

Tertiary Mortality In The German Cockroach

Purdue University research provides new insights about the impact of horizontal transfer on roaches.

By Grzegorz Buczkowski, Ph.D., Gary W. Bennett, Ph.D., and Clay W. Scherer, Ph.D.

We've all heard that cockroaches are able to reproduce in exponential numbers. The German cockroach's rapid reproductive cycle allows the population to double every two weeks. Under optimal conditions, a single female cockroach and her offspring can produce more than 500,000 cockroaches in one year. Such impressive reproductive potential gives the German cockroach a unique ecological advantage and is most likely the primary factor responsible for its enormous success as a household pest.

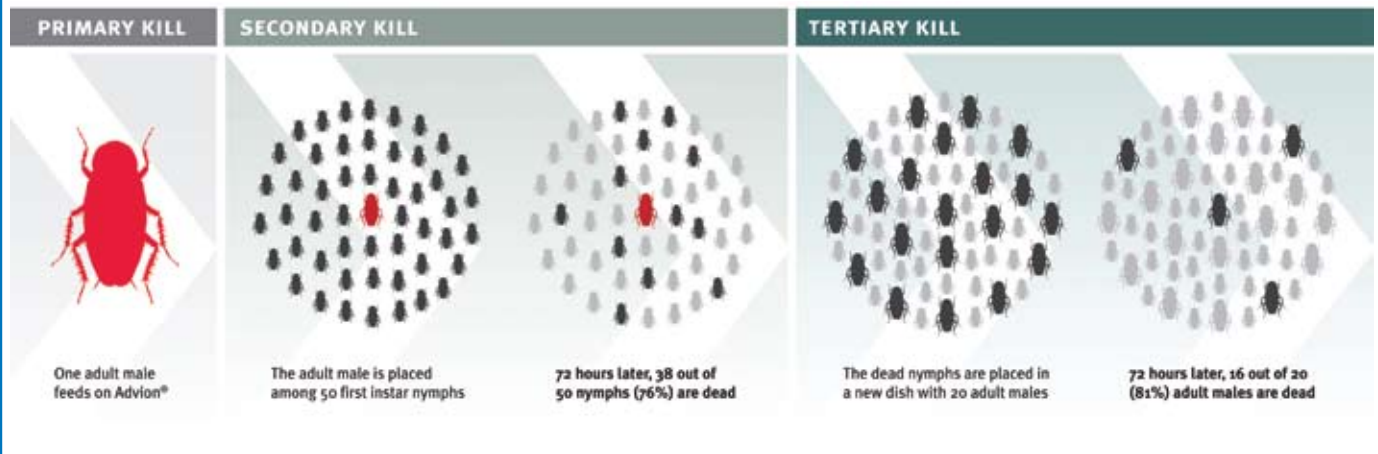
Traditionally, cockroach infestations have been fought with various chemical and non-chemical tools, often with mixed results. Recent research conducted at Purdue University by entomologist Dr. Grzegorz Buczkowski shows that there is a new tool that may assist pest management professionals in countering the German cockroach's remarkable reproductive potential. True Exponential Control™ (a term coined by DuPont Professional Products)

refers to a unique process of horizontal transfer whereby a single donor cockroach fed Advion® Cockroach Gel is capable of transferring the bait's active ingredient, indoxacarb, to a large number of recipient cockroaches, thus killing them. The process is unique because it involves two levels: *secondary kill* and *tertiary kill*. While secondary kill has been demonstrated with many cockroach baits, tertiary kill has not been previously demonstrated with any insecticide. Thus, we demonstrate that the high killing potential of indoxacarb effectively fights the high reproductive potential of the German cockroach.

