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GRDC
GROWNOTES™

GRDC
GRAINS RESEARCH
& DEVELOPMENT
CORPORATION

LENTIL

SECTION 13

STORAGE AND HANDLING

KEY POINTS | HANDLING LENTIL | GRAIN CLEANING | GRAIN QUALITY IN STORAGE | GRAIN STORAGE PRINCIPLES | INSECTS IN STORAGE | SEALING SILOS | SILO BAGS

Storage and handling

Key points

- Lentil, especially green lentil types, is very prone to mechanical damage.
- Re-cleaning lentil after harvest is sometimes necessary.
- Lentil stored above 12% moisture requires aeration cooling to maintain quality.
- Lentil will darken in storage.
- Meticulous hygiene and aeration cooling are critical for preventing pest incursions.
- Fumigation is the main option available to control pests in stored lentil; this requires gas-tight, sealable storage.
- Avoiding mechanical damage to the grain will maintain market quality and seed viability, and deem the grain less attractive to insects.

FEEDBACK

13.1 Handling lentil

Lentil, especially green lentil types, is very prone to mechanical damage, particularly during rough handling. This applies to:

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

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

- the number of handling stages are minimised wherever possible; and
- efficient handling techniques that minimise damage are used.

The use of tubulators or belt conveyors can reduce damage compared to conventional spiral augers.[1]

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 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.

MORE INFORMATION

For further information see GRDC Grain Storage GrowNotes™, https://grdc.com.au/grain-storage-grownotes

13.2 Grain cleaning

Re-cleaning lentil after harvest is sometimes necessary. Although ccereals can be cleaned from most other pulses, lentils' similar size means this is not possible. It is preferable to clean cereals out of lentil in the paddock with the use of herbicides. This is done when lentil and the cereals are still plants, and prior to the production of any grain.

Vetch (and tare) seeds are difficult to remove from lentil grain by cleaning. Prior to planting, if the proposed lentil paddock has a potential vetch or tare problem, a suitable sized variety to assist with grading should be chosen. For example, a small-seeded variety like PBA Hurricane XT$^{\Phi}$ might be chosen so that the vetch is retained on top of the sieve. Alternatively, a large seeded variety like PBA Jumbo2$^{\Phi}$, PBA Jumbo$^{\Phi}$ or PBA Giant$^{\Phi}$ might be chosen so the vetch falls through the screen.[2]

When cleaning, 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, thus avoiding the problem.

Milk thistle bud can be difficult to separate and contaminate the lentil sample as it is similar in size and weight to peas. However, if desiccated, or given time to dry, the bud will disintegrate when put through an auger and can then be easily separated.

Soil and most small weed seeds can be separated in rotary screens; however, the soil will increase wear on the components of the cleaner.

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

2 Pulse Australia (2016) Southern Lentil: Best Management Practices Training Course. Pulse Australia

FEEDBACK

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

(Photo: M. Raynes, formerly Pulse Australia)

MORE INFORMATION

Refer to Section 12 Harvesting lentil for information on how to minimise damage to lentil grain before and during harvest.

13.3 Grain quality in storage

Monitoring the quality of grain before and during harvest is extremely important. The lentil seed coat and kernel (cotyledon) can be discoloured by crop-topping or premature desiccation if sections of the paddock have uneven maturity. Staining of seed caused by green plants in the crop or a mixture of splits, weeds, stones etc will reduce the value of the grain and result in deductions to the final price received.

