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HORIZONTAL TRANSFER OF A NOVEL ISOCYCLOSERAM BAIT ON GERMAN COCKROACHES (BLATTODEA: ECTOBIIDAE)

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Abstract Isocycloseram is a novel insecticide with fast activity on a broad range of pests, including German cockroaches, *Blattella germanica* (L.). Gel baits are common insecticide formulations used against cockroaches and can indirectly kill through horizontal transfer of bait toxicants between conspecifics. We examined the horizontal transfer potential of a 0.1% isocycloseram gel bait formulation on a susceptible strain of German cockroaches (UCR) in comparison with commercial baits available in the United States containing 0.6% indoxacarb, 0.05% fipronil, 0.5% dinotefuran, or 0.5% clothianidin + 0.5% pyriproxyfen. To examine coprophagy and emetophagy, adult male cockroaches were provided access to bait in a choice test with dog food as the alternative food source, which killed 85–100% of cockroaches within 24 h. The bait and carcasses were removed, and new groups of adult males were transferred to the arenas containing excretions from previous males. The secondary exposure killed 93–100% of cockroaches within 7 d (mean survival time 1.6 d for 1% isocycloseram; other baits 1.0–3.5 d). To examine the effect of necrophagy, adult males were exposed to bait for 24 h, which killed 92.5–97.5% of cockroaches across all baits. The dead adult males were transferred to clean arenas with 30 first and second instars with access to dog food. Nymphs exposed to isocycloseram-killed males experienced 99.2% mortality within 14 d, while mortality with other baits was 15.3–96.7%.

Key words Isocycloseram, German cockroach, bait, horizontal transfer, insecticide resistance

INTRODUCTION

The German cockroach is a global urban pest that infests indoor environments, producing allergens and mechanically transmitting pathogens (Lee and Wang, 2021). The novel compound of isoxazoline insecticide, isocycloseram, has been demonstrated to be effective against insecticide-resistant German cockroach strains when incorporated in a bait formulation (Lee et al., 2024; Saran et al., 2025).

Baits may indirectly kill cockroaches through horizontal transfer of lethal doses from treated conspecifics. This can occur through the consumption of insecticide-contaminated excretions (emetophagy/coprophagy) or cannibalism of bait-killed carcasses (necrophagy) (Buczkowski et al., 2008; Hamilton et al., 2023). In this study, we compared the horizontal transfer effects of a 1% isocycloseram bait with four commercial bait insecticides on a susceptible strain of German cockroach.

MATERIAL AND METHODS

Insects We used the UCR susceptible strain, which has been reared without insecticide exposure for >40 years under conditions of 24 $\pm$ 2ºC, 30% R.H., and 12:12 L:D photoperiods.

Insecticides The following cockroach gel baits (% active ingredient) were used in this study: 1% isocycloseram (Syngenta Crop Protection LLC, Greensboro, NC, USA), Maxforce FC Magnum (0.05% fipronil, Environmental Science U.S., LLC, Cary, NC, USA), Advion CR Gel Bait (0.6% indoxacarb, Syngenta Crop Protection LLC, Greensboro, NC, USA), Alpine CR Gel Bait Rotation 2 (0.5% dinotefuran, BASF Corporation, Research Triangle Park, NC, USA), and Vendetta Nitro (0.5% clothianidin, 0.5% pyriproxyfen, MGK Company, MN, USA).

Horizontal Transfer—Coprophagy and Emetophagy Exposures were carried out in glass petri dishes (10 cm diameter) with fluon-coated inner walls to prevent escape. Baits were placed in 0.3 g on weigh boats with walls removed for access. Water was provided in 1.5 ml microtubes with cotton plugs. Five randomly selected adult males were placed in a petri dish with 0.3 g of bait and water, while controls received dog food instead of bait. Mortality was recorded after 24 h. The cockroaches and bait were removed, and the dish was reused for the next experiment. Ten 1st instar nymphs were introduced to Petri dishes that had previously contained bait and adult males. Nymph mortality was recorded daily for 7 d, and dead nymphs were removed. Each treatment was replicated four times.

Horizontal Transfer—Necrophagy All exposures were conducted in plastic arenas (~20 x 14 cm) with Teflon-coated walls to prevent escape. Baits were applied in 0.3 g amounts on weigh boats with the walls removed for access. Each arena also contained a piece of dog food, water in a glass vial (8 ml), and a folded paper harborage (~5 x 8 cm). Primary donors (direct exposure group) were prepared by introducing ten randomly selected adult males to an arena without bait for 24 hours. Then, bait was introduced for 24 h, and mortality was recorded. Controls were not given any bait. Secondary recipients (thirty 1st–2nd instar nymphs) were acclimatized in a clean arena without bait for 24 h. Afterward, ten adult males (primary donors) were introduced into the arena. Adult males from the untreated control group were introduced after being killed from freezing. Nymph mortality was recorded daily for 7 d, then at 10 and 14 d, with dead nymphs removed from the arena.