HORIZONTAL TRANSFER. Horizontal transfer of insecticides occurs when active ingredients contained within baits or liquid spray insecticides are passed among individuals within an insect population. Active members of a population, most often foraging adults, acquire the active ingredient,

Tertiary Kill: HOW IT WORKS

A graphic representation of Dr. Grzegorz Buczkowski's research demonstrating tertiary kill appears below. The precise definition of the term tertiary – pronounced tûr'shē-ēr'ē – is "third in order, degree or rank," according to *The American Heritage Dictionary*. "When an active ingredient is transferred successfully from a donor cockroach to a recipient cockroach, resulting in death, that's considered horizontal transfer, which is commonly referred to as secondary kill," Buczkowski said. "What we've shown in our research at Purdue is a third level of control with indoxacarb we're calling tertiary kill. With each additional step, the amount of active ingredient that is available to the insect declines which explains why we didn't see any evidence of quarternary kill in our studies."



return to the nest or an aggregation, and subsequently share the insecticide with more sedentary members of the population which often cannot feed or do not feed independently. The recipients may obtain the insecticide directly from the donors (e.g., mutual grooming, direct contact) or by consuming and/or contacting insecticide-containing excretions deposited by the donors (e.g., coprophagy, emetophagy).

In the German cockroach, *Blattella germanica*, three mechanisms have been shown to facilitate the horizontal transfer of insecticides: coprophagy, necrophagy and emetophagy. Coprophagy, or the ingestion of feces, is especially important in targeting first instars, which represent a significant proportion of the total population under normal conditions, yet may be the most difficult to reach with baits because they do not forage independently, spend the majority of time within the shelter and rely on adult feces for nutrition. Thus, adult cockroaches that feed on the bait directly can be used to deliver the bait to more sedentary stages such as young nymphs. Coprophagy is most effective with slow-acting insecticides, primarily hydramethylnon, which are more likely to be transferred because cockroaches that feed on the bait have plenty of time to return to their shelter and produce insecticide-laden feces before they die. Necrophagy, or ingestion of dead conspecifics, also plays an important role in the transfer of bait toxicants and has been demonstrated with several commercial baits. Finally, emetophagy, or the ingestion of insecticide-induced regurgitate, has been shown to be an important mechanism by which fast-acting, emetogenic insecticides (e.g., fipronil) are disseminated within cockroach aggregations.

All three mechanisms have been shown to contribute significantly to the overall efficacy of baits by causing secondary kill within cockroach populations. However, the propo-

sition that horizontal transfer may continue beyond secondary mortality and may involve higher levels such as tertiary or quaternary mortality has never been examined. Thus, the goal of our project was to investigate tertiary kill with indoxacarb, a novel pyridoxyl oxadiazine insecticide discovered by Dow Professional Products.

STUDY DESIGN. In a two-part study, we first examined the horizontal transfer of indoxacarb from adult males to first instar nymphs (secondary mortality). We then investigated the transfer of indoxacarb from first instar nymphs (killed via secondary kill) to adult male recipients (tertiary mortality). The objective for the first phase of our study was to determine the number of nymphs that can be killed by excretions produced by a single adult male donor. We placed 50 first instars in a small Petri dish, provided them with water and harborage, and allowed them to acclimate to the dish for 24 hours without food (see box on page 90). A single bait-fed and symptomatic male was added to the dish at the end of the acclimation period. Mortality in the nymphs was examined at 72 hours.

To examine tertiary mortality we investigated the horizontal transfer of indoxacarb from first instar nymphs that died by feeding on excretions from a bait-fed adult male to adult male recipients. We determined that excretions from a single adult male are capable of killing 38 first instar nymphs. Thus, we examined tertiary transfer of indoxacarb from 38 first instars to 20 adult male recipients. We first set up dishes as described previously (single donor male plus 50 first instars) to obtain the secondary donors. We allowed the first instars to interact with the symptomatic male for 12 hours and then transferred 38 symptomatic nymphs to a clean dish that was provisioned with water and harborage and contained 20 recipient males which had been starved for 24 hours.

