Boric Acid Dust as a Component of an Integrated Cockroach Management Program in Confined Swine Production

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ABSTRACT Boric acid dust treatments were evaluated as a tool for the integrated management of the German cockroach, *Blattella germanica* (L.), in commercial confined swine production. The efficacy of boric acid dust was comparable to that of an organic residual insecticide, cyfluthrin, which is commonly used to control cockroaches in this environment. Fall treatments suppressed the cockroach population for longer durations than treatments in the Spring. Boric acid dust is an effective, inexpensive, and low risk (to animal and human health, and the environment) alternative for the management of cockroaches in livestock production systems.

KEY WORDS German cockroach, boric acid, cyfluthrin, swine production, integrated pest management (IPM)

SWINE PRODUCTION IN THE U.S. is dominated by vertically integrated companies that contract with individual growers to produce pork products for consumers. Integrators provide the animals, semen for fertilization, and feed, and are responsible for processing and marketing the pigs. For their part, growers build and maintain controlled environment production facilities and provide labor to care for the animals in exchange for a guaranteed contract price. North Carolina is a leading hog producer, second only to Iowa; the confined swine production is therefore a major component of North Carolina's agricultural economy.

Abandonment of traditional swine production in favor of confinement farms represents an "urbanization" of swine. Similar to urbanization of humans, biotic and abiotic features and practices make buildings of confined swine farms an optimal environment for structural and residential pests. Farrowing barns (for birthing and lactation) and nurseries, especially, are maintained at relatively high temperatures. Hog feed is always present, serving as an excellent source of nutrients not only for hogs but also for insect pests. Drinking spouts, sprinklers that keep sows cool, and frequent flushing of the underfloor pits and open floor gutters provide ample water for pests. In addition, walls and other voids are ideal refugia for pest aggregations. Consequently, many farms in NC and the Southeastern U.S. are heavily infested with large populations of the German cockroach, *Blattella germanica* (L.) (Fig. 1). Where such infestations originate is not at all clear, but vertical integration results in flow of animals, feed, and supplies from central processing facilities to contract farms and this may result in dissemination of cockroaches by a single infested supplier, or between farms and workers' homes.

Cockroaches have long been recognized as structural pests and potential mechanical vectors of foodborne and animal pathogens as well as a source of human allergens (Schal and Hamilton 1990, Brenner 1995, Rosenstreich et al. 1997). Swine suffer from a number of mechanically transmitted diseases caused by bacteria, viruses, and fungi, but the role of cockroaches in disease agent transmission is not known. To prevent and control pathogens and parasites, the swine industry has adopted an all-in-all-out management system wherein sows are separated based on their production stage (breeding, gestation, and lactation). Weaned piglets are kept in nurseries separated from the breeding stock to minimize cross-infection. Each farrowing room is populated, then emptied, washed, and disinfected on a ≈23-d cycle. However, because cockroaches move freely between different parts of a farm, they represent a potentially serious hazard to animal and worker health. Cockroaches have been observed at night on pig manure, feed, and around piglets and pigs (Waldvogel et al. 1999).

Pest management in swine production relies heavily on broadcast applications of broad-spectrum residual organic insecticides, primarily organophosphates and pyrethroids, usually every ≈23 d. Such frequent applications of the same active ingredient can lead to the development of insecticide resistance and thus compromise insecticide efficacy (Cochran 1989, 1995a).

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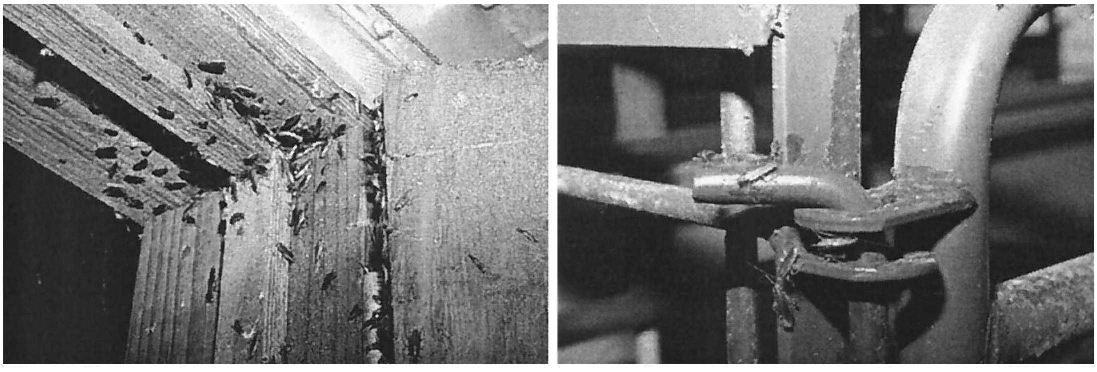


Fig. 1. Typical infestations of the German cockroach in farrowing rooms of confined swine production. Left: One of six entry doors into a farrowing room. Right: A farrowing pen, showing cockroaches emerging from the hollow pen. Both photographs were taken during the day; cockroaches are much more active, and therefore, observable, at night.

