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ASSESSING THE EFFICACY OF NEW CHEMISTRY INSECTICIDES AGAINST SUBTERRANEAN TERMITE

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ABSTRACT

Termite attacks can significantly reduce crop and forest productivity by 10 to 25 percent, with traditional chemical insecticides commonly used in Pakistan. The present study, however, aimed to assess the effectiveness of ten different insecticides in controlling subterranean termites at various concentrations and time intervals. Fipronil and Chlorpyrifos were the most effective insecticides at a concentration of 125 ppm, resulting in 100% mortality rates after 24 hours of exposure, while Emamectin Benzoate had the lowest mortality rates, but gradually increased over time. All insecticides tested at a concentration of 250 ppm resulted in varying degrees of mortality rates, with Imidacloprid, Fipronil, and Bifenthrin being the most effective. At a concentration of 500 ppm, all insecticides were effective, with Imidacloprid showing the fastest onset of mortality. Similarly, all insecticides at a concentration of 1000 ppm were effective, with Fipronil being the most effective insecticide. The data suggested that some insecticides were more effective than others in controlling subterranean termites, and the duration of exposure also played a crucial role in the effectiveness of the insecticides. The study found that higher dosages of new chemistry-based termiticides result in maximum subterranean termite mortality after a minimum exposure time. Fipronil, Imidacloprid, and Bifenthrin were the most effective treatments achieving 100% termite mortality at specific dosages and exposure times, while Chlorfenapyr and Emamectin Benzoate showed lower effectiveness. The new chemistry insecticides are considered eco-friendly, safe for humans and non-target fauna, and might be a competent choice for integrated pest management programs.

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INTRODUCTION

About three thousand termite species have been reported so far. Termites are eusocial entities which are decomposers as well as enhance soil fertility and crop productivity (Ahmad et al., 2021). Subterranean termites build up underground galleries and tunnels to seek food, influence soil features with respect to its texture, water percolation levels and nutritional contents at different spatial levels (Freymann et al., 2008). Katayama et al. (2008) reported that 43 species of termites are taken as food by humans and is also included in the diet of livestock in under-developed regions where malnutrition is common, so termite proteins are regarded as good diet. They are also extensively taken in conventional medicines to deal with bronchitis, whooping cough, asthma and influenza.

In termites colony, only infestation is caused by workers (Miller, 2010), possessing soften bodies and do various colony tasks such as feeding (Indrayani et al., 2007), developing mud tunnels (Li and Su, 2008), cleaning and foraging etc. (Randall, 2000). Their eating capability depends on the size of species as well as dietary value of food located (Hickey, 2006). Subterranean termites possessed excellent finding mechanism comprising of architectural technique in the form of branched tunnel system (Hupokotuwa and Grace, 2011). Such mud galleries are helpful in the searching of termite potential infestation.

Despite termite significant ecological importance, most of the termite species are harmful for agricultural cultivation as well as buildings in urban areas. Oi (2022) reported that the worldwide financial implication of termites is accounted about 40 billion USD per annum and about 80 percent of the total implication is caused by the subterranean termites. According to Rouland-Lefèvre (2010), subterranean termites are specifically major pest for tree planting, wooden materials and agricultural crops. *Odontotermes obesus* (Order Isoptera and Family Odontotermitidae) is regarded as highly damaging polyphagous pest (Upadhyay et al., 2012). Such termite species may induce significant deficits to agricultural cultivations comprising wheat, sugarcane, sesame, cotton, maize and gram in Pakistan. Termites are a major threat to wooden materials both in rural and urban localities (Ahmed et al., 2005). Agricultural crop productivity is considerably decreased because of termite attack (Upadhyay, 2013) and may induce 10 to 25 percent deficits in field cultivations like sugarcane, cotton, maize, wheat, and pulses as well as in forests (Rajagopal, 2002).

In Pakistan, the main common genera of termite are *Microtermes*, *Odontotermes* and *Coptotermes* while the most damaging species of termite are *Microtermes obesi*, *Odontotermes obesus* and *O. guptai* in arid as well as semi-arid localities (Aihetasham et al., 2017). In Pakistan, *M. mycophagus* is one of the most economically important species inducing infestation to woody textures as well as agricultural cultivations (Iqbal and Saeed, 2013). Ahmed et al. (2016) assessed the impact of botanical materials against *Heterotermis indicola* which is main alert for agricultural crops globally. The fungus increasing termites are significant pests with respect to agricultural cultivation and buildings particularly in Asian and African countries (Iqbal et al., 2019). Kumar et al. (2017) stated that *O. obesus* and *M. obesi* are considered as main threat to maize, wheat and chickpea cultivations.

