DPI&F note

Grain storage – resistance to phosphine fumigant

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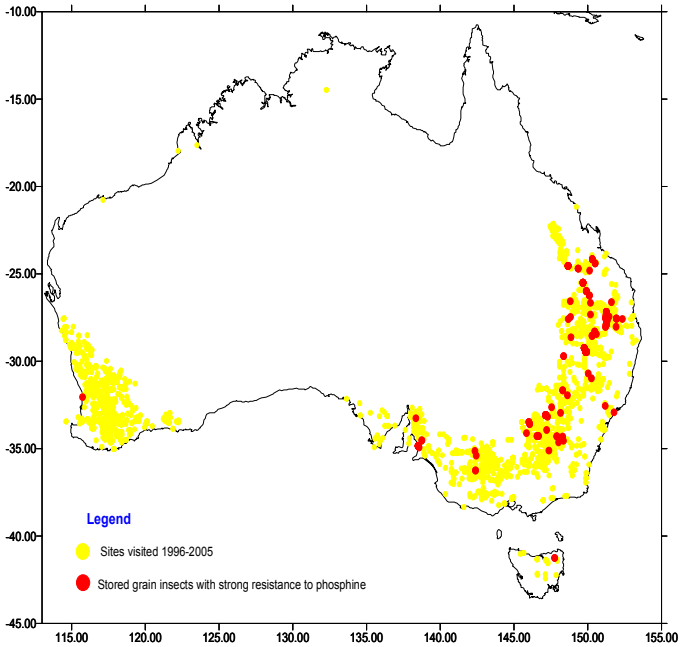
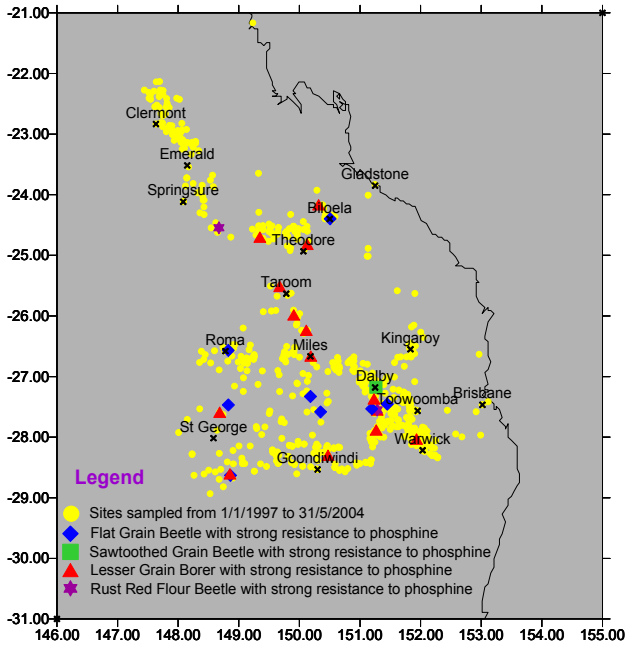
Importance of phosphine

Australia's grain industry relies heavily on phosphine fumigation to meet market requirements for insect free grain. About 80% of Australia's cereal grains are treated by phosphine fumigation. Alternative treatments are more expensive and some are not as widely accepted by markets.
Prolonging the effective life of phosphine is in the interests of everyone involved in the grains industry, including growers, handlers and merchants.

Importance of insect resistance to phosphine

Resistance is a threat to the future effective use of phosphine. Weak resistance to phosphine has been common in Queensland for a decade. Strong resistance has been identified, and is widespread, but not yet common.





What are the observed trends in resistance development so far?

The frequency of strong resistance to phosphine is increasing in four of the five major insect pest species. This resistance was first detected in 1997. About 5% of insect populations contain individuals with this strong resistance.
Strong resistance occurs throughout Eastern Australia but has not yet been detected as endemic in the Western grain region. The highest level of resistance occurs in the lesser grain borer (l.g.b.) *(Rhyzopertha dominica)* and

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DPI&F's Food Protection Team have based our new recommendation for use of phosphine on this l.g.b. resistance.

Several resistant strains of tiny grain pests called psocids have been found, particularly in South Australia. We expect that the number of resistant insects found will increase rapidly over the next five years. Resistance is likely to appear in all grain growing areas in that time.
To understand the importance of resistance, you need to understand how phosphine works. Phosphine is usually applied as aluminium phosphide tablets. These react with moisture in the air to release phosphine gas in a day at high temperatures, or over as long as 4 days at low temperatures. The gas moves around by diffusion and in air currents inside the silo.