Visual appearance of lentil is critical. Human food markets demand a quality sample without cracking, staining, de-hulled grain or insect damage. Grain samples indicating no mechanical damage from harvesting will always be more acceptable to a buyer. The smaller seed of lentil makes it less prone to mechanical damage than larger-seeded crops like faba bean; however, damage can still occur with poor handling. Minimising the number of times grain is transferred in augers will greatly reduce the chances for damage to the grain.[3]

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

Basic storage principles

Key points to remember with regard to storing pulses are:

- Pulses stored above 12% moisture require aeration cooling to maintain quality.
- Meticulous hygiene and aeration cooling are critical for preventing pest incursions.
- Fumigation is the main option available to control pests in stored lentil; this requires gas-tight, sealable storage.
- Avoiding mechanical damage to the grain will maintain market quality and seed viability, and deem the grain less attractive to insects.[4]

3 Pulse Australia (2016) Southern Lentil: Best Management Practices Training Course. Pulse Australia

4 Grains Research and Development Corporation (2012) Storing Pulses. Grains Research and Development Corporation, www.grdc.com.au/GRDC-FS-GrainStorage-StoringPulses

FEEDBACK

MORE INFORMATION

Refer to the GRDC Factsheet: Storing pulses.
www.grdc.com.au/GRDC-FS-GrainStorage-StoringPulses

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

GRDC video: Stored Grain Storing Pulses
https://youtu.be/CeWA-OdhhSk

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

GRDC Video: Stored grain: 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 – Lindon Price
https://youtu.be/V9pSYmh_cO0

Growers contemplating medium-long term storage (six to twelve months) need to be aware that lentil continues to age, and quality will deteriorate over time, especially in sunlight with high temperatures and humidity.

Lentil 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 grain at harvest; and
- sunlight.

To maintain lighter seed coat colour and minimise darkening of seed, any pulses stored above 12% moisture content will require aeration cooling to maintain quality.

Mature grain, subject to field weathering in the paddock prior to harvest, will deteriorate at a more rapid rate in storage, compared to non-weathered grain, even if stored under ideal conditions for temperature and relative humidity.

Avoid short to medium storage of weather-damaged lentil.

Stored lentil, with high germination and vigour, can remain viable for at least 3 years providing the moisture content of the grain does not exceed 11%.[5]

The storage life of pulses is determined by temperature, moisture content, insects and diseases. Careful management of these factors is critical to avoid deterioration during storage.

When grain enters storage, it requires regular monitoring to allow early action and intervention if insects or grain quality issues arise. **Monitoring grain at least monthly for insects, moulds, grain temperature and moisture should be standard practice.**

Refer to GRDC Fact Sheet: Vigilant monitoring protects grain assets, https://grdc.com.au/Resources/Factsheets/2012/03/Vigilant-monitoring-protects-grain-assets

Moisture

Pulses harvested at 14% moisture or higher must be dried before entering storage to preserve seed germination and viability. As a rule, every 1% rise in moisture content above 11% will reduce the storage life of pulse seed by one-third (Figure 13.1). Any pulse stored above 12% moisture content will require aeration cooling to maintain quality.[6]

Refer to Section 13.4 Grain storage principles for preventing moisture migration and drying grain.

Temperature

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 1 and Figure 1.

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

Grain in large silos (>75 t) will remain cooler as grain is a poor conductor of heat and day to 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.

5 Grains Research and Development Corporation (2012) Vigilant monitoring protects grain assets. Grains Research and Development Corporation, https://grdc.com.au/Resources/Factsheets/2012/03/Vigilant-monitoring-protects-grain-assets

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

FEEDBACK

Table 1: 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

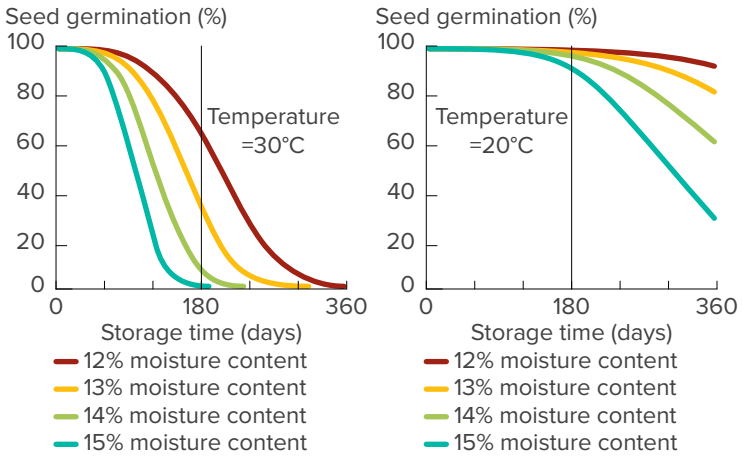


Figure 1: *Generalised graph of storage temperature* and moisture effects on seed vigour.*

