Resistance to phosphine in stored grain insects from farm storages in south-eastern Australia: 2021

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Key findings

- Approximately 3% of all stored grain insects collected had strong resistance to phosphine – a marked reduction from 18% in 2016.
- Improved hygiene is the probable reason for the observed reduction in resistance.
- Rusty grain beetle resistance remains the most serious issue as it is not controlled by current label rates.

Keywords resistance, stored grain, insects, phosphine, rusty grain beetle, hygiene

Introduction

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 require sealed, gas-tight storages, which are limited on some farms.

Phosphine is the most commonly used fumigant with over 80% of stored grain treated with this product. Phosphine 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 licensed fumigator. However, over-reliance on this product has led to resistance developing in all major stored grain pests.

There are 2 levels of resistance to phosphine: weak and strong. The strengths of these differ with insect species. Currently, phosphine label rates are sufficient to control all life stages of strongly resistant pests of all the major pest species except the rusty grain beetle (RGB – *Cryptolestes ferrugineus*). Our team 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 is part of a national study that has been conducted for over 20 years. The aims of these projects are to monitor and detect strong resistance to phosphine in the 5 major stored grain beetle pests as well as record all details that might have led to any development of resistance. The objective is to control these outbreaks, develop a phosphine resistance management strategy and consequently prolong the life of phosphine as an effective fumigant.

This paper concentrates on the results from south-eastern Australia for 2021 and relates this information to data from the past decade in order to provide an insight into the future of phosphine resistance.

Methodology

This study focuses on strong resistance to phosphine in the 5 major stored grain beetle pests of south-eastern Australia:

1. lesser grain borer (LGB – *Rhyzopertha dominica*)
2. rice weevil (RW – *Sitophilus oryzae*)
3. flour beetle (FB – *Tribolium castaneum*)
4. saw-toothed grain beetle (SGB – *Oryzaephilus surinamensis*)

5. rusty grain beetle (RGB – *Cryptolestes ferrugineus*).

Stored grain insects were collected 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 submitted samples. Farms were selected by driving around a district and calling in when silos were observed. Permission was obtained before sampling and insect surveys were from January 2021 to March 2022. However, due to the time taken to culture the insects to provide sufficient numbers required for the resistance bioassays, the majority of these results are from insects collected from grain harvested in and before 2020.

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 type of 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 (WWAI) where they were separated into species, provided with unique identifier numbers and cultured on an appropriate feed source. Populations were considered separate if they were sourced from different storages (e.g. different silos). Consequently, one site could have multiple populations.

Once sufficient numbers were cultured, phosphine bioassays were conducted by placing 50 individuals in a plastic cup with air holes within a desiccator. A known discriminating dose of phosphine gas, generated from phosphine tablets, was then injected into the sealed desiccator. Replicates, reference strains and controls (desiccators without any gas added) were included to ensure fidelity of results. After the specified gas exposure duration, insects were assessed as alive or dead. 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 2021, a total of 402 insect populations were collected from 139 farms throughout south-eastern Australia (51 NSW, 42 Vic, 46 SA) (Figure 1). In addition, there were a further 125 farms (53 NSW, 48 Vic, 24 SA) where no insects were found. The 2 main species collected were FB and LGB, comprising 32.8% and 28.9% of the samples, respectively. Species composition was relatively similar across the 3 states, with no association between state and species collected (Chi-square: P = 0.09, DF = 8) (Figure 2).

