SECTION 13

Storage

More information

Australian pulse standards 2015/2016

More information

See the GRDC Stored Grain GrowNote and fact sheets

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 chickpeas.

The Australian Pulse Standards stipulate standards for heat-damaged, bin-burnt, mouldy, caked or insect-infested chickpeas, and breaching of any of these can result in the discounting or rejection of product. [1] Effective management of stored chickpeas can eliminate all these risks to pulse quality.

Growers contemplating medium–long-term storage (6–12 months) need to be aware that chickpeas continue to age, and that quality deteriorates over time.

Desi chickpeas will darken considerably in storage, with the rate of seed coat darkening being accelerated by:

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

Condition of the seed at harvest

- Seed subject to field weathering prior to harvest will deteriorate a lot quicker in storage, even when stored under 'acceptable' conditions of temperature and relative humidity.
- Conditions of high relative humidity and high temperatures result in rapid deterioration in grain colour.
- To maintain yellow colour and minimise darkening of seed, any grain stored >12% MC will require cooling.
- Growers should avoid even short–medium storage of weather-damaged grain. [2]

1 Australian pulse standards 2015/2016. http://www.pulseaus.com.au/storage/app/media/markets/2015-16_pulse-standards.pdf

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

Figure 1: Meticulous hygiene and aeration cooling to manage storage temperature and moisture are crucial to prevent insect damage and moulds in stored chickpeas.

13.1 How to store chickpeas on-farm

Aeration of stored pulses in silos is the key non-chemical tool used to minimise the risk of insect infestations and spoiling through heat and/or moisture damage. For storage period longer than 2 months, silos with aeration cooling that can be sealed gas-tight when fumigation is required are essential (Table 1).

Well-designed and properly operated on-farm storage provides the best insurance that a grower can have to manage the quality of chickpeas to be out-turned. Storages must be used in conjunction with sound practices, which include monthly sieving for insects, regular grain quality inspections and ensuring that aeration cooling equipment is operating as required (Table 2).

Successful storage of pulses requires a balance between ideal harvest and storage conditions. Harvesting at 14% MC captures grain quality and reduces mechanical damage to the seed, but requires careful management in aerated silos to avoid deterioration during storage. [3]

[3] P Burrill, P Botta, C Newman, C Warrick (2014), GRDC Fact Sheet, July 2014. https://grdc.com.au/Resources/Factsheets/2014/07/Grain-Storage-Fact-Sheet-Storing-Pulses

Table 1: Maximum recommended storage period for pulses

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

Source: CSIRO Stored Grains Research Laboratory

Table 2: Storage life of chickpeas

Moisture content	Grain temperature (°C)			
	20	30	40	
12	66.6	16.6-21.6	3.6-4.3	Longevity of seed (months)
15	23-28	6-10	1-1.6	

More information

http://storedgrain.com.au/wp-content/uploads/2013/07/GRDC-GS-FACILITIES-Booklet-2013_Final.pdf

P Burrill, P Botta, C Newman, C Warrick (2014), GRDC Fact Sheet, July 2014

Because chickpeas are susceptible to splitting at the ideal storage MC of ≤12%, cone-based rather than flat-based silos are recommended for easy out-loading with minimal seed damage. Always fill and empty silos from the centre holes. This is especially important with pulses because most have a high bulk density. Loading or out-loading off-centre will put uneven weight on the structure and could cause it to collapse. [4]

Detailed information about selecting, locating and fitting-out silos is contained in the GRDC Grains Industry Guide: 'Grain storage facilities: Planning for efficiency and quality'.

Use of a belt conveyor instead of an auger is advisable when handling chickpeas. If movement via auger cannot be avoided, minimise the number of times that augers shift grain and adjust auger settings to ensure the chickpeas are handled as gently as possible. Follow these rules to minimise auger damage to chickpeas:

- Ensure augers are full of grain and operated at slow speeds.
- Check auger flight clearance—optimum clearance between flight and tube, in order to minimise lodging and damage, should be half the grain size.
- Operate augers as close as possible to their optimal efficiency, usually an angle of 30°.

