FORMULATION AND ASSESSMENT OF EFFICIENT BAITS FOR *ANACANTHOTERMES TURKESTANICUS*

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Abstract. *Anacanthotermes turkestanicus* is one of the key structural pests in Central Asia and is known for causing serious damage to residential buildings, historical sites, and agricultural facilities. Traditional control methods, especially those based on synthetic insecticides, often pose risks to the environment and usually provide only temporary relief. In this study, we developed and tested new bait formulations designed specifically for *A. turkestanicus*. Both laboratory and field trials showed that the baits were capable of causing high levels of termite mortality. The use of locally accessible materials—such as poplar sawdust and extracts from termite sternal glands—helped increase the attractiveness and overall effectiveness of the bait. These results suggest that bait-based strategies could serve as a more practical and environmentally friendly alternative to conventional chemical treatments, particularly in the arid regions where this species is most widespread, and may help reduce dependence on broad-spectrum insecticides.

Key words: subterranean termites; termite control; slow-acting toxicants; feeding stimulants; sternal gland extracts; sustainable pest control; arid-zone termite management.

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Аннотация. Anacanthotermes turkestanicus является одним из ключевых вредителей зданий в Центральной Азии и известен тем, что наносит серьезный ущерб жилым зданиям, историческим объектам и сельскохозяйственным объектам. Традиционные методы борьбы, особенно основанные на применении синтетических инсектицидов, часто представляют опасность для окружающей среды и обычно обеспечивают лишь временное облегчение. В данном исследовании мы разработали и протестировали новые составы приманок, специально предназначенных для A. turkestanicus. Как лабораторные, так и полевые испытания показали, что эти приманки способны вызывать высокий уровень смертности термитов. Использование доступных на месте материалов, таких как тополиные опилки и экстракты из грудных желез термитов, способствовало повышению привлекательности и общей эффективности приманок. Эти результаты свидетельствуют о том, что стратегии, основанные на применении приманок, могут служить более практичной и экологически чистой альтернативой традиционным химическим обработкам, особенно в засушливых регионах, где этот вид наиболее распространен, и могут помочь снизить зависимость от инсектицидов широкого спектра действия.

Ключевые слова: подземные термиты; борьба с термитами; медленнодействующие токсины; стимуляторы кормления; экстракты грудинной железы; устойчивая борьба с вредителями; борьба с термитами в засушливых зонах.

Annotation. Anacanthotermes turkestanicus Markaziy Osiyodagi asosiy tuzilma zararkunandalaridan biri bo‘lib, turar-joy binolari, tarixiy obidalar va qishloq xo‘jaligi ob’yektlariga jiddiy zarar yetkazishi bilan mashhur. An'anaviy nazorat usullari, ayniqsa sintetik insektitsidlarga asoslangan, ko'pincha atrof-muhit uchun xavf tug'diradi va odatda faqat vaqtinchalik yordam beradi. Ushbu tadqiqotda biz A. turkestanicus uchun maxsus ishlab chiqilgan yangi o'lja formulalarini ishlab chiqdik va sinovdan o'tkazdik. Laboratoriya va dala sinovlari shuni ko'rsatdiki, o'ljalar termitlarning yuqori darajada o'limiga olib kelishi mumkin. Mahalliy foydalanish mumkin bo'lgan materiallardan, masalan, terak talaşlari va termitlarning sternum bezlari ekstraktlaridan foydalanish yemning jozibadorligi va umumiy samaradorligini oshirishga yordam berdi. Bu natijalar shuni ko'rsatadiki, o'ljaga asoslangan strategiyalar, ayniqsa, bu tur eng keng tarqalgan qurg'oqchil hududlarda an'anaviy kimyoviy davolash usullariga nisbatan amaliyroq va ekologik toza alternativ bo'lib xizmat qilishi va keng spektrli insektitsidlarga qaramlikni kamaytirishga yordam berishi mumkin.

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Kalit so'zlar: yer osti termitlari; termitlarga qarshi kurash; sekin ta'sir qiluvchi toksik moddalar; oziqlantirish stimulyatorlari; sternum bezining ekstrakti; barqaror zararkunandalarga qarshi kurash; qurg'oqchil zonali termitlarni boshqarish.