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

13.4 Grain storage principles

MORE INFORMATION

Refer to the GRDC Fact Sheet: Storing pulses. www.grdc.com.au/GRDC-FS-GrainStorage-StoringPulses

IN FOCUS

Key storage principles for lentil include:

- lentil grain should only be stored if it is clean and dry;
- moisture content of all grain entering storage must be accurately assessed with a moisture meter;
- moisture content of grain during harvest can change during the day and evening;
- sealable, gas-tight silos should be fumigated immediately after filling to stop any insects that are present from creating moisture; and
- grain must be maintained at low temperatures and moisture content for maximum storage time.

FEEDBACK

Silo capacity

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
Example: Silo of lentil	67.4	53,920	620

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)

Photo 2: *On-farm storage enables a timely harvest and a planned marketing strategy.*

(Photo: M. Raynes, formerly Pulse Australia)

FEEDBACK

Photo 3: *On-farm storage is becoming more sophisticated with aeration facilities and sealing capability to enable a quality product to be out-turned.*

(Photo: W. Hawthorne formerly Pulse Australia)

Photo 4: *A range of on-farm storage options for both short and long-term prospects.*

(Photo: W. Hawthorne formerly Pulse Australia)

Cooling grain and 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 lentil. 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. 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.

FEEDBACK

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

VIDEO

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

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

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

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. Always ensure this amount of air will be pushed through the column of grain, and is directly related to how the fans perform under 'back pressure' from the grain. Reputable suppliers of aeration equipment will ensure fans recommended will meet this requirement.

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 aerations controllers that select optimum fan run times provide the most reliable results and are deemed best for convenience.

Preventing moisture migration

Moisture migration is where convection currents cause moisture to concentrate in the top centre of the silo/storage. Moisture also moves from warmer to cooler grain on the sidewall of bins when warm grain goes into winter storage. Grain affected by moisture migration often feels damp or tacky at the surface and may form a crust when grain warms in the spring.

Grain stored in sealed silos must be of sufficiently low moisture content to prevent moisture migration. Grain with excess moisture should not enter a sealed store where there is no escape of moisture. An exception is where the silo is aerated and has adequate ventilation fitted.

In a sealed silo, there is no free venting and, therefore, no escape for moisture into the headspace. This means that moisture can migrate to the upper grain layers causing condensation. There will also be some loss of moisture to the atmosphere. This top area of the grain is at high risk from mould and insect colonisation.

Moisture sources

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.

Grain insects: Insects or mites in the grain release moisture and heat into air spaces as they respire. If grain in storage is less than 14% moisture, and is free of insects, moisture content increase in the upper layers of the grain will be insignificant.

If grain in storage is above 14% moisture content, then enough moisture may be carried into upper grain layers to place that grain at risk of mould. Moisture from insects builds up faster than moisture from grain respiration and to higher levels. There is no moisture migration in an aerated silo as the entire stack is normally cooled to one temperature (20°C or less).

Condensation impact: Moisture carried into the silo headspace can condense on a cold roof and fall back as free water. This can then 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 there is a greater incidence of mould and insect growth.

FEEDBACK

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

GRDC factsheet: Dealing with high-moisture grain. www.grdc.com.au/GRDC-FS-HighMoistureGrain

For general information on handling, drying and cooling see: Agridry Rimik Pty Ltd http://www.agridry.com.au

VIDEO

Watch GRDC Groundcover TV Episode 16 Stored Grain: Stay Safe Around Grain Storage: https://youtu.be/CM2mgmo3jWU

A GRDC video on stored grain is at 'Stored grain: managing sealed & unsealed storage' https://youtu.be/TIs0S-7DwxA

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

Drying grain and aeration drying

The purpose of drying grain is to remove excess moisture to prevent spoilage during storage.

