INTEGRATED COCKROACH (DICTYOPTERA, BLATTELLIDAE) MANAGEMENT IN CONFINED SWINE PRODUCTION

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Abstract - Swine production is an important component of North Carolina's agricultural economy. Cockroaches have long been recognized as important pests in swine production and severe infestations may contribute significantly to disease maintenance and transmission. However, management of cockroach populations is severely constrained by many factors including: cultural and production practices used at the facility, building design, and inadequate sanitation, well as frequent re-introduction of cockroaches by workers and suppliers. In addition, regulatory restrictions on the types and classes of pesticides that can be used in such facilities frequently result in overuse of a narrow spectrum of chemicals, increasing the potential for insecticide resistance in the cockroach population. The overall goal of this project was to document and demonstrate reduced-risk integrated pest management approaches in confined swine production systems. Central to the philosophy of integrated pest management (IPM) is the idea that treatment should be based on need. Yet, current cockroach suppression practices rely heavily upon multiple scheduled applications of broad-spectrum insecticides with little concern about pest population size. This is due primarily to lack of efficient detection and monitoring tools for cockroaches. Therefore, a major motivation of our research was to study the utility of cockroach pheromones and visual inspections in the implementation of IPM principles in managing cockroaches. Specific objectives included identification of available pest management alternatives for broad-spectrum pesticides, developing and evaluating these alternative approaches for integrated pest management, demonstrating the efficacy of this program, and quantifying reduction in risks to animal and human health and the environment. The ultimate goal of this study will be to deliver an education program to production managers to allow them to continue an effective site-based pest management strategy.
Key words - *Blattella germanica*, integrated pest management, resistance, monitoring, baits.

INTRODUCTION

In the U.S., traditional swine production, wherein pigs serve as an adjunct to cropping systems, has given way to a modern specialized swine industry, with concomitant growth in farm size, animal production, and pest problems. Today, the U.S. swine market is dominated by farms of more than 2,000 head each and swine has become a major agricultural cash commodity. North Carolina's 10 million hogs (16% of the U.S. total) have a cash value exceeding $1 billion, making NC the second largest producer in the U.S.

Several features of the swine production system are conducive to growth of pest populations. However, some of these features are integral components of the cultural and production practices that are pivotal to efficient swine growth and barn bio-security. For example, piglets require a warm, dry environment of about 35°C. In the same cage, sprinklers wet the sows for evaporative cooling; pigs are also provided with ample nutrient-rich diet. Farm buildings are roughly constructed and walls and other voids (e.g., confinement cages) provide excellent pest refugia. These conditions are optimal for growth and reproduction of cockroaches and cockroach infestations are particularly prevalent in farrowing (birthing and lactation) and nursery barns.

The consequences of arthropod pests in swine production are poorly understood, and the cost of managing such pests is rarely quantified. Yet, it is clear that pest populations, if not managed, can expand to hundreds and even thousands of individuals per m^2 and pose problems to both swine and workers. Cockroaches have long been recognized as pests of medical, economic, and aesthetic concern (Brenner, 1987; Brenner, 1995). Both the German cockroach, *Blattella germanica* (L.), and the Oriental cockroach, *Blatta orientalis* L., are recognized as vectors of medical and veterinary importance, and hypersensitivity to cockroaches is particularly common among people who experience high intensity and long

Proceedings of the 3rd International Conference on Urban Pests.
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duration of exposure to cockroaches (Rosenstreich *et al.*, 1997). The role that cockroaches play in worker and swine inhalant and ingested allergies is not known.

Swine suffer from a number of mechanically transmitted diseases. Mycotoxins, bacteria, viruses, including Porcine Reproductive and Respiratory Syndrome (PRRS) and Transmissible Gastroenteritis (TGE), and endoparasites, most dramatically affect the young, growing pig. Prevention and control of pathogens and parasites include good sanitation, particularly because transmissible nematode eggs and other pathogens can persist for long periods. The swine industry has adopted an All-In-All-Out (AIAO) management system wherein breeding, gestating, and lactating sows are separated. Weaned piglets are kept away from older breeding stock to minimize cross-infection and each barn is washed and disinfected on a ca. 23-day cycle. However, because cockroaches readily move between various barns and nurseries, and in night-time surveys we routinely see cockroaches on pig manure, feed, and around pigs, and within the structure of the cage that confines pigs, they comprise an important, yet under-appreciated, weak link in barn bio-security.

