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ONE-YEAR PROTECTION OF STORED WHEAT WITH SEVERAL GRAIN PROTECTANTS

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ABSTRACT

This study was initiated in order to determine how long several grain protectants will provide acceptable protection against *Sitophilus oryzae* (L.), *Rhyzopertha dominica* (F.), and *Tribolium castaneum* (Herbst.), when applied to clean white winter wheat of 13.6% moisture content. The treatments in the experiment were: mixture of diatomaceous earth and deltamethrin (DE/DM insecticide) applied at 100 ppm containing 90 ppm of DE and 0.1 ppm of deltamethrin active ingredient (a.i.); spinosad technical 92% powder applied at 1 ppm a.i.; Storicide II a mixture of chlorpyrifos methyl (CM) and deltamethrin (DM), applied at 3 ppm CM and 0.5 ppm DM a.i.; Actellic 5 E (pirimiphos methyl) applied at 10 ppm a.i. Bioassays were initiated immediately after treatment (zero day), 30, 120, 180 and 360 d after the initial treatment and were maintained at 30±1°C and 70±5% air relative humidity during the twelve months. The treatment of wheat with DE/DM mixture and Storicide II provided effective protection against the adults and the progeny of all three species. Actellic at zero day controlled adults and the progeny of *S. oryzae* and *T. castaneum* (96% to 100%). However it did not control the adults and the progeny of *R. dominica* (38% adult's mortality and 96% progeny reduction). The effectiveness of Actellic on 360 d old deposit on grains was reduced against adults of *S. oryzae* to 12%, *R. dominica* to 45%, and *T. castaneum* to 38% and did not control completely their progeny. Spinosad did not control the adults and the progeny of *S. oryzae* and *T. castaneum* at zero day and 360 d. However, the effectiveness against adults and the progeny of *R. dominica* was 100% at zero and 360 d. The treatment of wheat with DE/DM mixture and Storicide II provided 100% protection against the adults and the progeny of all three species.

Key words: Grain protectants, Storicide II, diatomaceous earth and deltamethrin mixture, Actellic 5E, spinosad, *Sitophilus oryzae*, *Rhyzopertha dominica*, *Tribolium castaneum*, wheat

INTRODUCTION

Integrated pest control (IPM) strategy is used to protect stored agricultural commodities. Different measures are included in IPM strategy such as prevention, monitoring and control (Mueller, 1998). The use of grain protectant insecticides is an important part of IPM strategy. Due to new regulations fewer options are available for providing long term protection of grain (Ignatowicz and Olejarski, 2010). Grain protectants had proven effective against grain insects

when used alone and in a combination (Daglish, 1998; Korunic, 1998; Chintzoglou et al., 2008; Subramanyam et al., 2003). Pesticides residues in food are recognized as a major safety concern (Fishwick, 1988; Fields, 1999).

The objective of this study was to determine if grain protectants Storicide II (mixture of chlorpyrifos methyl and deltamethrin), Actellic 5E (pirimifos methyl), spinosad technical powder and the mixture DE/DM (diatomaceous earth and deltamethrin) applied at registered and recommended concentrations can protect wheat grain during 12 months of storage controlling the adults and the progeny of *Sitophilus oryzae* (L.), the rice weevil, *Rhyzopertha dominica* (F.), the lesser grain borer and *Tribolium castaneum* (Herbst), the red flour beetle.

MATERIALS AND METHODS

Mixed-sex adults of *S. oryzae*, *R. dominica* and *T. castaneum*, 7 to 21 d old, were used in the experiment. *Sitophilus oryzae* and *R. dominica* were cultured on wheat with approximately 14% moisture content (m.c.). *Tribolium castaneum* was cultured on white flour with 5% brewer's un-activated yeast. Insect rearing was conducted at 30±1ºC and 70±5% air relative humidity (r.h.). Un-infested clean eastern white wheat from Ontario, Canada, with 13.6% moisture content (m.c.) was used in the experiment. Moisture content of the grain was measured using a dielectric moisture metre (AACC method 44-11). Dockage was removed by sieving the grains for 45 seconds in a sieve with 2.36 mm openings (8 mesh).

