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Laboratory and Field Trials of Commercial Imidacloprid and Fipronil Gel Baits against *Periplaneta americana* Linnaeus [Blattodea: Blattidae] and *Blattella germanica* Linnaeus [Blattodea: Ectobiidae]

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Abstract

This study evaluated the efficacy of Imidacloprid (2.1%) and Fipronil (0.05%) gel baits against *Periplaneta americana* and *Blattella germanica* through laboratory and field trials. In the field, pre-treatment monitoring over seven days revealed moderate to high cockroach activity, particularly among *B. germanica*. Following the application of 0.5 g of each gel bait, complete elimination of both species was observed within seven days, indicating 100% reduction in population. Laboratory trials involved graded bait concentrations applied in duplicate tanks, with ten individuals per dose. Imidacloprid induced rapid knockdown in *P. americana* within 55 minutes, while *B. germanica* exhibited delayed knockdown at approximately 7 hours and 20 minutes. Fipronil showed strong bait attraction in *P. americana*, with abdominal shivering observed around 6 hours post-ingestion. *B. germanica* responded more acutely to Fipronil, with faster mortality and no withdrawal behavior. LD_{50} values ranged (0.055 - 0.854) g across species and concentrations, with dose-dependent increases in toxicity factors. No mortality occurred in control groups. These findings confirm the high efficacy of both gel bait formulations, with Imidacloprid being most effective bait for *P. Americana* cockroach management

Keyword: American cockroach, German cockroach, Gel baits, Knockdown time, Urban ecology.

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INTRODUCTION

The persistent infestation of Cockroaches in Nigerian households presents a significant challenge to public health and sanitation. Despite the widespread use of conventional method, especially the use of residual insecticide sprays, resistance development and bait avoidance behaviors (Gondhalekar & Scharf, 2012), have reduced their effectiveness. Studies conducted in Nigeria (Atoyebi *et al.,* 2020, Hossain *et al.,*2023, Busari *et al.,* 2025, Adeogun *et al.,* 2025) and other tropical regions (Şengül Demirak& Canpolat 2022, Hazarika *et al.,* 2025) have highlighted the need for alternative control strategies that are both effective and environmentally stable.

Cockroaches are among the most ancient insect groups, with fossil records dating back over 300 million years (Vršanský&Kazimírová 2023). They are classified into five families across two major

phyletic lines, Blattoidea and Blaberoidea, based on reproductive strategies and morphology (Bell *et al.,* 2007). Blattoidea species are oviparous, producing rigid egg cases that are discarded shortly after formation while on the opposite, Blaberoidea exhibited varied oviposition strategies, including internal embryogenesis and pseudo-viviparity. Scientific research has historically focused on a few domiciliary species as Bell *et al.*, (2007) emphasized, our wide knowledge is largely based on laboratory studies of these two species: *Periplaneta Americana* (Linnaeus, 1758) and *Blattella germanica* (Linnaeus, 1767), ecological data on wild populations were still limited.

Gel bait formulations have emerged as a viable alternative, offering discreet application, reduced human exposure, and high palatability to cockroaches. However, Understanding cockroach physiology is essential for developing effective baits. for instance, Oyebanji *et al*., (2014) investigated the distribution of digestive enzymes in *P. americana*, and provided insights into it nutrient absorption and bait palatability that in female, y-amylase and lipase enzymes were absentin the hindgut which implies that bait rich in fat might not be effective due to inability to process it in later digestion stages, and therefore, protein or carbohydrate formulation would be preferred. This kind of physiological data can inform the design of bait matrices that align with cockroach feeding behavior. In recent times, Active ingredients such as Imidacloprid and Fipronil have shown strong insecticidal activity, even under the humid and variable conditions typical of tropical climates (Agrawal & Tilak, 2006; Abdullah *et al*., 2023). These baits are particularly effective when integrated into pest management programs that emphasize sanitation, monitoring, and species-specific treatment strategies (Gondhalekar *et al*., 2021). And this must due to their formulation (Wang *et al*. 2004).According to Srinivasan *et al*. (2005) fipronil's effectiveness across various surfaces, with mortality rates ranges from 16% to 96%. Study in Benin by Padonou *et al*. (2023) claimed that 2.15% imidacloprid gel bait under laboratory and field conditions. Mortality rates exceeded 94% among adult cockroaches, and the bait showed strong performance in kitchens and latrines, although it did not prevent egg hatch from oothecae. Anikwe *et al*. (2014) validated the effectiveness of indoxacarb gel bait in Lagos, achieving up to 99.8% population reduction within two weeks. Jiang *et al*. (2015) confirmed that fipronil-based gel bait retains its potency even under extreme heat, a critical factor for Nigerian climates. Hence, this study aim to test, efficacy of a commercial Imidacloprid (2.1%) and Fipronil (0.05%) gel bait formulations against *Periplaneta americana* and *Blattella germanica* through laboratory and field trials, with emphasis on mortality rates, knockdown time, behavioral responses, and dose-dependent toxicity. First, by conducting laboratory trials as well as field trials in selected households in Lagos metropolis. These insights are purposefully, to improved pest management strategies and support evidence-based recommendations for urban cockroach control in Nigeria.