Different approaches like chemical based insecticides, plant based products and physical barriers have been employed for the control of termites (Addisu et al., 2014). In Pakistan, farmers mainly depend upon traditional chemical based insecticides (organochlorines, pyrethroids, organophosphates and carbamates) to eliminate and prevent the attack of subterranean termites (Manzoor et al. 2011). Just because of non-observance of legislative rules as well as the extensive application of chemical based insecticides which are toxic and persistent have produced the resistance in termites (Kranthi et al., 2002; Zhu et al., 2016). Throughout the world, farmers rely on synthetic insecticides to eradicate the termites and in this way such insecticides are an integral part of crop protection. Production of crops to feed world's population is impossible without the application of insecticides against agricultural pests (Carvalho, 2006). Furthermore, sole dependence upon synthetic pesticides has initiated various problems comprising outbreaks of secondary pests, extinction of biodiversity, contamination of ecosystem and developing resistance in insect pest (Desneux et al., 2007). The most effective way for farmers to control the termite is to apply the conventional as well as newly approaches in mixed form. Baiting techniques have been utilized efficiently to manage subterranean termite populations. Biological methods including entomophagy also play a vital role in the management of termite colonies. Thus, it is essential to find out the eco-friendly alternatives for eradicating pests through insecticides with novel mode of action.

Different investigations against termites have been done by the application of novel chemistry insecticides like fipronil, indoxacarb, thiamethoxam, spinosad, chlorfenapyre and imidacloprid (Wang et al., 2007; Iqbal and Saeed, 2013; Vargo and Parman, 2012). New chemistry insecticides have possessed various modes of action in comparison to older insecticides. Such insecticides are often slightly sustained, fast recyclable, highly focusing on target and eco-friendly as well as safe to humans and fauna (Grafton-Cardwell et al., 2005; Ishaaya and Degheele, 2013). So, these new chemistry insecticides may be competent IPM agents to reduce the insecticidal resistance hurdles.

Viewing the infestation prospect of subterranean termites as well as the impact of synthetic sustained insecticides on the ecosystem, the present study was planned to determine and screen out the more effective novel chemistry based insecticidal dosages under laboratory circumstances which can be suggested to local farmers for subterranean termites' management.

MATERIALS AND METHODS

Mass culturing of termites

Before the application of treatments, termite species belonging to Termitidae family and order Isoptera were obtained with the help of folded cardboard lures in PVC pipes located at 4 different sites in the city campus as well as new campus, Ghazi University, D. G. Khan. Termites were in abundance and mainly present in such sites and thus accumulated for proceeding this research project.

Insecticidal Based Treatments

The insecticidal based treatments (Table 1) were applied against termites for evaluating the cumulative mortality of termites.

Treatments mixture

The mixture of insecticidal treatments was made at the rate of 125 ppm, 250 ppm, 500 ppm and 1000 ppm with respect to measure their effectiveness (toxicity) toward termites.

Preparation of treatments mixture

Mixture in the form of ppm of insecticidal based treatments was made separately on the basis of active material present in it. Initially the required amount of insecticidal treatment was added in 1000 ml of water in order to make the 1000 ppm mixture of insecticidal treatment and further by using such 1000 ppm (mixture), other mixtures like 125, 250 and 500 ppm were made through the process of dilution.

Soil bioassay

From field, the soil was collected for performing the bioassay. In such soil, there was no dosage of insecticidal based treatments. Firstly, such soil was filtered through a screen of size 30 mesh.

Insecticides treated soil bioassay

This bioassay was inoculated by applying various insecticidal formulations (ppm) in Petri-dishes comprising 50 g of soil with a sugarcane slice of size 1.5 × 6 cm. This slice of sugarcane was provided as a dietary supplement for termites. Such slices were kept in Petri-dishes. Each treatment comprised of four formulations viz. 125, 250, 500 and 1000 ppm of insecticidal treatments along with control (insecticidal free treatment). All such treatments were 3 times replicated. Petri-dishes possessing soil along with sugarcane slices were moistened through hand sprayer of insecticidal mixtures of about 12 ml. In the control treatment, to prevent the termite death rate just because of dehydrating conditions, water of about 12 ml was included in all Petri-dishes containing soil during bioassay. Fifteen alive or active termites were released in the Petri-dishes possessing insecticides treated as well as un-treated soil. The mortality of termites was analyzed after the time exposure of 2 h up to 12 h and further this observation was done after the time interval of every 12 h until attaining 100% mortality rate of termites.