Effective suppression of cockroach populations is needed to alleviate health-related problems and is mandated by federal regulations. Cockroaches and other pests are generally controlled with broadcast applications of broad-spectrum insecticides and inorganic dusts applied according to the swine production schedule. Insecticides, while reducing pest populations when properly applied, may expose workers, animals, and the consumer to health and environmental risks. Multiple applications of the same insecticide hasten the development of resistance and diminishes the efficacy. Regulatory restrictions under the U.S. Food Quality Protection Act (FQPA) of 1996, and the cost of registration of pesticides have further limited the availability of effective pesticides. Therefore, alternative approaches for scheduled insecticide applications are needed, as is the development of safe, effective, and environmentally compatible integrated pest management strategies. Within this context we are developing and implementing a monitoring and management program for cockroaches. Spiders, flies, and other insects, which expose workers and swine to health risks and nuisance, are also targeted in an integrated pest management program that addresses cockroaches as the primary pest.

MATERIALS AND METHODS

Farms

We report work conducted only in farrowing barns of commercial farms located in Sampson and Duplin Counties, NC. Each farm contained 16 farrowing barns. Each 250 m^2 barn housed 54 sows and was vacated, power washed, and disinfected every ca. 23 days.

Monitoring

Initially, cockroaches were monitored with glue traps. However, populations were so great the traps became saturated, and we switched to a 15 min visual transect in each barn. In heavily infested barns, individual cockroaches were too numerous to count but were estimated by the hundreds; after treatments were applied individual cockroaches were counted.

Pesticide treatments

The 16 barns were assigned to 5 different treatments, ranging from 2 to 4 replicate barns per treatment. Perma-Guard D-20 dust (Albuquerque, NM), containing 88% silicon dioxide from diatomaceous earth, 0.2% pyrethrins, and 1% PBO, was applied by farm personnel to 4 barns. This represented their standard treatment applied every 23 days. Two residual spray formulations were tested: Tempo 20WP (Bayer, Kansas City, MO), containing cyfluthrin, was applied as a 0.1% aqueous solution, and Empire 20 (Dow, Indianapolis, IN), containing microencapsulated chlorpyrifos, was applied as a 0.4% solution. Each barn was treated with 11.25 liters applied to all joints between surfaces, conduits, and visible cockroach aggregations. The cages housing hogs were not treated. Two bait formulations were tested: Avert Gel Bait Formula 2 (Whitmire Micro-Gen, St. Louis, MO) contained 0.05% abamectin, and Maxforce Bait

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Gel (Clorox, Pleasanton, CA) contained 2.15% hydramethylnon. Six hundred grams of each formulation were applied per barn to cockroach refugia, including hollow pipes that formed the confinement cages.

In a later study, we also tested Optashield CS (Whitmire Micro-Gen, St. Louis, MO), containing 6% microencapsulated cyfluthrin (as a 0.1% aqueous solution), and Drax Roach Kil Gel (Waterbury Companies, Waterbury, CT), which contained 33.3% boric acid.

Data Analysis

Data were analyzed by analysis of variance or Student's *t*-test.