Organic insecticides also expose workers, animals and the consumer to health and environmental risks. Regulatory restrictions under the U.S. Food Quality Protection Act (FQPA) of 1996 limit the availability of effective pesticides and few active ingredients are specifically labeled for use in this environment. Therefore, alternative approaches for pest management in the swine industry are needed.

We have explored various alternative approaches, including altering production practices, eliminating refugia, developing a pest monitoring program, and implementing threshold-based treatments. Herein, we consider incorporation of inorganic insecticides into this program. The inorganic insecticide boric acid has a favorable safety record; absorption of boric acid through unbroken skin is negligible, and in contrast to organic insecticides it does not volatilize (Pfeiffer 1951, Valdes-Dupena and Arey 1962, Ebeling 1995, Fail et al. 1998). Boric acid has been used in various formulations to control cockroaches since the middle of the 19th century (Lintner 1882, cited in Ebeling 1995). However, boric acid use has declined recently, primarily because organic insecticides provide much faster kill.

In this study, we tested the efficacy of boric acid dust against German cockroach infestations in farrowing rooms of a swine farm and compared it to the efficacy of a residual organic insecticide, cyfluthrin, commonly used for cockroach control in this industry.

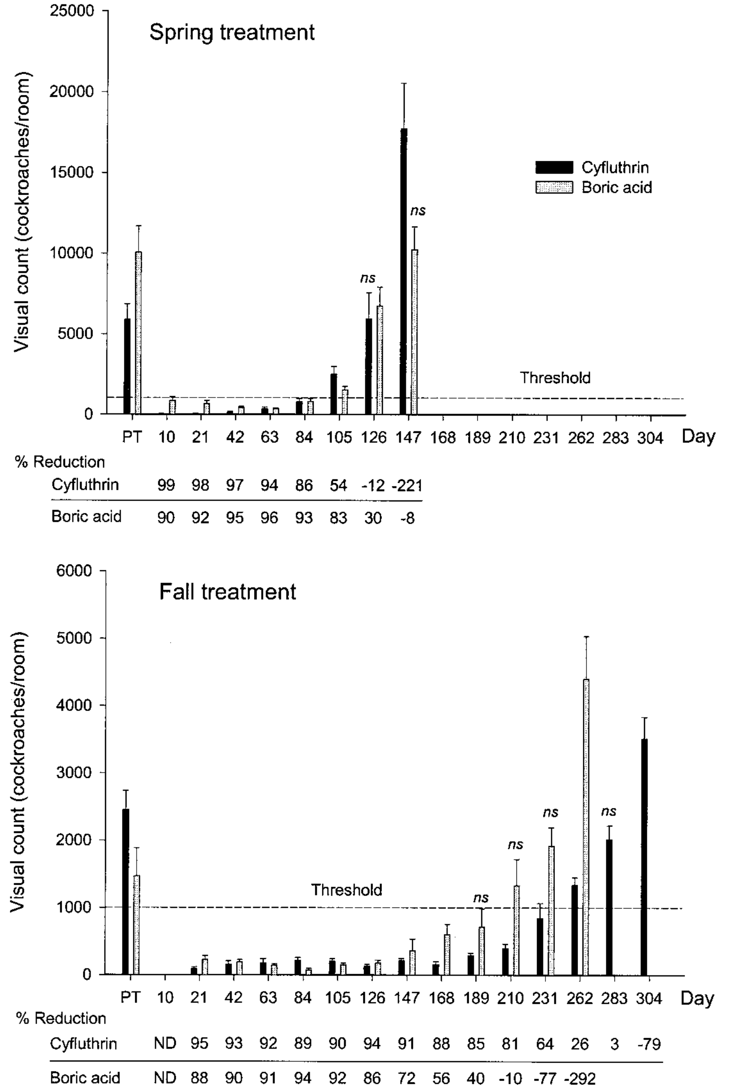
Materials and Methods

Farms. Trials were conducted in two farrowing barns of a commercial farm located in Duplin County, NC. Each barn consisted of eight farrowing rooms (FR) and each 167 m^2 room housed 36 sows. The farrowing barns were connected by two screened 12 × 1.5 m corridors devoid of food, water, and temperature regulation. Every ≈23 d, each FR was vacated, power washed, and disinfected before a new group of pregnant sows was brought in.

