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SUPPLEMENT

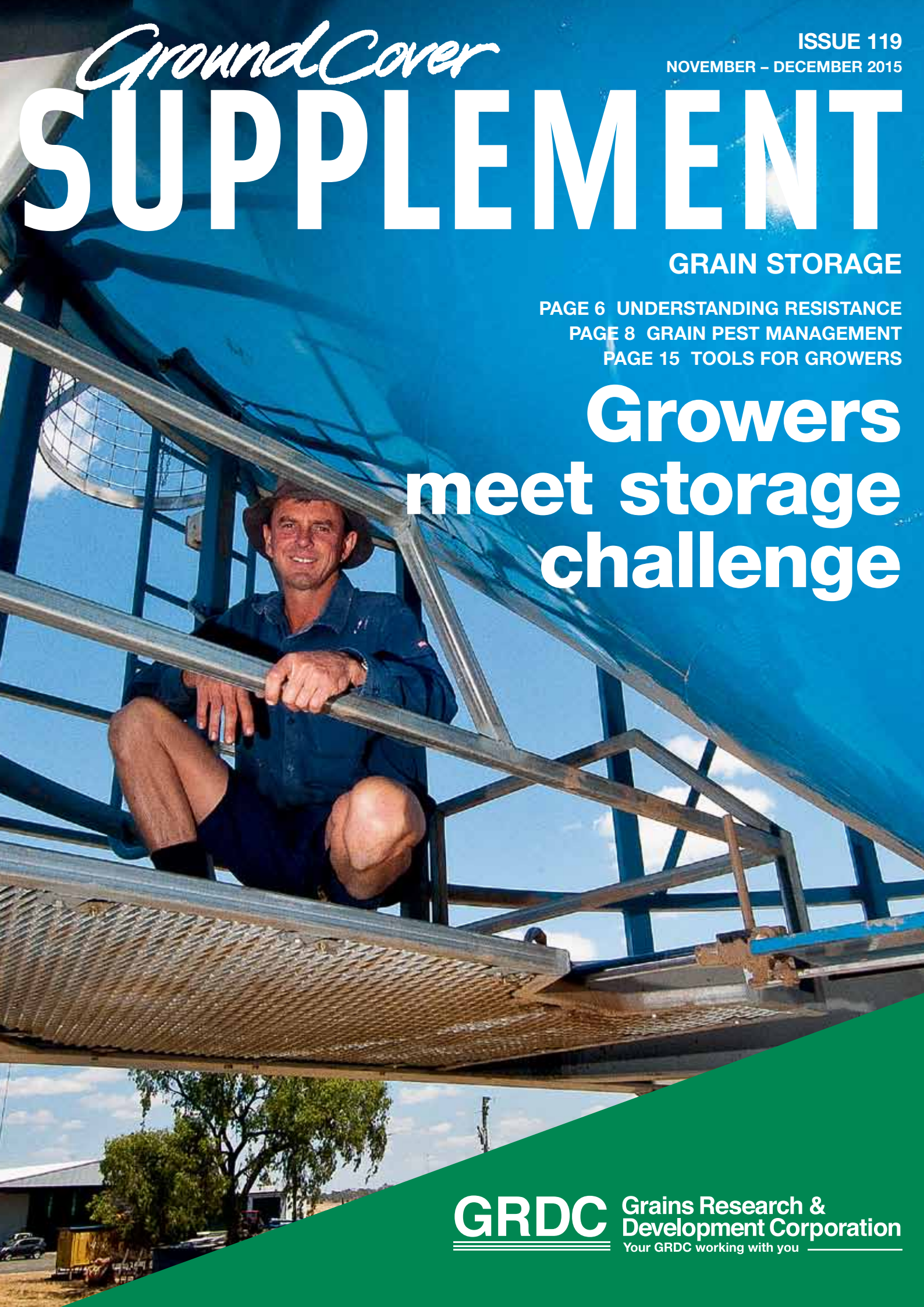
GRAIN STORAGE

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Growers meet storage challenge



GRDC

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STORAGE OPENS GATE TO MARKETING OPPORTUNITIES

By Ken Young



Grain storage has moved beyond a 'feed and seed' role on many farms as growers take advantage of the opportunity to store, segregate or blend their grain to capitalise on market opportunities.

Whatever the reason for storing grain on-farm – storing for own use, managing harvest logistics or capturing premiums – and regardless of whether it is for stockfeed, seed or human consumption, the implications of grain storage management can affect the whole industry.

Never has storage management been so important than in the face of zero tolerance of live insects in grain export shipments, strictly enforced maximum residue limits, increased resistance to phosphine – the mainstay of storage pest management – and continuing investment in storage by growers.

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GROUND COVER SUPPLEMENT edited by Rebecca Jennings

Queensland grower Phillip Otto looks out over his family's cropping operation near Clermont.

COVER PHOTO: CLARISA COLLIS

In response to the increase in on-farm storage following the deregulation of grain marketing, the GRDC invests in research to equip growers with practical information to maintain grain quality and market access.

Central to this is our ongoing support of the Plant Biosecurity Cooperative Research Centre, which has a stable of research projects addressing phosphine resistance, insect control alternatives, best-practice storage management and new technologies.

Insect management is a crucial aspect of on-farm storage. The heat, humidity and high grain moisture content that characterises storage of many Australian crops creates a haven for insects, requiring a dedicated approach to protecting grain in storage. (Contrast this to our export competitors in the Northern Hemisphere, where growers harvest in autumn and store in winter, which reduces the storage pest burden.)

Trials by the Queensland Department of Agriculture and Fisheries' post-harvest grain protection team provide us with valuable insights into the ecology of the main grain-storage insects. We know that flying beetles can infest grain located in silos at least two kilometres away, which has clear implications for disposing of waste grain.

GRDC-funded research is also monitoring resistance to phosphine across Australia. The number of populations with insects highly resistant to the fumigant phosphine has increased from about five per cent in 2010 to 10 per cent in 2015.

Off-label use of phosphine, such as applying it in unsealed structures, has contributed to increased resistance. To put the risk of losing phosphine as a control option into context, if Western Australian growers had to replace this cheap product with the only effective alternative fumigant available for export-bound grain, sulfuryl fluoride, it is estimated it would cost the industry an extra \$40 million a year.

The GRDC supports research to find alternatives to phosphine and synergies to prolong its use, with non-chemical options such as nitrogen showing promise. Trials in WA have also identified aeration as a sound economic choice for integrated pest management.

On-farm storage is at the interface between the grower and the end user, so best-practice management is critical to maintain grain quality. It is also the final stage in the on-farm supply chain where growers can influence grain quality.

So, storage requires a management approach on par with other aspects of crop management, with strategies to address resistance, integrated pest management, safe practices and sound economic decisions.

From 2012-15, the GRDC National Grain Storage Extension Project delivered best-practice grain management information and resources, based on research, tailored to growers across the three GRDC growing regions.

As well as guiding growers through storage hygiene, selection and management, this project addressed the bottom line. Grain storage is an opportunity to diversify a farm business and, like any investment, it needs to be economically sound. The national project has developed tools to calculate return on investment.

The project has been extended for another three years to continue building growers' knowledge of grain-storage management practices and delivering tools to respond to issues.

By investing in grain-storage research, the GRDC aims to support growers to introduce and maintain excellent stored-grain management for human consumption, stockfeed and seed. □

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OXYGEN STARVATION TRIAL

WA growers will put controlled-atmosphere technology through its paces this harvest, as part of research into chemical-free alternatives for stored-grain insect control

By Rebecca Jennings

NITROGEN TO PROTECT stored grain is not a new concept. The potential to control atmosphere to prevent insects has been known for more than 30 years. However, new and more affordable technology is positioning it as a viable protection option.

Research by Murdoch University, funded by the GRDC through the Plant Biosecurity Cooperative Research Centre (CRC), is taking high-nitrogen (low-oxygen) atmosphere trials out of the laboratory and into the field to assess the impact on on-farm grain-storage pests.

This controlled-atmosphere approach offers growers a non-chemical alternative to phosphine to control pests in grain storage.

Nitrogen generators reduce the levels of oxygen in storage structures and most insects cannot exist for long without oxygen.

The Plant Biosecurity CRC project takes membrane-based gas-separation technology, commonly used in industrial applications such as mining, and applies it to grain storage.

Murdoch University post-harvest biosecurity researcher Professor YongLin Ren, who leads the project team, says that in initial laboratory evaluation, nitrogen controlled all adult and immature stages of *Trogoderma variabile* (warehouse beetle) and phosphine-resistant and susceptible strains of *Tribolium castaneum* (red flour beetle), *Rhyzopertha dominica* (lesser grain borer) and *Sitophilus granaries* (grain weevil).