The insecticides tested in the experiment were: chlorpyrifos-methyl + deltamethrin (Storicide II, 216 mg active ingredient (a.i.) of chlorpyrifos-methyl in 1 ml and 37 mg a.i. of deltamethrin in 1 mL (Bayer Crop Science, Research Triangle Park, NC), which is registered in the USA on wheat and rice at the rates of 3 ppm of chlorpyrifos-methyl and 0.5 ppm deltamethrin applied at 3 ppm a.i. of chlorpyrifos methyl and 0.5 ppm a.i. of deltamethrin; spinosad technical materials 92% a.i. (the producer BioSeen, China), which is registered in the USA and has a label rate of 1 ppm for wheat, maize and rice applied at 1 ppm a.i.; pirimiphos-methyl (Actellic 5E, 480 mg a.i. in 1 mL, which is registered in the USA on maize at 8 ppm.) (Agriliance, St Paul, MN), and in some European countries, applied at 10 ppm of a.i.: mixture of diatomaceous earth (DE) and deltamethrin technical (DM) (formulation developed by Z. Korunic) applied at 100 ppm containing 90 ppm of DE and 0.1 ppm of DM a.i.

At the beginning of the test, five of 14 kg groups of wheat were weighed, and the grain m.c. was determined. Four groups were treated with insecticides and one group served as untreated (control) group. Immediately after the initial treatment, 600 g of grain was removed from each container containing treated and untreated grain. This 600 g grain was evenly divided between three 500 mL jars (3 replicates containing 200 g grain per jar). After introducing 50 adult insects of each species into jars, jars were maintained at 30±1°C and 70±5% r.h. The containers with treated and untreated grain (groups) during twelve months were maintained under the same conditions (30±1°C and 70±5% r.h.). Bioassays had been initiated 0, 30, 120, 180, 270 and 360 d after the initial treatment.

To determine mortality in each treatment, grain was sieved 7, 14 and 21 d after insects were introduced, and the number of dead and live insects was recorded. All dead insects were removed 7 and 14 d post-introduction and all dead and live insects were removed 21 d after introduction. The jars were maintained under the same conditions for an additional 21 d (totally for 56 d after introduction) before being sieved again to determine the number of adults' offspring generated.

Mortality and progeny data were subjected to analysis of variance (ANOVA) according to the GLM (General Linear Model). Significant differences in the means were separated by using LSD test (least significant difference). Data processing was conducted by SAS/STAT software 9.1.3 (2003).

RESULTS AND DISCUSSION

The results of the effectiveness of tested grain protectants against the progeny and the adults of *S. oryzae*, *R. dominica* and *T. castaneum* immediately after treatment (zero day), after 180 d and 360 d post-treatment and the exposure of adults during 7 and 21 d to treated and untreated grain are presented and discussed in present study. These results showed clearly the values of tested insecticides for long term grain protection. Immediately after the treatment (zero day), 180 and 360 d, the mixture DE/DM and Storicide II successfully controlled the adults of *S. oryzae*, *R. dominica* and *T. castaneum* and their progeny (Table 1 and 2). The mixture DE/DM was developed to mitigate the disadvantages of DE on grain and to reduce deltamethrin residues in grains (Korunic and Rozman, 2010).

Actellic applied at 10 ppm of a.i. at zero day successfully controlled adults and the progeny of *S. oryzae* and *T. castaneum*. However, the same concentration didn't control the adults and the progeny of *R. dominica* (38% adult's mortality after 21 d and 97% progeny reduction). At 360 d and the exposure period of 21 d the effectiveness of Actellic against *S. oryzae* and *T. castaneum* was significantly reduced from 100% at zero days to 12.6% at 360 d (*S. oryzae*) and to 38.6% at 360 d (*T. castaneum)*. The effectiveness against adults of *R. dominica* was pretty low during all 12 months but the progeny was reduced more than 95% (Table 1 and 2).

