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GRDC
GROWNOTES™

GRDC
GRAINS RESEARCH & DEVELOPMENT CORPORATION

FABA BEAN

SECTION 13

STORAGE

KEY POINTS | HANDLING FABA AND BROAD BEAN | GRAIN CLEANING | COMPARING STORAGE OPTIONS | SILOS | GRAIN QUALITY | MOISTURE CONTENT AND TEMPERATURE | COOLING AND DRYING PULSES | AERATION COOLING | AERATION DRYING | HEATED AIR DRYING | PREVENTING MOISTURE MIGRATION | PULSE QUALITY RISKS WITH GRAIN BAGS | INSECT PESTS IN STORAGE | FARM AND GRAIN HYGIENE | FUMIGATION IN SEALED SILOS | USING PHOSPHINE | ALTERNATIVE FUMIGANTS FOR PULSES

MORE INFORMATION

GRDC Grain storage Fact Sheet Pressure testing sealable silos, http://www.grdc.com.au/GRDC-FS-PressureTestingSilos

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

Grain Stoage GrowNotes™, https://grdc.com.au/resources-and-publications/grownotes/technical

VIDEO

GRDC Video: Storing pulses, https://youtu.be/CeWA-OdhhSk

VIDEO

GRDC Video: Oilseed & Pulse Storage, https://youtu.be/JvzfJ2Xo6Sg

Storage

Key points

- **Faba and especially broad beans are a very large, plump grain and are very prone to mechanical damage during handling.**
- **Harvest faba bean at 14% moisture content to minimise the risk of damage to grain during handling, but do not store above 12% moisture.**
- **Pulse grain placed in storage with high germination and vigour can remain viable for at least 3 years, providing the moisture content of the grain does not exceed 11%.**
- **Store grain at a low temperature and low moisture content for maximum storage time.**
- **When storing for longer than 3 months only use storage that is suitable for aeration cooling and gas-tight fumigation.**
- **Hygiene is the first and most important step in protecting pulse grain from insect pests.**
- **Fumigation options are limited for pulses; successful fumigation requires a gas-tight, sealable silo.**

FEEDBACK

VIDEO

GRDC Video: Stay safe around grain storage, https://youtu.be/CM2mgmo3jWU

CASE STUDIES

GRDC Video: Over the Fence: On-farm storage pays in wet harvest – May 2011, https://youtu.be/ejywX-WytTs

GRDC Video: On-farm storage delivers harvest flexibility and profit, https://youtu.be/UWr7CTMxVMg

GRDC Video: On-farm storage in the SA Mallee with Corey Blacksell, https://youtu.be/fFKJYylp0hk

GRDC Video: On-farm storage in SA with Lindon Price, https://youtu.be/V9pSYmh_cO0

Harvesting pulses at 14% moisture content preserves grain quality and reduces mechanical damage.[1] 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.

Regular monitoring is required to ensure grain quality in storage is maintained.[2] 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.

13.1 Handling faba and broad bean

Faba and especially broad beans are a very large, plump grain and are very prone to mechanical damage during handling.[3] Human food markets demand a quality sample without cracking, staining, de-hulled seeds or insect damage. Harvest at the right time to ensure that the seed is not too dry (<10% moisture content). Crops that have been exposed to weather damage prior to harvest will be more vulnerable to mechanical damage.

Grain can be handled up to six times before delivery to receival points, so it is important to minimise the number of times grain is augured or handled and use efficient handling techniques.[4] Move seed gently to minimise cracking.

If using augers:

- Ensure augers are full of grain and operate at slow speeds.
- Use large-diameter augers.
- The flight pitch should be greater than the auger diameter.
- The length of the auger should be no longer than is necessary. The shorter the better.
- Operate augurs as close as possible to their optimal efficiency – usually at an angle of 30 degrees.
- Check flight-to-barrel clearance to minimise lodging and damage – the optimum clearance between the flight and tube is half the grain size.
- Auger drives should be at the discharge end, and not on the intake.

