Efficacy of dust formulations of spinosad for controlling insects infesting stored wheat

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Abstract

Laboratory experiments were conducted to compare the efficacy of three new dust formulations (B1, C3, and D1) of spinosad as grain protectants on stored wheat. Evaluations were conducted on grain that was held for 1 d and 12, 24, 39, and 52 wk after insecticide treatments were applied. Bioassays for adult mortality and progeny production were conducted at 28°C and about 65% r.h. Dust formulations B1 and C3 effectively controlled adult *Rhyzopertha dominica* and prevented progeny development for 52 wk while formulation D1 was less effective. Only formulation B1 controlled *Sitophilus oryzae* adults (> 91% parental mortality) but did not prevent progeny production. None of the dust formulations were effective against *Tribolium castaneum* adults but progeny production was lower on grain treated with formulations B1 and C3. Egg mortality of *Plodia interpunctella* was similar for all treatments although overall progeny production was less on grain treated with formulation B1. The type of dust formulation of spinosad is critical in controlling stored grain insects.

Keywords: Spinosad dust formulations, *Rhyzopertha dominica, Sitophilus oryzae, Tribolium castaneum, Plodia interpunctella*

1. Introduction

Alternative insecticides are needed for controlling stored-product pests, especially in raw grain. Spinosad is a broad-spectrum insecticide that is derived from two metabolites of a naturally occurring actinomycete soil bacterium *Saccharopolyspora spinosa* Mertz & Yao and is produced by fermentation (Mertz and Yao, 1990). It is registered by the U.S. Environmental Protection Agency as a reduced risk pest control product and the active ingredient is registered for use on more than 250 different crops.

Laboratory studies (Fang et al., 2002a) have shown that spinosad is highly effective as a grain protectant against several stored grain insect species. ang et al. (2002b) also demonstrated that spinosad residues on wheat placed in mesh pouches and exposed in farm bins for 12 mo degraded very little from the application rate.

The objective of our research was to determine the effectiveness of three spinosad dust formulations as grain protectants applied to wheat on three species of stored grain beetle pests, *Rhyzopertha dominica* (F.) (Coleoptera: Bostrychidae), *Sitophilus oryzae* (L.) (Coleoptera: Curculionidae), and *Tribolium castaneum* (Herbst) (Coleoptera: Tenebrionidae), and one moth species, *Plodia interpunctella* (Hübner) (Lepidoptera: Pyralidae), at five time periods after treatment up to 52 wk.

2. Materials and methods

A total of 2 kg of hard red winter wheat was placed in each of twenty-one 3.8 L glass jars. Seven treatments were tested during this experiment with each treatment having three replications:

a) Spinosad B1 (0.5% w/w; Bayer CropScience) applied at 1 ppm.
b) Spinosad C3 (0.5% w/w; Bayer CropScience) applied at 1 ppm.
c) Spinosad D1 (0.5% w/w; Bayer CropScience) applied at 1 ppm.
d) Secure™ dust (0.5% w/w; Bayer CropScience) applied at 1 ppm.
e) SpinTor® (22.8% w/w; Dow AgroSciences) applied at 1 ppm.
f) Storcide™ II (816.5 g chlorpyrifos-methyl and 140.6 g of deltamethrin per 3.8 L; Bayer CropScience) applied at 3 ppm chlorpyrifos-methyl and 0.5 ppm deltamethrin.
g) Each control received 1.39 g of water only.

Secure is an older dust formulation, Spintor is a liquid formulation of spinosad, and Storcide II served as a positive control.

After application of insecticides or water to the sides of the 3.8 L jars, 2 kg of wheat was added to each jar and the jars were turned end for end 10 times and then rotated a full revolution 10 times. Jars were left to sit on the lab bench for 2 h and then turned and rotated as before. Sealed jars of treated wheat were placed in an environmental chamber maintained at 28°C for storage during the experiment. The experiment had five time periods: 1 d, and 12, 24, 39, and 52 wk post-treatment. Prior to using grain for each period, 3.8 L jars were rotated end for end 10 times before removing wheat for the experiment.

The experimental unit for beetles used in the experiment was a 236.6 mL glass jar containing 100 g of diet. The diet for *R. dominica* and *S. oryzae* was 100 g of whole kernels and jar lids were fitted with a circular piece of US # 40 mesh copper screen sandwiched between two pieces of filter paper. For jars receiving *T. castaneum*, 95 g of whole kernels and 5 g of ground treated kernels were used, and jar lids were fitted with two pieces of filter paper. Ground kernels were obtained by grinding kernels for 30 sec using a laboratory blender. For *P. interpunctella*, the experimental unit was a 25-mL glass vial. Into each vial was placed 2.5 g of whole kernels and 2.5 g of ground kernels. Lids of vials were each fitted with a piece of paper toweling.