Spinosad applied at 1 ppm did not control the adults (88% at zero day and 99% at 360 d and the progeny of *S. oryzae* (approximately 38% progeny reduction) and the adults (22% at zero day and 38% at 360 d) and the progeny (approximately 20% to 40% reduction) of *T. castaneum*. However, spinosad successfully controlled the adults and the progeny of *R. dominica* during 12 months (Table 1 and 2).

Table 1.The mortality of *Sitophilus oryzae*, *Rhyzopertha dominica* and *Tribolium castaneum* at zero day, 180 and 360 d post-treatment after 7 and 21 d of adults' exposured to grain protectants treated and untreated grain

Formulation	Concentr. (ppm)	*Sitophilus oryzae* Average adult mortality (%) ± SE					
		Zero day post-treatment***		180 d post-treatment****		360 d post-treatment*****	
		7 d	21 d	7 d	21 d	7 d	21 d
Untreated	0	0.6±0.6^{d}	10.0±3.0^{c}	10.6±3.5^{c}	28.6±2.4^{b}	4.6±1.7^{c}	6.6±2.4^{c}
*DE/DM	100	99.3±0.6^{a}	100.0±0.0^{a}	98.6±1.3^{a}	100.0±0.0^{a}	98.6±0.6^{a}	100.0±0.0^{a}
Actellic E5	10	100.0±0.0^{a}	100.0±0.0^{a}	29.3±2.9^{b}	96.0±2.0^{a}	2.0±1.1^{c}	12.6±4.6^{x}
**StoricideII	3CP;0.5DM	100.0±0.0^{a}	100.0±0.0^{a}	100.0±0.0^{a}	100.00±0.0^{a}	100.0±0.0^{a}	100.0±0.0^{a}
Spinosad	1	71.3±6.3^{b}	88.6±2.9^{b}	92.0±4.6^{a}	97.3±1.7^{a}	36.6±4.0^{b}	99.3±0.6^{a}
Formulation	Concentr. (ppm)	*Rhyzopertha dominica* Average adult mortality (%) ± SE					
		Zero day post-treatment***		180 d post-treatment****		360 d post-treatment*****	
		7 d	21 d	7 d	21 d	7 d	21 d
Untreated	0	2.0±1.1^{c}	2.6±0.6^{c}	4.0±1.1^{e}	24.6±1.7^{d}	6.0±1.1^{f}	18.0±1.1^{e}
*DE/DM	100	97.3±1.7^{a}	100.0±0.0^{a}	78.0±1.1^{b}	100.0±0.0^{a}	97.3±0.6^{ab}	100.0±0.0^{a}
Actellic E5	10	7.3±1.7^{c}	38.0±7.2^{b}	23.3±5.8^{d}	45.3±6.9^{c}	14.0±1.1^{e}	45.3±1.3^{d}
**StoricideII	3CP;0.5DM	98.6±1.3^{a}	100.0±0.0^{a}	69.3±5.4^{bc}	100.0±0.0^{a}	70.0±6.9^{c}	100.0±0.0^{a}
Spinosad	1	100.0±0.0^{a}	100.0±0.0^{a}	85.3±6.9^{ab}	100.0±0.0^{a}	92.0±3.4^{ab}	100.0±0.0^{a}

Formulation	Concentr. (ppm)	*Tribolium castaneum* Average adult mortality (%) ± SE					
		Zero day post-treatment***		180 d post-treatment****		360 d post-treatment*****	
		7 d	21 d	7 d	21 d	7 d	21 d
Untreated	0	0.6±0.6^{e}	5.3±1.3^{d}	3.3±1.7^{e}	15.3±5.2^{d}	2.6±1.7^{d}	11.3±2.9^{d}
*DE/DM	100	68.6±5.8^{b}	100.0±0.0^{a}	50.6±3.7^{b}	100.0±0.0^{a}	52.6±4.0^{b}	100.0±0.0^{a}
Actellic E5	10	100.0±0.0^{a}	100.0±0.0^{a}	11.3±1.3^{d}	40.6±2.4^{bc}	8.6±2.9^{d}	38.6±4.6^{bc}
**Storicide II	3CP;0.5DM	100.0±0.0^{a}	100.0±0.0^{a}	56.0±5.0^{b}	100.0±0.0^{a}	58.6±3.3^{b}	99.3±0.6^{a}
Spinosad	1	0.0±0.0^{e}	22.0±1.1^{c}	11.3±1.3^{d}	41.3±2.4^{bc}	10.0±1.1^{d}	38.0±2.0^{c}