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

2 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

3 P Matthews, H Marcellos (2003) Faba bean. Agfact P4.2.7. 2nd edn. NSW Agriculture, http://www.dpi.nsw.gov.au/content/agriculture/broadacre/winter-crops/pulses/beans/faba-bean

4 Pulse Australia (2015) Southern faba & broad bean best management practices training course – 2015. Pulse Australia

FEEDBACK

MORE INFORMATION

Stored Grain Project (2013) *Grain storage facilities: Planning for Efficiency and Quality, A Grains Industry Guide*. GRDC, June 2013, http://storedgrain.com.au/grain-storage-facilities/

Economics of on-farm grain storage booklet and cost-benefit analysis spreadsheet from the Stored Grain information hub (http://storedgrain.com.au/economics-booklet/).

13.2 Grain cleaning

Re-cleaning of samples after harvest is sometimes necessary. Cereals can be cleaned from most pulses (not lentil) with a 3 or 4 mm rotary screen. The 3.75 mm slotted screen is popular and will help screen out split grain. The paddles or agitators in rotary screens should be either new or sufficiently worn so that the grain being harvested cannot jam between the outside of the paddle and the rotary screen.

Screens or paddles can be damaged beyond repair if the grain jams. Fitting the screens with a spacer will provide additional clearance to overcome this 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.

13.3 Comparing storage options

As pulses are sold into the human food market protecting grain quality is vital. There are many options to consider when selecting appropriate storage for grain and growers will need to consider the advantages and disadvantages of different types of storage options (Table 1).

For growers considering investing in new storage to protect their pulse crop a benefit-cost analysis is useful to compare the expected return from investing in good-quality grain storage with other farm investments. Growers can download the *Economics of on-farm grain storage* booklet and cost-benefit analysis spreadsheet from the Stored Grain Information hub.

FEEDBACK

Table 1: Advantages and disadvantages of grain storage options.

Storage type	Advantages	Disadvantages
Gas-tight, sealable silo	• Gas-tight, sealable status allows phosphine and controlled atmosphere options to control insects • Easily aerated with fans • Fabricated on-site or off-site and transported • Capacity from 15 t up to 3,000 t • Up to 25-year + 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 t up to 3,000 t • Up to 25-year + 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 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 3 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 + 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 via Stored Grain Project (2013) Grain storage facilities: Planning for Efficiency and Quality, A Grains Industry Guide. GRDC, June 2013, http://storedgrain.com.au/grain-storage-facilities/

FEEDBACK

MORE INFORMATION

For details on comparing storage costs, please see the 2013 booklet by C Warrick *"Economics of on-farm grain"* at: http://storedgrain.com.au/economics-booklet/

13.4 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.[5] When storing for longer than 3 months only use storage that is suitable for aeration cooling and gas-tight fumigation. Ideally, an aeration controller should be used to optimise aeration efficiency and cooling of the grain. 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 below. 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.

One cubic metre of faba bean = 750 kilograms of faba bean (or 9.2 x 3-bushel bags)

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)

MORE INFORMATION

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

13.5 Grain quality

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.

All faba and broad beans will darken considerably in storage, and the rate of seed coat darkening is accelerated by:

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

Faba and broad bean seed stored for more than 9 months is usually unsuitable for the export market.[6]

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

6 A Ware, R Kimber, J Paull, W Hawthorne (2013) Bean variety trials. Conmurra MFMG Bean Variety Trial 2012. Online farm trials website, http://www.farmtrials.com.au/trial/16758

FEEDBACK

13.6 Moisture content and temperature

Store grain at a low temperature and low moisture content for maximum storage time.

Cooler grain temperatures have several advantages:

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

Accurately check the moisture content of all grain entering storage with a moisture meter. Moisture content of grain during harvest can change during the day and evening. Fumigation as soon as the silo is filled can stop any insects that are present from creating additional moisture.