MATERIALS AND METHODS

Study Site and gel bait acquisition

This was conducted in a residential apartment at Shomolu, Lagos State, Nigeria. The site was selected based on visible signs of cockroach infestation and accessibility for daily monitoring. The gel baits used in this study, Maxforce® (Imidacloprid 2.1%) and Sniper® (Fipronil 0.05%): were purchased from a licensed insecticidal store situated in Ojuelegba, Surulere, Lagos.

Three specific locations within the residence were targeted for bait application: the kitchen cabinet, the store room, and the

area behind the air conditioning unit. These sites were chosen due to their high likelihood of cockroach activity and harborage. Prior to treatment, a visual survey was conducted to assess the cockroach population in each location. Gel bait was applied in 0.5 g portions on filter paper, which were then taped securely at each designated site. Monitoring was carried out daily for a period of fourteen days, during which the number of live cockroaches observed at each site was recorded.

Laboratory bioassay

Laboratory experiments were conducted at the Entomology Laboratory of the Department of Zoology, University of Lagos, under ambient conditions of 27 ± 2ºC and 70 ± 5% relative humidity. In the laboratory trials, exposure was conducted in quadruplicates. For each concentration level tested, four separate tanks were used, each containing five individual cockroaches, resulting in a total of twenty organisms per concentration. Two cockroach species were used: the German cockroach *(Blattella germanica)* and the American cockroach *(Periplaneta americana)*. A total of 20 individuals of each species, comprising mixed sexes, were used for each treatment group.

German cockroach exposure

For *B. germanica*, gel bait concentrations of 0.05 g, 0.1 g and 0.2 g and Control (0g) were tested for both Imidacloprid and Fipronil gel bait formulations. The baits were not applied directly to the Petri dish but instead smeared onto circular Whatman® filter paper fitted the dish. Each Petri dish contained five cockroaches, and each concentration was replicated ten times. The dishes were covered with their respective lids to prevent escape while allowing air circulation.

American cockroach exposure

For *P. americana*, bait concentrations of 0.3 g, 0.5 g and 1.0g gel baits of both test compounds were tested alongside the Control. The cockroaches were placed in 3-liter round-bottom plastic containers, each fitted with a perforated lid to allow ventilation. The bait was applied to plain pieces of paper and placed inside the container. Each treatment group contained ten cockroaches, and each concentration was replicated accordingly.
All experiments lasted for 24 and 48 hrs hours, during which knockdown time (KD_T) was recorded.

Statistical analysis

Mortality data were analyzed using Probit regression to determine the 50% Lethal Dose (LD_{50}). Knockdown times were recorded manually. Statistical comparisons between bait types and concentrations were performed using SPSS version 27.0. All graphs were plotted with MS-Word Excel 2013.

RESULTS AND DISCUSSION

Field experiment

During the seven-day pre-treatment observation period, populations of *Periplaneta americana* and *Blattella germanica* were recorded at three locations within the residence: the cabinet, store, and wall corners.