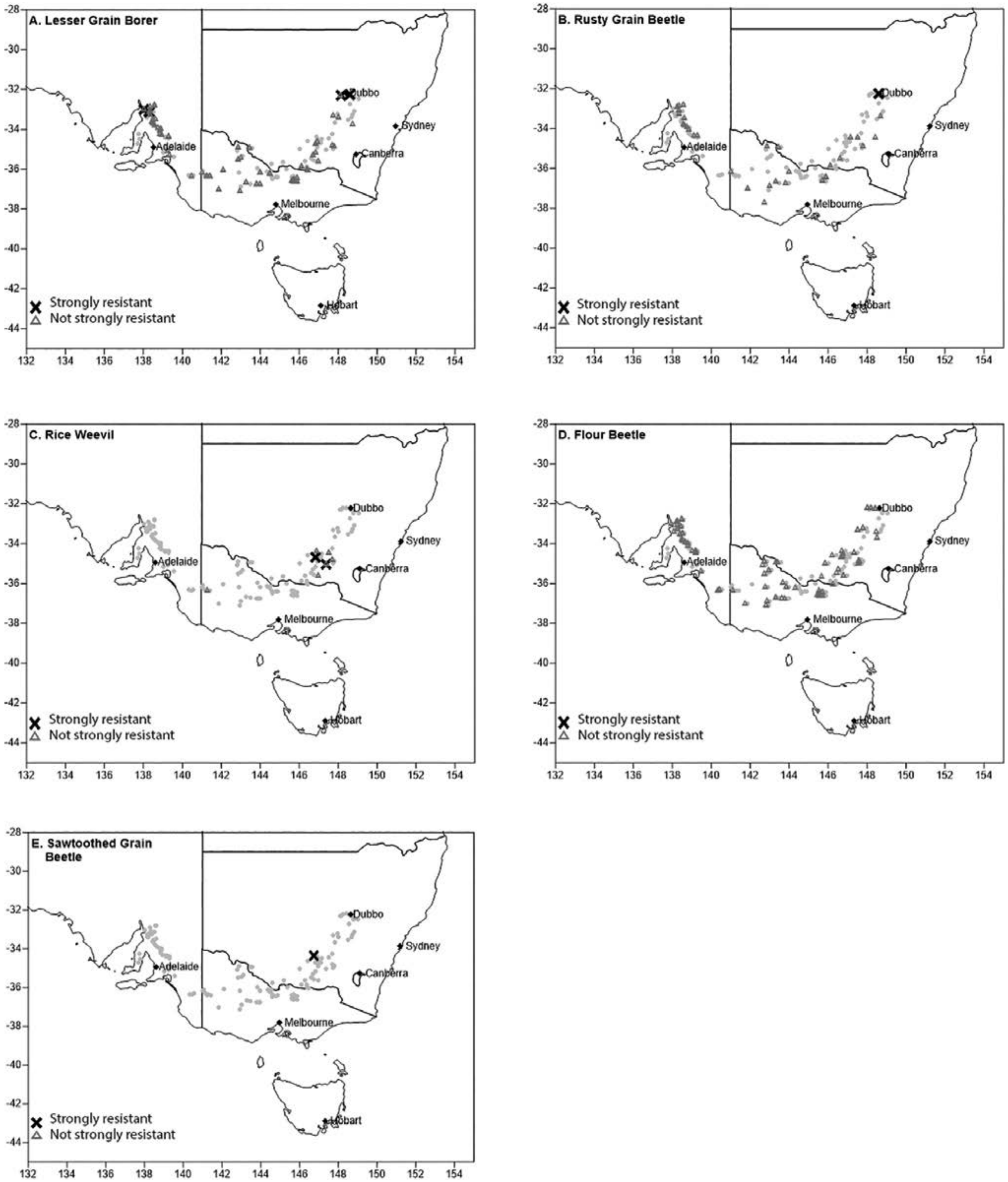

Figure 1 Locations of sampling sites (grey dots) and sites of strong resistance to phosphine in stored grain species (black crosses) from 2021.

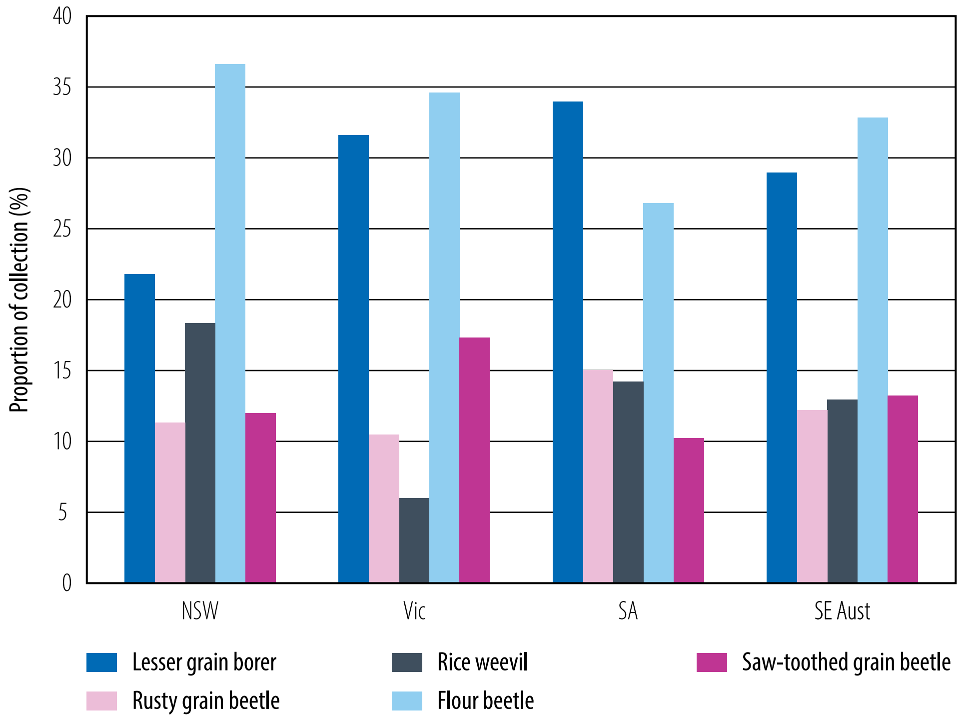

Figure 2 Proportions of stored grain beetle pests sampled from farms throughout south-eastern Australia in 2021.