Continuous-flow or batch dryers provide reliable drying, although they can reduce quality if run at too high a temperature. **Temperature should not exceed 45°C when using heat to dry lentil.** Check the specifications or talk to the manufacturer about safe conditions for drying lentil.[7]

High capacity aeration systems can also be used to dry grain, and are ideally suited for drying grain harvested at 15–16% moisture content. Aeration drying has a lower risk of cracking and damaging lentil, which can occur with hot air dryers. Aeration drying requires a larger capacity fan to move high volumes of air through the grain at a faster rate than that required for cooling only.

Flow rates of at least 15–25 L/second/tonne are required for aeration drying. By comparison, an airflow rate of as little as two to three L/s/tonne can achieve aeration cooling.

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

13.5 Insects in storage

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

It is important to note that there are exotic bruchids (not present in Australia) that do attack lentil.

Refer to the exotic pests section in Section 9 Pest management.

One exception appears to be in cases where lentil is loaded into storages containing residues of cereal grain already infested with cereal insect pests such as flour beetles (*Tribolium* spp.) and grain borers (*Rhyzoptherha* spp.) These prior infestations can develop and spread in lentil. Removal of these residues prior to loading is essential. In some cases, grain insects can cross-contaminate lentil storage from cereal storage. Monitoring and minimising the potential for infestations should prevent this from happening.

Farm and grain hygiene

Maintaining good farm hygiene in and around storage facilities plays a crucial role in overcoming many problems associated with storage pests. Prevention is much easier than cure.

Good hygiene practices, combined with aeration cooling, should prevent infestations developing.

Good hygiene practices include:

- removing all grain residues from empty storage facilities. Residues from all grain handling and carriage equipment must also be removed before new grain is stored and equipment used;
- cleaning up spillages around silos and destroying all residues to prevent reinfestation;
- once storages and equipment have been cleaned, treat them with an inert dust treatment;
- ensure insects or weeds are not carried onto the property via farm equipment (i.e. harvesters); and
- all equipment should be thoroughly cleaned after use.

7 Pulse Australia (2015) Best Management Guide – Lentil Production: Southern Region. Pulse Australia, http://www.pulseaus.com.au/growing-pulses/bmp/lentil/southern-guide

FEEDBACK

MORE INFORMATION

For more information, refer to GRDC factsheets:

Hygiene and structural treatments for grain storage
www.grdc.com.au/GRDC-FS-HygieneStructuralTreatments

Storing pulses.
www.grdc.com.au/GRDC-FS-GrainStorage-StoringPulses

VIDEO

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

GRDC Video: Applying Diatomaceous Earth Demonstration
https://youtu.be/L-IyCgstkc0

MORE INFORMATION

Refer to:
- Section 13.6 Sealing silos; and
- GRDC factsheet: Pressure testing sealable silos
http://storedgrain.com.au/pressure-testing/

Insect development

Most insect development ceases at temperatures below 20°C. Freshly harvested grain usually has a temperature of around 30°C and above which is an ideal breeding temperature for many storage pests. Silos with aeration rapidly reduce grain temperatures, reducing insect breeding and aiding grain quality.

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

Temperature (°C)	Insect and mould development
40–55	Seed damage occurs, reducing viability
30–40	Mould and insects are prolific
25–30	Mould and insects active
20–25	Mould development is limited
18–20	Young insects stop developing
<15	Most insects stop reproducing, mould stops developing

Insect control programs should principally aim to control insects in the growing crop. However, fumigating grain in sealable, gas-tight storages will control infestations in stored grain.

Treatment options for controlling insects in stored lentil

If treatment is required for insects in stored lentil, the only control options are:

- phosphine fumigation;
- an alternative fumigant such as nitrogen gas; or
- carbon dioxide gas.

Phosphine fumigation is the main method for insect control of grain in storage.