For *Periplaneta americana*, the Cabinet recorded a total of 4 individuals over 7 days, with daily counts of 1,0,2,0,0, 0, and 1 for Days 1 to 7 respectively (**Fig. 1**). The Store showed slightly higher roach activity, with a cumulative count of 17 individuals collected as follows; 2,3,1,3,1,3, and 4 on Days 1 to 7 respectively (**Fig. 2**). No *P.americana* roach were observed at the wall corners (Fig. 3), throughout the entire week (zero activity in that location).

In the case of *Blattella germanica,* it exhibited significantly higher population levels compared to American cockroach. The Cabinet recorded a total of 38 individuals, with daily counts of 7,4,3,3,5,7 and 10 on Days 1 to 7 respectively (**Fig. 1**). The Store had the highest cumulative count of 103 individuals, with counts of 16,10,15,12,9,20, and 21 on Days 1 to 7 respectively (**Fig. 2**). Wall corners had a moderate activity, with a total of 29 individuals: 3,6,3,4,5,2, and 6 on Days 1 to 7 respectively (**Fig. 3**).

Following the application of 0.5 grams of each gel bait, Maxforce® (Imidacloprid 2.1%) and Sinper® (Fipronil 0.05%), no cockroach activity was observed anymore during the subsequent seven-day monitoring period. The complete eradication of both *P. americana* and *B. germanica* across all surveyed locations was recorded and quantify 100% reduction in observed population.