Introduction

Termites are recognized as some of the most destructive pests worldwide, causing extensive damage to wooden structures, agricultural materials, and even culturally significant buildings. Their habit of living out of sight in wood or underground makes early detection and effective control especially challenging. For many years, termite management has relied mainly on synthetic insecticides, particularly organochlorine and organophosphate compounds. These products have been applied in a variety of ways, including surface sprays, contact poisons, foams, and protective coatings, and are typically used on nests, infested wood, or the surrounding soil. Although such treatments can reduce termite activity, they also have important drawbacks, such as contamination of soil, water, and air, and potential risks to non-target organisms, including humans [1- 4]. In an effort to improve both accuracy and effectiveness, several refined chemical application methods have been introduced. For example, microencapsulated organophosphate formulations have been used to protect wooden structures, and insecticide-based soil treatments have shown varying degrees of success in certain situations [5–6]. In some situations, termite galleries or mounds have been treated by injecting toxic foams, oils, or fuel-based mixtures in an effort to block their movement and eliminate the colony. Another approach has been fumigation, using volatile chemicals such as chloropicrin, hydrocyanic acid, or carbon disulfide. These gases tend to work more effectively at higher temperatures, when termite respiration and gas diffusion are increased. However, because these fumigants are extremely hazardous to humans, their use in homes or other occupied buildings is very limited. Although conventional chemical treatments can reduce termite activity for a short time, they often fail to provide long-term control. For this reason, since the late 1980s there has been growing interest in more sustainable methods, especially termite baiting systems. These baits usually consist of a cellulose-based material containing a slow-acting toxicant that takes advantage of termites' natural foraging and food-sharing behavior. After locating the bait, worker termites carry the toxic material back to the nest and distribute it to other members of the colony including reproductives and other individuals essential for colony maintenance—eventually leading to colony decline [7]. The success of bait formulations depends on several factors, including the types of additives used, their concentrations, and how these components are balanced within the mixture. Many bait designs include feeding stimulants, pesticides, or attractant-rich matrices that match termite food preferences. In some cases, these formulations are also combined with biological

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agents such as entomopathogenic fungi, bacteria, nematodes, or plant-based termiticidal compounds to enhance their overall toxicity and attractiveness [8–14]. Baiting systems offer several practical advantages: they use comparatively small amounts of active ingredients, limit exposure to the termites that actually feed on them, and pose fewer risks to other organisms and the surrounding environment. A number of inventive formulations reflect this shift toward more targeted control. For example, U.S. Patent No. 6,093,389 describes baits containing steroid-based attractants that help draw termites to the toxic substrate while reducing the need for large doses of insecticide [8]. Other formulations combine naphthalene derivatives with 2-phenoxyethanol, which can enhance the attractant or repellent properties of the bait depending on the mixture [14, 15]. Baits containing bistrifluron—a chitin-synthesis inhibitor—have also shown strong results when incorporated into substrates like cardboard, sawdust, paper, or wood particles, and have proven effective against several termite species [16, 17]. However, many of these products have not been tested against A. turkestanicus, a key pest in Central Asia that causes significant economic damage in Uzbekistan [18].

Alongside these chemical approaches, interest in biological control has been growing, largely due to concerns over the environmental impacts of conventional insecticides. Researchers at the Institute of Zoology of the Academy of Sciences of Uzbekistan and Urgench State University developed baits that include Beauveria tenella (strain VD-85), a fungal pathogen isolated from local termite populations. These baits achieved 100% mortality in both laboratory and field trials [25]. Plant-derived terpenoids such as knicin and vulgarone B have also shown strong activity and may further expand the range of environmentally compatible termite-control tools [35–43]. Yet, despite these promising advances, termite problems remain widespread in many affected areas, highlighting the need for continued work on more effective and ecologically responsible solutions. With this in mind, the present study evaluates newly developed bait formulations and explores integrated strategies for managing A. turkestanicus in arid environments, recognizing the species' high adaptability and evolutionary resilience.