No insecticide sprays are currently registered for use on lentil. Markets are particularly sensitive to insecticide residues, so detection of any residues on lentil could result market loss, not just the rejection of a contaminated delivery.

Residual sprays should not be used on storage and handling equipment that is to be used for lentil.

Using diatomaceous earth as a structural treatment is possible if the storage and equipment is washed and dried before using pulses. This will ensure the diatomaceous earth does not discolour the grain surface. If unsure, the grain purchaser must always be consulted regarding delivery standards and/or allowances.

Fumigation

Phosphine is the only fumigant currently registered for use in pulses.

Fumigation basics

Effective fumigation is both the control of all insect life stages, and the reduction in risk of resistance development. To achieve this, fumigation must be undertaken in a sealable, gas-tight silo.

New silos purchased should comply with Australian Standard AS 2628 to ensure they are sealable to a gas-tight standard. Once erected, silos purchased as gas-tight should be checked by performing a standard pressure test. When they are filled they should be checked again, prior to fumigation. An annual silo maintenance routine, when the silo is empty, should include pressure testing, as well as checking and replacing worn or damaged seals and carrying out any repairs.

Conduct a pressure test to ensure the silo is gas-tight before fumigating.

FEEDBACK

Minimum fumigation times following application of phosphine are:

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

Grain below 15°C should not be fumigated with phosphine as insects are very hard to kill at low temperatures.

It is important to note that fumigant takes longer to distribute in storages with more than a few hundred tonnes capacity, unless forced circulation is used.

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.

Fumigation success

Provided fumigation is carried out correctly, the fumigant will penetrate the grain and destroy all stages of insects in the treated grain at the time of fumigation: adults, eggs, larvae and pupae. This also includes insects that may have developed resistance to phosphine.

Effective fumigation with phosphine needs a concentration (chemical to air ratio) of:

- 300 parts per million (ppm) for 7 days at grain temperatures above 25°C; or
- 200 ppm for 10 days at grain temperatures 15–25°C.

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.

When to fumigate?

Storages should be cleaned prior to filling with new grain (refer to Section 13.4 Grain storage principles). However, if there is reason to believe there are stored grain insects in a silo, fumigation should be carried out as soon 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.

Using phosphine

Phosphine is a highly toxic substance (Schedule 7). To purchase and use phosphine a relevant chemical user registration must be held relevant to 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.

MORE INFORMATION

Refer to GRDC Fact Sheet: Fumigating with phosphine, other fumigants and controlled atmospheres
www.grdc.com.au/GRDC-Booklet-FumigatingWithPhosphine

FEEDBACK

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.

Warning signs must be clearly displayed when fumigation is in process (Figure 2). 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.

Figure 2: *Phosphine warning sign.*

This phosphine warning sign can be downloaded from www.storedgrain.com.au.

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 600 tonnes 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 same amount of phosphine must be applied regardless of the amount of grain in the silo.

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 2m^3).

Always read the product label to confirm recommended application rates.

Bag chains may be hung in the head space, or rolled out flat in the top of a gas-tight silo, so air can pass freely around them.

Tablets should be spread out evenly on trays and then hung in the head space or placed level on the grain surface.

MORE INFORMATION

For fumigation product information, hazardous substance database and protective equipment also see www.draeger.com.au

FEEDBACK

Table 4: Recommended rates of phosphine tablets (sealable, gas-tight silo only).

Cubic metres	Bushels	Tonnes	Number of tablets
18	500	14	28
37	1000	28	56
56	1500	42	84
74	2000	56	111
92	2500	70	138

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.

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 fumigant's effectiveness.

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. See www.draeger.com.au

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**.

FEEDBACK

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.

Other fumigants

There are other fumigants for the control of insect pests in grain storage.

Methyl bromide fumigation

The Australian Government phased out most uses of methyl bromide from 1 January 2005. Methyl bromide may only be used on pulses for an approved quarantine or pre-shipment use.