The maximum moisture content set in the national receival standards for pulse receival is 14%, but bulk handlers may have receival requirements down to 12%.

Harvesting pulses at the higher moisture content (around 14%) reduces field mould, mechanical damage to the seed, splitting and preserves seed viability. However, pulse grain must be dried before going into storage to preserve seed germination and viability.

Pulse grain placed in storage with high germination and vigour can remain viable for at least 3 years providing the moisture content of the grain does not exceed 11%.

As a general rule, every 1% rise in moisture content above 11% will reduce the storage life of pulse seed by one-third. Any pulse stored above 12% moisture content will require aeration cooling to maintain quality.

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.

Typical harvest temperatures of 25°C–35°C and grain at a moisture content greater than 13–14% can provide the ideal condition for mould and insect growth (Figure 1 and Table 2).[7] 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.

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

FEEDBACK

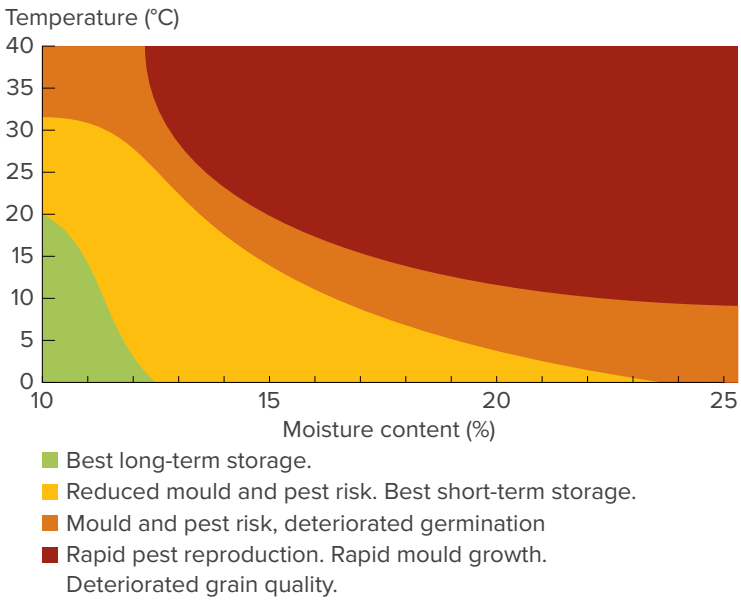


Figure 1: *Effects of temperature and moisture on stored grain.*

Source: CSIRO Stored Grains Research Laboratory via Stored Grain Project (2013) Dealing with high-moisture grain fact sheet

Table 2: The influence of temperature and moisture on stored grain Insect and mould development.

Grain 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 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 via GRDC (2013) Grain storage pest control guide

MORE INFORMATION

Booklet: *Aerating stored grain*, www.grdc.com.au/GRDC-Booklet-AeratingStoredGrain

13.7 Cooling and drying pulses

Grain with a higher moisture content can be stored for longer if the temperature is cool (Table 3). Options for grain that is above the standard safe storage moisture content of 12.5% include:[8]

- **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 t of grain at a time with a high volume of pre-heated air, usually using a transportable trailer.

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

FEEDBACK

VIDEO

GRDC Video: Grain Storage with Philip Burrill — Using Aeration Controllers, https://youtu.be/vxoBO71rTDg

VIDEO

GRDC Video: Grain storage cooling aeration, https://youtu.be/qb3WAXZOl1g

VIDEO

GRDC Video: Pressure testing sealed silos, https://youtu.be/BHKUNjnnhIE

Table 3: Maximum storage period for grain by temperature and moisture content.

Moisture content (%)	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 via Stored Grain Project (2014) Storing pulses

To store pulses without reducing quality, growers should assess what storage they currently have, identify gaps in best practice and work out a plan to meet current and future needs.[9]

A practical way of reducing temperatures is to paint the silo white, as dark-coloured silos will absorb more heat. Silos aligned in an east—west orientation rather than north—south provide extra shading and can reduce heating of the silos.

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.