For each time period, a total of three replications for each species per treatment were set up. One replication came from the grain in each of 3.8 L jars for each treatment (e.g. three 3.8 L jars were treated with spinosad B1 and 100 g of grain were then taken from each of the three different 3.8 L jars for a given treatment and placed in a 236.6 mL jar). This was repeated for each beetle species. A total of 50 adult beetles were placed on the grain in each 236.6 mL jar. Beetles were approximately 2-3 mo old and obtained from laboratory colonies. A total of 20 *P. interpunctella* eggs that were less than 24 h old were placed on double-sticky tape attached to a strip of black filter paper. Filter paper strips were then placed on the grain in the vials. Three replications for each treatment were conducted. All experimental units were placed in an environmental chamber maintained at 28°C and about 65% r.h. with a photoperiod of 16:8 L:D.

In each treatment, adult beetles were removed from the jars and counted as live, moribund, or dead after 1 wk of being placed on the grain. Moribund and dead adults were placed in a 9-cm Petri dish containing a piece of filter paper moistened with 0.5 mL of water. These insects were then re-evaluated after 24 h for recovery. Jars were held in the environmental chamber for an additional 6 wk and then progeny were counted. There were two response variables for each treatment: mortality of adults after 1 wk and number of progeny after 6 wk.

Plodia interpunctella eggs in each treatment were evaluated for hatch after 2 wk. At the same time, larvae present were counted and then returned to the vial with the grain. After an additional 3 wk in the environmental chamber, progeny – larvae, pupae, and adults - were counted. There were three response variables for each treatment: mortality of eggs after 2 wk, number of larvae after 2 wk, and number of progeny after 5 wk.

Data were analyzed using the General Linear Models (GLM) Procedure of the Statistical Analysis System (SAS, 2007), with adult beetle mortality, beetle progeny production, moth egg mortality, and moth survivors as the response variable and treatment as the main effect. Percentage data for adult beetle mortality and moth egg mortality were transformed (arcsin sqrt [%/100]) before analysis.

3. Results

Spinosad dust formulations B1 and C3 effectively controlled adult *R. dominica* and prevented progeny development for 52 wk while formulation D1 was less effective (Tables 1 and 2). One hundred percent control was observed for adult *R. dominica* for treatments B1 and C3 for all post-treatment time periods except for grain treated with C3 at 24 wk post-treatment where the adult mortality was 99.3%. There were no *R. dominica* progeny produced on grain treated with B1, Secure, Spintor, or Storcide II at post-treatment periods of 12, 24, 39, and 52 wk (Table 2). Progeny production on grain treated with C3 was < 1.0 for the same time periods. On grain treated with D1, progeny production varied from 18.0 to 56.7 adults during these post treatment periods.

Table 1 Mean percent mortality (±SE) of adult beetles exposed for 7 d to various spinosad formulations at 52 wks post-treatment (n = 3).

Treatment	*T. castaneum*	*R. dominica*	*S. oryzae*
Control	1.4 ± 0.7 b	4.8 ± 3.8 c	0 c
Storcide II	6.9 ± 0.6 a	96.0 ± 1.2 b	91.8 ± 4.8 ab
Spintor	0 c	100 a	96.7 ± 2.4 a
Secure	1.4 ± 0.7 b	100 a	79.3 ± 9.7 b
Spinosad B1	0 c	100 a	97.3 ± 0.7 a
Spinosad C3	0 c	100 a	86.0 ± 8.1 ab
Spinosad D1	0 c	100 a	0 c

Means within a column followed by the same letter are not significantly different (P > 0.05; Fisher's least significant difference test). Percentage data were transformed (arcsin sqrt [%/100]) before analysis; untransformed values are presented.

Table 2 Mean progeny (±SE) per 236.6 ml jar of adult beetles exposed for 7 d to various spinosad formulations at 52 wks post-treatment (n = 3).

Treatment	*T. castaneum*	*R. dominica*	*S. oryzae*
Control	82.3 ± 8.1 a	207.7 ± 47.7 a	362.3 ± 19.9 ab
Storcide II	0 b	0 b	13.7 ± 8.1 c
Spintor	0 b	0 b	103.7 ± 59.9 c
Secure	0.3 ± 0.3 b	0 b	320.3 ± 129.4 ab
Spinosad B1	0 b	0 b	75.0 ± 21.0 c
Spinosad C3	1.7 ± 0.3 b	0 b	212.3 ± 86.8 bc
Spinosad D1	89.3 ± 9.8 b	39.0 ± 12.7 b	511.7 ± 60.9 a

Means within a column followed by the same letter are not significantly different (P > 0.05; Fisher's least significant difference test).