Data Analysis Kaplan Meier survival analysis and log-rank tests were used to quantify and compare survivorship under different treatments using SPSS Ver 29.

RESULTS AND DISCUSSION

In the coprophagy and emetophagy experiment, direct exposure to cockroach baits killed 100.0% of adult males in 24 h, except for Advion, which killed 85.0%. When first instars were exposed to the fecal matter and vomitus of bait-treated adult males, all baits resulted in 100% mortality within 7 d, except Advion, which caused 93% mortality (Table 1).

Table 1. Mean survival time and mortality of nymphs after exposure to fecal material and vomitus of bait-treated adult males for 7 d.

Treatment	n	Mean Survival Time (d)	95% CI	% Mortality
1% isocycloseram	42	1.6	1.3–1.8	100.0%
Maxforce FC Magnum	40	1.0	1.0–1.0	100.0%
Advion	43	3.5	3.0–4.1	93.0%
Alpine	42	3.0	2.4–3.6	100.0%
Control	41	-	-	0.0%

Maxforce FC Magnum caused the quickest decline in survivorship (MST of 1.0 day), followed by 1% isocycloseram (1.6 days), Alpine (3.0 days), and Advion (3.5 days) (Table 1, Figure 1).

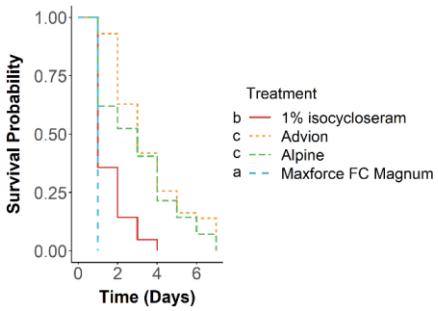

Figure 1. Survivorship of 1st instar nymphs exposed to fecal material and vomitus of bait-treated adult males. Different letters by figure legend indicate significant difference between treatments (log-rank test; $\alpha = 0.05$)

In the necrophagy experiment, primary donor (direct bait exposure) adult males experienced 92.5–97.5% mortality in 24 h. Nymphs (secondary recipients) exposed to adult males killed by 1% isocycloseram or Maxforce FC Magnum experienced the fastest decrease in survivorship with MST of 3.9–4.1 d (Table 2, Figure 2).

Table 2. Mean survival time and mortality of nymphs after exposure to bait-killed adult males for 14 d.

Treatment	n	Mean Survival Time (d)	95% CI	% Mortality
1% isocycloseram	121	4.1	3.5–4.8	99.2%
Maxforce FC Magnum	122	3.9	3.3–4.4	96.7%
Advion	122	9.6	8.8–10.4	66.4%
Alpine	110	7.7	6.5–8.8	51.8%
Vendetta Nitro	131	12.1	11.4–12.9	15.3%
Control	120	-	-	0.0%

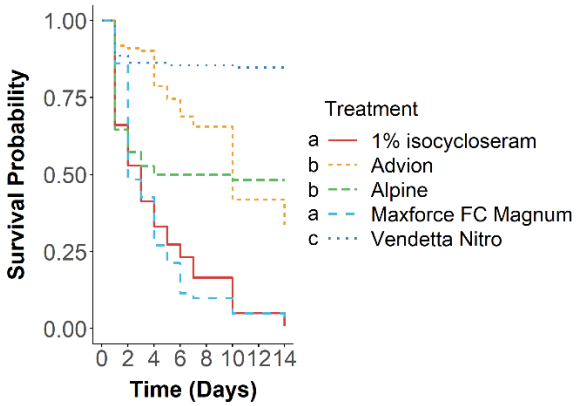

Figure 2. Survivorship of nymphs exposed to bait-killed adult males. Different letters by figure legend indicate significant difference between treatments (log-rank test; $\alpha = 0.05$)

Nymphs exposed to Advion, Alpine, and Vendetta Nitro-treated males survived longer with MST of 7.7–12.1 d (Figure 2). The 1% isocycloseram-treated males killed the most secondary recipients (99.2% versus 15.3–96.7% mortality in other treatments) (Table 2).

Like commercial bait products, the 1% isocycloseram bait retained a high degree of toxicity through indirect exposure to poisoned conspecifics. The comparable or better performance of the 1% isocycloseram bait may be due to its high toxicity. It is more toxic on contact with adult males than the other active ingredients used in this study, except for fipronil, which coincides with the magnitude of their horizontal transfer effects (Lee et al., 2024). Additionally, isocycloseram is not known to require a bioactivation process, which may explain its advantage over the indoxacarb bait (Advion) (Gondhalekar et al., 2016; Blythe et al., 2022).

CONCLUSION

Secondary horizontal transfer effects of the bait were observable through emetophagy, coprophagy, and necrophagy, causing ~100% mortality with both exposure modes. Only the Maxforce FC Magnum bait was comparable or faster acting than 1% isocycloseram, indicating a high degree of bioavailability even if the insects are not directly exposed to the bait. Additional studies involving insecticide-resistant strains and more complex arenas can better inform the potential of this mechanism to improve control in the field.

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