* DE/DM – diatomaceous earth/chlorpyrifos methyl; **3ppm chlorpyrifos; 0.5 ppm deltamethrin

*** Means in the columns for zero day post-treatment followed by the same letters are not significantly (P>0.05) different as determined by the LSD-test

****means in the columns for 180 d post-treatment followed by the same letters are not significantly (P>0.05) different as determined by the LSD-test

*****Means in the columns for 360 d post-treatment followed by the same letters are not significantly (P>0.05) different as determined by the LSD-test

Table 2.The progeny of *Sitophilus oryzae*, *Rhyzopertha dominica* and *Tribolium castaneum* at zero day, 180 and 360 d post-treatment

Formulation	Concentr. (ppm)	*Sitophilus oryzae* Average adult number (progeny) ± SE		
		Zero day post-treatment*** after 56 d	180 d post-treatment**** after 56 d	360 d post-treatment***** after 56 d
Untreated	0	429.3 ± 37.7[c]	500.3 ± 41.3[c]	508.0 ± 5.1[d]
*DE/DM	100	0.0 ± 0.0[a]	0.0 ± 0.0[a]	0.0 ± 0.0[a]
Actellic E5	10	0.3 ± 0.3[a]	1.3 ± 0.3[a]	4.6 ± 1.6[b]
**Storicide II	3CP;0.5DM	0.0 ± 0.0[a]	0.0 ± 0.0[a]	0.0 ± 0.0[a]
Spinosad	1	163.6 ± 11.8[b]	181.0 ± 7.1[b]	176 ± 34.3[c]
Formulation	Concentr. (ppm)	*Rhyzopertha dominica* Average adult number (progeny) ± SE		
		Zero day post-treatment after 56 d	180 d post-treatment after 56 d	360 d post-treatment***** after 56 d
Untreated	0	229.3 ± 18.0[c]	279.6 ± 10.0[c]	312.6 ± 10.1[c]
*DE/DM	100	0.0 ± 0.0[a]	0.0 ± 0.0[a]	0.0 ± 0.0[a]
Actellic E5	10	7.3 ± 1.7[b]	7.3 ± 2.0[b]	12.0 ± 2.5[b]
**Storicide II	3CP;0.5DM	0.0 ± 0.0[a]	0.0 ± 0.0[a]	0.0 ± 0.0[a]
Spinosad	1	1.3 ± 0.6[a]	1.0 ± 0.5[a]	0.6 ± 0.3[a]
Formulation	Concentr. (ppm)	*Tribolium castaneum* Average adult number (progeny) ± SE		
		Zero day post-treatment after 56 d	180 d post-treatment after 56 d	360 d post-treatment***** after 56 d
Untreated	0	101.0 ± 4.0[c]	99.6 ± 8.7[d]	107.3 ± 6.9[d]
*DE/DM	100	0.0 ± 0.0[a]	0.0 ± 0.0[a]	0.0 ± 0.0[a]
Actellic E5	10	0.6 ± 0.6[a]	2.0 ± 0.5[b]	3.3 ± 0.8[b]
**Storicide II	3CP;0.5DM	0.0 ± 0.0[a]	0.0 ± 0.0[a]	0.0 ± 0.0[a]
Spinosad T	1	40.0 ± 17.0[b]	24.0 ± 4.0[c]	28.0 ± 3.7[c]

* DE/DM – diatomaceous earth/chlorpyrifos methyl; **3ppm chlorpyrifos; 0.5 ppm deltamethrin
*** Means in the columns for zero day post-treatment followed by the same letters are not significantly (P>0.05) different as determined by the LSD-test
****Means in the columns for 180 d post-treatment followed by the same letters are not significantly (P>0.05) different as determined by the LSD-test
*****Means in the columns for 380 d post-treatment followed by the same letters are not significantly (P>0.05) different as determined by the LSD-test

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