Only formulation B1 controlled *S. oryzae* adults above 91% but did not prevent progeny production which ranged from 75.0 to 769.0 during the post-treatment periods. All other spinosad formulations had high numbers of progeny produced at all time periods. Formulation D1 did not cause adult mortality at 24-, 39-, and 52-wk post-treatment. Formulation C3 only resulted in a range of 69.6 to 86.0 % mortality of adults for the duration of the experiment. Overall, Storcide II was the best product for reducing *S. oryzae* progeny production but only achieved 100% control for 1-d and 12-wk post-treatment. Progeny production reached a high of 13.7 adults at 52-wk post-treatment on grain treated with this product.

None of the dust formulations or the liquid formulation were effective against *T. castaneum* adults where mortality was ≤2% at all post-treatment periods. Progeny production was significantly lower on grain treated with formulations B1 and C3 than D1 at all post-treatment periods. Storcide II was the only treatment where no progeny were produced during the entire testing period.

Table 3 Mean percent mortality (±SE) of *Plodia interpunctella* eggs exposed for 7 d to various spinosad formulations at 39 wks post-treatment and mean number of survivors after 4 wks (n = 3).

Treatment	Egg Mortality	Survivors (total larvae, pupae, and adults)
Control	8.3 ± 6.0 a	11.3 ± 0.3 a
Storcide II	11.7 ± 1.7 a	0 c
Spintor	18.3 ± 8.8 a	0.3 ± 0.3 bc
Secure	6.7 ± 4.4 a	3.0 ± 1.5 b
Spinosad B1	11.7 ± 6.7 a	0.7 ± 0.7 bc
Spinosad C3	5.0 ± 2.9 a	5.3 ± 1.2 bc
Spinosad D1	11.7 ± 6.7 a	12.7 ± 1.5 a

Means within a column followed by the same letter are not significantly different (P > 0.05; Fisher's least significant difference test).

Percent egg mortality of *P. interpunctella* was similar for all treatments within a post-treatment period and varied from 3.3 to 36.6% during the study. Progeny production was much lower (≤1%) on grain treated with formulation B1 than formulations C3 and D1 for post-treatment periods 1-d, and 12-, 24-, and 39-wk (Table 3). Storcide II was the only treatment where no progeny were produced until the 52-wk post-treatment period.

4. Discussion

Formulation is a critical factor in the effectiveness of spinosad against stored grain insect pests. Overall, all formulations of spinosad tested were effective in controlling *R. dominica* adults which corresponds to previous studies (Fang et al., 2002a; Nayak et al., 2005). This species is one of the most important stored-product pests to control because it causes insect damaged kernels (IDK). IDK is a discount factor when selling grain so controlling pests that cause IDK is essential in a management strategy. Although not statistically significant, of the new formulations, B1 and C3 prevented progeny production by *R. dominica*. In a management strategy, a grain manager does not want even a few *R. dominica* in his grain so B1 would be the product of choice of the three new formulations.

Sitophilus oryzae was not effectively controlled by any of the spinosad products. However, of the three new dust formulations tested, B1 was the most effective. Athanassiou et al. (2008) also found that *S. oryzae* adults were less susceptible than *R. dominica* adults to spinosad dust containing 0.125% spinosad. *S. oryzae* also causes IDK that affects grain value. Progeny were not reduced in number by any of the spinosad products probably because eggs are laid inside kernels where larvae are protected from pesticide exposure.

Spinosad is not an effective product for controlling *T. castaneum* adults although formulation B1 was more effective than C3 and D1 in reducing the number of progeny. Even Storcide II lost its effectiveness against adults after the 1-d post-treatment exposure and steadily declined during the study. However, Storcide II prevented any progeny production at all post-treatment periods where the spinosad products did not, especially at 1-d, 12-wk, and 24-wk post-treatment periods (data not shown).

For *P. interpunctella*, formulation B1 was better at reducing progeny production than formulations C3 and D1 for the first four post-treatment periods. However, no spinosad formulation was 100% effective in controlling progeny production.

Overall, new dust formulation B1 was more effective than C3 and D1 but it still had its limitations. It was very effective against *R. dominica*, however, it has limited success against the other insects tested during this study. Therefore, an integrated approach is necessary to control a complex of stored grain insects infesting grain.

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