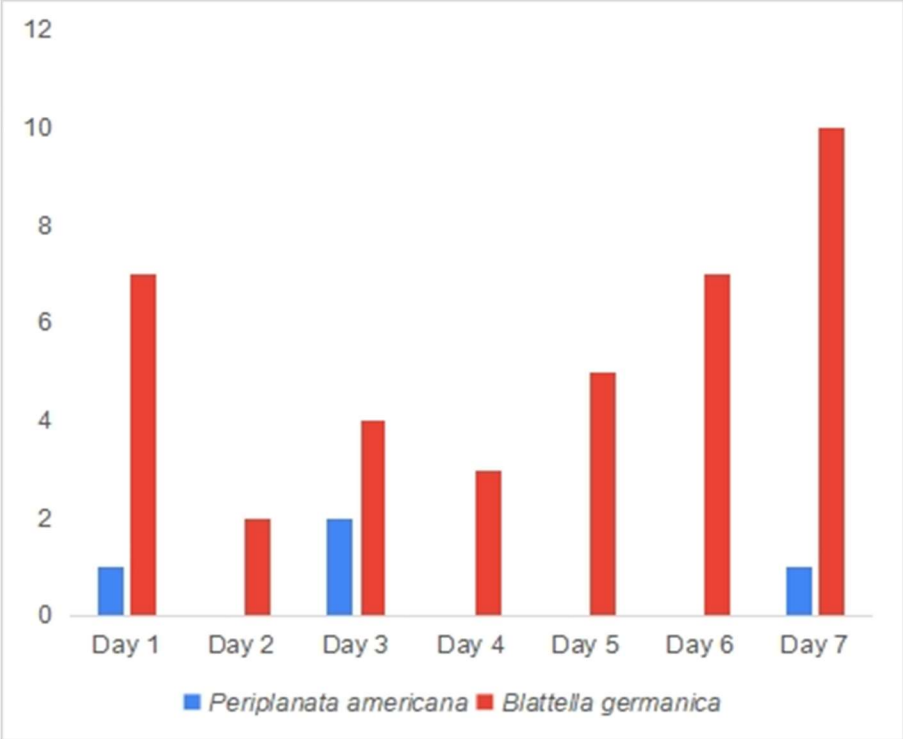

Figure 1: Population dynamics of both species in the cabinet

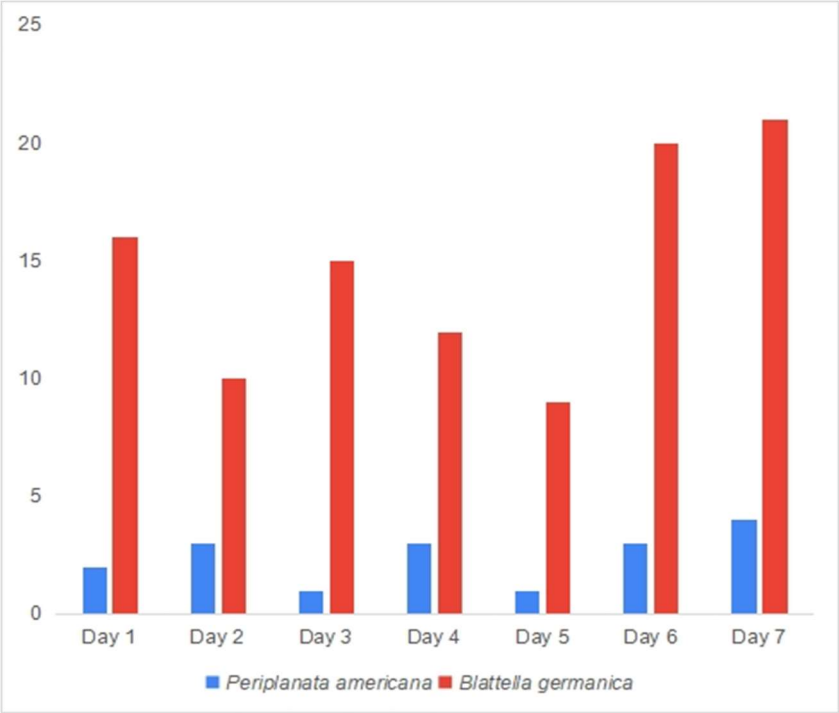

Figure 2: Population of both species in the store room

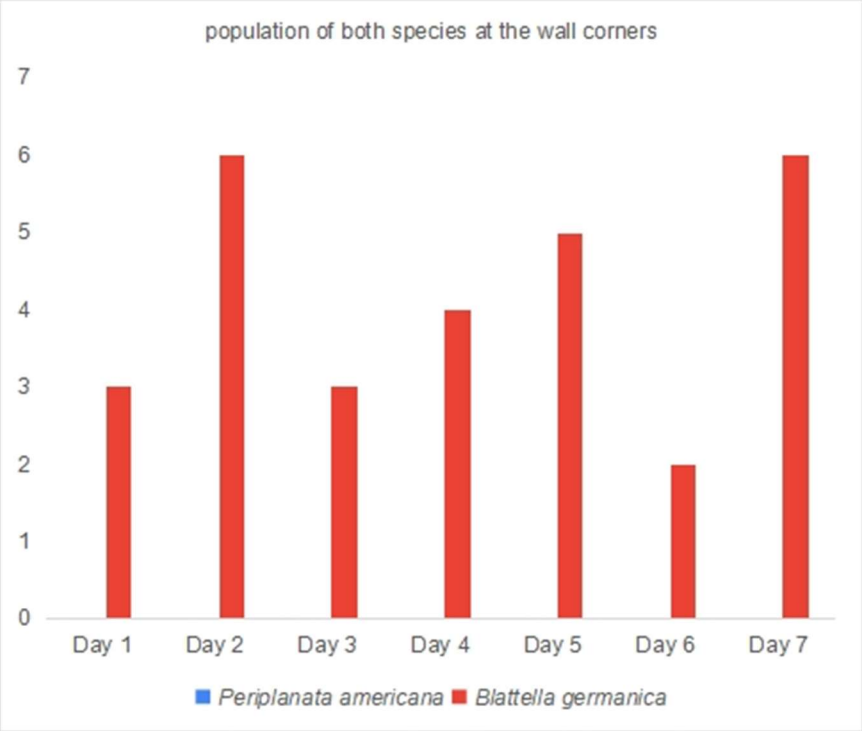

Figure 3: Distribution of *P. americana and B. germanica* at the wall corners

Behavioural response in Laboratory

Behavioural observations revealed distinct species-specific responses to the gel baits. *P. americana* exposed to Imidacloprid showed rapid knockdown within 55 minutes of contact, while those exposed to Fipronil were attracted to the bait and consumed lethal doses, with some individuals exhibiting rapid abdominal shivering approximately 6 hours post-ingestion. However, *B. germanica* responded to Imidacloprid by withdrawing after minimal contact, with knockdown occurring at approximately 7 hours and 20 minutes. Fipronil exposure in *B. germanica* resulted in more immediate toxicity, with no notable withdrawal behavior.