At industry level, it is within growers' best interests to house grain in aerated, sealable storages to help curtail the rise of insect resistance to phosphine. This resistance has come about because of the prevalence of silos that are poorly sealed or unsealed during fumigation. [5]

The Kondinin Group 2009 National Agricultural survey revealed that 85% of respondents had used phosphine at least once during the previous 5 years, and of those users, 37% used phosphine every year for the past 5 years. A Grains Research and Development Corporation survey during 2010 revealed that only 36% of growers using phosphine applied it correctly, in a gas-tight, sealed silo (Figure 2).

Research shows that fumigating in a storage that does not meet the industry standard 'silo pressure test' does not achieve a high enough concentration of fumigant for a long enough period to kill pests at all life-cycle stages (Figure 3). For effective phosphine fumigation, a minimum of 300 parts per million (ppm) gas concentration for 7 days or 200 ppm for 10 days is required. Fumigation trials in silos with small leaks demonstrated

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

5 C Warrick (2012) Fumigating with phosphine, other fumigants and controlled atmospheres: Do it right—do it once. GRDC Grains Industry Guide, January 2011. Reprinted Aug. 2012, http://www.grdc.com.au/~/media/5EC5D830E7BF4976AD591D2C03797906.pdf

that phosphine levels are as low as 3 ppm close to the leaks. The rest of the silo also suffers from reduced gas levels. [6]

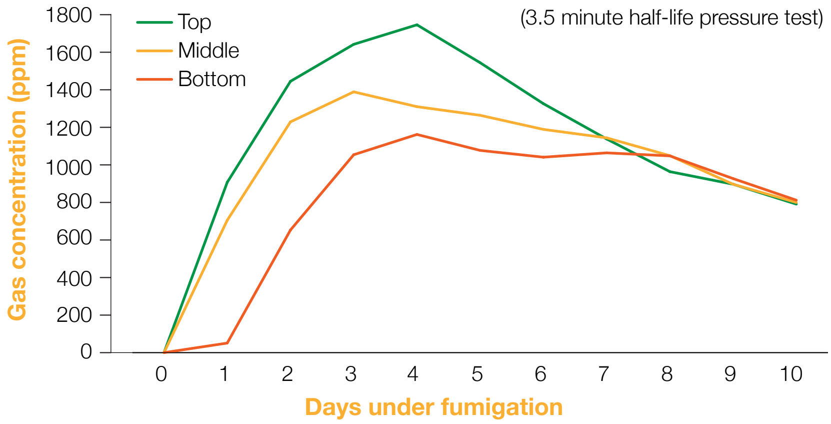

Figure 2: Gas concentration in gas-tight silo.

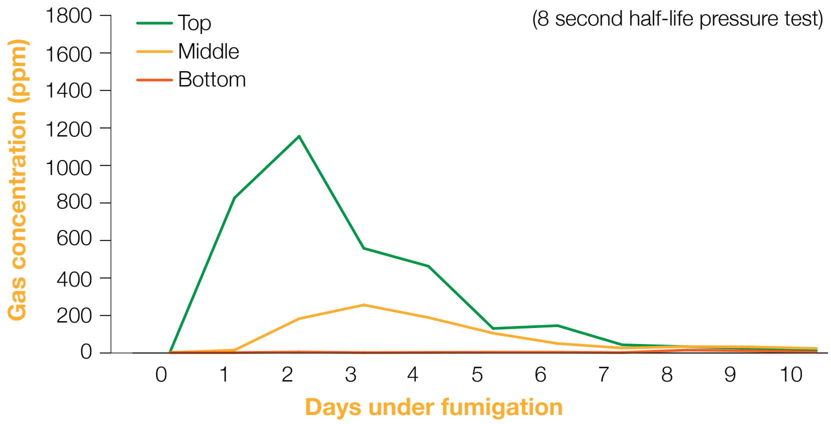

Figure 3: Gas concentration in a non-gas-tight silo.

