Effectiveness of Deltamethrin

Research examines efficacy of insecticide in controlling stored-product insects.

Milling Journal's *regular contributor Bhadriraju Subramanyam (Subi), a Don Wilbur Sr. Endowed Professor of Postharvest Protection, Department of Grain Science and Industry, Kansas State University (KSU), Manhattan, co-wrote this column with Blossom Sehgal, a research assistant in the Department of Grain Science and Industry. It explains their key findings on evaluating the effectiveness of deltamethrin in controlling several insects when applied to concrete surfaces and on hard red winter (HRW) wheat.*

The application of insecticides to clean, empty grain storage facilities and to uninfested grain, as it is loaded into a storage facility, is an essential component of integrated management of stored-grain insect pests.

Several insecticides are approved for treatment of both empty storage facilities and stored grain. These include Storcide™ II, a combination product containing 3 ppm chlorpyrifos-methyl and 0.5 ppm deltamethrin; Diacon® IGR, an insect growth regulator containing *S*-methoprene; and several formulations of diatomaceous earth or enhanced diatomaceous earth.

Storcide™ II is labeled for use on wheat, barley, rice, oats, and sorghum intended for storage and in empty storages receiving these grains.

Diacon® IGR can be used on all stored grains, spices, and seeds and in empty bins.

The diatomaceous earths can be used on small and coarse grains and in empty storages.

One insecticide exclusively used to treat empty storage facilities is Tempo® SC Ultra (ß-cyfluthrin). Actellic® 5E (pirimiphos-methyl) is intended only for treatment of corn and sorghum, and Sensat™ (spinosad) is approved for use on barley, bird seed, corn, millets, oats, rice, sorghum, triticale, and wheat.

In the second quarter of the 2013 *Milling Journal* (pages 34-38), under the Pest Management column, the effectiveness of ß-cyfluthrin and chlorpyrifos-methyl plus deltamethrin applied to concrete surfaces against laboratory and field strains of stored-grain insects

was described in detail.

Recently, a new formulation of deltamethrin, Centynal™, was released by Wellmark International, Schaumburg, IL. It is labeled for direct treatment of barley, corn, oats, popcorn, rice, rye, sorghum, and wheat intended for storage, as well as empty bins receiving these grains. It also can be used as a tank mix with *S*-methoprene.

In this article, we report laboratory tests conducted to determine the susceptibility of adults of laboratory and field strains of the red flour beetle, sawtoothed grain beetle, and lesser grain borer to deltamethrin applied to concrete surfaces and HRW wheat.

Concrete surfaces were used to represent the floor of empty storage structures.

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Additionally, such data provide baseline information on insect susceptibility which may be important in pest management and resistance management programs.

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Insect Strains

Farm sites in Kansas were visited in 2011 to collect adults of the three species from farm bins holding mostly wheat and some corn and sorghum.

In addition, two strains of red flour beetle and one strain of lesser grain borer collected from flour mills in the United States prior to 2011, and two strains of red flour beetle, one each obtained from Oklahoma and Texas in 2013, also were included in this study, along with the laboratory strains of each species.

These laboratory strains have been in rearing, without insecticide exposure, since 1999 in the Department of Grain Science and Industry at KSU and served as the standard reference strains. These strains were assumed to be insecticide-susceptible.

Red flour beetles were reared on wheat flour plus 5% by weight of brewer's yeast.

Sawtoothed grain beetles were reared on rolled oats plus 5% by weight of brewer's yeast, and lesser grain borers were reared on clean, organic HRW wheat.

Insecticide Treatment of Concrete Surfaces

Ready-mix concrete (Rockite, Hartline Products Co., Inc., Cleveland, OH) was mixed with tap water to make a slurry. This slurry was poured into 9-cm-diameter (surface area, 62 square cm) and 1.5-cm-high plastic Petri dishes (Fisher Scientific, Denver, CO).