Statistical analysis

By counting the mean value of three repeats, the cumulative death rate (mortality) values of termites were calculated. By using MSTATC software, the mean values in different insecticidal treatments were contrasted through Least Significant Difference Test).

RESULTS

Mortality of subterranean termite at 125 ppm

The Table 2 displays the effect of different insecticides at a concentration of 125 ppm on the mortality of subterranean termites after different time durations. The higher the percentage of mortality, the more effective the insecticide is in killing the termites. The data in the Table 2 suggested that different insecticides had varying degrees of effectiveness against subterranean termites. Fipronil and Chlorpyrifos were the most effective insecticides, resulting in mortality rates of 100% after 24 hours of exposure. In contrast, Emamectin Benzoate had the lowest mortality rates, with only 4.44% of the termites dying after 2 hours of exposure, but it gradually increased and reached 97.77% after 84 hours of exposure. Overall, the data in the Table 2 suggest that some insecticides are more effective than others in controlling subterranean termites, and the duration of exposure also plays a crucial role in the effectiveness of the insecticides.

Mortality of subterranean termite at 250 ppm

Table 3 presents the effect of insecticides at a concentration of 250 ppm on the mortality of subterranean termites after different time durations. The results of the experiment showed that all insecticides tested resulted in varying degrees of mortality of subterranean termites.

Table 1: Detail of insecticides used for the management of termites.

Sr. No.	Insecticidal Treatments	Trading Name	Recommended Formulation
1.	Fipronil	Refree 5% SC	500 ml
2.	Alphacypermathrin	Bestox 5 EC	250 ml
3.	Emamectin benzoate	Proclaim 19 EC	200 ml
4.	Chlorpyrifos	Lorsban 40 EC	1000 ml
5.	Lambda Cyhalothrins	Karate 2.5 EC	330 ml
6.	Chlorfenapyr	Alert 36% SC	200 ml
7.	Imidacloprid	Confidor 200 SL	250 ml
8.	Chlorantraniliprole	Coragen 20 SC	50 ml
9.	Nitenpyram	Jasper 10 SL	200-250 ml
10.	Bifenthrin	Talstar 10 EC	200-250 ml

Table 2: Effect of insecticides at 125 ppm on the mortality of subterranean termite after different time durations.

Treatment	Mortality after (hours)										
	2	4	6	8	10	24	36	48	60	72	84
Chlorantranilliprole	8.88 bcd	19.99 d	33.33 bc	42.21 c	53.33 c	66.66 cd	75.55 cd	84.44 bc	93.33 ab	97.77 a	100 a
Chlorfenapyr	6.66 cd	22.22 cd	33.33 bc	42.22 c	53.33 c	79.99 abc	79.99 bcd	84.44 bc	91.11 ab	95.55 a	100 a
Imidacloprid	15.55 abc	33.33 abc	44.44 b	59.99 ab	71.10 ab	91.10 ab	97.77 a	100 a	100 a	100 a	100 a
Emamectin Benzoate	4.44 d	17.77 d	26.66 c	39.99 c	48.88 c	59.99 d	68.88 d	77.77 c	88.88 b	93.33 a	97.77 a
Alphacypermethrin	8.88 bcd	20 d	35.55 bc	48.88 bc	60 bc	86.66 ab	93.33 ab	97.77 a	100 a	100 a	100 a
Lambda Cyhalothrins	8.88 bcd	19.99 d	35.55 bc	44.44 bc	57.77 bc	82.22 ab	84.44 abc	88.88 ab	93.33 ab	97.77 a	100 a
Bifenthrin	17.77 ab	39.99 a	46.66 ab	59.99 ab	75.55 a	91.11 ab	95.55 ab	100 a	100 a	100 a	100 a
Fipronil	22.21 a	35.55 ab	57.77 a	73.33 a	82.22 a	95.55 a	97.77 a	100 a	100 a	100 a	100 a
Nitenpyram	11.10 bcd	22.21 cd	37.77 bc	44.44 bc	59.99 bc	75.55 bc	91.10 ab	97.77 a	100 a	100 a	100 a
Chlorpyrifos	13.33 abcd	24.44 bcd	35.55 bc	44.44 bc	62.22 bc	86.66 ab	93.33 ab	100 a	100 a	100 a	100 a