In the trials, nitrogen was maintained between 97 and 99 per cent for three weeks for wheat, barley, oats, lupins and canola stored at 25°C.

Professor Ren says an advantage of the membrane-separation system is that integrity of grain is preserved: “There was no change of moisture, protein, oil, starch or colour after this treatment in any of the grains tested.”

Professor Ren is now working with the Mingenew–Irwin Group in Western Australia to field test low-oxygen environments in grain storage using the membrane-separation generator – a first for the Australian grains industry.



PHOTO: PLANT BIOSECURITY CRC

(From left) James Newman, Murdoch University, David Eagling of the Plant Biosecurity CRC, Mingenew–Irwin Group chief executive Sheila Charlesworth and YongLin Ren, Murdoch University, pictured with the membrane separation nitrogen generator to be trialled in WA this harvest.

If nitrogen levels fall to 96 per cent or below, it can take up to 70 days to control adult grain borers.

This will see the technology applied to canola and chickpeas to ensure nitrogen has no effect on these crops’ market qualities such as oil content and colour.

ADVANTAGES

Nitrogen application, particularly using membrane separation, offers integrated technology to reduce post-harvest biosecurity threats, such as managing phosphine resistance, insects and grain quality control.

However, Murdoch University’s laboratory business and industry liaison manager James Newman says growers do require adequate infrastructure to maintain nitrogen levels for rapid insect control.

“You need a well-sealed structure to achieve and maintain a nitrogen level of about 98 per cent,” he says.

Control of insects drops off sharply when nitrogen levels fall to 96 per cent or below – at that level it can take up to 70 days to control adult grain borers.

Nitrogen technology offers freedom from residue and no environmental impact. The development of lower-priced units is reducing cost barriers to on-farm uptake of nitrogen technology.

“Based on some early sums, we believe the price per tonne for a

nitrogen treatment would generally be less than \$1,” Mr Newman says.

The nitrogen generator was displayed at the Mingenew–Irwin Group’s spring field day in August – attended by about 300 WA and interstate growers – where it received positive feedback.

“This generator is ideal in capacity for on-farm storage and would cost between \$50,000 and \$60,000,” Mr Newman says. “Growers were enthusiastic about the prospect of a co-owned unit purchased among a group of growers storing grain on-farm.

“This would enable them to invest in the technology without the initial significant capital cost, given that the nitrogen generator would only be required for a few days on each farm per year.”

He says the membrane gas separation units are relatively maintenance-free and the membrane modules have a life of about 20 years.

“I think the idea of using nitrogen for storing grain on-farm will gain momentum over the next few years among growers who can see the economic benefits of storing grain on-farm and selling into the market when it suits them, knowing that the product they offer is high-quality, clean and ‘green’ grain, with no chemical residues.” □

GRDC Research Code NPB00013
Plant Biosecurity CRC Code 3099

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PHOTO: CHRIS WARRICK

Average on-farm storage capacity increased by 70 per cent between 2009 and 2014.

More than 8000 growers attended 345 workshops that were run as part of the GRDC National Grain Storage Extension Project.

SCIENCE BACKS GROWERS IN SMARTER STORAGE TREND

For the past three years, a GRDC project has delivered tips and tools to more than 8000 growers across Australia to ensure on-farm storage is not a 'fill and forget' activity

By Rebecca Jennings

AUSTRALIAN GROWERS HAVE responded strongly to national industry efforts to implement science-backed best practice in on-farm grain storage.

Their efforts have been facilitated by the GRDC National Grain Storage Extension Project, which provides a central point for farm storage management information. The project has delivered 345 grain-storage workshops to growers since 2013, tailored to each of the three GRDC regions.

It has now been extended until 2018 to continue supporting growers' management of pest control, grain quality and storage investment.

National coordinator Chris Warrick says the project reflects the continuing change in on-farm storage. An initial increase in on-farm storage in response to deregulation of the grain-marketing system has not slowed, with many growers investing in their own infrastructure to take advantage of marketing opportunities and for harvest efficiency.

The Kondinin Group's national agricultural survey revealed the average farm storage capacity increased from 850 tonnes in 2009 to 1449t in 2014, an increase of more than 70 per cent.

"On-farm grain storage offers growers another enterprise to value-add to their crop, take advantage of marketing opportunities and increase the bottom line," Mr Warrick says.

However, he adds that growers now need to manage their storage differently to the past approach of short-term storage for harvest, or just storing seed and feed for their own use.

PHOSPHINE

A central message of the workshops has been the need to manage resistance to the most common grain insect fumigant, phosphine.

A concern has been that some growers are relaxing their approach, such as fumigating in structures that are not gas-tight sealed, as the consequences of applying phosphine incorrectly are not immediately felt.

The project workshops have emphasised the long-term damage and cost that would be incurred if the industry lost phosphine as a pest-management tool by guiding growers through an integrated approach. This includes applying fumigants in Australian Standard (AS2628) gas-tight sealed storage, practising grain storage hygiene, introducing aeration cooling, and considering non-chemical alternatives to manage resistance issues.

Many growers seek grain-storage advice from manufacturers, so the project delivered 41 training events, which resulted in manufacturers improving their products and knowledge to align with best practice.

Other project outcomes included producing resources, such as grain-storage checklists and economic tools, which are available from the Stored Grain Information Hub (www.storedgrain.com.au), and setting up the 1800 WEEVIL hotline to connect growers with grain-storage experts.

The project included an economic component to understand the cost

structures of on-farm storage.

"Growers need to realise multiple benefits from their on-farm storage to make the investment worthwhile, such as from marketing, improved harvest logistics, freight savings or premiums from blending products," Mr Warrick says.

IMPACT

The first phase of the project contributed to widespread practice change.

The Kondinin Group national agricultural surveys have measured trends in on-farm storage management, including:

- **more sealed (gas-tight) storage:** the proportion of growers with on-farm storage who have at least one gas-tight structure increased from 57 per cent in 2009 to 66 per cent in 2014;
- **incorrect phosphine use:** 35 per cent of growers who reported using phosphine during the past five years do not own a sealed silo, suggesting best practice is not being followed;
- **increased aeration cooling:** growers with aeration cooling facilities in their on-farm storage increased from 28 per cent in 2009 to 32 per cent in 2014; and
- **economics:** the introduction of economics-focused workshops to the project saw 64 to 73 per cent of participants apply an economic rationale to storage planning and purchasing.

The project will now focus on

improving grower knowledge of what constitutes a sealed silo (gas-tight sealable, based on a pressure test) and encouraging growers to increase the frequency at which they monitor stored grain for pests.

The project will also develop an interactive e-learning manual, a

smartphone app to access grain-storage information and guidelines, and an online extension community where growers can ask grain-storage questions. □



PHOTO: BEN WHITE

Chris Warrick

GRDC Research Code PRB00001

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EXTENSION TAILORED FOR REGIONAL CHALLENGES

The GRDC National Grain Storage Extension Project regional team delivered more than 345 workshops nationally since 2013, during the 2012–15 phase of the project. Workshop presenters Philip Burrill, Peter Botta and Ben White share their observations about the challenges and opportunities of grain storage in each region.

Gas-tight sealed storage (Australian Standard AS2628) is important for effective fumigation.

NORTHERN REGION



Factors that promote insect activity in grain storage in Queensland and northern New South Wales include warm temperatures when wheat and barley are harvested, increased humidity from the summer storm cycle, and a higher moisture content of grain at harvest compared with southern areas and Western Australia.

“This higher moisture content, combined with subtropical ambient conditions and a year-round source of food from both summer and winter crops, creates ideal conditions for grain-storage pests,” Queensland Department of Agriculture and Fisheries senior agronomist Philip Burrill says.

Strong domestic demand for grain from feedlots, piggeries and layer/meat chicken farms in Queensland and northern NSW has helped drive a surge in on-farm storage.

“Growers with suitable on-farm storage can also better manage

harvest-time logistics and position themselves to take advantage of a strong container export market, with buyers sourcing grain direct off-farm to fill contracts,” Mr Burrill says.

Mr Burrill says that growers who follow the key storage guidelines (the segregation of quality traits, and the use of silos that are gas-tight and, later, easy to clean) and who carry out monthly pest checks, can not only take advantage of market opportunities, but also find themselves as preferred suppliers.

His top tip for growers is to invest in storage that is easy to clean, aerated, and set up for monthly grain sampling to check quality and detect insects. A good ladder will enable growers to access the top lid of the silo and maintain gas-tight seals (AS2628) into the future.



PHOTOS: BEN WHITE

Philip Burrill

SOUTHERN REGION



Consultant Peter Botta says growers in the southern region are investing in on-farm storage for a range of reasons.

“In the eastern states, on-farm storage gives growers options into domestic and export markets, while in South Australia – where the majority of grain goes to bulk handlers – growers tend to set up storage to improve harvest management.”