Monitoring. A 15-person-min (i.e., 15 min by one observer, 7.5 min by each of two observers) visual inspection of each FR was used for cockroach monitoring. Only the four walls of each FR were inspected, while the pens housing sows were not. Monitoring was consistently conducted by the same personnel and involved daytime counting of all visible cockroaches along the wall and within cracks and crevices with the aid of a flashlight and a mechanical counter. Individual cockroaches were counted when numbers were low, but in heavily infested rooms cockroaches were counted by fifties or hundreds. Our previous research (Schal et al. unpublished) has shown a close correlation between visual counts and overnight trap catches. The relative infestation was estimated immediately before treatments and then in 21-d intervals until the cockroach infestation rebounded to pretreatment levels.

Pesticide Treatments. Pesticide applications were made just after the rooms were washed and disinfected, but after the room had dried and before sows were brought in. One barn (eight FR) was used for the boric acid treatment while the second barn (eight FR) received the positive control treatment with cyfluthrin (Tempo 20 WP, Bayer, Kansas City, MO). Boric acid dust (National Boraxx Corp., Cleveland, OH) was applied (670 g per FR) with an electric duster (Techniduster, Anaheim, CA). Cyfluthrin was applied as a 0.1% aqueous solution (11.25 liters per FR) with a B&G pressurized sprayer (Plumsteadville, PA). Only areas with identified cockroach aggregations (e.g., walls, wall voids, joints between surfaces, doors, door frames, and conduits) were treated. We also treated utility areas between FR and corridors between barns, but cockroaches were not counted in these locations. Farrowing pens where sows are penned were not treated. The first treatment was conducted in the Spring. For the second (Fall) treatment, the barn previously treated with cyfluthrin was treated with boric acid, and vice versa.

Data Analysis. For each insecticide, cockroach counts in each FR were compared with the pretreatment counts using Student's paired *t*-test ($\alpha = 0.05$). To compare the relative efficacy of the two insecticides, cockroach counts at each census were con-



Spring treatment — % Reduction

	10	21	42	63	84	105	126	147
Cyfluthrin	99	98	97	94	86	54	-12	-221
Boric acid	90	92	95	96	93	83	30	-8

Fall treatment — % Reduction

	10	21	42	63	84	105	126	147	168	189	210	231	262	283	304
Cyfluthrin	ND	95	93	92	89	90	94	91	88	85	81	64	26	3	-79
Boric acid	ND	88	90	91	94	92	86	72	56	40	-10	-77	-292		

Fig. 2. The effect of cyfluthrin spray and boric acid dust treatments (Spring and Fall) on cockroach populations in 16 farrowing rooms of a confined swine production farm. Visual counts represent a 15-person-min visual inspection of each room. Percentage reduction was calculated relative to the respective pretreatment (PT) count. Error bars represent SE *ns* = not significant from the respective pretreatment visual count (Student paired *t*-test, $P > 0.05$), ND = not determined.

verted to percentages of the pretreatment counts, square-root transformed, and analyzed by repeated measures analysis of variance (ANOVA) (PROC GLM) in SAS 8.2 (SAS Institute 2001)

Results and Discussion

Based on an analysis of changes in cockroach counts after treatment with insecticides, we determined that a 15-person-min visual count of 1,000 cockroaches per room represented the action threshold (Waldvogel et al. 1999). The cockroach population in each room tended to grow exponentially above this threshold. Moreover, interviews with swine workers suggested that they became bothered by the cockroaches at densities that corresponded to counts higher than 1,000 cockroaches per room (Schal et al. unpublished data). In all cases, we began our studies with cockroach populations that exceeded this threshold.

Treatments with either cyfluthrin or boric acid in the Spring and again in the Fall reduced the cockroach counts below the threshold within 10 d (Fig. 2). The cockroach infestations were severe before the Spring treatment. Nonetheless, in cyfluthrin treated rooms the cockroach counts were reduced by $99.3 \pm 0.3\%$ within 10 d after the treatment (Fig. 2). The counts remained below the threshold for >3 mo before rebounding to pretreatment levels. The visual counts 126 d after the treatment were not significantly different from the counts before treatment (Fig. 2). At the conclusion of the study, the cockroach count in cyfluthrin-treated FRs was about threefold higher than the pretreatment counts.

Boric acid treatment likewise lowered the cockroach infestation by 90.4 ± 3.4% within 10 d and kept the counts below the threshold for >4 mo (Fig. 2). The infestation reached pretreatment levels by day 147, the last day of the Spring study.

A comparison of the two Spring treatments indicated highly significant effects of the insecticides ($F_{1,143} = 121.7$, $P < 0.0001$), day ($F_{1,143} = 42.9$, $P < 0.0001$), and day * insecticide interaction ($F_{1,143} = 10.8$, $P < 0.001$). The cockroach counts as a function of pretreatment counts declined significantly more in cyfluthrin treatments than in boric acid treatments in the first 21 d ($P < 0.04$). Between 42 and 84 d after treatment the two insecticides were equally effective ($P > 0.05$), but after day 105 the increase in cockroach counts was significantly slower in boric acid treated FRs than in FRs treated with cyfluthrin ($P < 0.02$).