The cause of resistance to phosphine

The cause of insect resistance to phosphine is the widespread practice of fumigation in unsealed silos, in farm storages, and in merchant and bulk handling storages. This results in frequent exposure of insect populations to sub-lethal dosages, allowing the rare individuals with a new resistance gene to survive treatment and continue breeding, passing on their resistance. Repeat fumigations favour the insects that carry the resistance gene, by allowing them to survive, but kill normal, susceptible insects.

Resistance and unsealed silos

As phosphine moves around, it leaks rapidly from silos that are not sealed to be gas-tight (Figure 1). Susceptible adult insects are killed quickly, usually within a day. However, immature insects in the egg and pupal stages are tolerant of phosphine and survive the short exposures to high concentrations of phosphine in unsealed silos (Figure 1). Strongly resistant adults can also survive fumigations in unsealed silos.

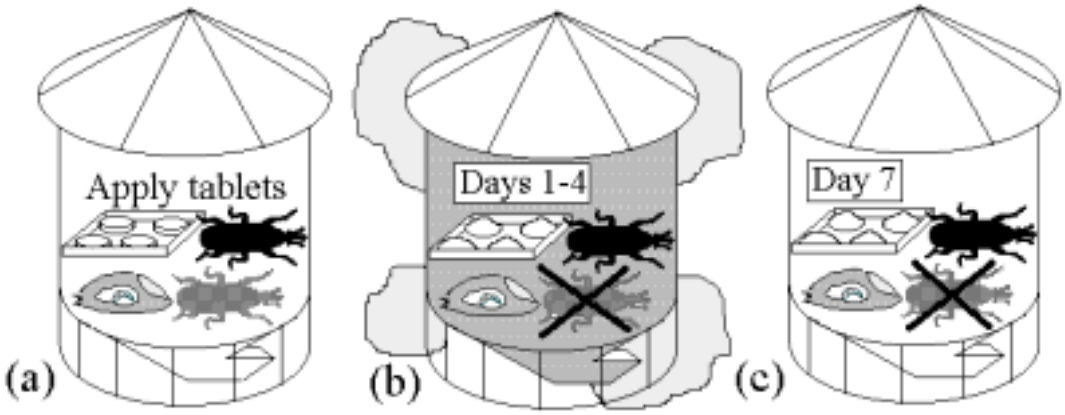

Figure 1. Phosphine fumigation in an *unsealed* silo: (a) Application of phosphine tablets in a silo with live weevils and immature weevils (eggs, larvae, pupae) inside the grains; (b) During the first few days, tablets react to release phosphine gas that kills susceptible adult weevils (grey) quickly, but not the eggs and pupae nor resistant adults (black), and the gas leaks out of the silo; (c) After 7 days little phosphine remains, and the eggs, pupae and resistant adult weevils survive.

