Resistance to phosphine in stored grain insects from farm storages in south-eastern Australia: 2016

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Key findings

- Almost 20% of all stored grain insects collected had strong resistance to phosphine.
- Rusty grain beetle resistance is the most serious, as it is beyond label rates to control.
- Strong resistance in lesser grain borer is the main problem in New South Wales; rice weevil in South Australia.

Background

Most Australian grain markets demand that all stored grain is free of live insects. Currently, there are limited options available for controlling insect pests, and all now require sealed, gas-tight storages, which might be limited on some farms.

Phosphine, a fumigant, is the most commonly used, with over 80% of stored grain treated with this product. This product is cheap, considered to be residue-free (meaning it is accepted by most markets), effective at controlling all life stages of all major stored grain pests and does not require a licenced fumigator. However, over-reliance on this product has led to the development of resistance in all the major stored grain pests.

There are two levels of resistance to phosphine: weak and strong, and the strengths of these differ with insect species. Currently, phosphine label rates are sufficient to control all life stages of strong resistant pests of all the major pest species, except the rusty grain beetle (RGB – *Cryptolestes ferrugineus*). NSW DPI first detected strong resistance in this species in 2006. It primarily evolved through repeated fumigations in non-gas-tight storages. Given that weak resistance is currently found in virtually all stored grain beetle populations, this study concentrated on detecting strong resistance.

This project was part of a national study that ran for nearly 20 years. The aim of these projects was to monitor and detect strong resistance to phosphine in the five major stored grain beetle pests, as well as record all details that might have led to any development of resistance, in order to control these outbreaks, develop a phosphine resistance management strategy and, consequently, prolong the life of this fumigant.

This study concentrates on the results from south-eastern Australia for 2016 and, as it was the final year of the project, relates the data to those of the past decade in order to provide an insight into the future of phosphine resistance.

Methodology

This study concentrates on strong resistance to phosphine in the five major stored grain beetle pests of south-eastern Australia: lesser grain borer (LGB – *Rhyzopertha dominica*), rice weevil (RW – *Sitophilus oryzae*), flour beetle (FB – *Tribolium castaneum*), saw-toothed grain beetle (SGB – *Oryzaephilus surinamensis*) and rusty grain beetle (RGB – *Cryptolestes ferrugineus*).

The majority of insects were obtained from randomly selected farm storages throughout the grain-growing regions of southern NSW (south of Dubbo), Victoria and South Australia. In addition, a small number of growers sent some samples. Farms were selected by driving around a district and calling in when silos were observed. Permission was obtained before any sampling.

To check for insects, approximately 1–2 kg of grain was extracted from the base of a silo, sieved and any live insects transferred to a plastic jar along with some untreated grain. Information was recorded on the storage, how long the grain had been stored and any chemical treatments applied to the grain. The insects were then transported to the entomology laboratory at Wagga Wagga Agricultural Institute where they were separated into species, provided with unique identifier numbers and cultured on the appropriate feed. Populations were considered separate if they were sourced from different storages (e.g. different silos). Consequently, one site may have multiple populations.

Once sufficient numbers were cultured, phosphine bioassays were conducted by placing 50 individuals in a plastic cup with air holes, and placing this in a desiccator. A known, discriminating dose of phosphine gas was then injected into the sealed desiccator. The gas was generated from phosphine tablets. Replicates, reference strains and controls (desiccators without any gas added) were included to ensure fidelity of results. After the specified exposure duration to the gas, insects were assessed as alive or knocked down. A population was defined as strongly resistant if any insect survived the high dose. Where possible, survivors were cultured and the population re-assessed to confirm the results.

Results

Species composition

During 2016, a total of 437 insect populations were collected from 145 farms throughout south-eastern Australia (35 NSW, 32 Vic, 78 SA) (Figure 1). In addition, there were a further 54 farms (12 NSW, 13 Vic, 29 SA) where no insects were found. The two main species collected were LGB and FB, comprising 33.4% and 24.5% of the samples, respectively.

Species composition was relatively similar across the three states, with no association between state and species collected (Chi-square: $P = 0.112$, DF = 8) (Figure 2). However, species composition can change from year to year as well as regionally, as was found in 2006 when RW was the dominant species collected from both Victoria (25.8%) and South Australia (45.2%), while FB was the primary pest in NSW (30.9%).

Phosphine resistance

When all species were combined, 18.3% of the 437 populations tested were found to have strong resistance to phosphine (Figure 3). This was a significant increase from 2011 and 2006 when resistance levels were 7.8% (590 populations) and 3.0% (167 populations), respectively. The highest levels were found in SA (22.6% of 261 populations), closely followed by NSW (19.6% of 97 populations). Victorian farms were much lower, with only 2.5% of the 79 populations detected with strong resistance to phosphine.

