On the brink of high resistance to phosphine

By Pat Collins[1]

A phosphine resistance monitoring program supported by the GRDC, was initiated in the early 1990s because of the ease with which grain insects became resistant to protectants. It was also because high levels of resistance to phosphine had been reported from India and Bangladesh. In addition, some level of resistance had already been detected in insects from Australia.

At that time the level of resistance was not regarded as a threat to control. But the Australian industry needed early warning of the 'Bangladesh' levels of resistance which appeared to be at a concentration that could threaten control.

Briefly, the method used has been to collect samples of insects from farms, central storages and grain merchant premises. These insects are then subjected to a 'discriminating dose' of phosphine that separates resistant from susceptible insects, and a second dose that separates known moderate or 'weak' resistance from higher levels of resistance.

Resistance levels and frequencies

In 1992 the frequency of weak resistance in the GRDC Northern region (northern NSW and Queensland) was already high at around 50 per cent of samples tested containing resistant insects (across five species being tested).

During the 1990s, the frequency of resistance steadily increased in all species as the grain industry came to rely more and more heavily on phosphine. The most rapid increase in frequency was in the lesser grain borer and in 1997 a new level of resistance (never seen before in Australia) was detected in this species.

Then in 2000, this stronger resistance was also detected in two further species – the rust-red flour beetle and the saw-toothed grain beetle, and finally, in 2007, it was detected in the flat grain beetle.

The last is an extremely strong level of resistance and we are concerned that it will threaten control with phosphine.

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AT A GLANCE…

- Phosphine resistant insects can be controlled but only by fumigating in a sealed silo.
- Fumigating in unsealed silos selects for resistance by allowing resistance 'carriers' to survive, interbreed and with further selection (exposure to phosphine) produce the very high two-gene resistance. Therefore…
- Do not repeat fumigate the same grain (which will contain the same insect population).

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Two gene resistance

Detailed research on resistance in the lesser grain borer indicated that two major genes control phosphine resistance and that both genes need to be present to express the 'strong' resistance. Individually, each factor produces a relatively weak resistance but when they are together in the same insect they work together to produce a very high resistance.

We also found that the resistance is close to recessive. This means that insects with one copy of the resistance (heterozygotes or 'carriers') carry the gene but do not express the resistance strongly. So for resistance to be fully expressed an individual must have both copies. And for strong resistance to be expressed an insect must be homozygous for both genes, that is, it must have both copies of both genes.

How is phosphine resistance selected?

When resistance genes first appear in a population they are rare and 'resistant' individuals carry only one copy. These insects have only a low level of resistance but it is enough to survive low doses of phosphine. This occurs for example, when phosphine is used in unsealed silos. The gas concentration is high enough to probably kill many susceptible insects but it also allows heterozygotes to survive.

These heterozygotes then become relatively more common and eventually they will breed with each other and produce homozygous resistant insects. Further fumigations continue to purify the insect population so that we end up with almost purely resistant strains.

Resistance monitoring has shown that this selection process has gone on in the northern region to the point where almost every strain we test has insects with at least one of the resistant genes. Insects with two copies of both genes are still relatively rare (about five per cent of samples) but we are on the brink of them becoming much more common.

How strong is 'strong' resistance?

Highest resistance levels occur in two species, the lesser grain borer and the flat grain beetle. Resistance was first detected in the lesser grain borer so this is the one we know most about. Through extensive laboratory work and field trials we have been able to characterise the resistance and understand what concentrations and exposure periods are required to control the insects.

We have also been measuring gas concentrations achieved in farm bins. This was to find out if growers are able to control resistant insects in their storages. We found that even strongly resistant insects cannot survive a fumigation undertaken in a sealed silo.

But fumigations in unsealed silos or in sealable silos where the seal was not properly maintained could not reach concentrations high enough for a long enough time period to control resistant insects. These fumigations run the risk of selecting for resistance.

Late in 2007 we detected strong resistance in the flat grain beetle. This is the highest resistance detected in any species and seems similar to the worst resistances reported from southern China.

Can we control highly resistant insects on-farm?

So the question is: Can we control these insects on farm? We don't yet have a complete answer but I can tell you about the information we have so far.

Early work is suggesting that it will take about 14 days at 400 ppm or about 25 days at 200 ppm at 25°C to completely control strongly resistant flat grain beetle.

These concentrations are easily achieved in sealed silos – but maintaining the concentration for such a long time is difficult. The gas retention characteristics of sealed silos vary greatly. When fumigating wheat, some silos will maintain 400 ppm for only 10 days while others will hold that concentration for 20 days.

This means that some fumigations, even in sealed silos, will control resistant insects while others may not.

On the positive side, concentrations of at least 600 ppm and up to about 1000 ppm are typically reached in sealed silos and because phosphine toxicity is additive, this extra amount of phosphine will help to reduce the time required for a successful fumigation.

If strongly resistant flat grain beetle becomes common on farms, it will mean that phosphine fumigations will be at least 16 days and growers will need to be measuring gas concentrations to ensure that effective concentrations are reached.

Strongly resistant flat grain beetle is something we don't want on farms. My recommendation for the present is to fumigate only in a sealed silo and that way avoid the selection of these strongly resistant insects.

Fumigation in sealed silos will help avoid the selection of strongly resistant storage insects.

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