Methyl bromide fumigation is an essential requirement for pulse exporters to comply with shipments of grain to India. This can only be done by licensed personnel. A certificate of fumigation is required by the Australian Quarantine and Inspection Service (AQIS). AQIS inspectors complete a phyto-sanitary certificate stating that the grain shipment leaving Australia does not contain live insects.

Carbon dioxide fumigation

If a silo meets a standard pressure test for sealable, gas-tight storage, carbon dioxide can be added, under pressure, from a cylinder. This provides a rapid initial purge to quickly achieve high carbon dioxide levels.

For thorough protection, a carbon dioxide concentration of 34% or more must be maintained for 10 days.[8]

13.6 Sealing silos

The Australian Standard (AS 2628-2010) allows growers to refer to an industry benchmark when purchasing a sealable, gas-tight, 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 meeting Australian Standard AS 2628. 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 5 An unsealed silo.).

Figure 3 and Figure 4 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).

Techniques have been developed which allow farm silos to be sealed to gas-tightness for effective fumigation. Any retro-sealing work undertaken must meet the Australian standards 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.

MORE INFORMATION

For more information on sealing silos go to:

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

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

GRDC Fact Sheet: Pressure testing sealable silos http://storedgrain.com.au/pressure-testing/

VIDEO

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

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

FEEDBACK

When retro-sealing, any sealing or modifications to a silo must be done by a qualified and reputable contractor who guarantees their work meets Australian Standards AS 2628 – 2010.

Any sealing or modifications to a silo must be done by a qualified and reputable contractor who guarantees their work meets Australian Standards AS 2628 – 2010.

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.

Photo 5: *An unsealed silo.*

(Photo: DPIRD)

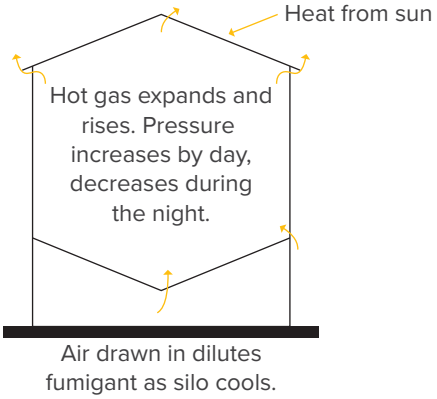


Figure 3: *Gas loss through heat effects.*

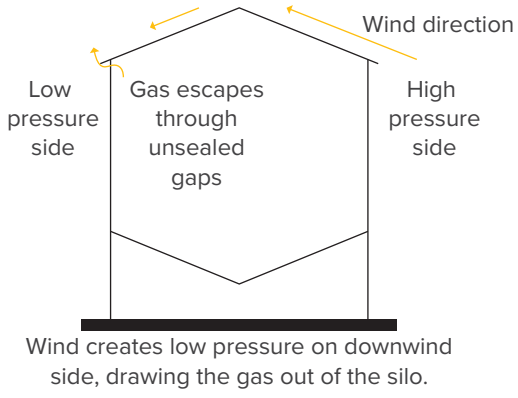


Figure 4: *Gas loss through wind effects.*

FEEDBACK

MORE INFORMATION

See the GRDC Grain storage factsheet "Pressure testing sealable silos"
http://storedgrain.com.au/pressure-testing/

Testing silos for seal

A pressure-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 6) with light hydraulic 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 5 and 6) by applying a 'five-minute half-life test'.

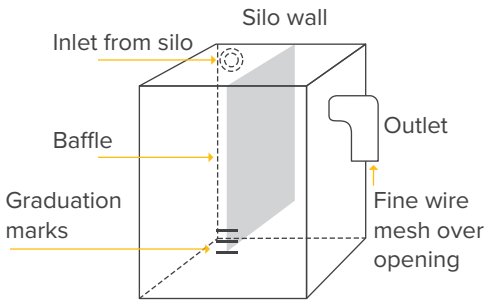
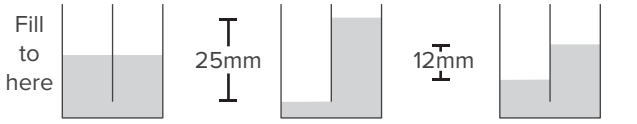