13.8 Aeration cooling

Aeration cooling is a vital tool when storing pulses in a silo.[10] It allows grain to be harvested earlier and at higher moisture levels, preserving grain quality and reducing mechanical seed damage.

Aeration cooling is suitable for longer-term storage of low-moisture grain by creating cool, uniform conditions.

High-moisture grain can be safely held for a short time (1–2 months) with aeration cooling before blending or drying. Run fans continuously to prevent self-heating and quality damage.

Samples with green pods and grains are at increased risk of mould developing, even at low moisture contents, and aeration cooling can reduce this risk. The space at the top of the silo will heat and cool each day and if moisture contents are greater than 12% condensation can form and wet the grain at the top of the stack.

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. With an aeration system, a waterproof vent on the top of the silo allows air forced from the base of the silo to escape. During fumigation this vent needs to be replaced with a sealed lid or a capped venting tube.

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

It is also important to know how fans will perform when pushing air through the grain. Grain exerts a back pressure on the airflow. Whilst larger grains exert less back pressure knowing the performance of the fans is important to ensure the correct amount of air is pushed through the grain. Fans should have a rating for this and reputable suppliers will be able to show pressure curve performance for fans.

9 J Severs (2016) Grain storage is about food and safety. GroundCover™, Issue 123, July—August 2016, https://grdc.com.au/resources-and-publications/groundcover/ground-cover-issue-123-julyaugust-2016/grain-storage-is-about-food-and-safety

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

FEEDBACK

MORE INFORMATION

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

Website: Agridry, http://agridry.com.au/

VIDEO

GRDC Video: Aeration drying – getting it right, https://youtu.be/vzMHzyHCWuw

Have the necessary fans for each storage dedicated to each silo. If a fan is ducted to more than one silo the silo with the least airflow resistance will get the majority of the airflow.

Correctly controlled aeration should aim to reduce grain temperature to less than 23°C in summer and less than 15°C in winter. Cooling achieved during storage depends on the moisture content of the grain and the humidity and temperature of the incoming air. Automatic aeration controllers that select optimum fan run times are the most reliable and convenient to use.

13.9 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.[11] 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 or at least 15–25 litres per second per tonne of grain. Aeration drying is a slow process that also relies on well-designed ducting for even air flow, exhaust vents in the silo roof and warm, dry weather conditions.

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.[12]

Once drying is complete all grain needs to be cooled regardless of whether supplementary heat was used. Storage pests stop breeding at temperatures below 15°C (Table 2). Aim for less than 23°C in summer and less than 15°C in winter.

13.10 Heated air drying

Use heated air with caution for drying pulses. Do not exceed 45°C when using heat to dry faba and broad bean.

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.

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

12 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/

FEEDBACK

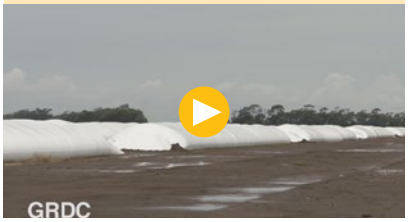
MORE INFORMATION

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

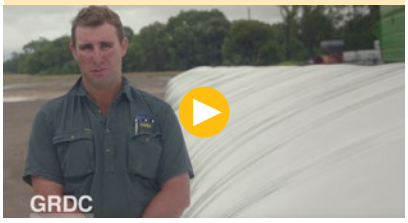
VIDEO

GRDC Video: Grain bags: best practice, https://youtu.be/Ab-A2Il6b1Q



VIDEO

GRDC Video: Grain bags – a grower's perspective, https://youtu.be/cLRgjjdEr0U



13.11 Preventing moisture migration

Grain stored in sealed silos must be of sufficiently low moisture content to prevent moisture migration. Use an aerated silo with adequate ventilation fitted.

Do not load grain with excess moisture (>12%) into a sealed store where there is no escape of moisture. In a sealed 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.

13.11.1 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.

13.11.2 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).

13.11.3 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.

