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GRAINS RESEARCH & DEVELOPMENT CORPORATION

DURUM

SECTION 9

HARVEST

OVERVIEW | MANAGING A WET HARVEST | GRAIN STORAGE

Harvest

9.1 Overview

Figure 1: *Durum wheat is a premium product and it is recommended the crop is harvested as soon as the grain reaches 'dead ripe' maturity stage.*

(SOURCE: GRDC)

Durum wheat is a premium product, trading into a high quality food market, and attention to detail at harvest is critical.

It is recommended the crop is harvested as soon as the grain reaches 'dead ripe' maturity stage.

Buyers of durum wheat typically consider grain appearance important and pay premiums for large, well-filled, hard, vitreous grain with a low percentage of mottled and bleached seeds.

Optimising grain quality requires close attention to harvester machine settings, careful segregation and clean, insect-free grain storage. Damaged, contaminated or insect-infested grain will typically be downgraded.[1]

Some durum wheat varieties are marginally more difficult to thresh than others and concave adjustments to the harvester may be necessary.

Durum wheat varieties are not prone to shedding, which can be a significant issue for bread wheats when wind and rain prevail at harvest, but their very hard grain has more tendency to fracture than the grain of bread wheats.[2]

MORE INFORMATION

Grain Trade Australia Wheat Trading Standards, 2016/17 season: http://www.graintrade.org.au/sites/default/files/Section_02-Wheat_Trading_Standards_2016-2017.pdf

GRDC 'Stored Grain' hub: www.storedgrain.com.au

GRDC Fact Sheet 'Grain Marketing and Pesticide Residues': www.grdc.com.au/GRDC-FS-ManagingMRLs

1 Hare, R (2006) Agronomy of the Durum Wheats Kamilaroi, Yallaroi, Wollaroi and EGA Bellaroi, Primefacts 140, NSW Department of Primary Industries, http://www.dpi.nsw.gov.au/__data/assets/pdf_file/0007/63646/Agronomy-of-the-durum-wheats---Primefact-140-final.pdf

2 Hare, R (2006) Agronomy of the Durum Wheats Kamilaroi, Yallaroi, Wollaroi and EGA Bellaroi, Primefacts 140, NSW Department of Primary Industries, http://www.dpi.nsw.gov.au/__data/assets/pdf_file/0007/63646/Agronomy-of-the-durum-wheats---Primefact-140-final.pdf

MORE INFORMATION

DPIRD 'Wheat Grain Quality — Falling Number and Sprouting Tolerance': https://agric.wa.gov.au/n/3124

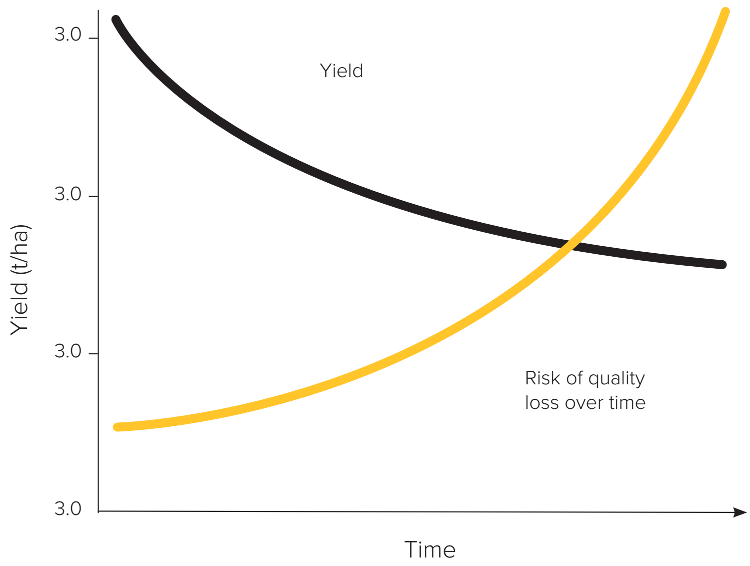
9.2 Managing a wet harvest

To optimise grain quality, harvest of durum wheat ideally needs to start as soon as the crop is mature.