More information

https://grdc.com.au/~/media/ReFocus-media-library/Document/GRDC-Document-Store/Publications-Media-and-Communications/Factsheets/Grain-Storage-FS-Pressure-testing-sealable-silos.pdf

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

There is no compulsory manufacturing standard for sealed silos in Australia. A voluntary industry standard was adopted in 2010. Watch this GRDC Ground Cover TV clip to find out more: http://www.youtube.com/watch?v=iS3tUbJZI6U.

To find out more about how to pressure-test silos, visit 'Fumigating with phosphine, other fumigants and controlled atmospheres' at http://www.grdc.com.au/~/media/FC440FBD7AE14140A08DAA3F2962E501.pdf.

Aeration controllers help to reduce the number of mistakes made by leaving the fan running at times of unsuitable ambient air (e.g. high relative humidity). They also reduce the time needed by operators to turn fans on and off. It remains vital that controllers and storages are checked regularly. Most controllers have hour meters fitted so run times can be checked to ensure they are within range of the expected total average of about 100 h per month.

Serious grain damage has occurred when fan performance has not met required airflow rate, as measured in litres per second per tonne (L/s.t). When cooling or drying grain

6 P Botta, P Burrill, C Newman (2010) Pressure testing sealable silos. GRDC Fact Sheet, September 2010, https://grdc.com.au/~/media/ReFocus-media-library/Document/GRDC-Document-Store/Publications-Media-and-Communications/Factsheets/Grain-Storage-FS-Pressure-testing-sealable-silos.pdf

with elevated moisture levels, inadequate airflow rate and/or poor system design can see sections of the storage develop very high grain temperatures. During aeration drying, moisture drying-fronts can be moving too slowly to prevent grain spoilage. Grain quality losses from moulds and heat damage can occur rapidly. This type of damage often makes the grain difficult to sell, and in some cases may cause physical damage to the silo itself. [7]

Researchers in Australia have developed a device that measures working airflow rates of fans fitted to grain storage. Called the A-flow, it has been validated under controlled conditions using an Australian Standard fan-performance test rig to be within 2.6% of the true fan output. The device was used on a typical grain storage that was in the process of aerating recently harvested grain. A fan advertised to provide 1000 L/s (equal to 6.7L/s.t on a full 150-t silo) was demonstrated to be only producing 1.8 L/s.t. Because of this test, the farmer recognised a need to make changes to the current aeration system design.

A number of changes may be required if airflow rates are not suitable for efficient aeration cooling or drying. A new fan that is better suited to the task could be installed; a second fan added; or the amount of grain in the silo reduced to increase flow rate per tonne of grain.

A GRDC factsheet explaining how to build and use an A-flow is available at: http://www.grdc.com.au/Resources/Factsheets/2012/08/Grain-Storage-Performance-testing-aeration-systems.

Chickpeas can be stored successfully in silo bags for up to 3 months, but this is a less desirable option than silo storage. Marketers have rejected pulse grain because of moulds, taints and odours from storage in grain bags. Such taints and odours are not acceptable in pulse markets. [8] Black discoloration of chickpeas due to moisture ingress into the base of grain bags has also occurred, causing serious losses in storage.

Insect pests in storage

Insects are not considered a major problem in stored chickpeas.

Exceptions appear to be in cases where chickpeas have higher levels of splits and damaged seed, or have been loaded into storages containing residues of cereal grain already infested with:

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

Where a prior infestation exists in storage facilities, it can spread and develop in the chickpeas. One example is where mungbeans are infested with bruchids (*Callosobruchus* spp.), which can also survive and breed at slower rates in chickpeas.

The key to control is to ensure that all handling equipment and storages are cleaned of old grain residues before they are used to handle chickpeas. Good hygiene, combined with aeration cooling, should prevent infestations developing.