RESEARCH RESULTS. Our results indicate that indoxacarb is effectively transferred from adult donor males and results in significant secondary mortality of first instar nymphs. In the test involving the transfer of indoxacarb from a single adult male to 50 first instars, 38 (76 percent) nymphs died within 72 hours after contacting the symptomatic male. Our results indicate that the transfer of indoxacarb continues beyond secondary mortality and results in significant tertiary mortality. When 20 adult males were exposed to 38 first instar nymphs that died by having contact with the primary donors (bait-fed adults), 16 of 20 (81 percent) adult males died in 72 hours.

Behavioral observations indicated that the mechanisms involved in the horizontal transfer of indoxacarb may include coprophagy, necrophagy and emetophagy. Coprophagy was evident as the recipients were attracted to the rectal region of dying cockroaches and appeared to feed on excretions and/or secretions from the posterior end (see Figure 1, page 92). Necrophagy also appeared to play an important role as we frequently discovered cadavers that had their heads detached and abdomens hollowed out, indicating feeding on the corpses (see Figures 2 and 3 on page 92). Even more apparent was emetophagy, or feeding on indoxacarb-induced regurgitate. We observed that cockroaches dying of indoxacarb poisoning exuded liquid excretions that were attractive and lethal to conspecifics. The exudates were highly attractive to recipient cockroaches, especially first instars. The nymphs aggregated around the symptomatic donors and horizontal transfer of indoxacarb appeared to occur by contact with and/or ingestion of the regurgitated bait.

CONCLUSIONS. Our study demonstrates a unique trophic cascade that leads to tertiary mortality. We describe a chain reaction in which a primary donor transfers



Figure 1. Nymphs feeding on excretions from the oral and anal regions of a dying cockroach.

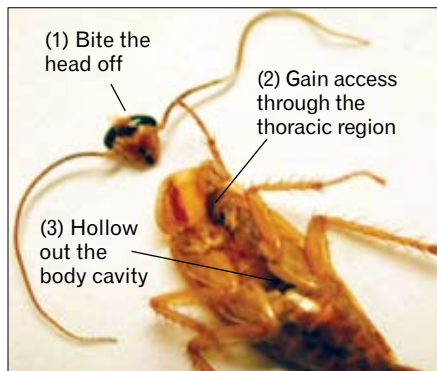


Figure 2. An example of a cannibalized adult cockroach that has consumed indoxacarb.



Figure 3. An adult roach cannibalized by young nymphs serves as a "walking bait arena."

insecticide to primary recipients, which then become secondary donors. We show that a single donor delivers a lethal dose of indoxacarb to a considerable number of young nymphs (secondary mortality). These recipients subsequently become donors to other cockroaches and are capable of causing significant mortality in other members of the population (tertiary kill). Although other insecticides have been shown to exhibit secondary mortality, indoxacarb is the first insecticide proven to cause multiple steps of transfer leading to tertiary mortality.

PROOF

Grzegorz Buczkowski is a Research Assistant Professor in the Department of Entomology and Director of the Industrial Affiliates Program at Purdue University; Gary W. Bennett is a Professor in the Department of Entomology and Director of the Center for Urban and Industrial Pest Management at Purdue University; and Clay W. Scherer is Global Product Development Manager for Professional Products at DuPont.

Want to Learn More?

Dr. Grzegorz Buczkowski's ground-breaking work on tertiary kill will be featured in an upcoming issue of the *Journal of Economic Entomology*. The bi-monthly publication publishes articles on the economic significance of insects on a wide range of topics including ecology and behavior, veterinary entomology, stored product pests, medical entomology, and household and structural insects. The editor-in-chief of the journal is John Trumble, Department of Entomology, University of California, Riverside. The journal's subject and associate editors, also members of the Entomological Society of America, volunteer their time reviewing manuscripts for possible publication. To access a copy of Dr. Buczkowski's article when it is published, or to learn more about the *Journal of Economic Entomology*, visit www.entsoc.org/pubs/periodicals/jee/index.htm.

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- ▶ See proof of Advion® exponential control in the June 2008 issue of the *Journal of Economic Entomology*.



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