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Research Article

REPELLENT AND TOXIC EFFECTS OF INDIGENOUS PLANT SEED EXTRACTS ON FUNGUS-GROWING SUBTERRANEAN TERMITES (BLATTODEA: TERMITIDAE)

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ABSTRACT

The indiscriminate use of synthetic pesticides to control fungus-growing termites has led to biological and environmental hazards and has contributed to the development of resistance in these pests. In the search for environmentally safe alternatives, plant-derived biopesticides have been explored as replacements for synthetic insecticides. The present study aims to shed light on the use of naturally occurring anti-termite compounds extracted from the seeds of indigenous plants. Specifically, seed extracts from *Moringa oleifera* (sohanjna) and *Citrullus colocynthis* (bitter apple) were tested using methanol and water as solvents in bioassays against fungus-growing subterranean termites. The entomotoxic properties of the methanolic and aqueous extracts from these plant seeds were examined to determine their effects on termite mortality, repellency, and foraging behavior. The results revealed that both plant seed extracts negatively impacted the survival and repellency of termites. *C. colocynthis* showed better results in terms of termite mortality and had lower LT50 values compared to *M. oleifera*. However, in terms of tunneling behavior, *M. oleifera*) showed more significant effects than *C. colocynthis*. Based on the outcomes of these trials, both *C. colocynthis* and *M. oleifera* demonstrated significant potential as effective termiticides. Therefore, it is recommended that these native plant seed extracts be incorporated into termite control strategies.

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INTRODUCTION

Termites are often mistakenly identified as ants, particularly white ants, but they differ significantly from ants, which belong to the order Hymenoptera. Termites, on the other hand, are classified under the order Blattodea. They exhibit a broad range of diversity and are abundant across the world, including regions like America, Asia, and Africa (Bignell and Eggleton, 1998; Collins, 1988). Termites play a crucial role in maintaining soil processes, water cycling, and nutrient retention, which contributes to the overall structure of the soil. Key termite families also enhance biodiversity by creating suitable environments for vegetation and other biological entities on Earth (Korb, 2008). Many termite species are integral to various ecological systems, contributing significantly to processes like recycling wood and plant material, burrowing activities, and soil aeration (Anonymous, 2000).

These soft-bodied pests have pale-colored bodies and feed on cellulose. Fungus-growing termites, closely related to cockroaches, have a long lifespan and are classified under the order Blattodea. A termite queen can lay approximately 300 eggs, with the offspring appearing yellow-white and undergoing development over 50 to 60 stages. Termite colonies include workers and soldiers, which are sterile, wingless, and typically blind. Workers and soldiers have long bodies, about 6 mm in size, and are pale green. Both types mature within a year and their life cycle spans approximately 3 to 5 years. Reproductive termites swarm during their nuptial flight, typically in April and May, signaling the onset of an infestation (Su and Scheffrahn, 2000).

Termite infestations pose significant threats to both plant life and infrastructure. These pests are particularly troublesome in tropical and low-humidity regions, where they cause extensive damage to crops and wooden structures. Although chemical pesticides are commonly used to manage termite attacks, they raise concerns about health and environmental impacts, as these compounds can affect non-target organisms. Fungus-growing termites are frequently found in decaying wood, timber, and plant materials, especially in soils rich in organic matter.

Several termite species, such as *Microtermes obesus* and *Odontotermes obesus* (Isoptera: Termitidae), are known as highly destructive polyphagous pests worldwide (Upadhyay et al., 2012). Termite infestations can significantly reduce crop yields (Upadhyay et al., 2010). Termites are found in various soil types, including sandy loam, red loam, and lateritic soils. Many species are subterranean or mound and nest builders. Key subterranean termite species include *Trinervitermes biformis*, *M. obesus*, *O. homi*, *Microcerotermes beesoni*, *C. heimi*, *Coptotermes ceylonicus*, and *Heterotermes indicola*. Major mound-building species include *O. wallonensis*, *O. redemanni*, and *O. obesus*.