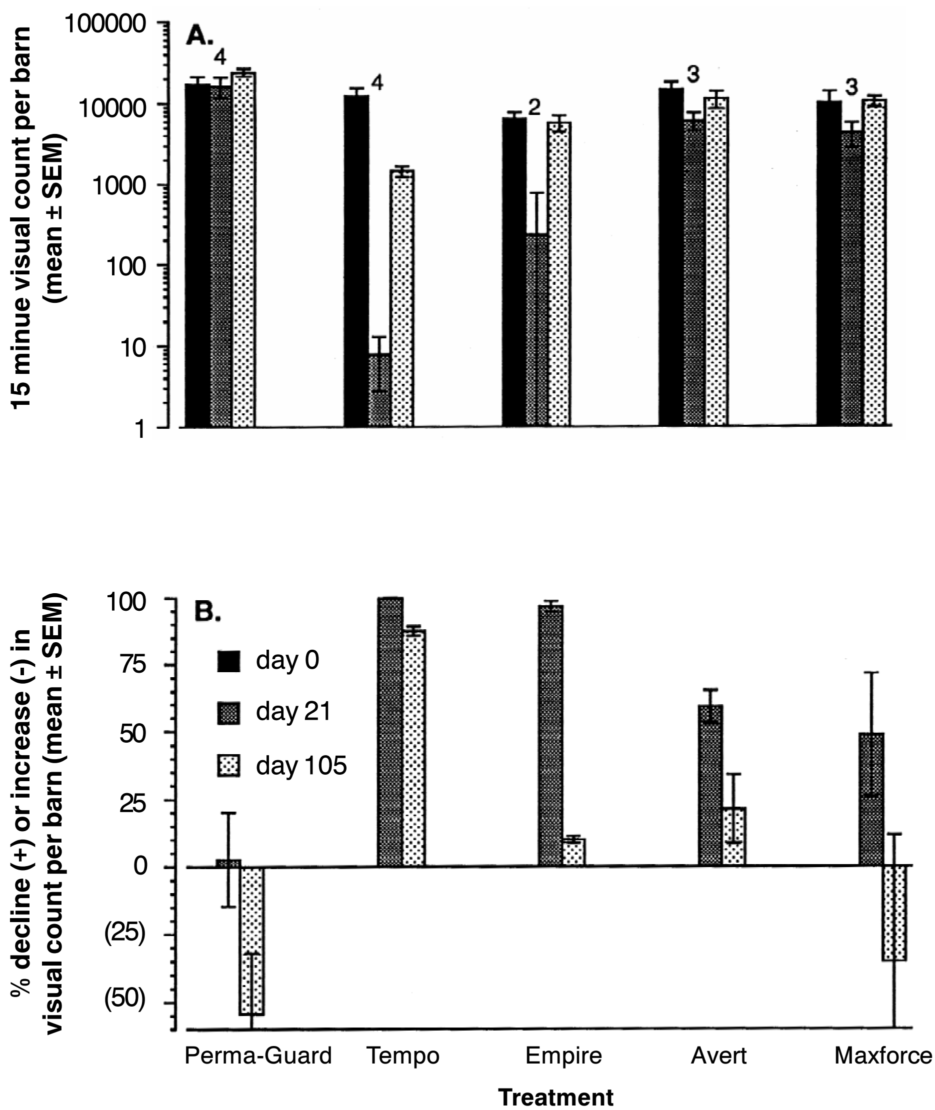

Figure 1. Results of a 3-months study of insecticide efficacy in swine farrowing barns.
A. Visual counts conducted during a 15-minute transect through each barn. Mean (± SEM) counts are plotted on a logarithmic scale. Day 0 is the day of treatment, day 21 represents one farrowing cycle, and day 105 represents ca. 5 farrowing cycles. The numerals above the bars represent *N*, the number of barns in the treatment.
B. The data in A. were converted to percentage decrease (positive number) or increase (negative number) in the cockroach visual count relative to the day 0 counts.

RESULTS

Pre-treatment counts

The mean pre-treatment population estimate was 12,818 ± 1,658 cockroaches (range: 4,900 to 21,000) per 15 min visual transect in each of 16 barns. There was no significant difference in pre-treatment cockroach populations among the five treatments (ANOVA, $F_{4, 11} = 1.153$, $P = 0.382$).