He says regardless of the motivation for investing in storage, growers can benefit in the long run by taking a forward-thinking approach.

“You might only plan to store grain on-farm for a short time, but markets can change, so investing in gas-tight sealable structures means you can treat pests reliably and safely and leave your business open to a range of markets.”

When Mr Botta speaks to growers at workshops, he suggests they approach storage as they would purchasing machinery: “Growers spend a lot of time researching a header purchase to make sure it is fit-for-purpose. Grain storage can also be a significant investment, and a permanent one, so it pays to have a plan that adds value to your enterprise into the future.”

His top tip for growers is to decide what they want to achieve with storage, critique any existing infrastructure and be prepared for future changes: “A good storage plan can remove a lot of stress at harvest – growers need a system that works so they capture a better return in their system.”



Peter Botta

WESTERN REGION



WA's export focus means western growers need storage systems that meet stringent market demands, according to workshop presenter Ben White.

Industry reliance on phosphine – the mainstay of pest control in grain storage – is under threat as grain markets become increasingly sensitive to pesticide residues and key insect pests develop phosphine resistance.

“Alternatives to phosphine are limited and costly,” Mr White says. “Replacing phosphine with sulfuryl fluoride, which must be applied by a professional fumigator, could cost the WA bulk-handling industry an extra \$40 million per year.”

He urges growers to practise grain-storage hygiene and consider alternative pest-control tools, such as aeration, and emerging

technologies, such as controlled atmosphere.

“WA has the lowest adoption of aeration of all states, at less than one per cent. However, trials run by the Mingenew–Irwin Group show it is an economically sound option, with aerated seed silos saving more than \$2 per tonne, predominantly through increased seed viability compared to non-aerated structures.”

His top tip for growers is to choose the right equipment and not skimp on ‘extras’ such as aeration controllers.



Ben White

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TRAVELLING INSECTS HELP RESISTANCE SPREAD

By Catherine Norwood

THE DEVELOPMENT OF phosphine resistance in stored-grain insects has, for the most part, been blamed on imperfect fumigation practices that allow survivors or carriers of resistance genes to survive and reproduce.

This makes each incidence of resistance the likely result of practices at a particular location, be it on-farm or a receival site, or possibly the transport of insects in grain between the two.

However, one of the major conclusions to come from ecological studies of several stored-grain insects, led by Queensland Department of Agriculture and Fisheries (DAF) entomologist Dr Greg Daglish, is that natural gene flow is also a likely contributor – as it is for so many other agricultural pest threats. Gene flow is the transfer of hereditary traits from one population to another through interbreeding.

Dr Daglish has been collaborating with researchers from the University of Queensland (UQ) and the New South Wales and Western Australian governments on ecological research for the Plant Biosecurity Cooperative Research Centre (CRC), with funding from the GRDC.

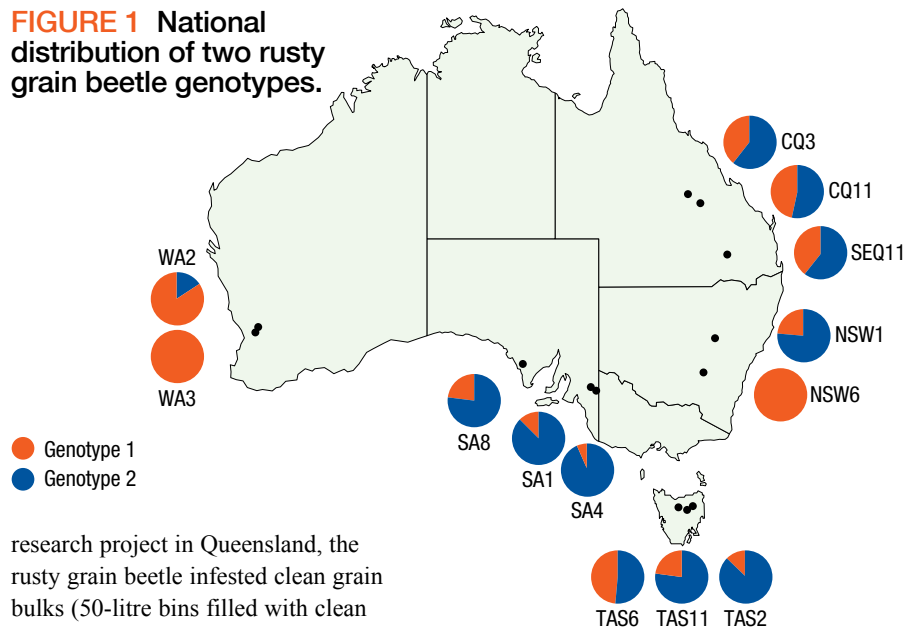
“When we first started investigating the ecology of grain pests almost 10 years ago, most people thought they were pretty much confined to the silos where they were found,” Dr Daglish says. “Maybe they could move 20 or 40 metres, to another silo, but that was about it. Now we know they can and do move much further afield.”

The first studies trapped the lesser grain borer (*Rhyzopertha dominica*) and the rust-red flour beetle (*Tribolium castaneum*) at significant distances from grain storages – more than five kilometres. In some cases the lesser grain borer was found up to 10km from the nearest grain storage, although there appeared to be no obvious alternative host plants for the insects.

Dr Daglish says it seems likely these species move to and from storages and other locations in the wider environment. The rice weevil (*Sitophilus oryzae*), however, has not been trapped at any great distance from storages.

More recent research has focused on the rusty grain beetle (*Cryptolestes ferrugineus*), which can develop a very strong resistance to phosphine. In one

FIGURE 1 National distribution of two rusty grain beetle genotypes.



SOURCE: UNIVERSITY OF QUEENSLAND

research project in Queensland, the rusty grain beetle infested clean grain bulks (50-litre bins filled with clean grain) placed adjacent to silos and 2km from the nearest storage, suggesting movement between the two.

However, it is the analysis of Australia-wide genetic sampling of this species that suggests natural gene flow may also be contributing to the spread of phosphine resistance.

Dr Alicia Toon (UQ) tested insects from 19 sites collected from farms across all grain-growing regions in late 2014. The first part of the analysis used markers from the mitochondrial DNA, which is inherited from the mother via the egg, for comparison.

This identified two distinct genetic lineages for the rusty grain beetle – so distinctive that researchers initially thought they may have been two different species.

“This is not just an academic point,” Dr Daglish says. “Species that are difficult to tell apart without DNA testing, but which potentially have different levels of resistance to phosphine would have considerably complicated identification and control strategies. Fortunately, the two lineages do mate, indicating that they are actually the same species, despite the differences.”

In addition to the two lineages, research using 10 microsatellite markers identified four distinct genetic clusters: in WA; on South Australia’s Eyre Peninsula; in eastern SA and Tasmania; and in Queensland, NSW and Victoria.

“The whole east coast is effectively one gene pool. And while there may be some movement between these four

There is a clear restriction on rusty grain beetle gene flow between the eastern states and Western Australia.

population groups, it is less likely,” Dr Daglish says. “There is also a clear restriction on rusty grain beetle gene flow between the eastern states and WA.”

A second genetic analysis has been completed for the red flour beetle in a project led by UQ’s Professor Gimme Walter, with funding through the India-Australia Strategic Research Fund. UQ population geneticist Dr Graham McCulloch made the unexpected discovery of a single national gene pool for this species.

“We thought at the very least there would be a difference between the east and west,” Dr Daglish says.

It is only through the use of DNA markers that the researchers have been able to identify the potential flow of insect genes – including for phosphine resistance.

“It would not have been possible through traditional trapping techniques. Understanding that stored-grain insect resistance genes can move into new areas, not just arise as a result of local selection, is important. Actions in one place can have implications further away. If you want to manage resistance you have to take a very broad-scale view. You can’t just look at your farm,” Dr Daglish says. □

GRDC Research Code NPB00013
Plant Biosecurity CRC Code 3039
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PHOSPHINE RESISTANCE ONE IN TEN

By Catherine Norwood

MONITORING OF STORED-GRAIN insects across Australia reveals that the number of populations with insects highly resistant to the fumigant phosphine has increased from about five per cent in 2010 to 10 per cent in 2015.

While the incidence is increasing, the monitoring program, which now has data for more than 30 years, has been crucial in extending the effective life of phosphine as a fumigant following the first discovery of strong resistance in 1997.

Overseas, the emergence of strong resistance has made phosphine ineffective for insect control in many areas. Principal entomologist with the Queensland Department of Agriculture and Fisheries (DAF) Dr Pat Collins says data is limited, but strong resistance to phosphine has been identified in 99 per cent of grain insect populations sampled in India.

In Vietnam and Brazil, strong resistance has been identified in the lesser grain borer in 97 per cent and 74 per cent of samples, respectively. Although there have been few formal surveys in the US, “resistance is easily found there”, Dr Collins says.