13.11.4 Leaks

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

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

VIDEO

GRDC Video: Stored grain: managing sealed & unsealed storage, https://youtu.be/TIs0S-7DwxA

13.12 Pulse quality risks with grain bags

Grain bags (also known as silo, sausage or harvest bags) are only recommended for short-term (3-month) storage as a harvest buffer (Photo 1).[13] Storage of high-value pulses or pulse seed crops in grain bags is not recommended.[14]

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

Grain bags are effectively sealed storage without aeration.

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.[15] 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.

Grain must be below 14% moisture content and the bag must remain sealed and undamaged, preventing moisture from entering during storage.

Punctures need to be sealed quickly and correctly. Inspect bags weekly or more often. Damage by vermin, birds and other pests is common.

The risks of storing pulses in grain bags are:

- Pulse grain may not retain its quality, colour or odour, especially if the seal is breached.
- 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.
- 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 that requires considerable periods of aeration to remove. There is nil tolerance of odours in pulse receival standards. (See Section 12.13 Receival standards).
- 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.

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

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

15 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

Photo 1: *Grain bags are only suitable as temporary storage for pulses.*

Photo: Unknown

13.13 Insect pests in storage

Insects are not considered a major problem in stored faba and broad bean. While seed beetles or bruchids (Bruchinae) are considered primary pests of pulse crops, very few bruchid species present in Australia attack faba bean.

There are exotic bruchids that attack faba bean, but they are not currently present in Australia (see Section 8.6.1 Exotic seed beetles/bruchids (*Coleoptera*: Family: *Chrysomelidae*, sub-family: *Bruchinae*)).

If faba and broad bean are loaded into storages containing residues of cereal grain already infested with cereal pest insects, these infestations can spread into the beans.[16] These include flour beetles (*Tribolium* spp.) and grain borers (*Rhyzoptherha* spp.).

Damaged seed is more vulnerable to insect pests.

The tolerance for live pests sold off-farm is nil. Growers need an integrated approach to pest control.[17] 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 2). 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.

16 GRDC (2015) GCTV Stored Grain: Storing pulses. GroundCover™ TV, theGRDC Youtube channel, https://youtu.be/CeWA-OdhhSk

17 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

FEEDBACK

MORE INFORMATION

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

VIDEO

GRDC Video: Grain silo hygiene, https://youtu.be/3VU7qJCoCwI

VIDEO

GRDC Video: Applying diatomaceous earth demonstration, https://youtu.be/L-lyCgstkc0

13.14 Farm and grain hygiene

Hygiene is the first and most important step in protecting pulse grain from insect pests as other opportunities for control are limited. Many growers do not have the gas-tight, sealed storage required to manage insects with fumigation. One bag of infested grain in the yard can produce more than one million insects over a year that can walk and fly to other grain storages.

If insects have nowhere to hide when grain storages are empty the risk of them infesting freshly harvested grain placed into storage is low.

Clean silos and storages thoroughly.[18] 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; and
- equipment brought onto the farm from outside.

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

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

Diatomaceous earth (DE) as a structural treatment can be used to treat storages after cleaning, but it is essential to wash and dry the storage and equipment before using for pulses. This will ensure the DE does not discolour the grain surface.

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

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

FEEDBACK

13.15 Fumigation in sealed silos

Pulses are a food product and need to be protected from insects, mould, fungi and chemical residues.[19] Forty per cent of growers store their products on-farm so understanding how to use fumigants safely is vital.

Even grain sold to dairy farmers can potentially impact on the safety of milk products. Traceability along the supply chain is important.

Fumigation options are limited for pulses.[20] Phosphine fumigation is used in most situation. Controlled atmosphere (such as carbon dioxide and nitrogen) may be suitable. Other grain protectants are not registered for pulses.