The slurry was allowed to dry, and the inside walls of the Petri dishes were coated with polytetrafluoroethylene (Insect-a-Slip, Bio Quip Products, Inc., Rancho Dominguez, CA) to prevent insects from crawling on the sides of dishes.

Concrete surfaces of dishes were treated with deltamethrin at the highest ▶

Fig. 1 (A - C)

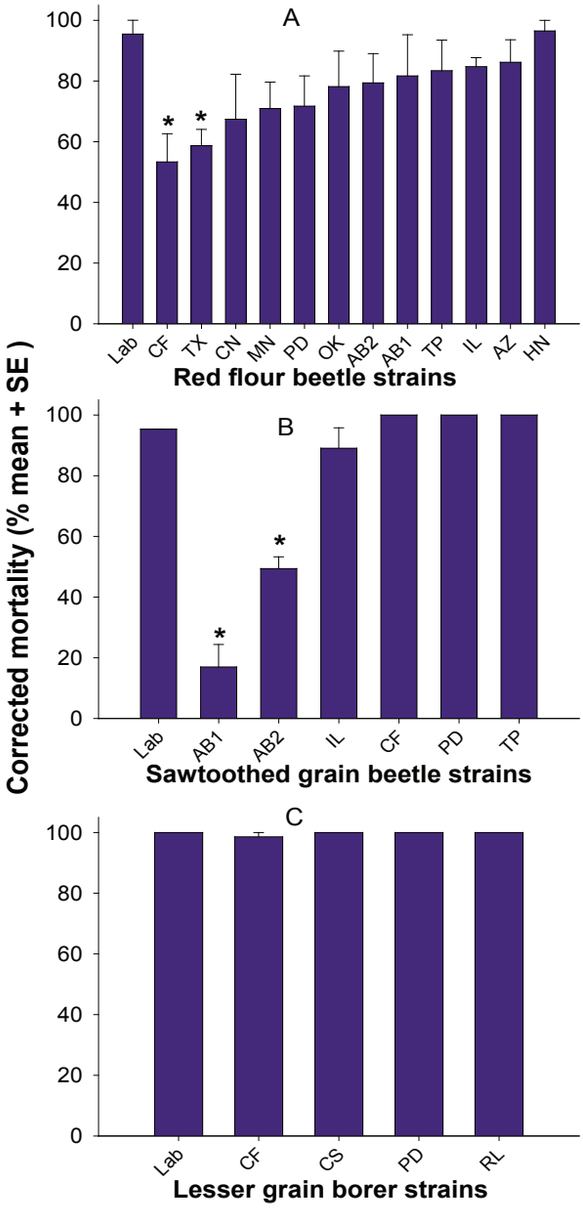

***Figure 1**. Corrected mean mortality (%) of laboratory and field strains of three insect species exposed to deltamethrin-treated concrete surfaces. The asterisk above the bars shows that the mortality of the field strain is significantly different ($P < 0.05$) from that of the laboratory strain (Dunnett's procedure). Control mortality among all the strains for the red flour beetle, sawtoothed grain beetle, and lesser grain borer ranged 0% to 5.0%, 0% to 6.1%, and 1.7% to 12.0%, respectively.*

Fig. 2 (A - C)