Australia is the only country to systematically monitor for and manage phosphine resistance. The program has been operating more than 30 years, and it has successfully provided an early warning system that has allowed the grains industry to develop and implement management strategies.

The strategy, developed through the National Working Party on Grain Protection, has a two-pronged approach:

- to reduce selection pressure by limiting the number of fumigations to three per parcel of grain, where possible, and to use non-chemical alternatives such as cooling and good hygiene to remove insect populations from the system; and
- to destroy resistant insects by making every fumigation count. This includes developing new fumigation protocols where necessary and monitoring gas concentrations during fumigation to ensure effectiveness.

For most of the past decade the stored-grain monitoring program, funded by the GRDC, has been coordinated through the Plant Biosecurity Cooperative Research Centre (CRC) and its predecessor the CRC

for National Plant Biosecurity and led by Dr Manoj Nayak, principal research entomologist, also from Queensland DAF. Dr Nayak reported on the findings of monitoring for the 2014-15 season at the Australian Grain Storage and Protection Conference held earlier this year.

Of the 1150 insect populations tested (Figure 1), strong resistance was found in 116 populations, with the rusty grain beetle the most common problem in central storages and the lesser grain borer the most common problem on-farm.

In eastern Australia, Plant Biosecurity CRC project staff collect insects from farms, merchants and central storages, although some bulk handlers send their samples to the relevant laboratories, particularly if they suspect resistance.

In Western Australia, samples are collected from farms by government biosecurity inspectors and CBH sends all insects found for testing.

“Sampling by region allows us to identify trends and efficacy of treatments over time. Where we find strongly resistant populations we visit the property to advise on eradication strategies and later revisit and resample those properties to ensure the successful management of resistant pests,” Dr Nayak says.

For bulk grain handlers, provision of same-day advice on the resistance status of a pest population using a recently developed rapid resistance test has allowed them to employ higher phosphine

Australia is the only country to systematically monitor and manage phosphine resistance in insects.



PHOTO: QUEENSLAND DAF

Phosphine-resistant insects: the saw-toothed grain beetle has developed some resistance to several grain insecticides.

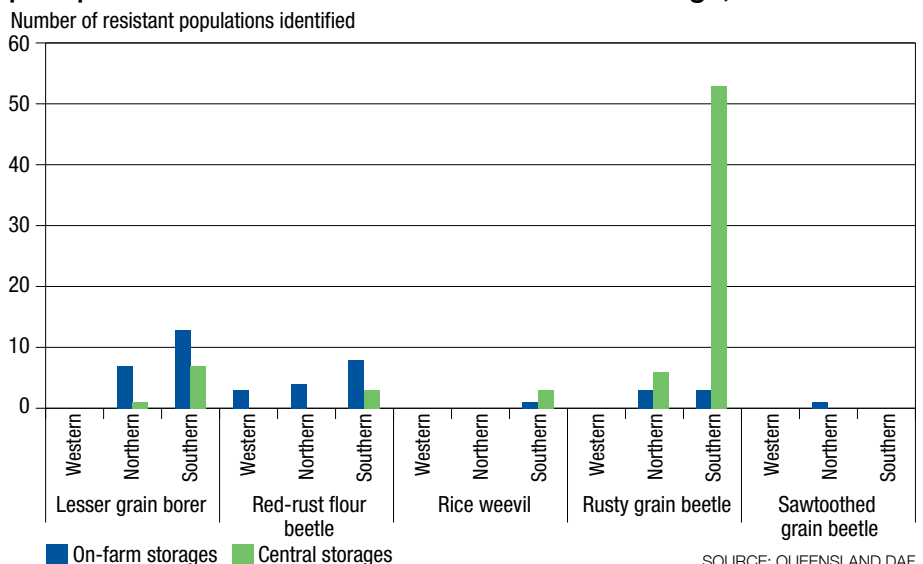
concentrations or alternative treatments when strong resistance is confirmed.

Where rapid testing identified strong resistance to phosphine in the rusty grain beetle, one application of sulfuryl fluoride significantly reduced the incidence of resistance in the following two years.

Dr Nayak says emerging challenges include the potential for more widespread occurrence of strongly resistant rusty grain beetles on-farm, and the development of strong resistance in rice weevil populations in the southern grain-growing region. □

GRDC Research Code NPB00013
Plant Biosecurity CRC Code 3035

FIGURE 1 Stored grain insect populations diagnosed with strong phosphine resistance in on-farm and central storage, 2014-15.



SOURCE: QUEENSLAND DAF



LONG DISTANCE INSECTS RAISE THE HYGIENE BAR

New insights into the ecology of three major insect pests of stored grain have implications for farm hygiene practices

By Dr Greg Daglish, Dr Andrew Ridley and Philip Burrill

THE LESSER GRAIN borer (*Rhyzopertha dominica*), red flour beetle (*Tribolium castaneum*) and rusty grain beetle (*Cryptolestes ferrugineus*) are among the most common pests on farms; however, not much is known about how and when they travel through cropping areas.

A lack of relevant information on the ecology of these pests prompted a national research effort coordinated by the Queensland Department of

Flying beetles can infest grain located at least 2km away, so burn or bury waste grain.

Agriculture and Fisheries (DAF) and supported by the Plant Biosecurity Cooperative Research Centre, of which the GRDC is a partner.

Trapping studies show these beetles fly more than was previously thought.

All three species have been trapped away from stored grain, sometimes more than 10 kilometres from the nearest farms. This means that beetles resistant to the fumigant phosphine or grain protectant insecticides can fly between farms.

Flying beetles pose a threat for much of the year, highlighting the need to minimise the chances of infestation by eliminating places to breed. These beetles are long-lived and females can produce many offspring in small amounts of grain.

There is strong seasonality in flight activity, with little or no flight occurring during the coldest months of the year. Limited flight during these months provides an opportunity for growers to get on top of infestations early. By undertaking their main storage facility clean-up during winter, growers can eliminate residual populations before rapid breeding and flight activity gets underway in spring.

Another study investigated the risk of newly harvested grain becoming infested on farms. The study showed that when there is an existing infestation in nearby silos, the risk of infestation is greatly increased. The risk is low on farms with no detectable infestations, emphasising the importance of managing pests in all storage areas.

Grain located 2km from farm silos was also at risk of infestation, but much less so than facilities located close to farm silos (especially infested silos).

The fact that flying beetles are not limited to the immediate storage environment and can infest grain located at least 2km away has implications for disposal of waste grain.

It is common practice for many growers to dump badly infested grain by the road near their properties. The results of the field studies show that there may be no safe distance from farm silos to dump waste grain.

Although the risk of infestation from waste grain will be reduced with distance, the safest option will be to bury or burn the waste to reduce the risk to nil. □

GRDC Research Code NPB00013

Plant Biosecurity CRC Codes 3039, 50089, 50149

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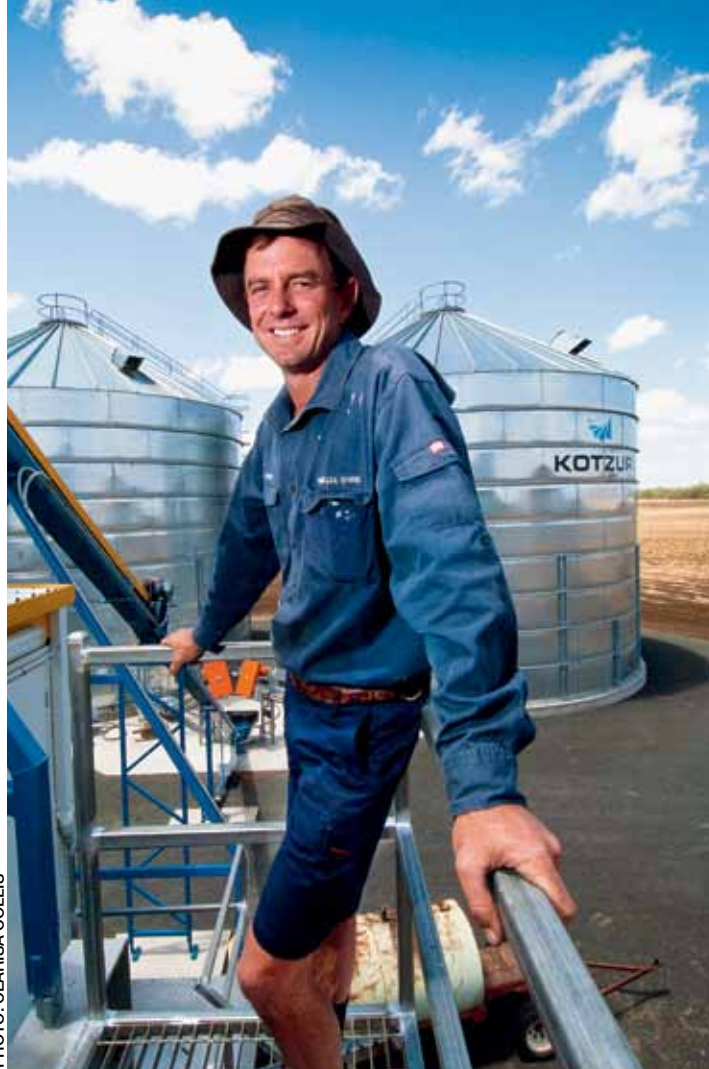


PHOTO: CLARISA COLLIS

Storage hygiene clips flying pests

Central Queensland growers Phillip (pictured) and Janelle Otto completed a new grain-handling system for their Clermont cropping operation in 2013, and the investment is paying off.