Harvest can (in theory) start as soon as grain moisture content falls below about 20 percent, although receival standards dictate a grain moisture content of 12.5 percent on delivery.

For each day a mature wheat crop remains in the paddock, it is exposed to ongoing yield and quality loss. This, in turn, impacts on returns, as illustrated in Figure 2.

Figure 2: *Impact of a delayed harvest on wheat yield and quality.*[3]



Rain during the harvest period impacts on grain quality through the development of mould and fungi, darkening of the grain and/or stimulation of germination (sprouting).

Sprouting uses the grain's energy stores and reduces bulk density, weight and ultimately yield. Yield losses of 10-50 percent have been recorded in years with exceptional sprouting events.[4]

Although durum wheat varieties have slightly better resistance to pre-harvest sprouting than current bread wheat lines, they can be downgraded to feed due to bleaching and softening of the grain in prolonged wet harvest conditions.

Weather-affected grain that is soft reduces the semolina extraction in the mill and results in low pasta dough strength due to the partial enzymatic breakdown of starches and proteins.

It is not advisable to leave durum wheat crop harvest until last in the program, relying on the crop's weathering resistance. This resistance is only relative to other varieties and can eventually fail. Weathered durum wheat grain is not as valuable as premium durum wheat grain and may be received as feed grain.

Weather-damaged grain can be retained and dried for planting the following year, provided there is no sign of embryo development (in the form of shoots and/or roots).

There are several methods to deal with high moisture grain at harvest, as outlined below, and the key is to act quickly and effectively.

3 DPIRD 'Wheat Grain Quality — Falling Number and Sprouting Tolerance': https://agric.wa.gov.au/n/3124

4 Metz, N (2006) The WA Guide to High Moisture Harvest Management, Grain Storage and Handling, CBH Group and The South East Premium Wheat Growers Association, http://catalogue.nla.gov.au/Record/4227397

Blending

- High-moisture grain is mixed with lower-moisture grain
- This creates a sample with acceptable moisture content
- Cost-effectively manages grain batches slightly above 12.5 percent moisture.

Aeration cooling

- For grain with moderate moisture content (up to 15 percent)
- Allows holding for a short time until drying equipment is available.

Aeration drying

- Big volumes of air force a drying front through the stored grain
- This slowly removes moisture
- Supplementary heating can be added
- Can be combined with blending and aeration cooling
- Can handle grain up to 18 percent moisture content
- Requires significant capital investment.

Continuous flow drying

- Grain is transferred through a dryer
- Uses a high volume of heated air to pass through the grain.

Batch drying

- Typically uses a transportable trailer
- Can dry 10-20 tonnes of grain at a time
- Uses a high volume of heated air
- Air passes through the grain and out of perforated walls.

Capital invested in managing high-moisture grain (such as for a grain dryer) is best considered on a per hectare basis in the context of the whole harvest program.

Analysis of costs per tonne in isolation can be misleading.

9.2.1 Harvesting high moisture grain

Harvesting crops with high moisture content requires careful machinery set-up and operation. High-moisture crops are heavier and more pliable in cool, damp conditions and typically do not break up as easily during threshing.

High-moisture crops tend to require slightly harder threshing and the grain sieves of harvesting machines can experience heavier loads. This can slow harvesting capacity and increase fuel consumption.

Green or damp straw puts an additional load on harvester knives and dry matter can build up under the knife fingers. Slowing the ground speed or lowering the cutter height can help. This allows the crop to receive more threshing attention and the grain cleaning sieves are not placed under as much load.

Stripper fronts (purpose-built header fronts which strip the crop head from the stalk rather than cutting it) can prove more effective in consistently damp conditions in some areas.