Phosphine resistance

When all species were combined, 3.2 % of the 251 populations tested were found to have strong resistance to phosphine (Figure 3). This is a significant drop from both 2011 and 2016 when resistance levels were 7.8% (590 populations) and 18.3% (437 populations), respectively. The highest levels were found in NSW (7.7% of 78 populations), followed by South Australia (2.6% of 76 populations). No strong resistance was found in stored grain insects collected from Victoria during 2021.

Looking at individual species, RW and LGB had the highest proportions of strong resistance in 2021 with 25.0% and 5.3%, respectively, followed by RGB (3.1%) and SGB (2.5%). It should be noted that only 8 populations of RW were collected. No strong resistance was detected in FB populations. This contrasts with 2016 when 27% of populations were found to be strongly resistant to phosphine.

The proportion of strong resistance to phosphine throughout south-eastern Australia has decreased since 2016 in all species. Easing drought conditions, high grain prices and the prospect of a bumper harvest resulted in old, stockpiled grain being removed, and silos cleaned and treated before the 2020 harvest. Consequently, potentially resistant insects due to repeated fumigations were removed. Conditions in many parts of south-eastern Australia were very dry before 2016 and a large amount of grain was held on farm for supplemental stock feed. Long-term grain storage often results in an increase in stored grain insect pests. Multiple fumigations on the same parcels of grain and insect populations, if not performed to standard, increases the chance of strong resistance developing. However, by the 2020 harvest, conditions had improved, and a good harvest was expected. This allowed the silos to be completely emptied, cleaned, and treated. Consequently, any insects, resistant or otherwise were removed.

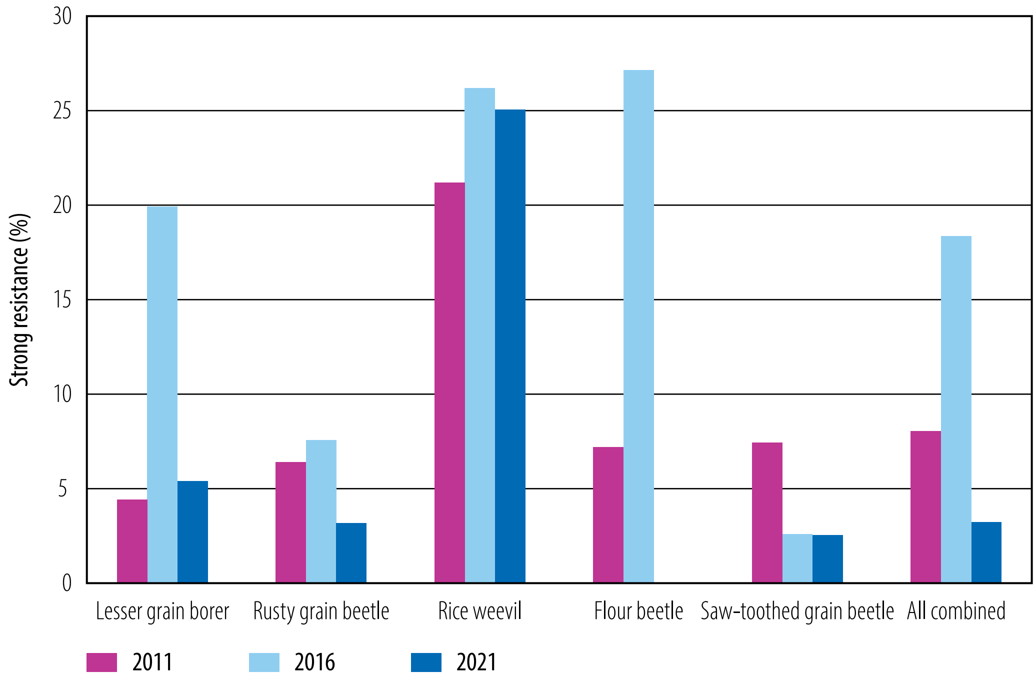

Figure 3 Combined levels of strong resistance to phosphine found in stored grain beetle pests sampled from farms throughout south-eastern Australia in the past decade.

Summary

The abundance of strong resistance to phosphine in stored grain beetle pests on farms has decreased substantially since 2016, most probably due to improved hygiene on farms in anticipation of bumper harvests. The most common species detected with strong resistance to phosphine was LGB. There were no detections of strong resistance in FB populations collected from farms during 2021. The highest number of strongly resistant insect populations were detected in NSW while none were found in Victoria.

If performed correctly, current fumigation label rates will control even strongly resistant populations of all stored grain beetle pests except RGB. Only one population of strongly resistant RGB was detected in on-farm storages in 2021. It is important that strong resistance, particularly in this species is controlled. If left unchecked, live insects might be detected in grain deliveries and subsequently rejected at delivery points.

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