

# Is there a role for spinosad in protecting Australian grain from insects?

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**Abstract.** The potential for using spinosad to protect Australian grain from storage insects is discussed. Spinosad is produced from the metabolic by-products of a soil-dwelling bacterium, and is active against a range of insect species. Studies on relevant susceptible and resistant strains of a range of beetle and psocid pests indicate that spinosad efficacy varies greatly between species. Among the five beetle species tested, spinosad was most effective against *Rhyzopertha dominica* and least effective against *Oryzaephilus surinamensis*. In contrast, spinosad failed against all four psocid species tested. These preliminary results suggest that the most promising use of spinosad would be against *R. dominica*, which has proven very successful in developing resistance to grain protectants. Laboratory experiments suggest that an application rate of 1 mg/kg in wheat may be suitable for controlling *R. dominica* strains that are resistant to organophosphates, pyrethroids or the insect growth regulator methoprene. Studies are needed to establish the efficacy of spinosad during long-term storage.

## Introduction

There is no guarantee that insecticides currently registered for disinfestation or long-term protection of grain will be available in the long term. The major threats to these insecticides are the ability of insects to develop resistance and the potential for deletion of maximum residue limits (Daglish and Wallbank 2002; Wallbank et al. 2002). Insecticides remain important to the grain industry. Insecticides are important in situations where storage structures are not sufficiently gas-tight for effective fumigation or controlled atmosphere storage. In 1998–1999, only 17% of the national storage capacity on farms was estimated to be sealable (Turner et al. 2002) and therefore capable of being fumigated effectively. Although similar estimates are not available for other sectors of the grain industry, grain protectants and dichlorvos are used by most of the bulk handling companies. The search for new grain insecticides is warranted, given the threats identified above and the continued need for insecticides by the grain industry.

One chemical worthy of consideration is spinosad, which is produced from the metabolic by-products of a soil-dwelling bacterium, and which is active against a range of insect species (Thompson et al. 2000). Spinosad is a ‘soft’ chemical in the sense that it degrades rapidly in the environment and has minimal impact on non-target organisms (Thompson et al. 2000). Studies in the United States of America on several species of insects show that, among stored grain insects, spinosad is particularly effec-

tive against *Rhyzopertha dominica* (F.) (Fang et al. 2002a,b; Toews and Subramanyam 2003). Although spinosad breaks down quickly in sunlight, limited published data suggest that spinosad in stored grain will be stable and loss of efficacy will be negligible (Fang et al. 2002b). In this paper we report preliminary findings on the efficacy of spinosad against representative strains of beetles and psocids, and discuss the potential for spinosad in the Australian grain storage system.

## Materials and methods

### Insects

The test strains used and their resistance characteristics are summarised in Table 1. *R. dominica* and *Sitophilus oryzae* (L.) were reared on wheat, *Tribolium castaneum* (Herbst) was reared on whole wheat flour + yeast (20:1 wt:wt), *Oryzaephilus surinamensis* (L.) was reared on rolled oats, and *Cryptolestes ferrugineus* Steph. was reared on rolled oats + yeast (10:1 wt:wt). Psocids were reared on a wheat-based medium (Nayak and Collins 2001). Rearing conditions for beetles were 25°C (*S. oryzae* strain QLS2) or 30°C and 55% relative humidity (RH), and psocids were reared at 30°C and 70% RH.

### Grain treatment

Spinosad (22.8% a.i.) was diluted with deionised water before being applied to wheat at the rate of 10 mL/kg. Wheat with a moisture content of 11% was used in order

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to achieve moisture content of 12% after the application of the insecticide solution. The diluted spinosad was applied to each jar of wheat by spiraling the pipette around the inside of the jar just above the surface of the grain. The jars were shaken briefly before being mechanically tumbled for 15–30 minutes until no grain was seen sticking to the sides of the jar. Control grain was treated with water only.