The replacement of synthetic insecticides with bio-rational pesticides is considered a globally appropriate and effective approach. Plant-derived products, such as repellents, pesticides, and anti-feedants, offer a promising alternative. Several plants with termiticidal properties include Australian blackwood (*Acacia melanoxylon*), black wattle (*A. mearnsii*), khair (*A. catechu*), pod mahogany (*Afzelia cuanzensis*), desert date (*Balanites aegyptiaca*), mitserie tree (*Bridelia micrantha*), oak (*Casuarina cunninghamiana*), red gum (*Eucalyptus camaldulensis*), samaan (*Albizia saman*), cocoa's mother (*Gliricidia sepium*), African mahogany (*Grevillea glauca*), and iple-iple (*Leucaena leucocephala*) (Anonymous, 2001). Leaf extracts from silver oak are rich in anti-termiticidal compounds and are considered effective botanical insecticides for termite management in wooden products (Afzal et al., 2019). Plant essential oils, leaves, seeds, bark, and fruit extracts, which are environmentally safe, can be effectively used in termite IPM strategies. A wide variety of plants contain termicidal substances, with approximately 1,000 species containing flavonoids or alkaloids in their roots, seeds, foliage, and stems, which are toxic to pests (Shahid, 2003).

The plant *Citrullus colocynthis*, also known as sour cucumber or colocynth, belongs to the Cucurbitaceae family. It is widely distributed and commonly found in Asia and sub-Saharan Africa (Pravin et al., 2013). The bitter apple plant is known for its diverse bioactive compounds, which have deterrent, insecticidal, and antifertility effects on insects (Soam et al., 2013).

Moringa oleifera, commonly known as the Sohanjna plant, is widespread across various regions. Its leaves, flowers, and seeds are highly nutritious and valuable food sources. Extracts from the leaves and seeds of *M. oleifera* exhibit anti-tumor, anti-fungal, anti-bacterial, and anti-cancer properties. The termiticidal properties of *M. oleifera* have been observed by several researchers. The water-soluble lectin from the seeds of *M. oleifera* has shown promising effects on the growth and survival of *Aedes aegypti* mosquito larvae (Coelho et al., 2009). Ileke and Oni (2011) reported that *M. oleifera* powder caused adult mortality and reduced larval emergence in the weevil (*Sitophilus zeamais*) in stored wheat grains. Another study by Ferreira (2009) demonstrated the lethal effects of crude aqueous extracts from *M. oleifera* seeds on the progeny and third instar larvae of *A. aegypti* mosquitoes. Considering the economic importance of termites as persistent agricultural pests and their impact on various plant species, this study aimed to evaluate the efficacy of seed extracts from bitter apple (*C. colocynthis*) and *M. oleifera* using water and methanol as solvents in controlling termite populations.

MATERIALS AND METHODS

Experimental site

The experiment was conducted at the Entomological Laboratory, Department of Plant Protection, Airport Campus, Ghazi University, Dera Ghazi Khan. The research aimed to evaluate the toxic effects of indigenous plant seed extracts on the mortality and tunnel formation of fungus-growing termites.

Experimental layout

The trials were arranged in a Completely Randomized Design. There were two treatments with plant seed extracts at concentrations of 10%, 20%, and 40%, alongside a control (0%) without extract, each replicated three times.

Collection of termites

Workers and soldiers of fungus-growing subterranean termites were collected from PVC monitors (pipes) with cardboard inserts placed at various locations in the field at the Airport Campus, Ghazi University, Dera Ghazi Khan.

Treatments

The experiment included the following treatments using plant materials:

T1: *Citrullus colocynthis* (Kortumma)

T2: *Moringa oleifera* (Suhanjna)

Preparation of termiticide solutions

Crude extracts from the seeds of *C. colocynthis* and *M. oleifera* were prepared using two solvents: water and methanol. Extract concentrations of 0%, 10%, 20%, and 40% were then prepared for use in bioassays.