Figure 5: *Pressure-relief valve.*



Start
Fill up to central line with recommended oil

Silo inflated
Using a farm compressor, pump air through the tubeless tyre valve until the fluid moves down to the bottom line

Oil level should take at least 5 minutes to fall to the half-way mark

Figure 6: *Testing the silo with the pressure-relief valve.*

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 sealing compliance (AS2628).
- Pressure test sealed silos upon erection, annually, and before fumigating with a 'five-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.

FEEDBACK

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, 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 5). It is important to ensure the silo is free of grain dust as it is explosive.

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

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.

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.

13.7 Silo bags

Silo bags (also known as grain bags, sausage bags or harvest bags) are becoming increasingly popular. However, **silo bags for lentil storage should be considered as temporary only, due to the likelihood of quality issues arising**.

There are success stories with silo bags when used to temporarily store grain, including pulses. There have also been failures when appropriate precautions were not taken.

Pulses are risky grains to store in silo bags.[9] Pulse grain has been rejected by markets because of objectionable taints and odours derived from improper storage in a silo bag.

Silo bags are a sealed storage with no aeration. To maintain grain quality in storage it is essential to bag the grain at the correct moisture content and to ensure that the bag remains sealed throughout the entire storage period to prevent moisture access.

High moisture grain, condensation, water aggregation under the film, or leaks can cause localised mould and widespread spoilage in pulses.

Even with adequate seals, hermetic conditions to protect against insects and mould (low oxygen O_2, high carbon dioxide CO_2) are difficult to achieve consistently. This is due to either high grain temperatures or low grain moisture content at the time of storage.

9 W Hawthorne, A Meldrum, G Cumming (2010) Grain Bags for Pulse Storage – Use Care. Pulse Australia, http://www.pulseaus.com.au/storage/app/media/crops/2010_APB-Pulse-grain-bag-storage.pdf

FEEDBACK

MORE INFORMATION

Pulse Australia Bulletin: Grain Bags for Pulse Storage – Use Care.
http://www.pulseaus.com.au/storage/app/media/crops/2010_APB-Pulse-grain-bag-storage.pdf

GRDC factsheet: 'Successful storage in grain bags.'
https://grdc.com.au/resources-and-publications/all-publications/factsheets/2012/03/grain-storage-fact-sheet-successful-storage-in-grain-bags

VIDEO

GRDC Video: Grain bags: best practice
https://youtu.be/Ab-A2ll6b1Q

VIDEO

GRDC Video: Grain bags – a growers perspective
https://youtu.be/cLRgjjdEr0U

Photo 6: *Silo bags for lentil storage should be considered as temporary only.*

(Photo: W. Hawthorne, formerly Pulse Australia)

Lentil quality risks and silo bags

There are risks associated with storing lentil in silo bags:

- Lentil grain may not retain its quality, colour or odour, especially if the seal is breached.
- Contamination and moisture can enter bags from vermin and other pests that create holes in the bag.
- Excessive grain moisture can result in condensation within the bag causing localised areas of mould and objectionable odours.
- Pockets of mouldy grain can develop in silo bags, along with an offensive, distinctive 'mouldy' odour throughout. There is a nil tolerance of this in receival standards.
- Marketers have rejected pulse grain in the past due to objectionable moulds, taints and odours acquired through storage in silo bags.
- Removing taints and odours in affected grain is not necessarily possible, even with further aeration.
- Grain stored in silo bags can develop an overall offensive, distinctive 'plastic' odour that requires considerable periods of aeration to remove. There is nil tolerance of odours in receival standards.
- Achieving and keeping hermetic conditions under Australian conditions is rarely achieved. Hermetic conditions should not be relied upon as the only source of control of insects in storage.
- Grain moisture of stored lentil is critical, and difficult to control in silo bags.