Successful fumigation requires a gas-tight, sealable silo (Photo 2). To be effective against all insect life 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 2: *Using an unsealed silo for fumigation is both ineffective and dangerous.*

Photo: Grain Legume Handbook (2008)

According to Australian Standard AS2628, a silo is only truly sealed if it passes a 5-minute half-life pressure test. 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 full of grain and before fumigation.
- As part of the annual maintenance routine.

19 J Severs (2016) Grain storage is about food and safety. GroundCover™, Issue 123, July—August 2016, https://grdc.com.au/resources-and-publications/groundcover/ground-cover-issue-123-julyaugust-2016/grain-storage-is-about-food-and-safety

20 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

FEEDBACK

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/resources-and-publications/groundcover/ground-cover-issue-119-nov-dec-2015/effective-phosphine-fumigation-takes-time

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

13.16 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.

Phosphine is the single most relied upon fumigant in the Australian grains industry.[21] Continued misuse is leading to poor insect control and developing resistance (Figure 2). 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.[22] A GRDC survey in 2010 showed that only 36% of users applied phosphine correctly in a gas-tight, sealed silo.

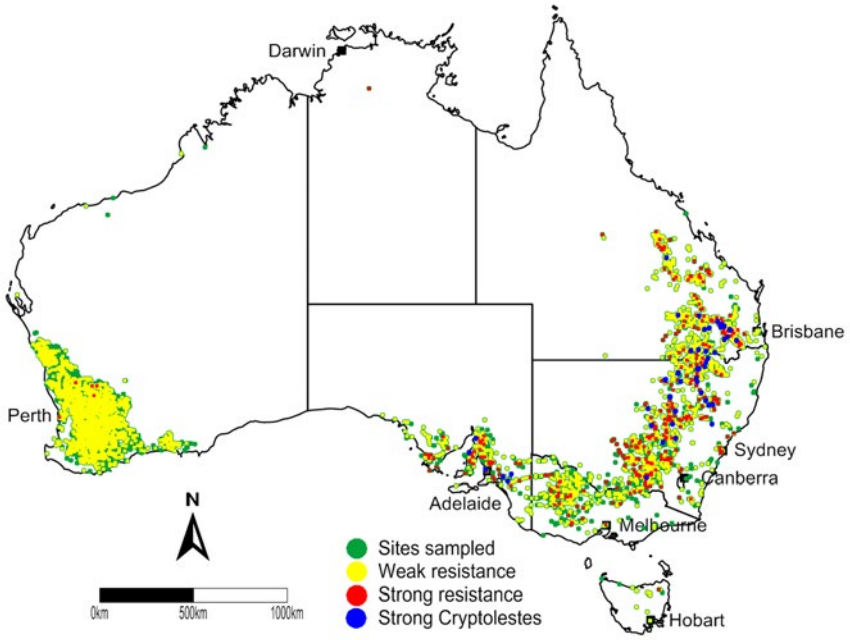


Figure 2: *Phosphine resistance in Australia 1986 to 2014.*

Source: DPIRD, via Emery (2014)

Minimum phosphine gas levels for fumigation are:

- 300 parts per million (ppm) for 7 days when grain is above 25°C; and
- 200 ppm for 10 days when grain is between 15°C and 25°C.
- Do not use phosphine below 15°C as insects are hard to kill at low temperatures.

Fumigant takes 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 fumigation may appear successful with some dead adults found, but those that survive are more likely to carry increased phosphine resistance.

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.

21 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/

22 Stored Grain Project (2014) Grain Fumigation: a Guide. Grain Storage Fact Sheet. GRDC, January 2014, https://grdc.com.au/GRDC-FS-GrainFumigationGuide

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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. Warning signs need to be displayed during fumigation (Figure 3).

Safety is important. Phosphine is a schedule seven (S7) poison. 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.

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.

Do not re-seal leftover phosphine tablets once they have been exposed to air as they can become explosive.

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

Figure 3: *A phosphine warning sign must be clearly displayed. They can be downloaded from http://storedgrain.com.au/phosphine-warning-sign/.*

Source: Stored Grain

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13.17 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, sealed 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.