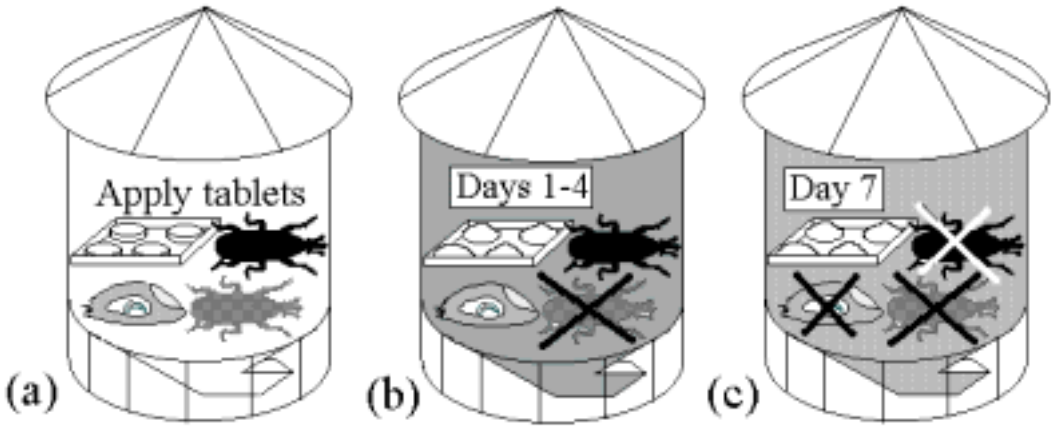

Figure 2. Phosphine fumigation in a *sealed* silo: (a) Application of phosphine tablets in a silo with live weevils and immature weevils (eggs, larvae, pupae) inside the grains; (b) During the first few days, tablets react to release phosphine gas that kills susceptible adult weevils (grey) quickly, but not the eggs and pupae nor resistant adults (black); (c) After 7 days phosphine remains in the silo at a high enough concentration to kill the eggs, pupae and resistant adults.
Phosphine fumigation in unsealed silos can give the appearance of success by killing susceptible adults. But when strongly resistant insects are present, **phosphine fumigation in an unsealed silo will have *virtually no effect*** on the insects.

Resistance and sealed silos

Silos that are sealed well enough to pass a pressure test (see GRDC Advice sheet 'Sealed Silos Save') hold a high enough concentration of phosphine for long enough to kill all stages of the insects, including resistant insects. ***Fumigation in sealed silos is a solution to the phosphine resistance problem emerging in Australia***.

A modern sealed silo, equipped with pressure relief valve and aeration. The pressure relief valve can be used to periodically test the integrity of the silo's seals.
It is impossible to kill phosphine resistant insect pests in stored grains in **un**sealed silos.

Slowing development of resistance

- You can affect the build up of resistance by adopting an Integrated Pest Management (IPM) approach to grain insect control, by close management of moisture content and temperature of grain in storage - the cooler and drier the grain, the less insects like it, by maintaining strict hygiene standards in grain handling equipment and storage facilities. These non-chemical pest management components greatly reduce the threat from insects and take pressure off fumigants (and protectant insecticides also) in the overall pest management programme.
- Use phosphine appropriately. It is simply **impossible with an unsealed storage**, to ensure adequate phosphine concentration and exposure time for killing all stages of the insect pest's life cycle. Some of these are concealed within the individual grains and are thus less susceptible to phosphine, unless it's used properly. **There is also no chance of killing resistant insects in an unsealed silo**. Even though the grain industry has to cope with strong phosphine resistance, Australian research has shown that resistant insect populations can be controlled in sealed storages. Investment in sealed, aeratable storages is essential for today's graingrower who is storing more grain for longer periods on-farm.
- Our researchers must strive to identify and test new chemical treatments.
- Limit insect populations by appropriate management of grain moisture and temperature using aeration and/or hot air drying while in storage.

Carbon dioxide can be used as an alternative fumigant to control phosphine resistant insects but it costs 5-10 times as much as phosphine, and also requires a sealed silo.

Alternative control options should be used in unsealed silos. These could include aeration cooling and/or protectant insecticides to prevent or slow development of insect infestations, and spraying grain with dichlorvos to kill insects in the grain.

What does the future hold?

- Based on our Australian and overseas experience, resistances can be expected to become more serious and widespread.
- Scientists are trying to improve their understanding of the mechanism of resistance development using the latest "biotech" techniques. With grain industry support through GRDC, University of Queensland scientists are searching for a "rapid test" for phosphine resistance.
- We'd like to retain phosphine as a principal fumigant for the foreseeable future because of its low cost, its ease of use and its acceptance by all markets, ie, there is no ready alternative.
- We will see wider investment by the grain industry in sealed, aeratable silos. This is aimed at improving the effectiveness of phosphine useage. Some Australian manufacturers have already reported a marked increase in demand for such silos from graingrowers in recent years.
- The Australian grain industry will adopt a "Food Production " ethos in the management of grain production and marketing. There is a widespread trend overseas towards 'identity preservation' and Quality Assurance 'QA'.
- We will continue to investigate and develop new fumigants (and protectant insecticides) for industry adoption. For example, a new fumigant, "Vapormate" (ethyl formate and CO2 mix), is currently under development by BOC and CSIRO. There are other fumigants also under investigation, but are expected to be more expensive and more complex to apply than phosphine products currently in widespread use in Australia.

Further information

DPI&F Call Centre open from 8.00am to 6.00pm Monday to Friday (telephone 13 25 23 for the cost of a local call within Queensland; interstate callers 07 3404 6999) or email callweb@dpi.qld.gov.au

For information on control methods for stored grain pests, see DPI&F Note 'Grain Storage - insect control in stored grain', at WWW.dpi.qld.gov.au/fieldcrops/3947.html .■