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

7 P Burrill, A Ridley (2012) Performance testing aeration systems. GRDC Northern Update, Spring 2012, Issue 66, http://www.icanrural.com.au/newsletters/NL66.pdf

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

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

If insects are found in stored chickpeas, the only treatment options are controlled atmospheres (CO_2, N_2), or phosphine fumigation. When using phosphine, it is important that gas concentrations are held at high levels for the full fumigation exposure time. Immature stages of the insects and resistant strains that are being found more frequently will be controlled by phosphine only in a sealed, gas-tight storage. Phosphine is toxic to people as well as insects, so do not handle treated grain before the 7–10-day exposure period plus the required airing or venting period to remove the gas.

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

For structural treatments of silos, use an inert dust such as diatomaceous earth (DE) after a thorough cleaning of all old grain residues. [9] Pressure-hose washing out of a silo and then leaving it open to dry is also recommended, particularly if an insect infestation occurred in the previous stored grain.

13.2 Hygiene

Effective hygiene plus aeration cooling can overcome 75% of pest problems in on-farm storage. Clean out all grain and pulse residues when silos and grain-handling equipment are not in use to help minimise the establishment and build-up of pest populations. A bag of infested grain can produce more than one million insects during a year, and these can walk and fly to other grain storages where they will start new infestations. Meticulous grain hygiene involves removing any old grain that can harbour pests. These pests opt for dark, sheltered areas and breed best in warm conditions.

Successful on-farm storage hygiene involves cleaning all areas where grain and pulses become trapped. Pests can survive in a tiny amount of grain, which can go on to infest any parcel of fresh grain through the machine or storage. Clean out harvesters and handling equipment thoroughly with compressed air after use.

The process of cleaning on-farm storages and handling equipment should start with the physical removal, blowing and/or hosing out of all residues. Once the structure is clean and dry, consider the application of DE as a structural treatment.

Diatomaceous earth is an amorphous silica commercially known as Dryacide® and acts by absorbing the insect's cuticle or protective waxy exterior, causing death by desiccation. If applied correctly with complete coverage in a dry environment, DE can provide up to 12 months of protection for storages and equipment. To find out more about what to use, when and how to clean equipment and storages to minimise the chance of insect infestation, download the GRDC Grain Storage Fact Sheet: Hygiene and Structural Treatment for Grain Storages (June 2013): visit www.grdc.com.au/GRDC-FS-HygieneStructuralTreatments.

More information

www.grdc.com.au/GRDC-FS-HygieneStructuralTreatments

13.3 Fumigating chickpeas

Protectant insecticide sprays, as commonly used to protect cereal grains against insect infestations, cannot be used with pulses.

Phosphine is the only fumigant currently registered for use in pulses, and successful fumigation requires a storage that can be sealed gas-tight.

While phosphine has some resistance issues, it is widely accepted as having no residue issues for grain or pulses. The grain industry has adopted a voluntary strategy to manage the build-up of phosphine resistance in pests. Its core recommendations are to

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

limit the number of conventional phosphine fumigations on undisturbed grain to three per year, and to employ a break strategy. [10]

New research has identified the gene responsible for insect resistance to phosphine. Genetic analysis of insect samples collected from south-eastern Queensland between 2008 and 2012 has allowed researchers to confirm the increasing incidence of phosphine resistance in the region. Although few resistance markers were found in insects collected 5 years ago, an average of 5% of insects collected in 2011 carried the resistance gene. Further testing with DNA markers that can detect phosphine resistance is expected to identify problem insects before resistance becomes entrenched, and help to prolong phosphine's effective life. [11]

More information

http://www.grdc.com.au/~/media/FC440FBD7AE14140A08DAA3F2962E501.pdf

Achieve effective phosphine fumigation by placing the tablets at the rate directed on the label onto a tray and hanging the tray in the top of a pressure-tested, sealed silo or into a ground-level application system if the silo is fitted with recirculation. After fumigation, open top lids and ventilate grain for a minimum of 1 day with aeration fans running, or 5 days if no fans are fitted. A minimum withholding period of 2 days is required after ventilation before grain can be used for human consumption or stock feed. The total time required for fumigating ranges from 10 to 17 days. Read label directions.