Their system includes 3000-tonne storage capacity plus a certified weighbridge with a 38t elevated quick-fill silo.

Phillip says the ability to sell all their grain ex-farm has reduced costs by \$10/t in cartage costs to the local depot, \$2.50/t a month in warehousing fees and \$16/t on the depot's in-and-out fees.

The Ottos' grain marketing is underpinned by storage hygiene. Phillip ensures all spilled grain is cleaned up from the ground and he spends time ensuring his harvester, chaser bins and mother bins are clean. The Ottos have also invested in aeration cooling and an automatic controller to prevent insects infesting storage.

The Ottos' 2800-hectare property was one of 10 Central Queensland enterprises involved in a Plant Biosecurity Cooperative Research Centre insect ecology research project run by Dr Greg Daglish, who is a principal research scientist with the post-harvest grain protection team at the Queensland Department of Agriculture and Fisheries.

Phillip says the research, which measured how far storage pest species can fly to infest clean grain and the times of year they are active, reinforced the need for best-practice grain hygiene as it showed that insects such as flying beetles are not limited to the immediate storage environment and can infest grain located at least two kilometres away.



NEW LURE TO TRAP RUSTY GRAIN BEETLE

Identifying the presence of stored-grain insects is the first step in applying the most effective control strategies

By Catherine Norwood

AS AN ORGANIC chemist, Dr Stephanie Smith considers the use of pheromones as the most obvious and effective tool for monitoring grain pests.

Dr Smith has developed a lure that attracts a high-priority stored-grain insect, the rusty grain beetle (*Cryptolestes ferrugineus*), as part of a project funded by the GRDC through the Plant Biosecurity Cooperative Research Centre (CRC) to improve surveillance tools.

“The chemical compounds we are using are the same ones that these insects have been producing and responding to throughout their evolution,” she says.

“They are not going to become resistant to these pheromones in the way they become resistant to phosphine.”

Dr Smith is CEO of Research Directions, the Queensland company that has synthesised the pheromones and is commercialising the lures.

Although the rusty grain beetle is not as widespread as some other stored-grain pests, such as the lesser grain borer, it has rocketed up the priority list following the emergence of strong resistance to phosphine.

It is this development that has made monitoring more urgent.

It takes up to eight days to kill most stored-grain insects at the highest label rate of phosphine (720 parts per million) – but resistant rusty grain beetles are requiring 16 to 18 days of phosphine applied at the highest label rate.

Of Australia’s four major pests of stored grain, the rusty grain beetle was the only one not to have an existing commercial lure, until Dr Smith’s intervention.

Although the two aggregation pheromones the insect produces were discovered by Canadian researchers in the 1970s they had not been successfully synthesised for commercial manufacture. (Aggregation pheromones are not sex pheromones; they attract male and female insects equally.)

Dr Smith says the new lure uses two pheromones, one of which was particularly difficult to manufacture, and extensive experimental work has been

Until the development of a pheromone lure, the rusty grain beetle was the only major grain storage insect not to have a commercial lure.



The pheromone lures have been tested and found to kill rusty grain beetles.

required to optimise the efficiency of manufacture of the two components.

The lures have been successfully tested in the field by entomologist Dr Andrew Ridley from the Queensland Department of Agriculture and Fisheries, in collaboration with GrainCorp, earlier this year.

Kansas State University has also been conducting trials with the lures in the US. The lures have been found to attract both adult male and female rusty grain beetles, and all females caught have been young and fertilised.

Dr Smith says it should be possible to use the lures for both monitoring and control.

“It would be ideal to eliminate the pest from the grain, before it actually goes into the silos in the first place,” she says.

Research Directions will commercialise the lures internationally for use in monitoring stored grain and other food products for the presence of rusty grain beetles.

The lures cost \$8.50 each and are available from Research Directions, which will provide advice to customers on suitable traps for the lures. □

► GRDC Research Code NPB00013

Plant Biosecurity CRC Code 5073

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Scorecard shows industry awareness

The latest National Residue Survey (NRS) results indicate excellent compliance from 6238 stored grain samples, but contamination and herbicide-use issues need to remain front-of-mind for growers. This was the message from the Australian Department of Agriculture’s NRS director Ian Reichstein when he spoke at the Australian Grain Storage and Protection Conference earlier this year.

The NRS covers all tradeable grains for export and domestic markets, with all samples screened for insecticides (such as grain protectants), fungicides (including fluquinconazole and flutriafol), pre-emergent and post-emergent herbicides (including 2,4-D) and contaminants (such as organochlorines).

One in four samples are screened for special herbicides such as glyphosate, haloxyfop, paraquat and amitrole, and grain is also tested for environmental contaminants and fumigants.

Compliance with maximum residue limits (MRLs) for the 200 chemicals tested were:

- 99.86 per cent compliance from 3452 bulk-export samples (up from 99.7 per cent the previous year);
- 98.77 per cent from 2034 export container samples (98.9 per cent in 2013-14); and
- 97.34 per cent from 753 domestic samples (97.5 per cent in 2013-14).

Mr Reichstein said there were some issues that still need industry attention, including haloxyfop herbicide residues (which continue to be a problem despite changes to product labels in October 2014 to prevent late-growing-season application) and an increase in flutriafol residues.

Trace-backs showed flutriafol contamination is most commonly the result of back-loading flutriafol-treated fertiliser deliveries with grain, or from equipment coming into contact with the treated fertiliser.

The NRS has not previously routinely tested for fertilisers, but in response to these concerns delegates at the conference endorsed specific testing for up to 500 samples of grain in the 2015-16 NRS to identify the extent of fertiliser contamination.

Although there is no fully effective way to decontaminate equipment that has been in contact with flutriafol-treated fertiliser, improved truck hygiene could help eliminate basic fertiliser contamination. □

► More information: www.agriculture.gov.au/ag-farm-food/food/nrs

PHOTO: RESEARCH DIRECTIONS



SOLAR-POWERED AERATION COOLING SHOWS PROMISE

By Nicole Baxter

INDEPENDENT ENGINEERS AND grain storage specialists have demonstrated that the sun's energy can be harnessed to keep silos that are located away from a mains power supply cool and insect-free.

Tests in a 75-tonne silo at Wyalkatchem, Western Australia, 200 kilometres north-east of Perth, by independent engineers Ben White and Josh Giumelli and grain storage specialists Chris Warrick and Peter Botta showed it is possible to build an energy-efficient, solar-powered, aeration-cooling system.

The GRDC-supported project, led by Ben White, found aeration-cooling systems in 75t silos typically use 0.37-kilowatt, 240-volt motor-driven radial fans, which deliver about 200 litres of air per second at 200 pascal static head backpressure. This equates to a fan efficiency of about 1850 watt-seconds/m³.

For maximum efficiency, Mr White and his team selected a backward-inclined, curved blade centrifugal motorised impeller fan with an electronically commutated (EC) brushless direct-current motor. With this combination, specific fan power at comparable flow rates and backpressure was reduced to 560 watt-seconds/m³, a 330 per cent efficiency improvement on standard fan motors usually suggested for grain aeration cooling.

The use of an EC motor prevented the application of an off-the-shelf aeration control system, so the research team customised a solution to meet its requirements.

"The controller uses two internal thermocouple temperature sensors embedded in the grain and selects the hotter of the two. This temperature is then compared with the external ambient temperature," Mr White says.

"If the external ambient temperature is lower than the grain temperature, and the ambient relative humidity is below 80 per cent, the controller engages the fan at the nominated operation speed. Alternatively, the fan can be set to run continuously, except when ambient relative humidity exceeds 80 per cent."

To accommodate the fan, a manhole access door was modified to extend into the silo, allowing the fan to be mounted inside with a large open-area free-flowing plenum attached. To collect sunlight energy, four 260W multi-crystalline solar panels were chosen to provide a total array size of 6m².

For superior longevity at higher depth of discharge ratios, the team selected Absorbent Glass Mat (AGM) batteries.