At the 2 hour interval, Chlorantranilliprole had the lowest mortality rate of 8.88%, while Imidacloprid had the highest mortality rate of 26.66%. However, at the 48 hour and 60 hour intervals, all treatments resulted in 100% mortality rates. Based on the statistical analysis of the data, it can be concluded that there were significant differences in mortality rates between the different insecticide treatments ($p < 0.05$). The most effective treatments were Imidacloprid, Fipronil, and Bifenthrin, which consistently showed high mortality rates across all time intervals.

Mortality of subterranean termite at 500 ppm

The Table 4 showed the mortality rates of subterranean termites treated with different insecticides at a concentration of 500 ppm after different time durations. The mortality rates were measured at 2, 4, 6, 8, 10, 12, 24, and 36 hours after treatment. Overall, the results indicated that all the insecticides tested were effective in controlling subterranean termites. At the 36 hour time point, all the treatments resulted in 100% mortality rates. However, the onset of mortality and the speed of action varied between the insecticides. Imidacloprid showed the fastest onset of mortality, with mortality rates exceeding 90% at the 6 hour time point and reaching 100% at the 8 hour time point.

Table 3: Effect of insecticides at 250 ppm on the mortality of subterranean termite after different time durations.

Treatments	Mortality after (hours)									
	2	4	6	8	10	12	24	36	48	60
Chlorantranilliprole	8.88 cd	26.66 cdef	37.77 cd	53.33 cd	68.88 c	75.55 def	95.55 a	97.77 ab	100 a	100 a
Chlorfenapyr	11.10 cd	26.66 cdef	33.33 d	42.21 d	55.55 de	66.66 f	77.77 b	86.66 bc	95.55 a	100 a
Imidacloprid	26.66 a	33.33 bcd	53.33 ab	71.10 ab	77.77 abc	91.10 ab	97.77 a	100 a	100 a	100 a
Emamectin Benzoate	6.66 d	17.77 f	28.88 d	42.22 d	53.33 e	66.66 f	77.77 b	84.44 c	93.33 a	97.77 a
Alphacypermethrin	17.77 abc	31.10 bcde	48.88 bc	62.21 bc	77.77 abc	88.88 abc	97.77 a	100 a	100 a	100 a
Lambda Cyhalothrins	13.33 bcd	22.22 ef	35.55 d	51.10 cd	66.66 cd	73.33 ef	79.99 b	88.88 abc	97.77 a	100 a
Bifenthrin	22.22 ab	37.77 ab	57.77 ab	77.77 a	91.11 a	97.77 a	100 a	100 a	100 a	100 a
Fipronil	26.66 a	44.44 a	62.21 a	73.33 ab	86.66 ab	95.55 a	97.77 a	100 a	100 a	100 a
Nitenpyram	13.33 bcd	24.44 def	39.99 cd	55.55 c	73.33 bc	80 cde	82.22 b	88.88 abc	93.33 a	97.77 a
Chlorpyrifos	22.22 ab	35.55 abc	48.88 bc	62.22 bc	71.11 c	84.44 bcd	86.66 ab	93.33 abc	95.55 a	100 a

Means sharing common letters in each column do not differ significantly.

Table 4: Effect of insecticides @ 500 ppm on the mortality of subterranean termite after different time durations.