The pretreatment infestations were much lower in the Fall than in the Spring. Both Fall treatments were highly effective, reducing the cockroach populations to extremely low levels within 21 d and maintaining them below the 1,000 threshold for up to 7 mo (Fig. 2). The cockroach populations in cyfluthrin treated rooms recovered to the threshold level ≈231 d after the treatment; counts 262 d after treatment were not significantly different from the pretreatment counts. In the boric acid treated rooms, the cockroach population rebounded faster, reaching the threshold between 189 and 210 d after the application (Fig. 2).

A comparison of the two Fall treatments indicated highly significant effects of the insecticides ($F_{1,207} = 24.7$, $P < 0.002$), day ($F_{1,207} = 54.2$, $P < 0.0001$), and day * insecticide interaction ($F_{1,207} = 34.6$, $P < 0.0001$). The decline in cockroach counts as a function of pretreatment counts was not significantly different in the cyfluthrin and boric acid treatments through day 126 (Fig. 2). However, between 147 and 262 d after treatment, cockroach counts increased significantly faster in the boric acid treated FRs than in FRs treated with cyfluthrin ($P < 0.0005$).

The mode of action of boric acid against cockroaches remains unresolved. Ebeling (1995) suggested that both destruction of the digestive tract wall and penetration of the exoskeleton contribute to mortality. Cochran (1995b) confirmed that boric acid destroys the foregut epithelium and he suggested that cockroaches might die from starvation. Regardless of formulation— dust or bait—mortality because of boric acid is slower than with organic insecticides. This was apparent in our study, as cockroach populations in boric acid treated farrowing rooms declined more slowly than those in cyfluthrin treated rooms. In the Spring treatment, the maximum reduction of the cockroach counts (99.3%) by cyfluthrin was reached in 10 d. In contrast, the reduction peak by boric acid (95.5%) was achieved 63 d after the treatment (Fig. 2). Previous comparisons of residual sprays of cyfluthrin and chlorpyrifos also showed a dramatic reduction in the cockroach population within 4 d after treatment (Schal et al. unpublished data). However, pretreatment infestations in rooms treated with boric acid in the Spring were much more severe than in rooms treated with cyfluthrin. It is, therefore, possible that the delay in reduction was because of the higher initial infestation.

The much longer lasting suppression of cockroaches in the Fall can be explained by two observations. First, the pretreatment cockroach population in the Fall was much lower than in the Spring. Second, the efficacy of the Fall treatments was probably enhanced by low ambient temperatures which not only cause the cockroaches to aggregate in more readily accessible areas (Fig. 1), but they also slow cockroach development and the return to above threshold levels. Conversely, during the warmer Spring and Summer months cockroaches can retreat to refugia that are much more difficult to target with insecticides, such as attics and the pits under the plenum floor.

Overall, the efficacies of boric acid dust and cyfluthrin spray treatments against German cockroaches are comparable in the confined swine production environment. Boric acid dust is an inexpensive inorganic insecticide with a favorable safety track record and no known cases of insect resistance. Boric acid has been also reported to enhance the virulence of several pathogens including *Bacillus thuringiensis* (Berliner) subs. *kurstaki* against *Mamestra configurata* (Walker) (Morris et al. 1995), nucleopolyhedrosis virus against *Lymantria dispar* (L.) and *Spodoptera frugiperda* (Shapiro and Bell 1982, Cisneros et al. 2002) and *Metarhizium anisopliae* (Metschnikoff) Sorokin against the German cockroach (Zurek et al. 2002).

Boric acid is also formulated in solid baits against cockroaches (Nalyanya et al. 2001). However, thus far, our results indicate that such baits (e.g., Drax Roach Kil gel, Waterbury Comp., Waterbury, CT) are less effective in the swine environment, probably because of the plethora of alternative food sources available to cockroaches (Waldvogel et al. 1999). Furthermore, bait formulations are much more expensive and their proper placement requires substantially more time than other treatments.

This study shows that boric acid dust can be used as an adequate alternative to conventional organic insecticides for the management of German cockroach infestations; yet, its adoption into integrated cockroach management programs is significantly constrained by technical limitations. Although the dust itself is inexpensive and readily available, high volume precision dusters are expensive and relatively less available. Dust applications also may expose workers and swine to respiratory health risks associated with dust inhalation. And lastly, boric acid dust cannot be applied directly to the metal pens because it may cause rusting and accelerate their deterioration. To alleviate these issues, we are currently investigating the efficacy of liquid bait formulations of boric acid.

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