Mr White says these batteries offer charging rates five times higher than flooded deep-cycle cells and are more resilient to deep-cycle depth of discharging.

To manage panel energy and prevent overcharging the batteries, a 48V power management system including a 3000W pure sine-wave inverter was chosen. This was wired through a 240V power distribution board to provide a 240V outlet to run the aeration fan and controllers.

For testing, the components were mounted into and on top of a trailer with custom-built battery and solar-panel storage for transport, internal electrical inverter and panel mounting.

On site, the panels were mounted at 30 degrees to the horizontal. In the silo, airflow was distributed via the customised scroll surrounding the fan impeller and a plenum designed to minimise backpressure and maximise open area to about 0.3m².

The silo was filled with Scope[®] barley and airflow rates across a range of fan speeds and power draws were measured when the silo was half-full and full.

Airflow performance was found to be acceptable, with results showing the system could effectively cool barley to 15°C.

While the results for the prototype are encouraging, Mr White says further refinement of the components would be needed to suit specific silo applications. He also encouraged the use of a licensed electrician to ensure correct fitting of electrical components. □

GRDC Research Code BMW00001

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A power source trailer was custom-designed and positioned to maximise solar capture.

REDUCED PEST BURDEN SLOWS RESISTANCE

Growers in Western Australia are driving research to improve biosecurity and grain quality

By Catherine Norwood

PHOSPHINE RESISTANCE IS a very real challenge for Western Australian growers, with eight populations of stored-grain insects (predominantly red grain beetles) with strong resistance confirmed in the state.

A resistant population in the Mingenew region, identified in 2014, has sharpened the focus of local research into aeration strategies to improve grain-protection practices.

The Mingenew–Irwin region, 380 kilometres north of Perth, has had its own grower-funded group committed to research for the past 20 years.

In 2013, the Mingenew–Irwin Group (MIG) partnered with the University of Western Australia and the Kondinin Group, with support from the GRDC and the Plant Biosecurity Cooperative Research Centre (CRC), in a three-year project to assess the effectiveness of aeration in improving the quality of stored grain in the region.

MIG takes in 320,000 hectares and has more than 200 members who represent 95 per cent of growers in the region. The town of Mingenew is home to the largest inland receival point in the Southern Hemisphere, handling 500,000 tonnes of grain a year worth \$150 million, mostly for export.

The emergence of phosphine resistance is a major concern for MIG. Executive officer Sheila Charlesworth suggests it could cost the state bulk handler, CBH, as much as \$40 million a year in alternative treatments if phosphine was to fail as an effective fumigant.

While aeration will not kill insects, the MIG trial has already demonstrated that it can considerably slow insect life cycles and reduce insect burdens – by an average of 60 per cent in seed grain stored in aerated silos, compared with adjacent control silos. Reducing the insect burden is part of the national strategy to prevent the spread of phosphine resistance.

A financial cost–benefit analysis that included the cost of the aeration equipment



and controllers, which depreciated over the three years of the project, also demonstrated that growers were \$2/t better off with aerated silos when storing seed wheat at current prices.

At each of four MIG farms taking part in the trial, aeration fans with GrainSafe aeration controllers and monitoring equipment were installed in one silo. Monitoring equipment was also installed in a nearby non-aerated silo at each site. Aeration was operated from silo fill in 2013 until sowing in the 2014 season and again in the 2014-15 season.

Data loggers were installed to measure temperature and relative humidity while insect probe traps were set at three depths in the grain bulk (0 to 30 centimetres, 30 to 60cm and 60 to 90cm from the top of the grain). Grain samples were taken monthly to test for seed viability.

A structural treatment for insect control using diatomaceous earth was also added to both aerated and non-aerated control silos in the 2014-15 season, although these results are not yet available.

The aeration system reduced temperatures in the grain bulk down to an average of 19°C. The temperature in aerated silos was as much as 12°C lower than in the non-aerated silos, which helped to reduce the rate of insect reproduction and growth.

Five insect species were found at the trial sites and identified by University of WA entomologists. These were predominantly the red flour beetle (*Tribolium castaneum*) and lesser grain borer (*Rhyzopertha dominica*), but also the longheaded flour beetle (*Latheticus oryzae*), the hairy fungus beetle (*Typhaea stercorea*) and the rusty grain beetle (*Cryptolestes ferrugineus*).

Aeration reduced insect densities by an average of 60 per cent compared with the non-aerated silos, and in one case by 72 per cent. There was also an improvement in the seed viability, with only 2.3 per cent of unviable seed in the aerated silos, compared with 4.6 per cent in non-aerated silos.

Mrs Charlesworth says that before the trial growers did not realise the extent of insect infestations in their grain or the impact it was likely to have on their grain.

COST ANALYSIS

Project engineer and stored-grain extension officer Ben White says the aeration fans operated for an average of 400 hours between harvest and seeding. While growers expected power would be

Aerating silos can drop temperature by 12°C, reduce insect reproduction and save nearly \$2/t.



PHOTO: MIG

Mingenew-Irwin Group staff collecting grain samples and checking insect traps in a silo as part of the aeration research.

a significant cost, it equated to \$0.56/t for aeration in the cost-benefit analysis (based on \$0.24/kilowatt hour).

In the non-aerated silos the cost of storage and fumigations to control insects was estimated at \$13.50/t, also accounting for seed losses, based on a seed cost of \$300/t.

In the aerated silos, costs included the capital cost of equipment, depreciated over three years, and electricity, with savings made on fewer fumigations and increased seed viability. The total calculated cost of storing grain in an aerated silo was \$11.56/t.

Mrs Charlesworth says cost savings of about \$2/t could make a significant

impact to the bottom line for growers when grain margins are very tight.

“Every one per cent or half a per cent we can save on production costs makes a difference to our profitability.”

She says other growers in the Mingenew-Irwin region have already begun to adopt aeration and installed power to their silos, with some opting to install larger silos to further improve efficiencies.

MIG has also hosted visits from seven other grower groups from across Australia, at least two of which have also begun to install aeration in their silos. □

► **GRDC Research Code NPB00013**
Plant Biosecurity CRC Code 3076

BREAKDOWN OF COSTS

AERATED SILO COSTS

Power cost (total fan run time over 4.5 months):

■ $0.37\text{kW} \times 438 \text{ hours} @ 0.24/\text{h} = \$38.89/70\text{t} = \$0.56/\text{t}$

Capital cost (assumes one 0.37kW fan and a controller for four fans):

■ equipment cost: fan (@ \$830) + ¼ controller (\$5500/4=\$1375). Total = \$2205

■ cost amortised over 20 years = \$110.25/70t = \$1.58/t

Opportunity cost:

■ $\$2205 \times 8\% = \$176.40/70\text{t} = \$2.52/\text{t}$

■ subtotal cost of aeration treatment = \$4.66/t

Viable seed losses: 2.3% germination reduction @ \$300/t = \$6.90/t

Total: \$11.56/tonne

NON-AERATED SILO COSTS

Viable seed losses: germination reduction: 4.5% @ \$300/t = \$13.50

Total: \$13.50/tonne

■ Using MIG trial figures at \$300/t for seed.

■ Average cost of control including reduced germination: \$13.50/t.

■ Average cost of aeration including power, capital costs, opportunity cost and reduced germination: \$11.56/t.

■ \$1.94/tonne better off with aerated seed silos.



IT'S ALL IN THE SEAL

By Gio Braidotti

REPLACING OXYGEN IN grain storage silos with nitrogen has proven an effective way to remove insects at all stages of their life cycle, leaving stored grain – be it wheat or canola – preserved, residue-free and subject to no withholding periods.

Nitrogen is also the preferred storage option, says Western Australia grower Doug Clarke, who is the earliest adopter of the technology in its on-farm form.

Mr Clarke made the switch five years ago on his Lake Grace property, and has made his silos available to Murdoch University researchers led by stored-grain expert Professor YongLin Ren, with support from the GRDC.

Mr Clarke has hosted visitors over the years, including overseas buyers, and says he has learnt the extent to which insecticide-free grain is preferred by buyers.

While he says the system is performing well, he is committed to continuous improvement.

However, one challenge is that there is currently no price signal favouring residue-free grain to compensate for the investment and the extra work associated with nitrogen-based storage.

In relation to the technology itself, Mr Clarke has no issue with existing oxygen-purging systems. He says the nitrogen generator needed to purify nitrogen



PHOTO: NICOLE BAXTER

Doug Clarke, Lake Grace, WA, checks the oxygen content of his silos using a handheld meter.

from the atmosphere and pump it into a silo is a machine developed by the oil industry, which is widely available.

“At a rate of 30 cubic metres an hour, it costs about \$5 worth of diesel to purge a silo of oxygen all the way down to 0.05 per cent total content,” he says. “Best of all, insects never acquire resistance.”