Treatments	Mortality after (hours)							
	2	4	6	8	10	12	24	36
Chlorantranilliprole	13.33 d	42.21 b	59.99 b	80 b	93.33 ab	97.77 ab	100 a	100 a
Chlorfenapyr	17.77 cd	31.10 bc	51.10 bc	55.55 d	68.88 d	88.88 bcd	97.77 ab	100 a
Imidacloprid	33.33 ab	64.44 a	93.33 a	97.77 a	100 a	100 a	100 a	100 a
Emamectin Benzoate	11.10 d	31.10 bc	46.66 bc	62.22 cd	73.33 cd	84.44 cd	93.33 ab	97.77 a
Alphacypermethrin	17.77 cd	28.88 bc	53.33 bc	73.33 bc	91.10 ab	97.77 ab	100 a	100 a
Lambda Cyhalothrins	17.77 cd	19.99 c	37.77 c	53.33 d	68.88 d	82.22 d	95.55 ab	97.77 a
Bifenthrin	26.66 bc	44.44 b	62.22 b	79.99 b	95.55 ab	100 a	100 a	100 a
Fipronil	42.22 a	46.66 b	64.44 b	84.44 ab	95.55 ab	100 a	100 a	100 a
Nitenpyram	19.99 cd	33.33 bc	51.11 bc	62.22 cd	73.33 cd	82.10 d	91.11 b	95.55 a
Chlorpyrifos	22.21 bcd	40 b	55.55 bc	68.88 bcd	84.44 bc	93.33 abc	97.77 ab	100 a

Means sharing common letters in each column do not differ significantly.

Fipronil also showed fast action, reaching 100% mortality at the 12 hour time point. Chlorantranilliprole, Chlorfenapyr, Alphacypermethrin, Bifenthrin, and Chlorpyrifos showed moderate to fast onset of mortality, with mortality rates reaching 100% at the 24 hour time point or earlier. Emamectin Benzoate and Nitenpyram showed slower onset of mortality, with mortality rates reaching 100% at the 36 hour time point.

Mortality of subterranean termite at 1000 ppm

Table 5 presents the effect of insecticides at a concentration of 1000 ppm on the mortality of subterranean termites over different time durations. The results showed that all insecticides tested at this concentration were effective against termites, with varying degrees of mortality rates observed over time. Fipronil was found to be the most effective insecticide, with 100% mortality rate observed after 12 hours of treatment. Imidacloprid, Bifenthrin, and Chlorpyrifos were also found to be highly effective, with 100% mortality observed after 8 hours of treatment. Chlorantranilliprole, Chlorfenapyr, Emamectin Benzoate, Alphacypermethrin, and Nitenpyram showed lower mortality rates at this concentration, with 100% mortality observed after 12 to 24 hours of treatment. Lambda Cyhalothrins showed the lowest mortality rates, with 91.11% mortality observed after 12 hours of treatment.

Mortality of subterranean termite in control

Table 6 presents the effect of different insecticides at 0 (control) ppm concentrations on the mortality of subterranean termites after different time durations. These are the natural mortalities rates which increased overtime.

Table 5: Effect of insecticides @ 1000 ppm on the mortality of subterranean termite after different time durations.

Treatments	Mortality after (hours)					
	2	4	6	8	10	12
Chlorantranilliprole	33.33 bc	55.55 bcd	79.99 abc	91.11 ab	95.55 a	100 a
Chlorfenapyr	31.10 c	48.88 bcd	71.10 bcd	88.88 ab	97.77 a	100 a
Imidacloprid	48.88 b	68.88 b	88.88 ab	100 a	100 a	100 a
Emamectin Benzoate	24.44 c	37.77 de	55.55 de	75.55 bc	93.33 a	97.77 a
Alphacypermethrin	24.44 c	51.11 bcd	86.66 ab	97.77 a	100 a	100 a
Lambda Cyhalothrins	15.55 c	24.44 e	40 e	59.99 c	77.77 b	91.11 a
Bifenthrin	33.33 bc	60 bc	82.21 abc	97.77 a	100 a	100 a
Fipronil	71.11 a	93.33 a	100 a	100 a	100 a	100 a
Nitenpyram	22.21 c	37.77 de	64.44 cd	82.22 ab	95.55 a	100 a
Chlorpyrifos	33.33 bc	46.66 cd	64.44 cd	84.44 ab	97.77 a	100 a

Means sharing common letters in each column do not differ significantly.

Table 6: Effect of insecticides at 0 ppm (control) on the mortality of subterranean termite after different time durations.