Looking at individual species, FB and RW had the highest proportions of strong resistance in 2016, with 27.1% and 26.2%, respectively, followed by LGB (19.9%), RGB (7.5%) and SGB (2.53%) (Figure 3). This was due to the high concentration of strong resistance found amongst SA populations (FB 39.4%; RW 37.2%). In contrast, in NSW, LGB and RGB, with 40.5% and 11.1% of populations strongly resistant respectively, were the species with the highest proportion of strong resistance. Only low levels of resistance were detected in Victoria (LGB: 4.4% and FB: 4.6%).

The proportion of strong resistance to phosphine throughout south-eastern Australia has increased since 2011 in all species except SGB; most notably in LGB, with an almost 500% increase. In 2006, the proportion of strong resistance detected was below 5% for all species except RGB. This was the year when strong resistance to phosphine in RGB was first detected in Australia, and none had yet been found in RW.

Summary

The abundance of strong resistance to phosphine in stored grain beetle pests on farms is both increasing and spreading. Almost 1 in 5 populations tested were detected with strong resistance to phosphine throughout south-eastern Australia. While detections in Victoria remained low, both NSW and SA experienced a notable increase.

The fact that, with the exception of RGB, all species, even ones with strong resistance, should be able to be controlled by current phosphine label rates implies that many current fumigation practices are not being performed according to the guidelines, most likely in non-gas-tight silos.

It is known that LGB, RGB and FB all fly and have been trapped several kilometres away from any grain source. This implies that the genes that control resistance are also dispersed over long distances. Australia relies on its reputation for high quality, insect-free grain to obtain premium prices. The spread of phosphine resistance, particularly in RGB, puts this reputation at risk.

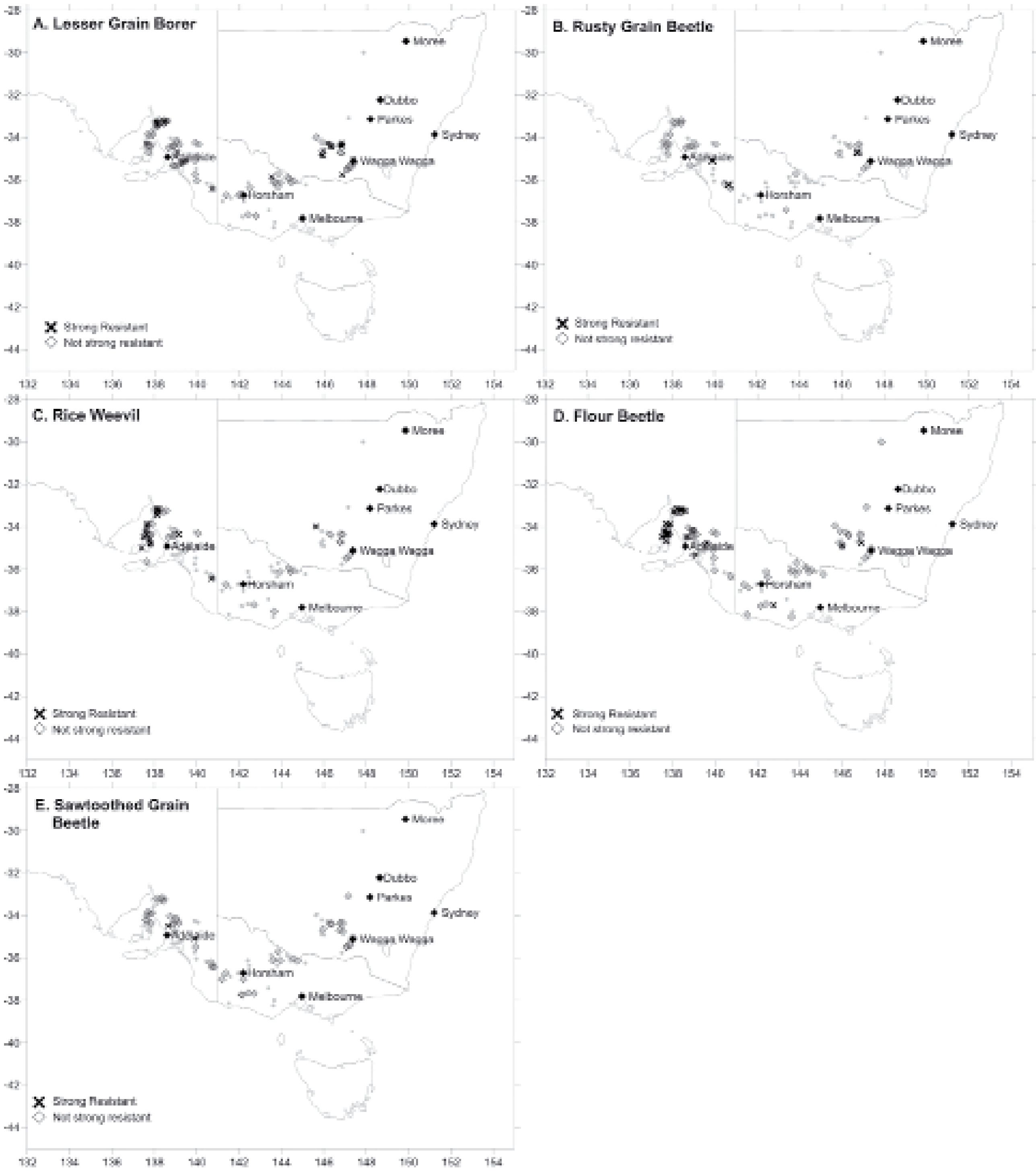

Figure 1. Locations of sampling sites (grey dots) and sites of strong resistance to phosphine in stored grain species: A–lesser grain borer; B–rusty grain beetle; C–rice weevil; D–flour beetle; and E–sawtoothed grain beetle (black ×) from 2016.