9.2.2 Pre-sprouting

Figure 3: *Durum wheat can be susceptible to sprouting damage if harvest conditions are conducive.*

(SOURCE: GRDC)

The susceptibility of durum wheat varieties to sprouting damage is due to a combination of several traits. Grain dormancy — the ability to resist germinating when water is absorbed — is the most important of these.[5]

Other traits impacting on sprouting damage include:

» Seed coat dormancy

» Dormancy inhibitors released from the glumes when wet

» Rate of water absorption

» Attributes that relate to the structure of the wheat head.

Historically, the term 'sprouting tolerance' has been associated with germination index (GI) because this has been regarded as the most important and easily measured trait. Unfortunately, experience shows that GI does not always provide an accurate indication of what will happen in the field after a rainfall event.

9.2.3 Falling number index

The response of durum wheat varieties to wet harvest conditions is measured by falling numbers (FN) at grain delivery. The falling number test provides an indication of the amount of sprouting damage that has occurred in a wheat sample.

Wheat varieties are rated for ability to maintain FN after rainfall events leading up to harvest.

The falling number index (FNI) encompasses GI and other attributes, such as head structure.[6]

On a scale of one to nine, the higher the FNI, the more likely a variety is to maintain FN (and the lower the susceptibility to sprouting leading up to harvest).

The highest FNI of currently available for WA wheat varieties (as at 2016) is seven.[7]

MORE INFORMATION

DPIRD 'Wheat Grain Quality: Falling Number and Sprouting Tolerance'
https://agric.wa.gov.au/n/3124

5 Hare, R (2006) Agronomy of the Durum Wheats Kamilaroi, Yallaroi, Wollaroi and EGA Bellaroi, Primefacts 140, NSW Department of Primary Industries, http://www.dpi.nsw.gov.au/__data/assets/pdf_file/0007/63646/Agronomy-of-the-durum-wheats---Primefact-140-final.pdf

6 Grain Trade Australia (2016-17), Guide to the GTA Grain Trading Standards, GTA, http://www.graintrade.org.au/commodity_standards

7 DPIRD, Wheat grain quality — falling number and sprouting tolerance, 2017, https://www.agric.wa.gov.au/wheat/wheat-grain-quality-falling-number-and-sprouting-tolerance?page=0%2C1

9.2.4 Protein content

Protein content is an important factor in grain classification of durum wheat at receival and can be affected by weather at harvest.

Classifications and premiums are:

» Australian durum 1 (ADR1) attracts a premium similar to Australian Prime Hard (APH), or better

» Australian durum 2 (ADR2) attracts a premium similar to Australian Hard (AH), or better.[8]

Grain from durum wheat varieties with adequate protein is very hard, vitreous and free from mottling. A shortage of protein will give a mottled, softer grain.

For milling, a small percentage of mottled grains can be tolerated in top grades. But a higher proportion will result in downgrading to a 'flour' or 'fines' formation, which has a lower economic value than that of semolina.

9.2.5 Black point

Black point is a dark discoloration at the germ end of otherwise healthy grain.

Research suggests it is not a disease caused by fungi, but a physiological character resulting from the formation of dark compounds in the outer layers of the grain. Some varieties are more prone to develop these dark compounds in warm and moist conditions.

In wheat, the discoloration occurs in the outer portions of the seed and — in some severe cases — may extend along the groove on the underside of the grain.

While durum wheat varieties vary in their tolerance to black point, they are more resistant to black point than bread wheat. But this may not offer sufficient protection in prolonged wet seasons.

It is advised to ensure all grain handling equipment, such as headers, bins, augers and silos, are free from contaminant grain.

The presence of foreign seeds (such as a maximum 3 percent bread wheat seed) can downgrade durum wheat grain.

A small percentage of discoloured seeds can be present after a wet pre-harvest period, when black point is most active. This level of incidence is typically below the minimum dockage limits in most seasons.

Black point tolerance is 3 percent for ADR1 and 3-5 percent for ADR2 and ADR3.[9] Because small fragments of bran are included in semolina, discoloured grain can leave small black specks that can be seen in the pasta.[10]

However, if retained for seed, grain with black point will typically germinate satisfactorily the following year.