Extraction method

Seeds of *C. colocynthis* and *M. oleifera* were collected from the Airport Campus, Ghazi University, D.G. Khan. The seeds were washed with distilled water and dried in the shade for a minimum of two weeks, ensuring ample airflow to prevent damping. The shade-dried seeds were ground using an electric grinder for about 1 min to form a powder.

Preparation of extracts

Aqueous seed extracts

To prepare the aqueous seed extracts, 100 g of seed powder from each plant were mixed with 200 ml of distilled water in a 1:2 (w/v) ratio. The seed powder was soaked in the solvent for 24 h, with intermittent shaking to prevent sedimentation. The extracts were then filtered through two layers of Whatman filter paper No. 42. This process was repeated three times to maximize extract yield. The filtered extracts were collected in a bottle and evaporated in a glass bowl to obtain the crude extracts, which were then weighed and used at the desired concentrations for further bioassays.

Methanol seed extracts

The methanol seed extracts were prepared using the same procedure as for the aqueous extracts.

Bioassay by treating soil with plant seed extracts

Soil for bioassay

Soil for the bioassays was collected from the same fields where the termites were gathered. The physical properties and composition of the soil were determined, and the soil was used in all bioassays. It was sieved through a 30-mesh screen, and soil moisture content was assessed for further experimentation.

Experimental setup

To evaluate the toxic effects of the plant seed extracts, experiments were conducted in Petri dishes measuring 10 cm in diameter and 1.5 cm in height. Each Petri dish contained 20 g of sterilized soil. Sugarcane strips (approximately 1.5 cm × 6 cm) were placed in each dish to sustain the fungus-growing termites. The treatments, including extract concentrations of 0%, 10%, 20%, and 40%, were replicated three times in a CRD. Thirty active workers and five soldiers were introduced into each Petri dish containing treated and untreated soil. The dishes were maintained under controlled temperature and humidity conditions. Termite mortality was recorded at 2-h intervals for up to 12 h and then every 12 h until all 30 workers and 5 soldiers had died. Probit analysis was used for toxicological assessment.

Effect of plant extracts on tunnel/gallery formation

Termites belonging to the family Termitidae create tunnels/galleries during feeding or foraging, reflecting their movement through the soil. The fungus-growing termites continued to construct tunnels/galleries along the bottom of each Petri dish around the sugarcane strips. The termites' tunneling behavior in response to the plant extracts at concentrations of 0%, 10%, 20%, and 40% (in both water and methanol solvents) was assessed after 5, 10, and 15 h. The lengths of the tunnels at each concentration were marked on cellophane paper and measured in millimeters using a planimeter.

RESULTS

Effect of various aqueous plant seed extracts on the mortality of subterranean termites

***C. colocynthis* aqueous seed extract**

Table 1 showed that the control (0%) concentration exhibited significant variation compared to the other concentrations. The lethal time (LT50) at 0% concentration was 290.889, with upper and lower bounds of 302.454 and 275.656, respectively. The 10% concentration showed a marked difference compared to the 40% concentration, with upper and lower bounds of

275.486 and 227.828, respectively. At 20% concentration, the LT50 was 215.728, with upper and lower bounds of 241.649 and 189.807, respectively. The LT50 for the 40% concentration was 182.980, with upper and lower limits of 213.100 and 152.859, respectively. The 40% concentration showed the greatest variation compared to the control (0%) concentration.

***M. oleifera* aqueous seed extract**

For *M. oleifera*, Table 1 indicated that the control (0%) concentration exhibited significant differences compared to the 40% concentration, with lesser differences observed at 10% and 20% concentrations. The LT50 at 0% was 352.066, with upper and lower bounds of 373.619 and 330.513, respectively. The LT50 at 10% concentration was 303.673, with upper and lower bounds of 333.150 and 274.196, respectively, showing significant differentiation from the 40% concentration. At 20% concentration, the LT50 was 271.489, with upper and lower bounds of 303.471 and 239.507, respectively. The LT50 for the 40% concentration was 226.199, with upper and lower limits of 262.363 and 190.036, respectively. The 40% concentration exhibited significant differences from the control (0%) and 10% concentrations but showed less variation compared to the 20% concentration.