Clean-out treatments

The standard Perma-Guard treatment failed to reduce the cockroach population as expected based on past failures on this farm. The cockroach population estimates 21 days after treatment were not significantly different from the pre-treatment estimates (paired Student's *t*-test, $t = 0.424$, $N = 4$ barns, $P = 0.700$) (Fig. 1A). Indeed, after about five farrowing cycles (105 days) the cockroach population significantly increased to 24,000 ± 2,426 cockroaches ($t = 3.347$, $P = 0.044$), 54.3 ± 22.4% higher than the pre-treatment count (Fig. 1B).

Tempo 20WP significantly reduced the cockroach population in the first farrowing cycle by > 99.9% from 12,325 ± 2,902 to 7.7 ± 5.0 cockroaches (*t*-test, $t = 4.251$, $N = 4$, $P = 0.024$). After 105 days, the population estimate was 1,447 ± 212, an 87.5 ± 1.8% reduction, and still significantly different from the pre-treatment count ($t = 3.959$, $P = 0.029$). Treatment of two barns with Empire 20 also reduced the population estimate from 6,400 ± 1,372 to 230.5 ± 550.4 cockroaches after 21 days (96.6 ± 2.0% reduction; $t = 11.207$, $P = 0.057$). However, after 105 days the population rebounded to 5,750 ± 1,327, a mere 10.0 ± 1.2% less than the pre-treatment counts ($t = 4.333$, $P = 0.144$).

Two bait treatments were substantially less effective. Avert gel significantly reduced the population by 59.1 ± 6.2%, from 14,733 ± 3,267 to 6,100 ± 1,553 cockroaches, after 21 days ($t = 4.231$, $N = 3$, $P = 0.052$), but only by 21.4 ± 12.8% after 105 days, to 11,333 ± 2,642 cockroaches ($t = 1.912$, $P = 0.196$). Although Maxforce gel treatment reduced the population by 48.6 ± 22.8% ($N = 3$) after 23 days (10,000 ± 3,961 to 4,300 ± 1,514 cockroaches) this decline was not statistically significant ($t = 1.811$, $P = 0.212$). Moreover, after 105 days the population estimate increased by 35.1 ± 46.8%.

At the conclusion of this trial we sought to compare the efficacy of a wettable powder and a microencapsulated formulation of cyfluthrin. Eight barns were treated with 22.5 liters of Tempo 20WP and 8 others with Optashield CS. Twenty-one days later, pairs of barns in each treatment were treated with Avert, Drax, or Maxforce gel baits to augment the effects of the residual treatments. Unlike before, there was a significant difference in the mean counts before treatment in the 2 sets of cyfluthrin-treated barns (unpaired *t*-test, $t = 2.502$, $df = 14$, $P = 0.025$), with means of 9,650 ± 1,315 and 17,337 ± 2,776 cockroaches in the Optashield and Tempo treatments, respectively (range: 5,200 to 31,000). Both formulations demonstrated excellent efficacy, reducing the population estimates within 21 days by >99.5% to 35.5 ± 7.0 and 7.6 ± 1.5 cockroaches, respectively. However, in the 2 barns treated with Optashield alone, the count declined more slowly (data not shown) and subsequently rebounded more rapidly. By day 105 the population estimate was reduced by 51.4 ± 0.6% relative to the pre-treatment count in Optashield-treated barns whereas in the Tempo-treated barns the pre-treatment count was reduced by 87.6 ± 2.8% by day 105. The latter result was remarkably similar to the result obtained in the first study (Fig. 1B).

Maintenance treatments

The three baits (Avert, Drax, and Maxforce) appeared to have some, but rather limited efficacy, even after the cockroach population was dramatically reduced with residual insecticides. In the absence of a follow-up bait treatment the population increased 265 ± 162-fold, from 16.7 ± 6.4 cockroaches on day 21 to 2,055 ± 453.6 by day 105 in the 4 barns treated with cyfluthrin. Treatment with Maxforce or Avert reduced the rebound in the cockroach population to 24.7 ± 6.6 and 29.9 ± 11.6-fold relative to the respective day 21 counts. However, Drax bait failed to slow the surge in the population, resulting in a 222.7 ± 131.4-fold increase between days 21 and 105, from 14.8 ± 6.1 to 2,273 ± 886.