To find out more, visit 'Fumigating with phosphine, other fumigants and controlled atmospheres: Do it right—do it once. A Grains Industry Guide'.

Non-chemical treatment options include:

- **Carbon dioxide:** Treatment with CO_2 involves displacing the oxygen inside a gas-tight silo with CO_2, which creates a toxic atmosphere to grain pests. To achieve a complete kill of all the main grain pests at all life stages, CO_2 must be retained at a minimum concentration of 35% for 15 days.
- **Nitrogen:** Grain stored under N_2 provides insect control and quality preservation without chemicals. It is safe to use and environmentally acceptable, and the main operating cost is the capital cost of equipment and electricity. It also produces no residues, so grains can be traded at any time, unlike chemical fumigants that have withholding periods. Insect control with N_2 involves a process using pressure swinging adsorption (PSA) technology, modifying the atmosphere within the grain storage to remove everything except N_2, starving the pests of oxygen. [12]

Silo bags can also be fumigated. Research conducted by Andrew Ridley and Philip Burrill from Department of Agriculture Fisheries and Forestry, Queensland, with Queensland farmer Chris Cook has found that high concentrations of phosphine can be maintained for the required length of time to fumigate grain successfully in a silo bag. Fumigation trials on a standard 75-m-long bag containing about 230 t of grain were successful in controlling all life stages of the lesser grain borer.

When using phosphine in silo bags, remember that it is illegal to mix phosphine tablets with grain because of residue issues. Separate them by using perforated conduit to contain tablets and spent dust. The 1-m tubes can be speared horizontally into the silo bag and removed at the end of the fumigation. Trial results suggest that the spears should be no more than 7 m apart and fumigation should occur over 12–14 days. In previous trials when spears were spaced 12 m apart, the phosphine diffused through the grain too slowly (Figure 4). [13]

10 P Collins (2009) Strategy to manage resistance to phosphine in the Australian grain industry, Cooperative Research Centre for National Plant Biosecurity, http://www.graintrade.org.au/sites/default/files/file/Phosphine_Strategy.pdf

11 D Schlipalius (2013) Genetic clue to thwart phosphine resistance. GRDC Ground Cover Issue 102, Jan.–Feb. 2013, http://www.grdc.com.au/Media-Centre/Ground-Cover/Ground-Cover-Issue-102/Genetic-clue-to-thwart-phosphine-resistance

12 C Warrick (2012) Fumigating with phosphine, other fumigants and controlled atmospheres: Do It right—do it once. A Grains Industry Guide. January 2011. Reprinted June 2012, http://www.grdc.com.au/~/media/5EC5D830E7BF4976AD591D2C03797906.pdf.

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

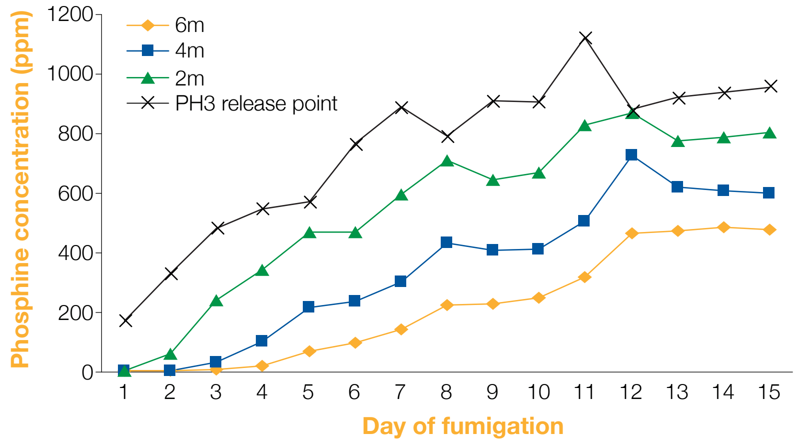

Figure 4: Spread of phosphine gas in a silo bag from a release point to gas-monitoring lines at 2, 4 and 6 m along a silo bag.

