructed from start to finish to be gas-tight and meet the standard.

Even if a silo can be sealed gas-tight for fumigation purposes, fitting aeration cooling will help immensely. Aeration, coupled with excellent hygiene, can overcome many potential problems.

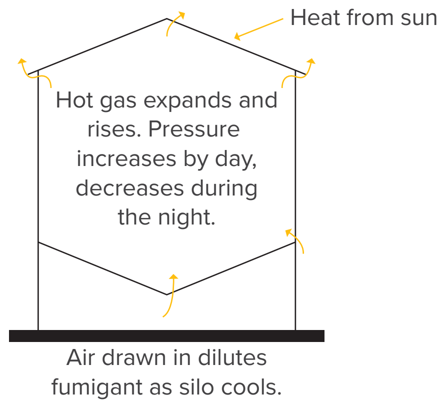

Figure 5: *Gas loss through heat effects.*

Source: Grains Legume Handbook (2008), https://grdc.com.au/grainlegumehandbook

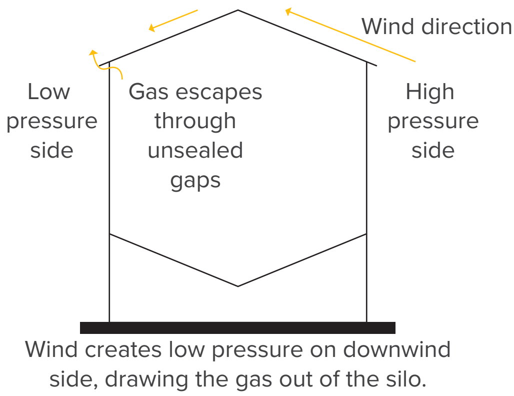

Figure 6: *Gas loss through wind effects.*

Source: Grains Legume Handbook (2008), https://grdc.com.au/grainlegumehandbook

12.15.1 Testing silos for seal

A relief valve fitted to sealable, gas-tight silos can also be used as a gauge for pressure testing. This allows for easy and regular seal tests. The relief valve should be filled to the second line (Figure 8) with light engine oil. Don't use water as it will evaporate. Vegetable oil is also unsuitable as it may react with the phosphine.

Test the silo for gas tightness using the pressure-relief valve (Figures 7 and 8) by applying a '5-minute half-life test'.

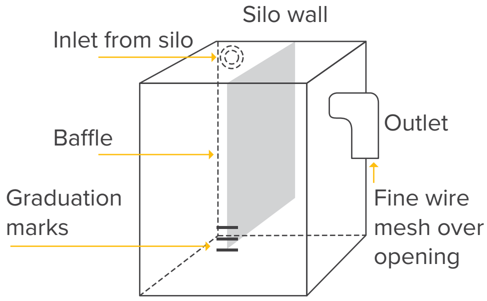

Figure 7: *Pressure-relief valve.*

Source: Grains Legume Handbook (2008), https://grdc.com.au/grainlegumehandbook

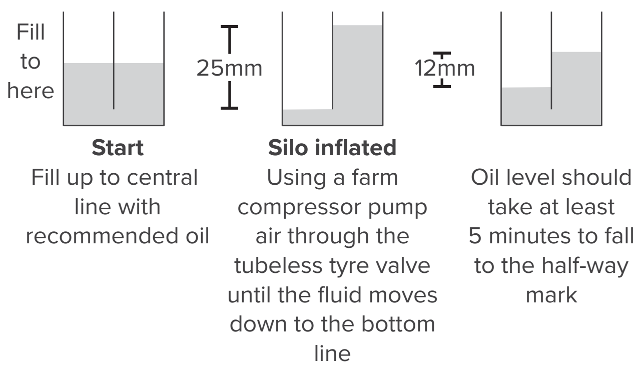

Figure 8: *Testing the silo with the pressure-relief valve.*

Source: Grains Legume Handbook (2008), https://grdc.com.au/grainlegumehandbook

Key points to note are:

- A silo sold as a 'sealed silo' needs to be pressure tested to ensure it is gas-tight.
- Check new sealable, gas-tight silos for Australian Standard pressure sealing compliance (AS2628).
- Pressure test sealed silos upon erection, annually, and before fumigating with a '5-minute half-life pressure test'.
- Maintenance of a quality, sealable, gas-tight silo is the key to ensuring a silo purchased as gas-tight maintains its gas-tight status.

Method of testing

Pressurise the silo using an air compressor, along with a tubeless tyre valve that is fitted to the silo wall.

This is done until a 25 mm difference is achieved in the heights of the fluid columns (or 250 Pascals); this should only take a few minutes.

The pressure fall to 12 mm (125 Pascals) is then timed; it should not be less than 5 minutes.

This seal test should only be conducted when weather conditions are stable, as fluctuations in the temperature, strength of sunlight or windy conditions can affect the readings. The best times for testing are early morning before heating or between 1 p.m. and 3 p.m., when temperatures are usually stable.

If the difference in fluid levels falls to 12 mm in less than 5 minutes, then this indicates an air leak. This will need to be found and sealed before fumigation can be effective.

All hatches should be checked first to ensure they are sealing properly. Then leaks in other parts of the silo can be located by applying a soapy solution to suspect areas: bubbles will indicate an air leak.

Alternatively, a boat flare may be released inside the silo (Photo 8). It is important to ensure the silo is free of grain dust as it is explosive.

When pressurising the silo, care must be taken to not exceed a difference of 30 mm in fluid levels. This high level of relief valve operation could damage the structure.

Every time sealing of a silo is undertaken, pressure testing must be done by following the above method.

When a sealable, gas-tight silo is not being used for fumigation, leave the top lid slightly open. When empty, leave the top lid and bottom hatch slightly open.[48]

48 J Lamb, A Podder (2008) Grain Legume Handbook for the Pulse Industry. Grain Legume Hand Book Committee, https://grdc.com.au/grainlegumehandbook