After *B. germanica* exposure, increasing bait concentrations correlated with faster knockdown times and higher mortality rates. The 0.2 gram dose yielded the most rapid and consistent toxic effects, while the control group showed no mortality, confirming the absence of external factors influencing death. In *P. americana*, the 1.0 gram dose produced the most immediate knockdown and highest mortality, while the 0.3 gram dose showed delayed effects. The control group remained unaffected anyway.

Imidacloprid acute toxicity

After 24hrs, *Blattella germanica*, the LD_{50} values were 0.092g and 0.056g at 48 hours, with slope values of 2.803 ± 2.902 and 2.046 ± 2.449 respectively. The toxicity factor increased from 4.65 to 7.64, and p-values of 0.621 and 0.877. In *Periplaneta americana*, LD_{50} values were higher, recorded at 0.428 g and 0.301g for 24 and 48 hours respectively, with slope values of 4.783 ± 1.765 and 5.916 ± 3.086. The toxicity factor rose slightly from 1.00 to 1.42, and p-values of 0.242 and 0.911 (**Table 1**).

Table 1: acute toxicity of Imidacloprid gel bait against *P. americana* and *B. germanica*

Species	Exposure(hrs)	N	Slope ±SE	LD_{50}(95%CL)	x^2	DF	p-value	TF
B. germanica	24	10	2.803 ± 2.90	0.092(0.046-0.157)	0.244	1	0.621	4.65
	48	10	2.046 ± 2.45	0.056(0.028-0.076)	0.024	1	0.877	7.64
P. americana	24	10	4.783 ± 1.77	0.428(0.294-0.591)	1.367	1	0.242	1.00
	48	10	5.916 ± 3.09	0.301(0.029-0.387)	0.012	1	0.911	1.42

TF: Toxicity factor, Df: Degree of Freedom, Cl: confidence limit

Fipronil acute toxicity

Blattella germanica, LD_{50} values were 0.139g at 24 hours and 0.055 g at 48 hours (**Table 2**): with slope values of 3.053 ± 2.615 and 3.188 ± 4.016. The toxicity factor increased significantly from 6.14 to 15.53, and p-values of 0.787 and 0.302. For *Periplaneta americana*, LD_{50} values were 0.854 g and 0.446 g at 24 and 48 hours respectively, with slope values of 3.067 ± 0.210 and 2.596 ± 0.910. The toxicity factor increased from 1.00 to 1.91, and p-values of 0.713 and 0.695.

Table 2: Acute toxicity of Fipronil gel bait against *P. americana* and *B. germanica*

Species	Exposure(hrs)	N	Slope ± SE	LD_{50}(95%CL)	x^2	DF	p-value	TF
B. germanica	24	10	3.053 ± 2.62	0.139(0.092-0.336)	0.073	1	0.787	6.14
	48	10	3.188 ± 4.02	0.055(0.009-0.081)	1.064	1	0.302	15.53
P. americana	24	10	3.067 ± 0.21	0.854(0.580-1.679)	0.135	1	0.713	1.00
	48	10	2.596 ± 0.91	0.446(0.090-0.799)	0.154	1	0.695	1.91

TF: Toxicity factor, DF: Degree of Freedom, CL: confidence limit, LD: Lethal Dose

Findings from the study corroborated the acclaimed high efficacy of both gel bait formulations to the test *Periplaneta americana* populations, with Imidacloprid being more effective gel bait compared with fipronil. This aligns with the findings of Appel (2003) who reported rapid mortality in *B. germanica* using indoxacarb, with LT_{50} values under 48 hours, reinforcing the efficacy of slow-acting neurotoxins in gel bait formulations. Srinivasan *et al* (2005) reported tht Fipronil gel bait recorded effective mortality with five days, with 16-100% and 51-100% mortality in *P. americana* and *B. germanica* populations respectively. Agrawal & Tilak (2006) evaluated Imidacloprid gel bait and found it highly effective against *B. germanica*, with mortality exceeding 90% within 72 hours. This supports our observation of delayed knockdown followed by 100% mortality in *B. germanica*, suggesting that behavioural aversion may precede acute toxicity. Similarly, Anikwe *et al*. (2014) reported that indoxacarb gel bait recorded 100% mortality in exposed *P. americana* within 4 days, and in *B. germanica* with 10 days. Equally, their observed LT_{50} values ranged from 40.65 to 145.6 hours depending on dose and species, which was consistent with the species-specific sensitivity observed in this study.