Table 1. Comparison of (LT_{50}) values at various concentrations in water extracts of *C. colocynthis* and *M. oleifera* seeds.

Plant extract	Concentration	LT_{50} (Hours) ± Standard error	95% Confidence interval	
			Lower limit	Upper limit
C. colocynthis seeds	40%	182.980 ± 15.367	152.859	213.100
	20%	215.728 ± 13.225	189.807	241.649
	10%	251.657 ± 12.158	227.828	275.486
	0%	290.889 ± 8.241	275.656	302.454
M. Oleifera seeds	40%	226.199 ± 18.451	190.036	262.363
	20%	271.489 ± 16.317	239.507	303.471
	10%	303.673 ± 15.039	274.196	333.150
	0%	352.066 ± 10.996	330.513	373.619

Effect of various methanol plant seed extracts on the mortality of subterranean termites

***C. colocynthis* methanol seed extract**

Table 2 showed that at the control concentration (0%), a significant variation was observed among all concentrations, with a lethal time (LT50) of 278.800 as the standard. The maximum and minimum LT50 values were 298.457 and 259.142, respectively. At the 10% concentration, there was a notable variation compared to the 40% concentration, with higher and lower LT50 values of 243.321 and 191.988, respectively. The 20% concentration exhibited an LT50 value of 177.125, showing variability among other concentrations, with lower and upper bounds of 146.264 and 207.987, respectively. For the 40% concentration, the LT50 was 157.656, with upper and lower bounds of 190.832 and 124.779, respectively. The 40% concentration demonstrated substantial variation compared to the control (0%) and the 10% concentration but showed less variation compared to the 20% concentration.

***M. oleifera* methanol seed extract**

For the methanol extract of *M. oleifera* seeds, the control concentration (0%) showed a marked difference compared to all other concentrations, with an LT50 value of 323.507 and upper and lower bounds of 349.942 and 297.071, respectively. The 10% concentration exhibited significant variation compared to the 40% concentration, with an LT50 value of 240.040 and corresponding upper and lower bounds of 274.867 and 205.212. At the 20% concentration, the LT50 value was 224.242, showing dissimilarity with other concentrations, with upper and lower bounds of 260.595 and 187.888, respectively. The 40% concentration had an LT50 value of 190.939, with upper and lower bounds of 230.296 and 151.583, respectively. This concentration showed a significant difference compared to the control (0%) and the 10% concentration, with minor variation from the 20% concentration.

Effects of seed extracts on the construction of termite tunnels/galleries

***C. colocynthis* aqueous seed extracts**

The data presented in Table 3 contrasts the effects of three time intervals on the formation of tunnels/galleries by subterranean termites across four concentrations of *C. colocynthis* seed water extract. The results indicate that the highest concentration (40%) resulted in the least tunnel construction compared to the lower concentrations of 0%, 10%, and 20%. After 10 h, the control group (0% concentration) exhibited minor tunnel formation (207.333 mm), which was notably higher compared to the other concentrations (10%, 20%, and 40%). After 15 h, the tunnel lengths were recorded as 260.33 mm, 106.00 mm, 74.33 mm, and 57.00 mm for the 0%, 10%, 20%, and 40% concentrations, respectively.

M. oleifera aqueous seed extracts

Table 3 also shows the effects of *M. oleifera* seed water extract on tunnel formation by subterranean termites at three different time intervals. Significant variations in tunnel formation were observed across all tested concentrations (0%, 10%, and 20%) after 5, 10, and 15 h. However, the 40% concentration exhibited less significant variation in tunnel formation across all time intervals. As a result, the 40% concentration led to the least tunnel formation compared to the other concentrations (20%, 10%, and 0% control).