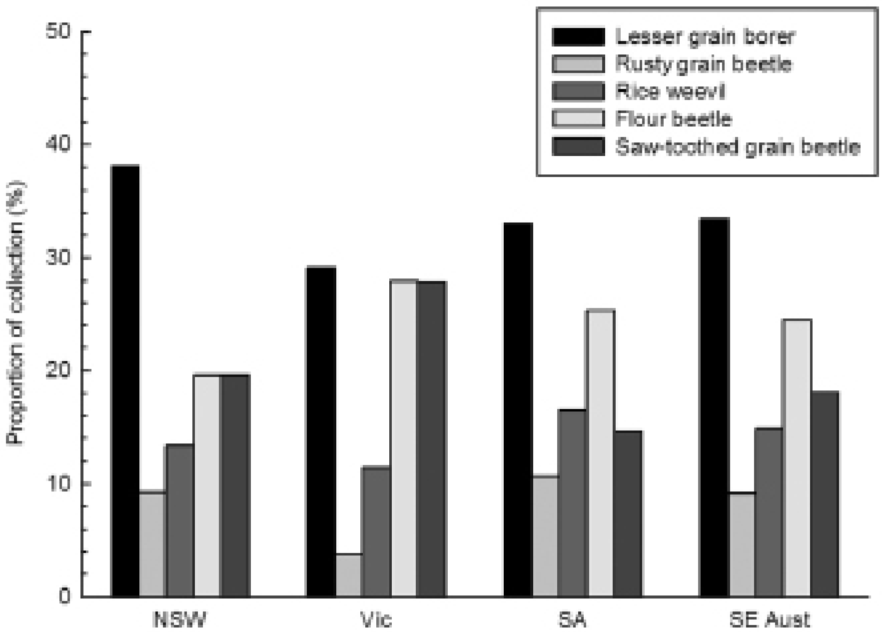

Figure 2. Proportions of stored grain beetle pests sampled from farms throughout south-eastern Australia in 2016.

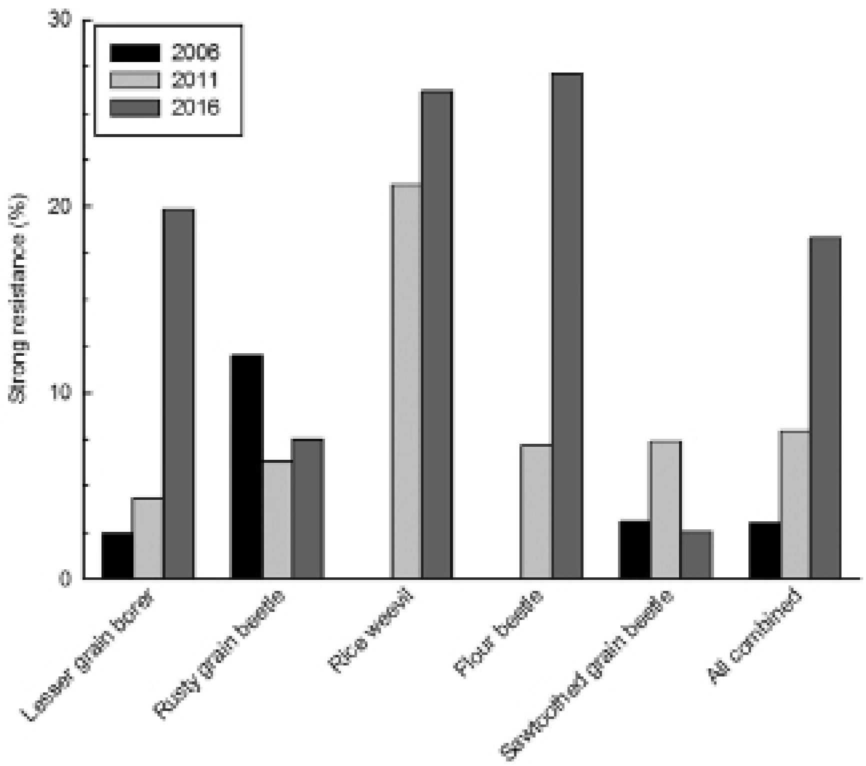

Figure 3. Combined levels of strong resistance to phosphine found in stored grain beetle pests sampled from farms throughout south-eastern Australia in the past decade.

Acknowledgements

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