Gondhalekar *et al*. (2021) emphasized the role of bait aversion and resistance in *B. germanica*, noting that glucose-averse strains may avoid certain formulations. Hence, the observed withdrawal behaviour after sub-lethal bait contact in *B. germanica* may reflect early signs of such aversion. In contrast, *P. americana* showed strong bait acceptance and rapid physiological response, consistent with findings by Abdullah *et al*. (2023): who reported high efficacy of both Imidacloprid and Fipronil gel baits in sewer systems. Their study also noted abdominal spasms and behavioural disruption in *P. americana*, mirroring our observation of abdominal shivering following Fipronil ingestion.

The justification for testing graded dosing of cockroach populations was corroborated by the findings of Reid *et al* (2014) who deployed a similar method of precise gram-based applications of Clothianidin gel baits evaluations for clear dose-response relationships between cockroach population and test compounds. Salehzadeh *et al*. (2020) tested multiple active ingredients including Imidacloprid and found that *B. germanica* exhibited variable responses depending on bait composition. Their results support the dual relevance of formulation and concentration in optimum cockroach management in domestic and industrial spaces. The laboratory trials also revealed clear dose-dependent toxicity, with *P. americana* showing rapid knockdown and mortality at higher bait concentrations, while *B. germanica* exhibited delayed but eventual complete mortality.

Results from the field trials in this study showed complete elimination of the two cockroach populations within 7 days of bait application, consistent with the 95-99.8%

reduction reported by Anikwe *et al*. (2014) across multiple urban locations in Lagos State. Field trials confirmed the practical value of these formulations, with 100% population reduction achieved within seven days of bait application.

Wang *et al*. (2004), Boné and Bellés, (2022) and Oz *et al*. (2023) highlighted the challenges of resistance in pyrethroid-treated populations, and advocated for alternative active ingredients such as Fipronil and Indoxacarb. Thus, findings from this study aligns with this assertion, as both Imidacloprid and Fipronil demonstrated high efficacy and can be adopted as viable alternatives or as complements in integrated cockroach management schedules where applicable.

Gel baits formulations offer targeted delivery, reduced environmental impact, and are long-lasting control agents. The findings from this study demonstrated high efficacy in the acute toxicity assay, with a transition to simulated field trials showing equally high efficacy per unit time. The continued assessment of gel baits against different populations of both *P. americana* and *B. germanica* in laboratory and field trials needs to be sustained, so as to provide evidence-based dosages for acute toxicity and residual efficacy in different climes, as well as determine early enough, when re-applications may be necessary especially in high-infestation zones or where bait consumption is rapid.

The quest for cockroach-free environments especially human-centred spaces requires multi-dimensional and sustainable control strategies, wherein accurate information on pest organism, population size, active ingredient, concentration, formulation and application modes are crucial towards ensuring optimized results per unit time. Equally, there is the need for consistent monitoring of targeted cockroach populations post-application of gel baits. This will enhance the rapid detection of resistant strains, and prevented the spread of such strains among cockroach populations and attendant adverse consequences on cockroach management.

CONCLUSION

The use of insecticidal gel bait formulations for cockroach control is gaining traction in Nigeria, especially in urban spaces like Lagos metropolis. There is the need to providing evidence-based information on efficacy of available brands with regards to dosage optimization on wild cockroach populations from different settings. The tested gel baits with different active ingredients have both proven to be effective against cockroach populations in laboratory and field trials. Thus their consideration and adoption for cockroach control in Lagos metropolis is recommended. Equally, there is a need for continued assessment of these gel baits especially in field trials, so as to further validate their efficacy against cockroach populations of different species/strains and wider terrains.

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