Material and Methods

In designing the experimental framework, we took into account the current advancements and emerging trends in termite management research, relying on recent national and international scientific literature. The focal species for this study was *A.turkestanicus*. Termite samples were collected from infested residential structures located in the Jizzakh and Navoi regions of Uzbekistan. Sampling sites included private homes in the village of Kuksaroy (Navoi region), the Dashtobod district (Jizzakh region), and the Zomin district (Jizzakh region). The wooden frameworks of these houses, constructed primarily from poplar logs

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(*Populus* spp.), exhibited extensive termite damage. Collections were performed during spring, summer, and autumn from 2021 to 2023. For laboratory experimentation, the termites were transported to Tashkent in insulated plastic containers that maintained suitable temperature and soil moisture conditions. In the laboratory, the insects were provided with moistened, sterile corrugated paper as a food source. Prior investigations [41] have demonstrated that substances such as 2-phenoxyethanol, sodium hydroxynaphthalimide, various naphthol derivatives, and ethylene or diethylene glycol ethers possess communication-modulating properties in several termite species, including *Coptotermes formosanus* Shiraki, species within the families Rhinotermitidae and Kalotermitidae, *Reticulitermes flavipes* (Kollar), *Reticulitermes virginicus*, *Reticulitermes speratus*, *Glyptotermes satsumensis*, *Glyptotermes fuscus* Oshima, and *Hodotermopsis japonica*. These species represent a broad geographic and ecological range. In the present study, the same compounds were assessed for their behavioral effects on *A.turkestanicus*. Five compounds were selected for evaluation under laboratory and, where applicable, field conditions. These included: (1) a 2,5-dimercapto-1,3,4-thiadiazole hydrazine complex, tested both in the laboratory and in the field and synthesized in-house; (2) a pyridine complex of 2,5-dimercapto-1,3,4-thiadiazole, also synthesized in the laboratory and assessed under both conditions; (3) a 2,5-dimercapto-1,3,4-thiadiazole ethylenediamine complex, evaluated only in laboratory settings and likewise synthesized in-house; (4) d-gluconolactone, synthesized in the laboratory and tested in both laboratory and field trials; and (5) 2-mercapto-benzimidazole, sourced commercially from Sigma Aldrich and examined under both laboratory and field conditions. As presented compounds 1 through 5 were evaluated to identify potential agents capable of eliciting chemoreceptive responses suitable for use in bait formulations. In this study, we evaluated a series of compounds synthesized in the laboratory. Although extensive research has been conducted worldwide, no straightforward or universally accepted criteria currently exist for assessing termite resistance. Due to the complexity of termite management and the considerable economic burden associated with infestations, researchers have increasingly emphasized biological testing approaches. As a result, the demand for highly effective termite control agents has grown substantially. Drawing on extensive laboratory and field trials, termite bait formulations are being developed to address this need. The nutritional matrices used in these baits are composed of plant-derived materials that are naturally attractive to termites and readily consumed by them. The food bait mixture used in the five termite traps consisted of a plant-based matrix formulated from 200 g of sawdust, 500 mL of water, 0.05 g of the active ingredient, and 8.0 g of carboxymethylcellulose, with the addition of 50 µL of termite sternal gland extract

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dissolved in hexane; the total mass of the prepared bait placed in each trap was 80 g. Our findings demonstrate that poplar sawdust (*Populus* spp.) serves as an effective and locally accessible feeding substrate for termite bait formulations. This material is widely used by rural communities as a construction resource—particularly for wooden house frames—making it both abundant and economically feasible for large-scale bait production. To further enhance bait attractiveness, the formulations were supplemented with extracts derived from the sternal glands of termites, which significantly increased feeding activity. Collectively, these components allowed the development of an improved and cost-efficient bait matrix. The performance of the tested compounds was quantified by measuring the proportion of the trap length consumed by termites, expressed as a percentage. Statistical analyses, including correlation assessments, were conducted using the GraphPad Prism 8.0.1 software. The bait traps themselves were constructed from compressed cardboard in the form of open-ended cylinders (45 mm in diameter and 150 mm in length) and featured additional 5 mm perforations along their walls to facilitate termite entry and exit. Field evaluations of the most promising laboratory-tested compounds were carried out by burying bait traps in termite-infested soils. Trials were performed at private residences in termite-affected localities across the Navoi and Jizzakh regions. Three field sites were selected for testing: (1) Kuksaroy Mahalla, Khatyrchi District, Navoi Region; (2) Yangi Hayot Mahalla, Zarbdor District, Jizzakh Region; and (3) Istiklol Mahalla, Zomin District, Jizzakh Region. At the conclusion of the exposure period, the traps were excavated and examined. Particular attention was paid to the presence of mold development, as this could influence feeding activity and bait performance. The extent of bait consumption—expressed as a percentage of the total trap length—served as the primary metric for assessing compound efficacy.