Table 2. Comparison of (LT_{50}) values at various concentrations in methanol extracts of *C. colocynthis* and *M. oleifera* seeds.

Plant Extract	Concentration	LT_{50} (Hours) ± Standard error	95% Confidence Interval	
			Lower Limit	Upper Limit
C. colocynthis seeds	40%	157.656 ± 16.927	124.779	190.832
	20%	177.125 ± 15.745	146.264	207.987
	10%	217.654 ± 13.095	191.988	243.321
	0%	278.800 ± 10.029	259.142	298.457
M. oleifera seeds	40%	190.939 ± 20.079	151.583	230.296
	20%	224.242 ± 18.548	187.888	260.595
	10%	240.040 ± 17.769	205.212	274.867
	0%	323.507 ± 13.487	297.071	349.942

Table 3. Comparison of termite tunnel formation time across different concentrations of water extracts from *C. colocynthis* and *M. oleifera* seeds.

Plant Extract	Time Interval (Hours)	Concentrations			
		0%	10%	20%	40%
C. colocynthis seeds	5	129.3 ± 17.95 b	71.0 ± 1.53 c	53.33 ± 3.84 a	48.33 ± 4.70 a
	10	207.33 ± 14.66 a	82.67 ± 3.38 b	68.67 ± 9.39 a	55.33 ± 5.93 a
	15	260.3 ± 22.42 a	106.0 ± 4.93 a	74.33 ± 11 a	57.00 ± 6.08 a
M. oleifera seeds	5	116.6667 ± 5.55 c	48.66 ± 1.76 c	40.00 ± 1.15 b	30.33 ± 3.93 a
	10	207.6667 ± 8.97 b	61.66 ± 4.48 b	47.66 ± 1.76 ab	39.00 ± 3.00 a
	15	281.0000 ± 17.35 a	76.00 ± 3.46 a	51.66 ± 3.76 a	39.00 ± 3.00 a

Effects of methanol seed extracts on the construction of termite tunnels/galleries

C. colocynthis methanol seed extract

Table 4 presents the comparison of gallery/tunnel formation in subterranean termites at different concentrations of methanol extract from *C. colocynthis* seeds over three time periods. The results indicate that at a 40% concentration, there is a significant reduction in tunnel formation after 5, 10, and 15 h compared to a 10% concentration and the control (0%). The 40% concentration resulted in the formation of only minor tunnels, contrasting sharply with the 0%, 10%, and 20% concentrations. The 20% concentration showed no significant difference in tunnel formation compared to the 40% concentration across all three time periods (5, 10, and 15 h). However, it was significantly different from the 10% concentration and the control (0%). The 10% concentration and the control (0%) exhibited non-significant differences between them but showed notable distinctions from the 20% and 40% concentrations.

M. oleifera methanol seed extract

The results presented in Table 4 for the methanol extract of *M. oleifera* seeds reveal significant variations in gallery/tunnel formation by subterranean termites across different concentrations (0%, 10%, and 20%) over the three time periods (5, 10, and 15 h). The 40% concentration consistently resulted in less tunnel formation compared to the 20%, 10%, and control concentrations. Conversely, the control (0%) concentration led to the highest tunnel formation among all the concentrations tested.

Table 4. Comparison of tunnel formation time in termites exposed to different concentrations of methanol extracts from *C. colocynthis* and *M. oleifera* seeds.