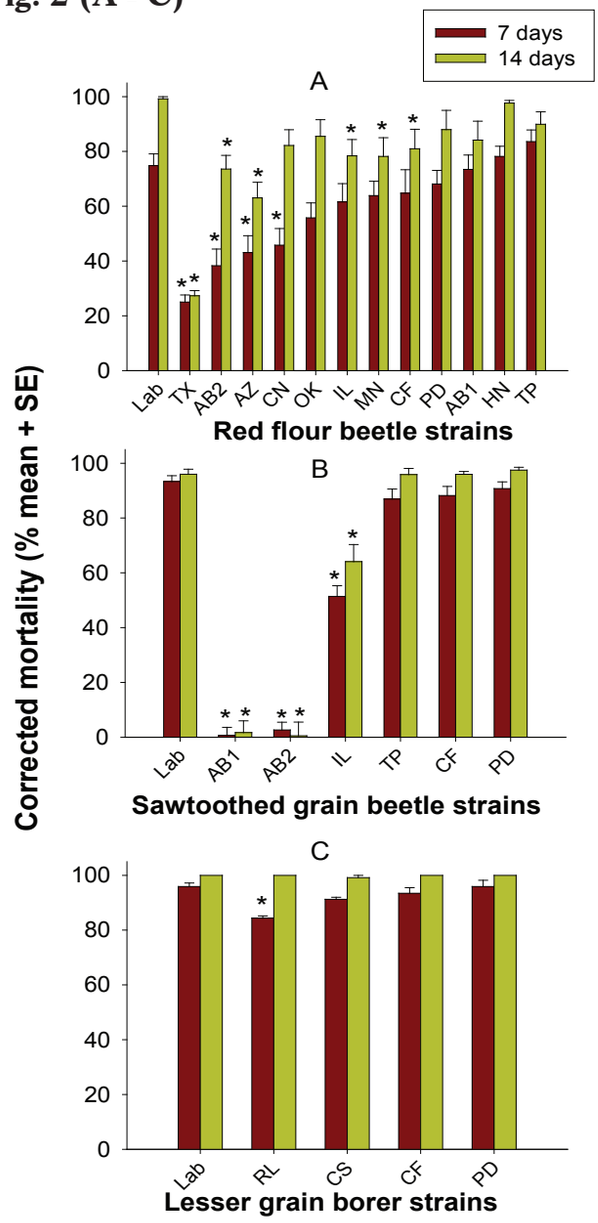

***Figure 2**. Corrected mean mortality (%) of laboratory and field strains of three insect species exposed to deltamethrin-treated wheat. The asterisk above the bars shows that the mortality of the field strain is significantly different ($P < 0.05$) from that of the laboratory strain (Dunnett's procedure). Mean 7- and 14- day mortalities on untreated wheat (control) for all red flour beetle, sawtoothed grain beetle, and lesser grain borer strains ranged from 0.7% to 4.8%, 0.8% to 13.6%, and 3.3% to 8.6%, respectively.*

labeled rate of 0.02 g (active ingredient) per square meter by applying 265 microliters of the spray solution per dish using a Badger 100 artist's airbrush (Model 100, Franklin Park, IL). Dishes sprayed with equal amounts of distilled water served as the control treatment. Treated dishes were allowed to dry under room conditions for 24 hours before exposing insects.

Time-response Tests

The laboratory strains of the three species were used to establish a time at which 100% or close to 100% mortality of adults occurred when exposed to the labeled rate of deltamethrin. This time was used to expose field strains of each species to concrete treated with the insecticide.

Twenty unsexed (1- to 2-week-old) adults each of the red flour beetle, sawtoothed grain beetle, or lesser grain borer from laboratory cultures were introduced into each dish, and the dishes were covered with Petri dish lids. Adults were exposed to treated dishes for one, two, four, eight, 12, and 24 hours. Separate dishes were used for each time period.

Each exposure time and species combination included an untreated control dish that was sprayed with distilled water. Each species and time combination, including the control treatment, was replicated three times.

After adult introduction, dishes were placed inside the growth chamber at 28 degrees C and 65% relative humidity. After the intended exposure period, all adults were transferred

Table 1. Adult Progeny Production of Red Flour Beetle Strains Exposed Continuously for 42 days to Deltamethrin at 0.5 mg (active ingredient) / kg of Wheat