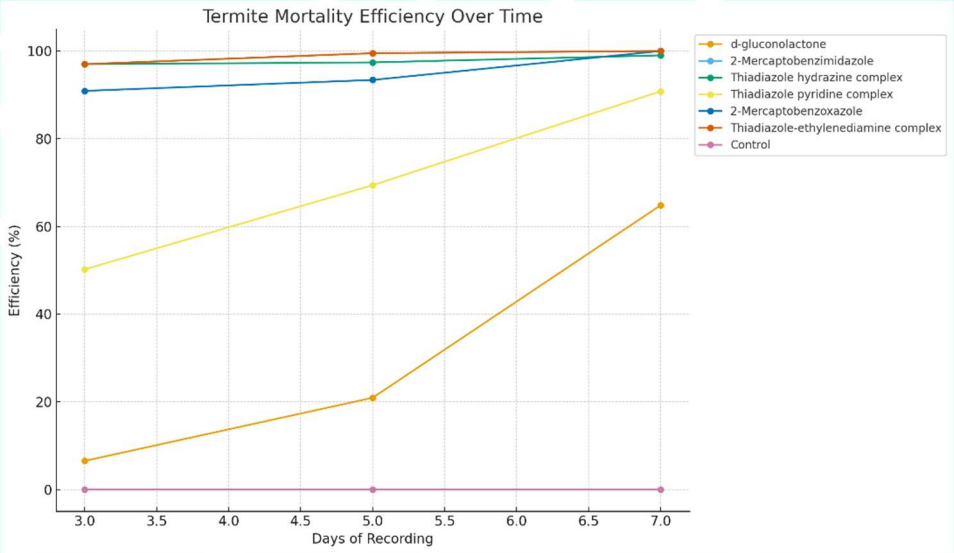
Results

Line graph №1 shows the efficacy of various chemical compounds at a concentration of 0.2% was evaluated against termites over a period of seven days. The number of live termites was recorded at three intervals (Day 3, Day 5, and Day 7), and the percentage reduction in termite numbers was calculated to determine the effectiveness of each compound. In the laboratory evaluation of seven treatments, each chemical compound was tested at a concentration of 0.02%. For d-gluconolactone, termite survival decreased from 100% before exposure to 92.0 ± 3.5%, 77.5 ± 1.8%, and 34.5 ± 1.1% on days 3, 5, and 7, corresponding to efficiencies of 6.5%, 20.9%, and 64.8%, respectively. Treatment with 2-mercaptobenzimidazole reduced live termites to 3.0 ± 0.2%, 0.5 ± 0.1%, and 0 by days 3, 5, and 7, achieving efficiencies of 97.0%, 99.5%, and 100%. The 2,5-dimercapto-1,3,4-thiadiazole hydrazine complex yielded survival rates of 3.0 ±