Another challenge relates to infrastructure: silos leaking.

“The standards for sealed silos are too low for nitrogen storage of grain,” Mr Clarke explains. “The accepted level on the seals for a silo is the loss of half an inch (12.7 millimetres) of water pressure in three minutes.”

The oxygen in the silo needs to be purged long enough to kill all insects. Mr Clarke has identified a relationship between eradication time (for all stages in an insect’s life cycle) under

nitrogen and grain temperature.

The eradication time is as low as one week at high temperatures, at 20°C it blows out to three weeks, and below that temperature he says it does not work.

It is these circumstances that have created resistance to insecticides and an interest in the latest sealing technology.

“What I am saying is that the better the seal, the better control you have under any fumigant. We need to be looking to the latest sealing technology, including polymers and 3D printers,” he says. “The area that now needs improving is the silo manufacturing.” □

GRDC Research Code NPB00013

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RESEARCH TESTED

By Rebecca Jennings

GRDC-FUNDED RESEARCH THROUGH the Plant Biosecurity Cooperative Research Centre (CRC) is being put to the test by growers and bulk handlers at five sites across Australia.

Plant Biosecurity CRC grains coordinator Dr David Eagling says the impact sites are a partnership with industry to work through implementation issues. Each site has different industry partnerships and a different focus:

- in central New South Wales, the impact site at the GrainCorp facility in Temora focuses on testing a new paint-based product to control storage pests;
- in southern Australia, research at the

Viterra facility at Bowmans, South Australia, includes insect monitoring to complement Plant Biosecurity CRC investments in grain insect ecology;

- in the west, the focus has been at the CBH facilities at the grain port of Kwinana, where the team has been putting low-oxygen/nitrogen technology through its paces;
- in the northern Western Australian grain region, the impact site is a partnership with the Mingenew–Irwin Group (MIG), with various activities located directly on grower’s farms (a particular focus over the past 18 months has been the deployment of aeration technology developed jointly by the GRDC and the Plant Biosecurity CRC); and
- in southern Queensland, the site has been a partnership with GrainCorp with an assessment of sulfurly

fluoride across various locations.

“The Plant Biosecurity CRC is conscious that research needs to be implemented into existing grower and bulk-handler processes and management to be successful,” Dr Eagling says.

“We are working on the best way to do this, as well as looking at the benefits of bringing together multiple research findings that can be integrated in a systems approach, rather than each one in isolation.

“The industry impact sites assess how a range of research outcomes fit together in the day-to-day operations on-farm, at ports and in bulk-handling facilities.”

He says the impact sites provide researchers with a central point for field testing and involve growers and bulk-handlers in deciding what research to test and how to go about evaluating the research findings.



SEARCH CONTINUES FOR PHOSPHINE ALTERNATIVES

By Catherine Norwood

IT SEEMS UNLIKELY there will be a single solution to replace the highly effective phosphine. Rather, a suite of alternatives will be required, applied with tactical precision to extend the life of phosphine and maintain Australia's export commitment of nil live insects in grain shipments. Nitrogen seems likely to play a major role as a phosphine alternative, with field trials at bulk storages and on-farm underway this year (see page 3). Another controlled-atmosphere strategy being investigated is the use of ozone.

OZONE APPROACH

As with nitrogen, ozone – or O_3 (as compared to oxygen gas O_2) – has been recognised for decades as an effective way to kill stored-grain insects. Although Murdoch University's Professor YongLin Ren, who leads several phosphine-alternative research projects for the Plant Biosecurity Cooperative Research Centre (CRC), says the technology is not new. Technical advances mean it could be an accessible and viable treatment.

The ozone research is being undertaken through the Plant Biosecurity CRC's partner Kansas State University in the US.

When O_3 is applied at a rate of 200 parts per million in laboratory trials, it kills all stages of strongly resistant stored-grain insects within two days.

Professor Ren says field trials using O_3

as a treatment in small-scale farm storages are likely to be held within the next six months. Other trials are planned to evaluate ozone in combination with nitrogen.

SULFURYL FLUORIDE

GRDC-supported research through the Plant Biosecurity CRC and led by Associate Professor Paul Ebert at the University of Queensland is focusing on the synergistic or additive effects of various chemical combinations.

Sulfuryl fluoride is an alternative that provides a resistance-breaker effect in the bulk-grain-handling system for the treatment of strongly resistant rusty grain beetles (*Cryptolestes ferrugineus*). However, it is more expensive than phosphine and has restrictions on its use to prevent residue issues. Professor Ebert says the combination of phosphine and sulfuryl fluoride is showing promise as a way to control insects in a suitable timeframe at reduced cost. He says 100 per cent control of all life stages of rusty grain beetle has been achieved with one-third of the concentration of phosphine combined with half the dose of sulfuryl fluoride needed when either is used alone.

A sublethal dose of the botanical pesticide dimethyl disulphide (DMDS) makes phosphine 10 times more effective against strongly resistant lesser grain borer.

Several other gases and volatile compounds that enhance the activity of

phosphine in a variety of ways are also being investigated. Victorian researcher Dr Ross Mann is examining the potential of volatiles from fungi as part of the Plant Biosecurity CRC work. Endophytic fungi live symbiotically with their host plants and emit volatiles to protect the plants from insect pests. Strains of fungi have been identified that produce volatile chemicals capable of killing the lesser grain borer, red flour beetle and rusty grain beetle.

SILICA POTENTIAL

The Plant Biosecurity CRC is investigating silica as a contact protectant for stored-grain insect control. Several synthetic silica compounds are being assessed and initial laboratory trials have identified compounds that provide strong control against key grain pests within 10 days. Field validation is now underway, with results showing possible competitive advantages for the silica compounds in price and efficacy.

The Plant Biosecurity CRC is also working on two possible market opportunities. One is the use of silica compounds as an admixture in grain flows. The other is as a structural treatment where the silica product acts as a barrier to insect movement when applied to both external and internal surfaces of structures used for the bulk storage of grains. □

GRDC Research Code NPB00013

Plant Biosecurity CRC Codes 3114, 3099

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“This allows the researchers, as well as the end users of the research, to see how different strategies or technologies interact with other activities and to identify any barriers to adoption, such as time or cost.”

BULK-HANDLER

GrainCorp grain protection manager Robin Reid says the bulk-handler has been involved in trials to assess the impact of phosphine and sulfuryl fluoride when applied at different concentrations and over different fumigation periods as part of the industry impact work.

“If the grains industry is to maintain the use of phosphine, we need to look for alternative products and think carefully about the destination of grain to ensure delivery into markets is below the maximum residue limits,” he says.

“It's important to support this research, as the industry relies on scientific data for

products to be registered and accepted in the marketplace. Without research which responds to challenges facing the industry we would run out of pest-control options.”

GROWERS

Growers involved in the Mingenew–Irwin industry impact site are accessing research tailored to their challenges, such as managing residue and resistance.

MIG executive officer Sheila Charlesworth says the benefits to growers from participating in an impact site are enormous.

“It ensures the end users of research can play a part in how this research is delivered, for maximum impact on-farm. Our growers are experiencing the research outcomes firsthand,” Mrs Charlesworth says. “It has also given our growers access to the Plant Biosecurity

Five sites are assessing how research outcomes fit together in the day-to-day operations on-farm, at ports and in bulk-handling facilities.

CRC's extensive collaborative network of researchers and organisations around Australia and overseas.

“As a result of this research, we are seeing growers extend power to their storage sites for aeration and show increasing interest in alternative non-chemical pest-control products such as nitrogen.” □

GRDC Research Code NPB00013

Plant Biosecurity CRC Code 3076

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DE PRODUCTS PUT TO THE TEST

Prevention rather than cure is always the best approach when it comes to grain storage hygiene

By Philip Burrill and Andrew Ridley

LOADING GRAIN INTO an infested silo guarantees problems down the track. On the other hand, diligently cleaning empty storages and grain-handling equipment significantly reduces the number of pest breeding sites on-farm.

The best hygiene results come from physically cleaning out/washing down residues, followed by a diatomaceous earth (DE) treatment. However, grower queries about the effectiveness of different DE products prompted Queensland Department of Agriculture and Fisheries (DAF) researchers to put them to the test.

Queensland DAF researchers in Brisbane tested the efficacy of four commercial DE products: Dryacide®, Permaguard®, Cut'n'dry® and Absorbacide®.

Three of the most common stored grain pests, the lesser grain borer (*Rhyzopertha dominica*), the rice weevil (*Sitophilus oryzae*) and the rust-red flour beetle (*Tribolium castaneum*) were contained on sections of steel treated with label rates of the DE products.



The lesser grain borer.