DISCUSSION

Pesticide usage patterns and pest management practices

There is a dearth of information about current usage patterns, amounts of pesticides used, and dependence on such applications in swine production. Therefore, an integral component of our on-going research is development of a grower survey that will generate reliable data on pesticide use, usage patterns, and pest management practices. Cockroach management options that are currently used are limited to silica-based dusts, organophosphate, and pyrethroid insecticides. Our pilot surveys have indicated that growers do not practice cultural, biological, or physical approaches and have little knowledge of pesticide resistance.

Most farms in NC appear to be severely infested with cockroach, most apply insecticides to control cockroach populations, and most applications appear to yield inadequate results. Where insecticides are deployed, applications are scheduled into the AIAO management scheme. Thus, in farrowing barns pesticides are applied about every 3 weeks, after the piglets have been weaned and the barn has been washed and disinfected, and before new pregnant sows are brought in. Using conventional "clean-out" application rates of chlorpyrifos (500 mg/m^2; Wickham, 1995), a 250 m^2 barn would be treated with 125 g AI and a typical 16 farrowing barn farm would thus receive a minimum of 2 kg AI per treatment or 34 kg AI per year for cockroach control. Our work shows that this can be substantially reduced with a proper "clean-out" application that precisely targets cockroach refugia. Cyfluthrin treatments would result in 0.076 g AI per barn, or ca. 1.2 g AI per farm. A single application appears to provide at least 3 months of residual activity.

Reduced-risk options for cockroach management

While the organophosphate and pyrethroid insecticides are effective and inexpensive for reducing large infestations, our goal is to prevent the increase in cockroach populations with other approaches, which would also forestall the development of insecticide resistance. Unlike the excellent efficacy demonstrated by many baits in most structural environments (Reierson, 1995), the follow-up bait applications were only marginally effective in swine barns. Moreover, they were substantially more expensive and their application was time-consuming and laborious. Other options under current investigation include juvenile hormone analogs and physical and mechanical control whereby favorable refugia, especially those in close proximity to the animals, are eliminated with boric acid (wall voids), silica gel (attic), and extensive baiting and caulking (cages). Removal of cockroaches with vacuum cleaners was deemed too labor-intensive, and failed to control house flies and the large populations of spiders, including the black-widow spider, *Latrodectus mactans* L.. Most biological control approaches are poorly developed in urban environments, and efforts in this area have proven relatively ineffective (Suiter, 1997). The swine production environment offers a unique opportunity to re-visit and evaluate their efficacy in a high humidity, moderate temperature habitat.

A critical component of our developing program is adapting *cultural* practices. The all-in all-out swine management offers several advantages, including the simultaneous emptying of barns, which can then be effectively targeted with pesticides, disinfectants, and physical approaches. We are examining the option of reducing by 50% the frequency of washing the walls. Because cockroaches, spiders, and flies are most abundant on/in walls, this can significantly reduce insecticide usage while increasing the efficacy of our management program. We are also reducing the movement of loose items between barns in a quarantine-like approach to reduce re-infestations.

In summary, we presented a progress report on our efforts to develop an integrated pest management program for the confined swine industry. We advocate a 3-step approach: 1) Large cockroach infestations are reduced with targeted minimal applications of residual insecticides that also reduce house fly and spider populations. Resistance monitoring and insecticide rotations are components of this approach. 2) The population is maintained at a low level by a combination of inorganic dusts, physical exclusion, biological control, insecticidal baits, and modified production practices. 3) A monitoring program, which is based on visual inspections and cockroach counts, constitutes the decision-making element of this program.

ACKNOWLEDGEMENTS

We thank Murphy Family Farms for excellent cooperation and providing us access to commercial farms, and Gil Pratt for coordinating the efforts. This study was supported by grants from the Southern Region SARE Program (AS95-21), U.S. Department of Agriculture Pest Management Alternatives Program (9804680), the Blanton J. Whitmire Endowment at North Carolina State University, a Research Excellence Award from Orkin Pest Control, and an Urban Entomology Scholarship from the North Carolina Pest Control Association.

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