Treatments	Mortality after (hours)						
	24	36	48	60	72	84	96
Chlorantranilliprole	2.22 a	2.22 a	2.22 a	4.44 a	6.66 ab	8.88 a	13.33 a
Chlorfenapyr	2.22 a	2.22 a	2.22 a	2.22 a	4.44 b	8.88 a	11.10 a
Imidacloprid	2.22 a	2.22 a	4.44 a	6.66 a	8.88 ab	13.33 a	15.55 a
Emamectin Benzoate	2.22 a	2.22 a	2.22 a	4.44 a	6.66 ab	8.88 a	15.55 a
Alphacypermethrin	0 a	2.22 a	2.22 a	2.22 a	8.88 ab	8.88 a	15.55 a
Lambda Cyhalothrins	2.22 a	2.22 a	2.22 a	6.66 a	11.10 a	13.33 a	17.77 a
Bifenthrin	0 a	2.22 a	4.44 a	4.44 a	4.44 b	11.10 a	17.77 a
Fipronil	2.22 a	2.22 a	2.22 a	4.44 a	6.66 ab	13.33 a	17.77 a
Nitenpyram	0 a	2.22 a	2.22 a	4.44 a	8.88 ab	13.33 a	17.77 a

Chlorpyrifos	2.22 a	2.22 a	2.22 a	6.66 a	11.10 a	13.33 a	17.77 a

Means sharing common letters in each column do not differ significantly.

DISCUSSION

The present investigations aimed to investigate the efficacy of new chemistry termiticidal treatments against subterranean termites. The treatments were applied at 125, 250, 500, and 1000 ppm dosages, and the mortality of subterranean termites was assessed at 2, 4, 6, 8, 10, and 12 hours after treatment. All treatments demonstrated highly significant results in terms of subterranean termite mortality. Fipronil, Imidacloprid, Bifenthrin, and Chlorpyrifos showed the highest mortality rates after 2, 4, 6, 8, 10, 12, and 24 hours of exposure.

The findings of this study supported the recommendation made by Iqbal and Evans (2017) that fipronil has potential as a toxic active material in lure systems for fungus-producing termites in tropical regions. At a rate of 125 ppm, Fipronil, Imidacloprid, and Bifenthrin achieved 100 percent termite mortality after 48 hours. Previous studies have shown the potential of Thiamethoxam and Fipronil for their lethal properties against Formosan termite (*Coptotermes formosanus*) and oriental eastern terminal (*Reticulitermes flavipes*). Thiamethoxam at 10 ppm and Fipronil at 1 ppm were effective against *C. formosanus* and *R. flavipes* (Remmen and Su, 2005). Saljoqi et al. (2014) conducted a study to investigate the effectiveness of three insecticides (Match, Regent, and Tracer) as slow-acting termiticides against the subterranean termite, *Heterotermes indicola*. The researchers observed an increase in the mean percentage of total termite mortality with the application of Fipronil (Regent), which caused 91%, 86%, 78%, 74%, and 62% mortality, while Spinosad (Tracer) resulted in 72%, 63%, 60%, 59%, and 28% mortality. In contrast, Lufenuron (Match) exhibited the lowest rate of termite mortality (49%, 31%, 26%, 22%, and 10%) after 10 days of application. Fipronil demonstrated the highest potency in killing and hindering termites, achieving 100% mortality even before 10 days with all doses applied. Hence, Fipronil was considered the most potent termiticide. Iqbal et al. (2019) corroborated the results of the present study and suggested that chlorfenapyr, thiamethoxam, and imidacloprid could be used as soil-termiticides, while Fipronil could be employed both as a soil-termiticide and in termite baiting programs. In this study, Fipronil soil-bioassay at a rate of 1000 ppm achieved maximum subterranean termite mortality (100%) after 12 hours.

Our findings are consistent with Ahmed et al. (2007), who demonstrated that imidacloprid at 150 and 300 mL is an approved terminal treatment because it resulted in a significantly lower number of termites compared to other treatments. In our study, we observed an increase in termite mortality after 36 hours of applying imidacloprid at a rate of 500 ppm. Similarly, Mukunthan et al. (2009) reported that insecticidal treatments (confidor, lindane, and E2Y45) provided protection for setts against termites for more than one month. Manzoor et al. (2014) evaluated the potency, repellent effects, and tunnel formation of imidacloprid against *Microtermes obesi* in laboratory conditions. They found that 90% termite mortality was observed after 96 hours of exposure to imidacloprid (100 µg per ml), while all trial termites were found dead after 168 hours at all the applied dosages.