Plant Extract	Time Interval (Hours)	Concentrations			
		0%	10%	20%	40%
C. colocynthis seeds	5	113.66±8.69c	74.33±5.04c	63.00±5.55a	35.00±5.77a
	10	193.33±10.14b	90.00±3.21b	56.66±4.93a	48.66±6.94a
	15	273.33±4.67b	107.66±3.71a	71.66±4.91a	50.33±7.31a
M. Oleifera seeds	5	165.00±20.82b	74.66±1.76c	70.00±2.31b	43.33±2.40a
	10	283.33±16.41a	94.33±2.73b	81.33±3.84a	49.00±3.06a
	15	286.00±7.23a	100.0±1.76a	85.00±2.31a	49.00±3.06a

DISCUSSION

C. colocynthis and *M. oleifera* are medicinal plants utilized in a bioassay to evaluate their effects on the fungal-growing system of subterranean termites. The experiment involved treating soil with different concentrations of two solvents, methanol and water. Active termite workers were released into Petri dishes, and the number of live and dead termites was recorded at regular intervals. During the trial, termites constructed burrows, and the area of these burrows was measured at different time points to assess the impact of increasing concentrations of the plant extracts.

The objective of the study was to explore the efficacy of naturally occurring termiticidal chemicals from indigenous plants, focusing on their lethality and influence on termite tunneling behavior. Seed extracts of *C. colocynthis* and *M. oleifera* in two solvents were used in the bioassay against fungal-growing termites, with concentrations of 10%, 20%, 40%, and 0% (control). The results confirmed the significant termiticidal properties of these medicinal plant extracts, as evidenced by reduced termite survival and altered tunnel formation. The findings align with previous research demonstrating the anti-termiticidal effects of plant extracts, as reported by Singh et al. (2002), Moein and Farrag (2000), Maistrello et al. (2001), Das and Chattopadhyay (2003), Badshah et al. (2004), Meepagala (2006), Verma and Verma (2006), Ogunsina et al. (2009), Hashim et al. (2009), Ding and Hu (2010), and Ahmed and Qasim (2011).

In the following studies, extracts from various parts of trees (leaves, bark, flowers, seeds) were prepared using alcohol and water and tested in bioassays against different termite species, including *Microcerotermes mycophagus*, *Coptotermes formosanus*, *Reticulitermes flavipes*, *C. curvignathus*, *Cryptotermes brevis*, *C. vastator*, *Microtermes obesus*, *C. vastator*, *Heterotermes indicola*, *Odontotermes obesus*, and *O. assamensis* (Rahman et al., 2005; Upadhyay et al., 2010).

The efforts of these researchers confirm the results obtained during the study, demonstrating that plant seed extracts have termiticidal effects. Khan and Siddique (1994) deliberately focused on six tree species, including rhizome, leaf, seed, and whole plant parts, using five different solvents on the larvae of *Pieris brassicae*. They reported that leaves and seeds of various plants exhibited better insecticidal activity compared to whole plants. Bioassays further demonstrated that leaf extracts also had toxic effects on the targeted insects.

The results showed that the LT50 (lethal time for 50% mortality) of seed extracts varied significantly, while the LT50 values of the controls did not differ substantially. In a general comparison of different plant seed extracts in two solvents at a 10% concentration, the lowest LT50 values were 251.657 h and 217.654 h for *C. colocynthis* water and methanol seed extracts, respectively. At a 20% concentration, the lowest LT50 values were 215.728 h and 177.125 h for *C. colocynthis* water and methanol seed extracts, respectively. At a 40% concentration, the lowest

LT50 values were 182.980 h and 157.656 h for *C colocynthis* water and methanol seed extracts, respectively. The results indicated that *C colocynthis* methanolic extracts exhibited the shortest LT50 hours.

As shown by the results, the LT50 estimations of seed extracts (*M. oleifera*) exhibited different LT50 values compared to the control. In the overall assessment of various plant seed extracts in two solvents at a 10% concentration, the minimum LT50 values were 303.673 and 240.040 h for *M. oleifera* water and methanol extracts, respectively. At 20% concentration, the minimum LT50 values were 271.489 and 224.242 h for *M. oleifera* water and methanol extracts, respectively. At 40% concentration, the minimum LT50 values were 226.199 and 190.939 h for *M. oleifera* water and methanol extracts, respectively. The results demonstrated that the *M. oleifera* methanolic extract exhibited the lowest LT50 values. These findings are consistent with previous studies indicating that plant seed extracts were highly effective against termites (Khan and Siddique, 1994; Ahmed et al., 2006).