PHOTO: QUEENSLAND DAF

Dryacide® was the fastest-acting product for all three species tested. The most significant difference between products was their efficacy against the rust-red flour beetle, with only two products showing acceptable results. Product performance from best to worst was – Dryacide®, Permaguard®, Cut'n'dry® and Absorbacide® (Figure 1).

APPLICATION

DE can be applied to structures and equipment either as a dry dust or added to water to form a slurry. The rate for dust application (straight out of the bag) is two grams per square metre, which is equivalent to one kilogram of DE over 500m². A Blow-Vac gun is one option for application.

DE dust can also be mixed into

water at 120g dust per litre of water and applied at a rate of 5L/100m², giving an application of approximately 6g/m² dry basis to the storage structure.

The label specifies a flat fan nozzle with at least 5L per minute flow rating, so an XR11015VK ceramic nozzle would be a suitable choice. The ceramic will withstand the abrasion much longer than a plastic nozzle. At 3-bar this nozzle will flow at 5.9L per minute.

GRAIN TREATMENT

The label allows for DE's use as a grain treatment. The problem for grain treatments at the label rate of 1kg DE/tonne of grain is that it affects grain flow characteristics and therefore handling. It also has an impact on grain 'angle of repose'.

For this reason most bulk-handling companies and other grain buyers do not accept bulk grain treated with DE.

The presence of DE in grain can also impact on milling quality and there may be other specific market objections to DE dust application to bulk grain.

Always check with buyers before applying it to grain. Current retail cost for DE ranges from \$6 to \$10/kg, making it an expensive treatment for bulk grain.

NOTES ON USE

DE dust particles kill insects by absorbing some of the waxy layer covering the insect's body. Damage to this outer 'waterproofing wax layer' leads to desiccation and eventual death over several days.

Research in the US indicates DE's impact on the insect's body is both abrasion and

Stored cereal grains must be at no greater than 12 per cent moisture content for diatomaceous earth to be effective.

DIATOMACEOUS EARTH (DE) is an inert dust made from the fossil remains of diatom skeletons. Diatoms are a type of green or brown algae that grows in freshwater lakes and marine estuaries. There are many species of diatoms and each has a unique size and shape. The various DE products are produced from different mine sites in Australia and overseas and as such have different properties. The way DE is processed also affects its insecticidal properties.

desiccation. Therefore, DE works best in low-humidity conditions. Stored cereal grains, such as wheat, must be at no greater than 12 per cent moisture content (60 per cent relative humidity) for DE to be effective.

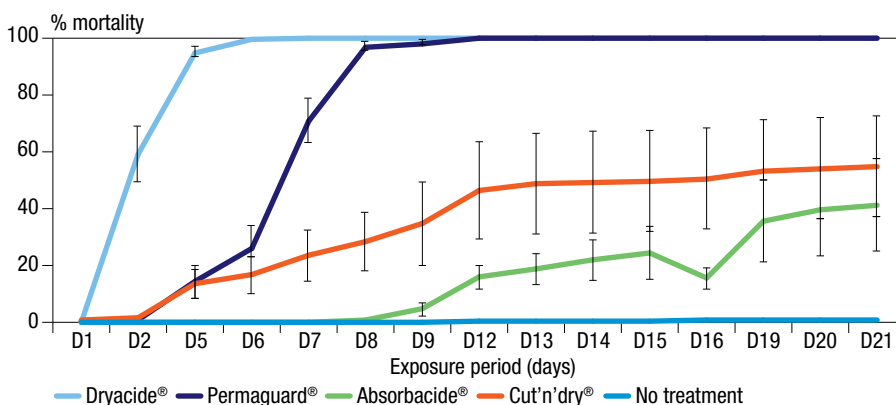
DE is one of the few products available as a structural treatment suitable for all cereal grains, pulses and oilseeds. Chemical insecticides such as fenitrothion can lead to chemical residues on oilseeds and pulses being detected by domestic and export grain buyers if used inappropriately.

The best approach for all storages and equipment is to physically clean and/or water wash all grain residues and dust, then consider using a DE structural treatment to deal with any remaining pests. □

GRDC Research Code PRB00001

More information: 1800 WEEVIL (1800 933 845); www.storedgrain.com.au; Queensland DAF's customer service centre, 13 25 23

FIGURE 1 Efficacy of four DE products and a no treatment control over three weeks against rust-red flour beetles on steel.



SOURCE: QUEENSLAND DAF



GRDC NATIONAL GRAIN STORAGE EXTENSION PROJECT

The GRDC Grain Storage Extension Project has developed an information hub for growers, advisers and storage manufacturers at www.storedgrain.com.au.

This site provides grain storage workshop details, best-practice guides and downloadable resources on a range of grain storage activities.



GRAIN AERATION

READ: 'Aeration cooling for pest control' fact sheet.

Grain aeration provides growers with a powerful tool to maintain grain quality during harvest and storage.

Aeration cooling may not eliminate the need for chemical insect control, but it will dramatically slow insect development.

WATCH: Grain storage consultant Peter Botta gives useful tips on cooling aeration in silos as part of a grain storage series for the GRDC's *Ground Cover TV*.



GRAIN QUALITY

CHECK: Grain storage checklist. This checklist and guide to grain storage best practice is useful to record site information and keep track of seasonal monitoring activities including fumigation, insect checks, grain-quality testing and aeration cooling. Growers and grain buyers can use the checklist to monitor grain quality management.



SAFETY AROUND GRAIN STORAGE

READ: 'Stay safe around grain storage' fact sheet. This guide aims to provide a safe workplace for everyone on the farm, including workers, contractors, families, visitors and the owner/managers. The fundamental approach to grain storage safety is the same as for all other farming activities. Safety is a three-step process: identify hazards, assess risk and address the hazard.

WATCH: 'Stay Safe around Grain Storage' video.



GRAIN STORAGE FACILITIES

READ: *Grain Storage Facilities: Planning for Efficiency and Quality* booklet. This grains industry guide outlines what factors growers should consider when selecting the right storage structure for their business – whether it be silos, storage bags or sheds – including capacity, construction, life span, pest-control options, health and safety considerations, proximity to harvest location, loading/unloading options, and cleaning and maintenance factors. The guide includes a checklist for buying silos.



ECONOMICS OF GRAIN STORAGE

CALCULATE: *Economics of On-farm Grain Storage: Cost-Benefit Analysis* booklet. As growers continue to expand on-farm grain storage, the question of economic viability gains significance. To make a sound financial decision, growers need to compare the expected returns from grain storage with expected returns from other farm business investments, such as more land, equipment or paying off debt. By calculating the costs and benefits of on-farm storage, growers can identify a return-on-

investment figure to compare with other investment choices. An Excel template is available for personalised cost-benefit calculations to compare different storage types or varying storage scenarios.



INSECT CONTROL

READ: 'Grain storage pest control guide – northern/southern regions and western region' fact sheet. The tolerance for live pests in grain sold off-farm is nil. With growers increasing the amount of grain stored on-farm, an integrated approach to pest control is crucial. This guide takes growers through strategies such as effective grain hygiene and aeration cooling, which can overcome 85 per cent of pest problems, correct fumigation procedure (in pressure-tested, sealed silos) and monthly monitoring of stored grain for moisture, temperature and pests.



GRAIN HYGIENE AND STRUCTURAL TREATMENTS

READ: 'Hygiene and structural treatments for grain storage' fact sheet. When it comes to controlling pests in stored grain, prevention is better than cure. Grain residues in storages or older grain stocks held over from last season provide ideal breeding sites. Meticulous grain hygiene combined with structural treatments, such as diatomaceous earth, can play a key role in reducing the number of stored-grain pests.

WATCH: Demonstration video by Chris Newman, Department of Agriculture and Food, Western Australia, on how to apply diatomaceous earth to a grain silo for insect control.



STORAGE PESTS AND INSECTS

READ: *Stored Grain Pests Identification – The Back Pocket Guide 2011*. This guide provides a snapshot of common pests found in stored grain in Australia. The tolerance for live storage pests in grain sold off-farm either for the domestic human consumption market or for the export market is nil. With more grain being stored on-farm growers need to identify pests early and monitor – at the very least – monthly. Regular inspection by sieving grain from the top and bottom of silos will provide an early warning of insects present.

GRAIN STORAGE HOTLINE:
1800 WEEVIL (1800 933 845)
www.storedgrain.com.au

Get the latest stored grain information online

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Booklets and fact sheets on all things grain storage

Workshops in all regions covering topics such as:

- Economics of on-farm storage
- Grain storage hygiene
- Aeration cooling or drying
- Managing high moisture
- Fumigation
- Insect pest management
- Managing different storages
- Storage facility design
- Storing pulses and oilseeds

Email info@storedgrain.com.au or phone **1800 WEEVIL** to arrange a workshop with your regional specialist