13.4 Aeration during storage

Pulses stored above 12% moisture content require aeration cooling to maintain quality. Australian Pulse Standards are set at a maximum moisture limit of 14% for most pulses, but bulk handlers may have receival requirements as low as 12%. As a general rule of thumb, the higher the moisture content, the lower the temperature required to maintain seed quality.

Aeration of chickpeas as soon as they go into the silo will provide uniform moisture conditions in the grain bulk and lower grain temperatures, which will minimise the effects of seed darkening, declining germination and seed vigour. Aeration cooling allows for longer term storage of low-moisture grain by creating desirable conditions for pulses and undesirable conditions for mould and pests (Table 3 and Figure 5). Unlike aeration drying, aeration cooling can be achieved with airflow rates as little as 2–3 L.s.t for pulses. High-moisture pulses can also be safely held for a short time with aeration cooling before blending or drying. Fans should be run continuously to prevent self-heating and quality damage. Inspect grain often when holding any high-moisture grain.

Pulses stored for longer than 6 weeks with a high moisture content of >14% will require drying or blending to maintain seed quality. Aeration drying has a lower risk of cracking and damaging pulses, which can occur with hot-air dryers. Unlike aeration cooling, aeration drying requires high airflow rates of at least 15–25 L/s.t and careful management. For more information on aeration drying, refer to the GRDC booklet 'Aerating stored grain, cooling or drying for quality control': http://www.grdc.com.au/GRDC-Booklet-AeratingStoredGrain.

Table 3: The effect of grain temperature on insects and mould (Kondinin Group table).

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 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

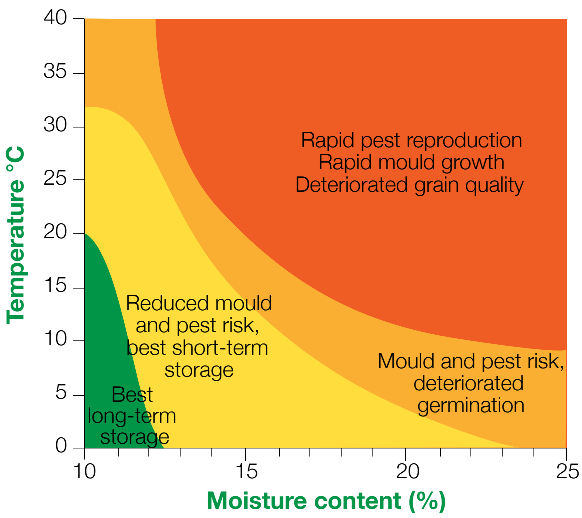

Figure 5: Effects of temperature and moisture on stored grain.

Source: CSIRO Ecosystems sciences as published in http://www.grdc.com.au/~/media/36D51B725EF44EC892BCD3C0A9F4602C.pdf

13.5 Monitoring chickpeas in storage

Like cereal grains, chickpeas need to be delivered with nil live storage insects. [14] Growers are advised to monitor all grain storages every 2 weeks during warmer periods of the year and at least monthly during cool periods of the year. It is essential that insect pests present in the on-farm storage environment are identified so that growers can exploit the best use of both chemical and non-chemical control measures to control them.

Through sieving and quality inspections, monitor your stored pulses and keep records of what you find. Use one of the GRDC stored pest identification publications. Also, record any fumigations. If safe, visually check, smell and sample grain at the bottom and top of the stack regularly. [15] Having sample ports fitted in the side of the silos also enables temperature probe checks and grain sampling.

Photographs and descriptions of pests can be found in the GRDC's 'Stored grain pest identification: Back pocket guide'. Download it from: http://www.grdc.com.au/~/media/8253D697BA6F4BF3AA5B5CBDFA7F4D2D.pdf.