9.2.6 Retaining seed

Durum wheat seed is, on average, about 20 percent bigger than bread wheat seed. The sowing rate for durum wheat varieties should be adjusted based on 1000 grain weight data to sow 100 seeds per square metre (in low rainfall zones) or 120-150 seeds/m^2 (in medium-high rainfall zones).[11]

A higher planting rate may be beneficial in some situations, such as when using seed with a low germination or when early or late sowing.

MORE INFORMATION

GRDC Fact Sheet 'Retaining Seed': www.grdc.com.au/GRDC-FS-RetainingSeed

8 Hare, R (2006) Agronomy of the Durum Wheats Kamilaroi, Yallaroi, Wollaroi and EGA Bellaroi, Primefacts 140, NSW Department of Primary Industries, http://www.dpi.nsw.gov.au/__data/assets/pdf_file/0007/63646/Agronomy-of-the-durum-wheats---Primefact-140-final.pdf

9 Hare, R (2006) Agronomy of the Durum Wheats Kamilaroi, Yallaroi, Wollaroi and EGA Bellaroi, Primefacts 140, NSW Department of Primary Industries, http://www.dpi.nsw.gov.au/__data/assets/pdf_file/0007/63646/Agronomy-of-the-durum-wheats---Primefact-140-final.pdf

10 Hare, R (2006) Agronomy of the Durum Wheats Kamilaroi, Yallaroi, Wollaroi and EGA Bellaroi, Primefacts 140, NSW Department of Primary Industries, http://www.dpi.nsw.gov.au/__data/assets/pdf_file/0007/63646/Agronomy-of-the-durum-wheats---Primefact-140-final.pdf

11 Hare, R (2006) Agronomy of the Durum Wheats Kamilaroi, Yallaroi, Wollaroi and EGA Bellaroi, Primefacts 140, NSW Department of Primary Industries, http://www.dpi.nsw.gov.au/__data/assets/pdf_file/0007/63646/Agronomy-of-the-durum-wheats---Primefact-140-final.pdf

Conventional sowing equipment can be used for durum wheats, but the bigger seed size may necessitate machinery adjustments.

To optimise seed germination and vigour, it is advised to use seed that is:

- True to type (varietal purity)
- Free of diseased seed and weed seeds
- Not cracked or containing small grains
- Not contaminated with barley and bread wheat grain
- High quality, preferably from certified seed stocks
- Has a germination percentage more than 80 percent.

When harvesting durum wheat paddocks for retained seed to use the following season, it is best to avoid paddocks with rogue off-types, contaminant crops or high weed burdens.

Seed grain for sowing in subsequent seasons is ideally stored in clean silos that can be aerated, are sealed for insect control and keep grain as dry and as cool as possible.

Such storage conditions will assist in the maintenance of high-viability seed for the following season.

It is advised to treat seed with an appropriately registered product just prior to sowing to control smut and bunt. Seed treatments can also offer protection to establishing seedlings from damping-off diseases.

It is worth noting that some chemical constituents have potential to reduce seed viability and seedling vigour if in contact with the seed for any length of time.

If durum wheat crops are weather damaged, some grain may still be viable as seed for the subsequent cropping season — provided any damaged seed dries out before the embryo starts to grow.[12]

Mild damage often appears as a loose and wrinkled seed coat. Severe damage can be identified through stained seed or signs of germination.

It is essential to determine whether the damage is cosmetic, or the symptom of a seed-borne disease, and whether it will impact on germination.

It is advisable to test and grade any retained seed for germination, vigour and disease pathogens.

Knowing the germination percentage of grain at harvest will help determine how much extra seed may be required at sowing. A germination test before sowing can enable sowing rates to be adjusted accordingly.

Achieving and maintaining low temperature, humidity and grain moisture levels for stored grain is important.