Numerous studies have shown that indigenous plant extracts can alter termite behavior (Grace and Yates, 1992; Maistrrello, 2001). The tunneling activities of fungus-growing termites in two indigenous plant extracts, dissolved in different solvents at varying concentrations (i.e., 10%, 20%, 40%, and 0%), were observed. The aqueous and methanolic extracts of *C. colocynthis* at 10% concentration resulted in tunnel lengths of 106.0 and 107.66 mm, respectively. At 20% concentration, the tunnel lengths were 74.33 and 71.666 mm, respectively. At 40% concentration, the aqueous and methanol extracts of bitter apple resulted in tunnel lengths of 57.00 and 50.00 mm, respectively.

In the seed extracts of *M. oleifera* using aqueous and methanolic solvents at different concentrations (10%, 20%, 40%, and 0%), the length of termite tunnels was measured. The aqueous and methanolic extracts of *M. oleifera* at 10% concentration resulted in tunnel lengths of 76.000 mm and 100.000 mm, respectively. At 20% concentration, the tunnel lengths were 51.667 mm and 85.000 mm, respectively. For the 40% concentration of the aqueous and methanolic extracts of *C. colocynthis*, the tunnel lengths were 39.000 mm and 49.000 mm, respectively.

The results of the current study are consistent with findings from previous research. Chemicals exhibiting antifeedant properties have shown potential for anti-tunneling activity in fungus-growing termites (Mao and Henderson, 2005; Mao et al., 2011). Termite tunneling can be significantly reduced in various agricultural settings where different plant-derived components restrict termite access (Ahmed et al., 2006; 2007).

The effects of solvents such as n-hexane, ethanol, and petroleum ether extracts of black pepper were studied on the dry wood termite, *Cryptotermes brevis*. The n-hexane extract demonstrated remarkable efficacy against termites. At a 0.5% concentration, n-hexane induced 50% mortality, which decreased to 4.76% and 14.28% with ethanol and petroleum ether, respectively, two days post-treatment (Moein and Farrag, 2000).

Ito et al. (2018) evaluated the effectiveness of peel extracts from Citrus species (*C. sinensis*, *C. limon*, *C. aurantifolia*) against termites (*Macrotermes* spp.). They tested lethal concentrations and termite mortality, using 0.21% aqueous solution as a negative control. As concentrations of citrus extracts increased from 10% to 30%, the termiticidal action against termites decreased. However, when exposure time increased from 24 to 72 hours, significant differences in termite mortality were observed. *C. aurantifolia* extract showed the highest mortality compared to *C. sinensis* and *C. limon*, with lethal concentrations of 17.50 mg/L for *C. aurantifolia* and *C. sinensis*, and 12.90 mg/L for *C. limon*. These findings suggest that citrus extracts could serve as a natural alternative to synthetic insecticides for termite management.

CONCLUSION

Laboratory trials were conducted using extracts from seeds of two native medicinal plants, *Citrullus colocynthis* (Bitter apple) and *Moringa oleifera* (Sohanjna), prepared in two different solvents to evaluate their potential as termiticides. The extracts of *C. colocynthis* demonstrated higher lethality compared to those of *M. oleifera*, as indicated by the lower lethal times across all concentrations tested against termites in soil. However, *M. oleifera* seed extracts exhibited superior results in minimizing burrowing/tunneling activity compared to *C. colocynthis*.

AUTHORS' CONTRIBUTIONS

MSN and SFD designed, formulated and laid out the study; SFD conducted the experiments; SFD and MSN collected, arranged and analyzed the data; MMM and AKK provided technical assistance; MSN supervised the work; MMM and AKK proofread the paper.

CONFLICT OF INTEREST

The authors declare no conflict of interest.

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