Strain	Mean ± SE number of adults		Percent reduction[a]
	Control	Deltamethrin	
Lab.	60.8 ± 4.8	0 ± 0	100
AB1	61.6 ± 6.5	0.2 ± 0.2	99.7
AB2	73.4 ± 6.0	0.2 ± 0.2	99.7
AZ	75.8 ± 6.9	6.4 ± 2.9	91.6
CF	46.6 ± 8.7	0 ± 0	100
CN	79.8 ± 10.8	0.8 ± 0.6	99.0
HN	66.4 ± 6.5	0 ± 0	100
IL	51.8 ± 1.2	1.2 ± 0.5	97.7
MN	77.4 ± 6.5	0.8 ± 0.4	99.0
OK	72.0 ± 8.7	1.2 ± 0.5	98.3
PD	57.0 ± 4.7	0 ± 0	100
TP	71.8 ± 5	0 ± 0	100
TX	6.0 ± 0.5	2.2 ± 1.3	63.3

[a]Percent reduction in adult progeny production of strains relative to production on untreated (control) wheat.

to 150-milliliter round plastic containers with 30 grams of the respective insect diet. The plastic containers had perforated lids with wire-mesh screens to facilitate air diffusion.

Containers were incubated at 28° C and 65% relative humidity for one week to determine end-point mortality following insect recovery on rearing diets.

Exposure of Field Strains

Deltamethrin produced 81% mortality of only the red flour beetle laboratory strain at the maximum exposure time of 24 hours; mortality was 100% for the laboratory strains of the other two species.

Therefore, field strains of the three species were exposed for 24 hours to distilled-water-treated (control) and deltamethrin-treated concrete surfaces, as explained earlier. The mortality data on deltamethrin-treated concrete surfaces were corrected for mortality in the respective control treatments.

Wheat Treatment Tests

Deltamethrin was evaluated at the labeled rate of 0.5 mg(active ingredient)/kg against laboratory and field strains of the three species. Stock solutions and dilutions for treatment of grain or concrete were made in distilled water.

One milliliter of the insecticide solution was applied to 1-kg lots of wheat, and each lot of wheat was treated with the insecticide in a 5-kg-capacity stainless steel drum, which was rotated mechanically for 10 minutes to ensure uniform coverage of the insecticide on kernels.

Wheat treated with one milliliter of distilled water served as the control treatment (0 mg[active ingredient]/kg). Treated wheat (50 g) was weighed in separate 150 milliliter plastic containers, and 25 unsexed 1- to 3-week-old adults of an insect species were introduced into each container.

After adult introduction, the containers were closed with lids with wire-mesh screens and filter papers and kept in an environmental chamber at 28 degrees C and 65% relative humidity.

The mortality of introduced adults was examined at seven and 14 days and adult progeny production after 42 days. Adults unable to move when prodded with a fine brush were considered dead.

The mortality data on deltamethrin-treated wheat were corrected for mortality in the respective control treatments.

Separate sets of containers were used for each observation period. Each combination of insect species and observation time was replicated five times, and each replicate was treated separately, as explained earlier.

> No progeny production was observed in strains exposed to deltamethrin due to effective control of adults or due to the high susceptibility of larvae hatching from eggs.

Overall Results

• **Tests on concrete.** The mean mortality of all red flour beetle field strains exposed to deltamethrin-treated concrete surfaces ranged from 53% to 96% (**Figure 1A**, preceding page).

The mortality responses of CF and TX field strains differed significantly from that of the laboratory strain. The mean mortality of three of the six sawtoothed grain beetle field strains was 100%, whereas it ranged from 17% to 89% for the other three strains (**Figure 1B**).

Mortality responses of AB1 and AB2 field strains differed significantly from that of the laboratory strain. Deltamethrin was extremely effective against lesser grain borer field strains (98-100% mortality) (**Figure 1C**).

• **Tests on wheat.** The 7- and 14-day mortalities of the red flour beetle field strains on deltamethrin-treated wheat ranged from 25% to 84% and 27% to 98%, respectively (**Figure 2A**, preceding page).