Damaged grain and grain retained for seed is best used within 12 months.[13]

12 GRDC (2011) Fact Sheet — Retaining Seed, GRDC, www.grdc.com.au/GRDC-FS-RetainingSeed

13 GRDC (2011) Fact Sheet — Retaining Seed, GRDC, www.grdc.com.au/GRDC-FS-RetainingSeed

FEEDBACK

MORE INFORMATION

GRDC 'Stored Grain' hub: http://storedgrain.com.au/

GRDC 'Grain Storage Workshops': http://storedgrain.com.au/events/category/western-region/

GRDC Back Pocket Guide 'Stored Grain Pests Identification': http://storedgrain.com.au/stored-grain-pests-identification-the-back-pocket-guide-2011/

9.3 Grain storage

Figure 4: *An on-farm storage system designed to promote good grain hygiene, including aeration and sealable silos for fumigation, is a valuable tool to maximise returns from durum wheat.*

(SOURCE: GRDC)

An on-farm storage system designed to promote good grain hygiene, including aeration and sealable silos for fumigation, is valuable to maximise returns from growing durum wheat.

Increasingly, WA growers are storing grain for up to 12 months to expand their marketing options. To do this effectively, the storage system needs to be set up to allow effective control of stored grain insect pests and maintain grain quality. Gas-tight, sealed and aerated storage is the best way to achieve this. Fumigating the grain (if necessary) kills any insects present and the aeration maintains grain quality. In a gas-tight sealed silo, grain can be fumigated effectively providing quick, inexpensive and long-lasting insect control.[14]

Actives that can be used in grain storage systems for pest control include (but are not restricted to):

- Chloropicrin
- Chlorpyrifos
- Deltamethrin
- Dichlorvos
- Ethyl formate
- Fenitrothion
- Maldison
- Methoprene
- Methyl bromide
- Phosphine
- Pirimiphos-methyl
- Spinosad
- Sulfuryl fluoride
- Triflumuron.

14 GRDC (2014) Fact Sheet — Grain Storage: Grain Fumigation Guide, GRDC, www.grdc.com.au/GRDC-FS-GrainFumigationGuide

Other registered treatments for grain storage include inert dusts, such as Amorphous silica and Diatomaceous earth (DE).

Although not fumigants, there are several seed treatments registered for control of grain storage pests, including:

- Imidacloprid (+fungicide active)
- Cypermethrin (+fungicide active)
- Triflumuron (+fungicide active).

Similarly to any piece of farm equipment, gas-tight sealed silos need to be well maintained to work efficiently.

It is recommended to check seals before each filling and replace these if worn or damaged. Always pressure test the silo to ensure it is sealed.

In conjunction with sound management practices, including checking grain temperatures and regular monitoring for insect infestations, an on-farm storage system that is well designed and maintained and correctly operated provides the best insurance for production of quality grain.

9.3.1 Types of on-farm storage

It is advised to conduct a cost:benefit analysis before investing in on-farm grain storage infrastructure.

Post-harvest can be a good time to plan future requirements, as grain storage issues and opportunities can be most easily identified at this stage of the season.[15]

The advantages and disadvantages of the main types of on-farm grain storage options are outlined in Table 1.

15 White, B (2012) Grain Storage Facilities — Planning for Efficiency and Quality, GRDC, www.grdc.com.au/GRDC-Booklet-GrainStorageFacilities

Table 1: Advantages and disadvantages of grain storage options.[16]