Several studies have investigated the effectiveness of novel chemistry insecticides such as fipronil, indoxacarb, thiamethoxam, spinosad, chlorfenapyre, and imidacloprid against termites (Wang et al., 2007; Iqbal and Saeed, 2013; Vargo and Parman, 2012). These new insecticides possess various modes of action compared to older insecticides. Riekert and Berg (2003) evaluated the efficacy of some insecticides against fungus-producing termites (*Allodonterrmes* sp., *Microtermes* sp., and *Odontotermes* sp.) in a maize field trial. Imidacloprid, carbofuran, fipronil, and chlorpyrifos were applied as preventative treatments to maize stems and soil surfaces near the plants. Imidacloprid spraying showed better results against termite species. Our study also found that maximum subterranean termite mortality was achieved after 36 hours of applying imidacloprid at a rate of 500 ppm. Jaipal and Chaudhary (2010) supported our findings by stating that imidacloprid effectively controls termites in sugarcane with 15-25% higher growth than previously recommended control methods using pesticides. Ahmed et al. (2006) assessed the toxic impact of imidacloprid, monomehypo, and chlorpyrifos at rates of 250 g, 9 kg, and 1000 mL per acre, respectively, on subterranean termites in sugarcane fields. Chlorpyrifos-treated plots showed less infestation on sugarcane setts than other tested treatments.

The present experiment revealed a low mortality rate even after 84 hours, 60 hours, and 36 hours of exposure to Chlorfenapyr at dosages of 125 ppm, 250 ppm, and 500 ppm, respectively. This finding supports the laboratory-based study conducted by Manzoor et al.

(2012), which aimed to determine the potential toxicity and repellent effect of four termiticidal treatments, namely Bifenthrin, Fipronil, Chlorfenapyr, and Imidacloprid, at different formulations against termite workers of *H. indicola*. The results of the study showed that termite workers exposed to these termiticidal treatments achieved a mortality rate of 97% in 8 hours. Bifenthrin treatment was found to act as repellent at all applied formulations, while Fipronil exhibited repellency at a dosage of up to 25 ppm, and Chlorfenapyr was observed to be non-repellent. The study found that the bifenthrin treatment for termites resulted in the highest mortality rate when administered at a dosage of 250 parts per million and exposure time of 60 hours. This finding is consistent with the research of Nisar et al. (2020), which also indicated that bifenthrin is effective as a termiticide among chemical-based alternatives, with relatively low LT50 values.

When the dosage of chlorantraniliprole was increased to 1000 parts per million, 100% mortality was observed in subterranean termites after a 12 hour exposure period. This finding is consistent with the results of Akbar et al. (2018), who conducted an experiment comparing ten new insecticides against *Odontotermes obesus* using a filter paper disc methodology. Chlorantraniliprole, chlorfenapyr, and pyriproxyfen demonstrated the highest mortality rates (100%) after 24 hours of exposure, followed by triflumuron and indoxacarb. Henderson et al. (2016) reported that fipronil had the lowest survival rate (2%-5%) after one month of exposure in both concentrations. Treatment concentrations of 10 ppm of imidacloprid and chlorantraniliprole resulted in 35% to 45% termite mortality. Furthermore, 1 ppm of chlorantraniliprole did not significantly increase mortality compared to the control group.

CONCLUSION

It can be concluded that higher dosages of new chemistry termiticidal treatments result in maximum subterranean termite mortality after minimum exposure time. Among the applied termiticidal treatments, Fipronil, Imidacloprid, and Bifenthrin achieved 100% termite mortality at dosages of 125 ppm, 250 ppm, 500 ppm, and 1000 ppm after 84 hours, 60 hours, 36 hours, and 12 hours, respectively. In comparison, Chlorfenapyr and Emamectin Benzoate termiticidal treatments demonstrated a lower mortality rate at dosages of 125 ppm, 250 ppm, 500 ppm, and 1000 ppm after 84 hours, 60 hours, 36 hours, and 12 hours, respectively. These new chemistry insecticides are emerging as a good choice to be included in integrated pest management (IPM) programs. They are often slightly sustained, fast recyclable, highly targeted, eco-friendly, and safe for humans and non-target fauna. Therefore, these new chemistry insecticides may be considered as competent IPM agents to overcome insecticidal resistance.

AUTHORS' CONTRIBUTION

MSN and AR designed, formulated and laid out the study, MSN, MMM performed the experiments, MSN, HR and SM collected, arranged and analyzed the data, AR provided technical assistance, MSN and AR supervised the work, MSN and SM wrote the manuscript, AR proofread the paper.

CONFLICT OF INTEREST

The authors declare no conflict of interest.

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