For beetles, the treated and control grain was then placed into 200 mL (*R. dominica* and *S. oryzae*) or 350 mL jars (*T. castaneum*, *O. surinamensis* and *C. ferrugineus*) in amounts of 80 g and 200 g, respectively. For *T. castaneum* and *C. ferrugineus*, 5% of the treated wheat was ground to flour and returned to the jars which were then lightly shaken by hand. For psocids, 10 g of treated or control grain was added to 29.5 mL plastic souffle cups. There were three replicates of each dose and the control. The grain was then held overnight before bioassays were commenced.

### Bioassays

Fifty adult beetles (1–3 weeks post-emergence) were placed into each 80 g or 200 g replicate of treated and control grain. These were held at 25°C and 55% RH for 7 days after which time adult mortality was assessed. The replicates were returned to the controlled temperature room and at 14 days a further assessment of adult mortality was performed. The adults were then discarded and the jars were held at 25°C (*S. oryzae* and *O. surinamensis*) or 30°C (*R. dominica* and *T. castaneum*) and 55% RH for progeny assessment after a further 6 weeks.

Fifty adult psocids (2–4 weeks post-eclosion) were added to each 10 g replicate of treated and control grain. These were held at 30°C and 70% RH for 7 days, then adult mortality was assessed. The live adults were transferred to another fresh batch of treated grain, and 14-day

mortality was assessed 7 days later. The second batch of treated or control grain had been treated at the same time as the first batch. Grain from the first exposure was kept at 30°C and 70% RH and the number of live progeny (nymphs and adults) was counted 3 weeks after removal of the parents.

## Results

### Beetles

Spinosad was more effective against *R. dominica* than other beetles (Table 2). Mortality of *R. dominica* adults in treated wheat increased between the 7- and 14-day assessments, although 7-day mortality was already high (>90%) in all strains at all application rates. The application rate of 0.5 mg/kg resulted in no live adult progeny in three of the four *R. dominica* strains. Although the remaining strain, QRD551, required 1 mg/kg to prevent the production of live progeny, there was almost complete control of progeny at the lower rate of 0.5 mg/kg.

None of the other beetle strains tested was controlled in the adult stage at any application rate. Spinosad was most effective against *C. ferrugineus* with a 14-day mortality of 96.1% at 1 mg/kg. Spinosad was least effective against the two *T. castaneum* strains, with negligible mortality at all rates. The remaining strains of *S. oryzae* and *O. surinamensis* were intermediate in their response to spinosad. In terms of control of progeny, spinosad was most effective against *C. ferrugineus* with no live progeny at 1 mg/kg and almost no live progeny at 0.5 mg/kg. Even at the highest rate (1 mg/kg), spinosad had little effect on the number of live progeny produced by *O. surinamensis* and *S. oryzae*. Despite the low efficacy of spinosad against

**Table 1.** Resistance status of the beetles and psocids tested (OPs = organophosphates).

Species	Strain	Resistance status
Beetles		
<i>Rhyzopertha dominica</i>	QRD14 QRD788 QRD318 QRD551	Susceptible Resistant to OPs Resistant to OPs and pyrethroids Resistant to OPs and methoprene
<i>Sitophilus oryzae</i>	QLS2 QSO393	Susceptible Resistant to malathion
<i>Tribolium castaneum</i>	QTC4 QTC279	Susceptible Resistant to malathion and pyrethroids
<i>Oryzaephilus surinamensis</i>	QOS302	Resistant to malathion and quite tolerant to other OPs
<i>Cryptolestes ferrugineus</i>	QCF31	Susceptible
Psocids		
<i>Liposcelis bostrychophila</i>	LQLB	Unselected
<i>L. entomophila</i>	LQLE	Unselected
<i>L. decolor</i>	LQLD	Unselected
<i>L. paeta</i>	LQLP	Unselected

*T. castaneum* adults of both strains, the number of live progeny at 1 mg/kg was reduced by >80%.

### Psocids

Spinosad failed to achieve complete control of any of the four *Liposcelis* species tested (Table 2). However, it produced very high adult mortality and progeny suppression of *L. entomophila*. At the highest rate of 1 mg/kg, 14-day adult mortality and progeny reduction was >90%. Efficacy against the remaining species was generally very poor irrespective of the rates applied.