Storage type	Advantages	Disadvantages	More information
Gas-tight sealable silo	Gas-tight sealable status allows phosphine and controlled atmosphere options to control insects. Easily aerated with fans. Fabricated on-site or off-site and transported. Capacity from 15 tonnes up to 3000 tonnes. Up to 25 year plus service life. Simple in-loading and out-loading. Easily administered hygiene (cone base particularly). Can be used multiple times inseason.	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.	http://storedgrain.com.au/managing-sealed-unsealed-storage/ http://storedgrain.com.au/stored-grain-silos-fumigation/ http://storedgrain.com.au/pressure-testing/ http://storedgrain.com.au/silo-pressure-test-demonstration/ http://storedgrain.com.au/national-standard-sealed-silos/
Non-sealed silo	Easily aerated with fans. 7–10% cheaper than sealed silos. Capacity from 15 tonnes up to 3000 tonnes. Up to 25 year plus service life. Can be used multiple times inseason.	Requires foundation to be constructed. Silo cannot be used for fumigation. Insect control options limited . Access requires safety equipment and infrastructure.	http://storedgrain.com.au/managing-sealed-unsealed-storage/
Grain storage bags	Low initial cost. Can be laid on a prepared pad in the paddock. Provide harvest logistics support. Can provide segregation options. Are all ground operated. Can accommodate high-yielding seasons.	Requires loader and unloader. Increased risk of damage beyond short-term storage (typically three months). Limited insect control options, fumigation only possible under specific protocols. Requires regular inspection and maintenance which needs to be budgeted for. Aeration of grain in bags currently limited to research trials only. Must be fenced off from livestock. Prone to attack by mice, birds, foxes etc. Limited wet weather access if stored in paddock. Single use only — need to dispose of bag after use.	http://storedgrain.com.au/successful-storage-in-grain-bags/ http://storedgrain.com.au/wp-content/uploads/2013/06/Insects-apest-in-harvest-bags.pdf
Grain storage sheds	Multi-purpose infrastructure. 30 year plus service life. Low cost per stored tonne. Aeration systems require specific design.	Risk of contamination from alternative purpose use. Difficult to seal for fumigation. Vermin control is difficult. Limited insect control options. Difficult to unload	http://storedgrain.com.au/managing-sealed-unsealed-storage/
Underground storage	Inexpensive and simple. Provides ideal insect control by excluding air. Can maintain grain quality during long-term storage.	Poor site selection and management can affect grain quality.	https://www.agric.wa.gov.au/barley/underground-storage-grain

16 White, B (2012) Grain Storage Facilities — Planning for Efficiency and Quality, GRDC, www.grdc.com.au/GRDC-Booklet-GrainStorageFacilities

Silos are the most common method of storing grain on-farm in Australia. These come in a variety of configurations, including flat-bottom or cone base, and are available as gas-tight sealable or non-sealed and aerated or non-aerated.

Other options include grain storage bags, bunkers and sheds.

Grain storage bags are increasing in popularity as a short-term storage solution to assist with harvest logistics. With careful management, growers can also use storage bags to provide short-term marketing opportunities.

Where options are limited, well-prepared sheds can be used to store grain during harvest, offering a similar storage time to grain storage bags.

9.3.2 Economics of grain storage

When making decisions about storage infrastructure, it is important to compare the expected returns from grain storage versus expected returns from other farm business investments, such as more land, a chaser bin, a wider boomspray, a second truck or paying-off debt.

Calculating the costs and benefits of on-farm storage will deliver a return-on-investment (ROI) value that can be compared with other investment choices.

To make a viable decision, it is necessary to realistically determine costs and benefits on a dollars per tonne ($/t) basis. For example, grain market projections are fraught with difficulty and are best kept conservative.

A more realistic approach is to use averages based on medium to long-term trends. Many growers who invest in on-farm grain storage have paid for the infrastructure in one or two years because they can sell into the market at its peak.

MORE INFORMATION

GRDC Stored Grain 'Economics of On-Farm Grain Storage, Cost Benefit Analysis': http://storedgrain.com.au/economics-booklet/

9.3.3 Grain storage pests

Grain for human consumption (especially export grain) must not contain live insects. If stored grain is not properly managed, it can become infested with stored grain insect pests.

Grain Trade Australia (GTA) has nil tolerance to live, stored grain insects for all grades of wheat — from premium milling grades to feed. GTA also stipulates standards for heat-damaged, bin-burnt, storage mould-affected or rotten wheat, all of which can result in the discounting or rejection of grain.[17]

Effective management of stored grain can help to eliminate these risks to wheat quality.

Hygiene, aeration and cooling are the three critical management tools for successful insect control in on-farm grain storage. Regular inspection of storage facilities will provide an early warning of any insect infestation.[18]

Protecting any stored grain from insect attack makes economic sense because even feed grain can lose value though loss of protein or palatability which can affect livestock growth rates.