This fact sheet outlines how to monitor your stored grain for infestations. Here are some basic points to follow when monitoring for insect pests in your pulses:

- Sample and sieve grain from the top and bottom of grain stores for early pest detection. Probe or pitfall traps placed into the top of the grain will often detect storage pest insects before you may see them in your sieve, as the traps remain in the grain all the time.
- Holding an insect sieve in the sunlight will encourage insect movement, making pests easier to see. Sieve samples on to a white tray, again to make small insects easier to see. Sieves should be of 2-mm mesh and need to hold at least 0.5 L of grain.
- One way to help identify live grain pests is to place them into a glass container and hold them in sunlight to warm the grain and insects. This will encourage activity without overheating or killing them. The rice weevil, cowpea bruchid and saw-toothed grain beetles can walk up the walls of the glass easily, but flour beetles and

14 Australian pulse standards 2015/2016. http://www.pulseaus.com.au/storage/app/media/markets/2015-16_pulse-standards.pdf

15 P Burrill, P Botta, C Newman (2010) Aeration cooling for pest control, GRDC Grain Storage Fact Sheet, September 2010, http://www.grdc.com.au/~/media/AB8938CFDCCC4811AD218B45C308BEBD.pdf

More information

http://www.grdc.com.au/~/media/3BFEE576F15F4AB8A6681659BE0A1627.pdf

lesser grain borer cannot. Look closely at the insects walking up the glass. Rice weevils have a curved snout at the front, saw-toothed grain beetles do not, and the cowpea bruchid has a globular, tear-shaped body. [16]

New research in southern and central Queensland has shown that industry may need to consider an area-wide approach to pest and resistance management. The research has indicated flight dispersal by the lesser grain borer and the rust-red flour beetle, both of which are major insect pests of stored grain. The research involved setting beetle traps along a 30-km transect in the Emerald district, which showed that the lesser grain borer is flying all year round in central Queensland, whereas the flour beetle appeared to be located mainly around storages during winter and then spread out into the surrounding district in summer. This study highlights the importance of finding and dealing with infestations to limit the number of pests that can infest clean grain. [17]

13.6 Structural treatments for chickpea storages

13.6.1 Applying inert dust

Inert dust requires a moving air-stream to direct it onto the surface being treated; alternatively, it can be mixed into a slurry with water and sprayed onto surface. See label directions. Throwing dust into silos by hand will not achieve an even coverage, so will not be effective.

For very small grain silos and bins, a hand-operated duster, such as a bellows duster, is suitable. Larger silos and storages require a powered duster operated by compressed air or a fan. If compressed air is available, it is the most economical and suitable option for on-farm use, connected to a venturi duster such as the Blovac BV-22 gun (Figure 6).

Figure 6: A blow/vac or air venture gun is the best applicator for inert dusts. (Photo: C. Warrick, Kondinin Group)

The application rate is calculated at 2 g/m^2 surface area treated. Although inert, breathing in excessive amounts of dust is not ideal, so use a disposable dust mask and goggles during application (Table 4).

13.6.2 Silo application

Apply inert dust in silos, starting at the top (if safe), by coating the inside of the roof then working your way down the silo walls, finishing by pointing the stream at the bottom of the silo.

[16] P Burrill, P Botta, C Newman, B White, C Warrick (2013) Northern and southern regions stored grain pests—identification. GRDC Grain Storage Fact Sheet June 2013, http://storedgrain.com.au/northern-southern-regions-stored-grain-pests-identification/

[17] G Daglish, A Ridley (2012) Stored grain insects: how they spread and implications for resistance, GRDC Northern Update, Spring 2012, Issue 66, http://www.icanrural.com.au/newsletters/NL66.pdf

If silos are fitted with aeration systems, distribute the inert dust into the ducting without getting it into the motor, where it could cause damage. [18]

Table 4: Inert dust (diatomaceous earth) application guide

Storage capacity (t)	Dust quantity (kg)
20	0.12
56	0.25
112	0.42
224	0.60
450	1.00
900	1.70
1800	2.60

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