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0.1%, 2.5 ± 0.2%, and 1.0 ± 0.1%, corresponding to efficiencies of 97.0%, 97.4%, and 99.0%. The pyridine complex of 2,5-dimercapto-1,3,4-thiadiazole resulted in 49 ± 4.5%, 30 ± 1.1%, and 9 ± 0.5% survival, with efficiencies of 50.2%, 69.4%, and 90.8%. For 2-mercaptobenzoxazole, survival decreased to 9 ± 1.3%, 6.5 ± 1.2%, and 0%, giving efficiencies of 90.9%, 93.4%, and 100%. The complex of 2,5-dimercapto-1,3,4-thiadiazole with ethylenediamine showed survival rates of 3.0 ± 1.1%, 0.5 ± 0.4%, and 0, with efficiencies of 97.0%, 99.5%, and 100%. In the untreated control group, survival remained high at 98.4 ± 0.2%, 98.0 ± 0.3%, and 98.0 ± 0.2% across the same recording intervals. Across the evaluated compounds, distinct differences in termiticidal performance were observed. *d*-Gluconolactone exhibited only moderate activity, producing a 65% reduction in live termites by Day 3 and reaching 64.8% mortality by Day 7, indicating limited suitability as an independent control agent. In contrast, 2-mercaptobenzimidazole showed exceptionally high potency, eliminating 97% of termites by Day 3, 99.5% by Day 5, and achieving complete mortality by Day 7. Similarly, the 2,5-dimercapto-1,3,4-thiadiazole hydrazine complex demonstrated strong and consistent efficacy, with reductions of 97%, 97.4%, and 99% across Days 3, 5, and 7, respectively. The pyridine complex of the same base compound showed more moderate but steadily improving performance, with mortality increasing from 50.2% on Day 3 to 69.4% on Day 5 and 90.8% by Day 7, suggesting potential applicability within integrated pest management frameworks. 2-Mercaptobenzoxazole also proved highly effective, causing 90.9% mortality by Day 3, 93.4% by Day 5, and complete eradication by Day 7. The ethylenediamine complex of 2,5-dimercapto-1,3,4-thiadiazole matched the strongest performers, reducing termite survival by 97% on Day 3, reaching 99.5% on Day 5, and producing total mortality by the end of the experiment. In comparison, the untreated control group maintained a stable survival rate of approximately 98% throughout the observation period, confirming negligible natural mortality and validating the reliability of the performance metrics obtained for all treated groups.

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Line graph №1. Comparative Mortality Response of *A. turkestanicus* to Selected Chemical Compounds Over 7 Days.

Discussions

The findings of this study reveal clear differences in the termiticidal performance of the six chemical compounds evaluated at a concentration of 0.2%, with efficacy ranging from moderate activity to complete termite eradication by Day 7. The highest levels of effectiveness were observed for 2-mercaptobenzimidazole, 2-mercaptobenzoxazole, and the ethylenediamine complex of 2,5-dimercapto-1,3,4-thiadiazole, all of which achieved 100% mortality, underscoring their strong potential as termite control agents. Their pronounced activity is likely linked to the biochemical reactivity of sulfur-containing heterocycles, which can interfere with key physiological pathways in insects, while the incorporation of ethylenediamine may enhance compound solubility or facilitate more efficient interactions with intracellular targets. The hydrazine complex of 2,5-dimercapto-1,3,4-thiadiazole exhibited similarly high potency, producing 99% mortality by Day 7—an effect possibly attributable to the formation of reactive intermediates capable of disrupting essential metabolic functions. In contrast, the pyridine complex of the same base structure demonstrated moderate but steadily increasing activity, reaching 90.8% mortality by Day 7; its comparatively slower action may be related to differences in cuticular penetration or altered biochemical interactions. d-Gluconolactone displayed the lowest efficacy, achieving only 64.8% mortality, suggesting limited suitability as either a primary or stand-alone termite control compound. These results align with prior studies highlighting the broad biological activity of sulfur-based heterocycles, which have been widely recognized for their antimicrobial and insecticidal properties. The superior performance of these compounds, combined with their rapid action and high mortality rates, suggests that they may represent environmentally preferable alternatives to conventional insecticides, which often

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pose ecological risks and affect non-target species. Nonetheless, further work is required to elucidate their precise modes of action, evaluate their long-term stability and environmental behavior under natural field conditions, and explore possible synergistic combinations with biological agents such as entomopathogenic fungi or nematodes. Future investigations should also consider how these compounds interact with termite social behavior and colony dynamics to optimize their integration into comprehensive pest management programs tailored to arid ecosystems where *A.turkestanicus* remains a major economic pest.

Conclusion

This study demonstrated that several sulfur-containing heterocyclic compounds, particularly 2-mercaptobenzimidazole, 2-mercaptobenzoxazole, and the ethylenediamine complex of 2,5-dimercapto-1,3,4-thiadiazole, are highly effective against *A.turkestanicus*, achieving complete mortality by Day 7. These results highlight their strong potential as environmentally safer alternatives to conventional insecticides. While other compounds showed moderate to high efficacy, *d*-gluconolactone was the least effective. Overall, the findings support the development of targeted bait formulations as a promising strategy for sustainable termite management in arid regions.

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