Retained seed is next year's investment and if insects are present they can destroy the germ of the grain.

The most common insect pests of stored cereal grains in Australia include:

» Weevils (*Sitophilus spp.*) — Rice weevil is most common in wheat
» Lesser grain borer (*Rhyzopertha dominica*)
» Rust-red flour beetle (*Tribolium spp.*)
» Saw-toothed grain beetle (*Oryzaephilus spp.*)
» Flat grain beetle (*Cryptolestes spp.*)
» Indian meal moth (*Plodia interpunctella*)
» Angoumois grain moth (*Sitotroga cerealella*).

MORE INFORMATION

GRDC Stored Grain 'Insect Control': http://storedgrain.com.au/category/information-hub/insect-control/

GRDC Fact Sheet 'Grain Storage — Stored Grain Pests — Identification, Western': www.grdc.com.au/GRDC-FS-StoredGrainPestID

Plant Biosecurity CRC: 'An Integrated Approach to Manage Pests and Resistance to Phosphine in Stored Grain': http://www.pbcrc.com.au/research/project/3150

17 Grain Trade Australia (2016-17), Guide to the GTA Grain Trading Standards, GTA, http://www.graintrade.org.au/commodity_standards

18 GRDC (2013) Fact Sheet — Grain Storage Pest Control Guide, Western Region, GRDC, www.grdc.com.au/GRDC-FS-GrainStoragePestControl

9.3.4 Managing stored grain pests — hygiene

A combination of meticulous grain hygiene, well managed aeration cooling and correct fumigation (if necessary) typically overcomes 85 percent of grain storage pest problems and helps to maintain grain quality.[19]

The first grain harvested is often at the highest risk of early insect infestation due to contamination of equipment.

It is advised to remove grain residues from empty storages and grain handling equipment, such as harvesters, field bins, augers and silos, to facilitate an uncontaminated start for new season grain.

Equipment can be cleaned by blowing or hosing out residues and dust and then using a structural treatment if needed.

Inert dusts, such as Dryacide®, Absorba-Cide®, Cut 'N Dry™ and Perma-Guard®, can be used to treat the header, storage and handling equipment for residual control. Always read and follow label directions.[20]

It is also recommended to remove and discard any grain left in hoppers and bags from the grain storage site so this material does not provide a habitat for pests during the off-season.

9.3.5 Managing stored grain pests — aeration cooling

Freshly harvested grain typically has a temperature of about 30°C, which is ideal for breeding of storage pests — as shown in Table 2 — and can reduce germination of retained seed.

Table 2: The effect of grain temperature and moisture on stored grain insect and mould development.[21]

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

Research has shown rust-red flour beetles typically stop breeding at storage temperatures of about 20°C, lesser grain borers at about 18°C and other storage pests at about 15°C or lower.[22]

It is advised to aim for stored grain temperatures of less than 23°C during summer months and less than 15°C during winter using aeration fans in storage systems. Research has found grain temperatures below 20°C can significantly reduce mould growth and insect development.[23]

19 Botta, P (2016) On Farm Grain Storage Creating Value for the Business, GRDC Update Papers, https://grdc.com.au/Research-and-Development/GRDC-Update-Papers/2016/07/On-farm-grain-storage-creating-value-for-the-business

20 Botta, P (2016) On Farm Grain Storage Creating Value for the Business, GRDC Update Papers, https://grdc.com.au/Research-and-Development/GRDC-Update-Papers/2016/07/On-farm-grain-storage-creating-value-for-the-business

21 GRDC (2013) Fact Sheet — Grain Storage Pest Control Guide, Western Region, GRDC, www.grdc.com.au/GRDC-FS-GrainStoragePestControl

22 Botta, P (2016) On Farm Grain Storage Creating Value for the Business, GRDC Update Papers, https://grdc.com.au/Research-and-Development/GRDC-Update-Papers/2016/07/On-farm-grain-storage-creating-value-for-the-business

23 Botta, P (2016) On Farm Grain Storage Creating Value for the Business, GRDC Update Papers, https://grdc.com.au/Research-and-Development/GRDC-Update-Papers/2016/07/On-farm-grain-storage-creating-value-for-the-business

9.3.6 Managing stored grain pests — insect control

Phosphine — sold in solid formulation of aluminium phosphide (AlP), under trade names such as Phostoxin® or Fumitoxin® — is the most common disinfestation treatment for insect pests in stored grain.[24]

Fumigating storage facilities with phosphine is a common component of many integrated pest control strategies.

