Managing strongly phosphine resistant rusty grain beetle

By Dr Manoj Nayak, DAFF (Qld) and Plant Biosecurity CRC

The rusty grain beetle (*Cryptolestes ferrugineus*), along with two other species of *Cryptolestes* (*C. pusillus* and *C. pusilloides*) have traditionally been looked at as minor pests of stored grain in Australia. But in recent years, there has been a significant enhancement in the pest status of the rusty grain beetle due to their development of a high level of resistance to phosphine – the key fumigant used by industry to disinfest stored grain.

The strength of this resistance is much higher than that previously reported in Australia for other stored grain pests such as the lesser grain borer (*Rhyzopertha dominica*) and psocids or booklice (*Liposcelis bostrychophila*). While the current registered dosage regimes of phosphine easily control all other established pests, they are not adequate against rusty grain beetles.

Since its first detection in 2007, there has been a steady increase in the incidence of strongly resistant populations of rusty grain beetle. This poses a serious threat to the market access of Australian grain – a market worth around $7 billion annually.

Phosphine is a unique fumigant with several positive attributes including its cheap price, ease of application, versatility and universal acceptance as a residue-free treatment.

Although several alternatives have been developed in the recent past (eg ethyl formate, ethanedinitrile, carbonyl sulfide and sulfuryl fluoride), they fail to match the attributes of phosphine. Moreover, with the imminent phase out of methyl bromide, it is expected that industry will rely on phosphine in the foreseeable future.

For these reasons, the industry focus is now on managing resistance to phosphine. So it is imperative that the current resistance problem in the rusty grain beetle be addressed.

The pathway to manage resistance involves three major stages:

- Measuring the strength of resistance;
- Monitoring pest populations to identify storages where they are emerging; and,
- Developing new fumigation protocols and alternative strategies to control the resistant populations.

How strong is the resistance in the rusty grain beetle?

The Australian grain industry has witnessed the development of strong levels of resistance to phosphine in the lesser grain borer, rice weevils and psocids over the past decade. But these resistance problems are now being managed effectively through development and adoption of new fumigation protocols.

A comparison of these resistant pests with the strongly resistant rusty grain beetle in relation to one of the registered rates is mentioned here to highlight the seriousness of the current problem.

For example, at 25°C and a phosphine dose of 1 mg/L (720 ppm); we require a fumigation period of 18 days to achieve complete control of all life stages (egg, larvae, pupae and adults) of strongly resistant populations of rusty grain beetle. This is more than twice the recommended...
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fumigation periods of eight, seven and five days for the control of strongly resistant populations of psocids, rice weevils and the lesser grain borers (Figure 1).

The long fumigation period – coupled with a very high concentration of phosphine required to manage the resistant rusty grain beetles – poses a number of logistical constraints. These include the maintenance of airtightness in the storage structure, the time constraint during export and the significantly increased cost of labour and resources.

**Where are they a problem?**

Australia’s unique national phosphine resistance monitoring program (run by PBCRC through DAFF Qld, NSW Department of Primary Industries and the Western Australian Department of Agriculture) has again proved its importance with the first detection of the strong resistance in the rusty grain beetle in 2007 in a large grain handling facility in northern NSW.

Since then, more than 100 populations of this pest have been diagnosed with strong resistance across all of the grain growing states of Australia except for Western Australia; although a

**FIGURE 1:** Time required for 720 ppm (1 mg/L) of phosphine at 25°C to achieve population extinction (mortality of eggs, larvae, pupae and adults) of strongly resistant populations of key stored grain pests

| RGB – rusty grain beetle (*Cryptolestes ferrugineus*); PSO – psocids (*Liposcelis bostrychophila*); RW – rice weevil (*Sitophilus oryzae*); LGB – lesser grain borer (*Rhyzopertha dominica*). |

**FIGURE 2:** Recent trend in strongly phosphine resistant populations of rusty grain beetle (*Cryptolestes ferrugineus*) in central storages in Australia
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weaker resistance is widespread in all grain growing regions (refer to map, Figure 2).

Strong resistance problems seem to be more prevalent in the bulk handling sector, which accounts for 97 per cent of the incidences compared with only two per cent on-farm.

**Development of a ‘quick test’ for same day diagnosis of strong resistance**

PBCRC research has resulted in the development of a ‘quick test’ being established that exposes rusty grain beetles to a high dose of phosphine and provides results within six hours of insects being delivered to laboratories for resistance diagnosis.

This test involves the exposure of adult insects to 1440 ppm (2 mg/L) of phosphine; which knocks down non-resistant insects in only 30 minutes and weak resistant insects within five hours. Any insects surviving five hours at this dose are diagnosed as strongly resistant.

This has been a major innovation considering that the previous diagnostic test required at least a 20 hour exposure period before final diagnosis could be assessed. The new test provides same day advice to the storage operators enabling them to pursue eradication strategies faster.

**Sulfuryl fluoride as an alternative to phosphine**

With the failure of the currently registered rates of phosphine, PBCRC researchers are developing sulfuryl fluoride (SF) as an alternative fumigant to manage strongly phosphine resistant rusty grain beetles. Research on developing effective fumigation protocols and their validation through large-scale field trials has delivered excellent results that support the potential of SF in managing this strong resistance problem.

Key findings include:

- The current registered rate of 1500 CT (concentration x time) of SF controls all resistant pests in Australia including the strongly resistant rusty grain beetles;
- A single fumigation with SF protects the grain in a bunker for at least three months from reinfestation; and,
- There has been a sharp decline in rusty grain beetle infestations in bulk storages after the adoption of SF by industry in 2010 (Figure 3).

**The eradication plan**

An action plan integrating all available strategies has been developed collaboratively under the PBCRC umbrella by grain bulk handling companies, NSW DPI and DAFF Qld aimed at eradicating infestations of resistant rusty grain beetle and preventing their spread. This plan involves the following components:

- If infestations detected at port, treat with methyl bromide;
- If infestations detected in bunkers (pad storages), treat with SF but do not use SF repeatedly on the same bulk and use this fumigant as a ‘resistant breaker’ only;
- If infestations detected in country depots, where permitted, use a registered; contact insecticide (eg chlorpyrifos-methyl or fenitrothion);
- Treat freshly harvested grain with a registered contact insecticide (eg chlorpyrifos-methyl or fenitrothion) to provide at least six months protection in storages with a history of reinfestation;
- Undertake an intensive hygiene program in all storages that includes detailed cleaning and structural treatments; and,
- Continue monitoring of insect populations through inspection, sampling and trapping and forward insects that survive treatments to DAFF Qld and NSW DPI for resistance testing.

**To sum up**

One key feature making phosphine a successful fumigant is that it can still control resistant populations if we alter its dosage regimes (concentration and exposure period). This has proven successful in managing strong resistance in the lesser grain borer and psocids over the past decade in Australia.

While developing an alternative fumigant such as SF to mitigate the current resistant problem of rusty grain beetles, we are also developing new phosphine fumigation protocols to enable industry to extend the usefulness of this important fumigant.

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