The laboratory strain was as susceptible as several field strains. The 14-day mortality of strains was generally greater than the 7-day mortality. The 7-day mortality of four strains, AB2, AZ, CN, and TX, and 14-day mortality ▶

Table 2. Adult Progeny Production of Sawtoothed Grain Beetle Strains Exposed Continuously for 42 Days to Deltamethrin at 0.5 mg (active ingredient)/kg of Wheat

Strain	Mean ± SE number of adults		Percent reduction[a]
	Control	Deltamethrin	
Lab.	106.2 ± 12.8	0.2 ± 0.2	99.8
AB1	23.0 ± 5.6	18.6 ± 4.7	19.1
AB2	66.0 ± 5.3	21.6 ± 7.1	67.3
CF	56.2 ± 9.2	0 ± 0	100
IL	61.4 ± 14.3	0.4 ± 0.2	99.3
PD	32.2 ± 3.6	0 ± 0	100
TP	41.2 ± 7.7	0 ± 0	100

[a]Percent reduction in adult progeny production of strains relative to production on untreated (control) wheat.

of six strains, AB2, AZ, CF, IL, MN, and TX, were significantly lower than that of the laboratory strain.

Adult progeny production among red flour beetle strains in the control treatment ranged from six to 80 adults/container (**Table 1**, preceding page). There was no progeny production in four out of the 12 field strains exposed to deltamethrin-treated wheat.

Except for the TX strain, reduction in progeny production relative to production on untreated (control) wheat ranged from 92% to 100%.

In seven strains, where minimal progeny production was observed, the numbers produced were significantly lower than in the corresponding control treatment. The progeny production of the TX strain exposed to deltamethrin was similar to production on untreated wheat.

The 7- and 14-day mortalities of all sawtoothed grain beetle strains on deltamethrin-treated wheat ranged from 0.7% to 93% and 0.5% to 98%, respectively (**Figure 2B**). The 7- and 14-day mortalities of three field strains, AB1, AB2 and IL, were significantly lower from that of the laboratory strain.

Adult progeny production among sawtoothed grain beetle strains in the control treatment ranged from 23 to 106 adults/container (**Table 2**).

There was no progeny production in three out of the seven strains exposed to treated wheat. In three strains, the numbers produced were significantly lower than in the corresponding control treatment. The progeny production of the AB1 strain exposed to deltamethrin was similar to production on untreated wheat.

Deltamethrin was effective against all lesser grain borer strains with 84% to 96% and 99% to 100% mortality after seven and 14 days of exposure (**Figure 2C**). Only the 7-day mortality of the RL strain was significantly lower than that of the laboratory strain.

Adult progeny production of lesser grain borer on the untreated wheat for the laboratory strain was 498 adults/container, whereas for the field strains, it ranged 59 to 92 adults/container.

No progeny production was observed in strains exposed to deltamethrin due to effective control of adults or due to the high susceptibility of larvae hatching from eggs.

Conclusions

On concrete surfaces, a majority of strains of the red flour beetle and a couple of the sawtoothed grain beetle strains were less susceptible to deltamethrin. Similar trends were observed for these two species on wheat. Only lesser grain borer strains were highly susceptible to deltamethrin on both concrete and wheat.

Even though there was wide variation in adult mortality among red flour beetle strains, ranging from 25% to 98% on wheat, there was a 92% to 100% reduction in progeny production relative to that on untreated wheat, except in the TX strain.

The low adult progeny production on deltamethrin-treated wheat indicated that the larvae hatching from eggs were highly susceptible to the insecticide. The field strains of sawtoothed grain beetle, especially AB1 and AB2, showed reduced susceptibility to deltamethrin when compared with the laboratory strain. This was true even at twice the labeled rate on wheat (data not shown).

Complete progeny suppression in these two field strains on treated wheat could not be achieved, which may be due to the lower susceptibility of larvae to deltamethrin. There may be natural tolerance or resistance in these field strains, and this aspect requires further confirmation.

The reduced susceptibility of field strains of the red flour beetle and sawtoothed grain beetle may be due to resistance. There have been reports from many countries regarding resistance in several species of stored-product insects to deltamethrin.

It is advisable to use deltamethrin in rotation with spinosad or other approved grain protectants as part of integrated insect pest management and resistance management programs.

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