But phosphine resistance in grain storage pests is widespread and phosphine should only be used in a pressure-tested, sealed silo.

Effective phosphine fumigation typically requires seven days when storage temperatures are above 25°C and 10 days when temperatures are 15-25°C. But always check the product label.[25]

Grain protectants Conserve Plus and K-Obiol®Combi are registered for use in WA — but by bulk handlers only. These products have strict application requirements that must be adhered to.

Insect infestations tend to be unevenly distributed in a silo but these pests seek out the most favourable places, such as the grain peak and around hatches where moisture can get in. If insects are found, or damage is detected, it is advised to treat the infestation. If grain is infested, the only way to eradicate insects is by fumigation.

Any grain found with holes is an indication that primary pests, such as the lesser grain borer or the rice weevil, have infested the grain. Correct insect identification is important to determine a suitable control tactic.

It is imperative any system that has some gas-tight sealed storage meets a standard pressure test. New grain storage facilities must meet Australian Standard AS 2628-2010 (Sealing requirements for storage control) to provide confidence that they are gas-tight.[26]

Research shows fumigation of grain storage that is not pressure sealed does not achieve a high enough concentration of fumigant for long enough to kill pests at all life cycle stages.[27]

In a gas-tight sealed silo, grain can be fumigated effectively and provide quick, inexpensive and long-lasting insect control. Market flexibility is enhanced because grain is stored residue-free.

24 Botta, P (2016) On Farm Grain Storage Creating Value for the Business, GRDC Update Papers, https://grdc.com.au/Research-and-Development/GRDC-Update-Papers/2016/07/On-farm-grain-storage-creating-value-for-the-business

25 Botta, P (2016) On Farm Grain Storage Creating Value for the Business, GRDC Update Papers, https://grdc.com.au/Research-and-Development/GRDC-Update-Papers/2016/07/On-farm-grain-storage-creating-value-for-the-business

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9.3.7 Managing stored grain pests — phosphine resistance

An almost total reliance on phosphine through the value chain puts WA at risk of the evolution of pest resistance.

Since 1982, an extensive phosphine resistance monitoring and management program has been in place.

This program involves grain insect samples from across WA being submitted by CBH Group, or collected by a network of DPIRD field staff, for resistance testing.

Insects are initially screened for phosphine resistance with a 30-minute 'Reichmuth' test, followed by tests designed to detect high resistance (if necessary).

During 2013-14, sampling found 60 percent of the 251 strains received for high resistance testing showed positive results (compared with 58 percent and 252 strains during 2013).[28]

Eradication involves regular insect trapping, sampling and resistance monitoring on an ongoing basis to ensure strongly resistant strains are completely controlled.

Many WA growers are now investing in large capacity (often up to 1500 t), flat bottom silos for storing grain on-farm.

Researchers are investigating if label directions for phosphine are appropriate for these bigger storage facilities, as these were first compiled in the 1970s (based on smaller storage facilities).

Key findings from fumigations in 1400 t silos carried out through this project include:

- Recirculation facilitates gas distribution in large silos
- Fumigation in large silos without recirculation leads to lower concentrations in the silo base — reducing effectiveness
- Peak concentration of phosphine typically occurs between day four and six and then drops
- The current pressure half-life standard (AS2628) of five minutes is appropriate for large silos and vital for effectiveness
- Fumigations are likely to fail where there are points of gas or fresh air leaks in a silo
- Pressure testing prior to fumigation is a vital step to identify and locate gas leaks.[29]

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