## Discussion

Efficacy of spinosad was evaluated against a total of 14 strains from nine beetle and psocid pests of stored grain. Spinosad efficacy varied greatly among the species tested, with *R. dominica* being the most susceptible to spinosad. In an American study, *R. dominica* of unknown resistance status was also found to be very susceptible to spinosad (Fang et al. 2002a), but our results show that, not only is spinosad very effective against susceptible *R. dominica*, but that it is very effective against representative resistant strains. Lower efficacy against *T. castaneum*, *S. oryzae* and *O. surinamensis* reflects American research on strains of unknown resistance status (Fang et al. 2002a). The results for *C. ferrugineus* and the four psocids are new, but indicate lower levels of efficacy than against *R. dominica*. Spinosad was much more effective against *L. entomophila*

than the other psocid species, and this contrasts with results for the currently registered protectants which are much less effective against *L. entomophila* than the other species (Nayak et al. 1998).

The results presented in the current paper suggest that the most promising use of spinosad would be against *R. dominica*, which has proven very successful in developing resistance to grain protectants (Wallbank et al. 2002). Spinosad applied at the rate of 1 mg/kg to wheat controlled all of the *R. dominica* strains tested. In Australia, combinations of protectants are used in order to control a wide range of species. Generally speaking, either a pyrethroid or methoprene is used against *R. dominica*, and an organophosphate is used against the other species, although the pyrethroid or methoprene may have some impact on the other species as well. The susceptibility of *R. dominica* to spinosad suggests that a combination with an organophosphate would be effective against a range of species. This would be advantageous where there are problems with pyrethroid-resistant or methoprene-resistant *R. dominica*, or in other areas where spinosad could be rotated with pyrethroids or methoprene as part of a resistance management strategy.

The results presented in this paper allow only a preliminary assessment of spinosad as a treatment for grain. Experiments are in progress which are aimed at detecting delayed effects such as those exhibited by some insect growth regulators (e.g. Desmarchelier and Allen 1992). There is the need to determine whether spinosad efficacy varies with grain type, as there is no guarantee that

**Table 2.** Mortality and progeny reduction of insects in wheat freshly treated with 1 mg/kg of spinosad.

Species	Strain	Adult mortality (%)		Progeny reduction (%)
		7 day	14 day	
<b>Beetles</b>				
<i>Rhyzopertha dominica</i>	QRD14	99.3	100	100
	QRD788	94.7	100	100
	QRD318	96.0	100	100
	QRD551	100	100	100
<i>Sitophilus oryzae</i>	QLS2	65.8	89.2	47.6
	QSO393	18.7	35.9	24.3
<i>Tribolium castaneum</i>	QTC4	0.7	0.7	98.4
	QTC279	0.0	0.0	81.9
<i>Oryzaephilus surinamensis</i>	QOS302	4.2	9.5	7.2
<i>Cryptolestes ferrugineus</i>	QCF31	81.6	96.1	100
<b>Psocids</b>				
<i>Liposcelis bostrychophila</i>	LQLB	_a	_a	_b
<i>L. entomophila</i>	LQLE	89.0	92.6	95.6
<i>L. decolor</i>	LQLD	26.9	55.5	70.6
<i>L. paeta</i>	LQLP	2.7	10.7	10.5

<sup>a</sup>Mortality in treated less than in untreated grain.

<sup>b</sup>More progeny in treated grain than untreated grain.

spinosad efficacy will be the same on sorghum, barley or other cereals. Experiments are needed to establish the efficacy of spinosad during long-term storage. The only published data on spinosad during storage come from a paper describing trials in farm silos in Kansas, USA (Fang et al. 2002b). In these farm trials, spinosad residues and insecticidal activity against *R. dominica* were stable, although the storage temperatures were generally lower than would be typically encountered in Australia.

## Acknowledgments

This research was supported by the Grains Research and Development Corporation. The sample of spinosad was supplied by Dow AgroSciences.

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