EFFICACY OF FIPRONYL 200 G/L AND TERMIDOR IN CONTROLLING TERMITES.A LABORATORY AND GRAVEYARD TRIAL TEST

BY

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DECLARATION

Declaration by the student

I declare that this thesis is my original work and has not been presented for a degree in any university. No part of this thesis may be reproduced without prior permission of the author and or University of Eldoret.

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ADM.NO (SC/PGB/002/13)

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DEDICATION

I would like to dedicate this project to my family for their moral support to pursue my course.

A further dedication goes to my classmates of M.Sc.

ABSTRACT

Fipronyl is chemical formulations of phenyl pyrazole insecticide acting on the chloride channel of nervous system of insects to hinder chloride metabolism of γ- amino butyric acid of insect's nervous system. It has good control against *Microtermes natalensis* from attacking buildings. This study evaluated the efficacy of Termidor and Fipronyl 200 g/l commercial formulations at various treatment concentrations on treated timber and treated sand. *Termidor* was the experimental standard. The experiments was laid out in a Randomised Block Design carried out in both laboratory and graveyard with 60 and 200 samples, five treatments and ten replicates. Both termicides were tested at Fipronyl 200 g/l concentrations (2 ml/l, 4 ml/l and 6 ml/l) and *Termidor* under concentration of (10 ml/l) by treating *Eucalyptus grandis* and *Grevillia robusta*. The research was carried out at the Forest Products Research Centre of the Kenya Forestry Research Institute. This was a Wood preservation experiment with the main aim of treating timber commonly used in the construction and furniture industry in Kenya. The mode of wood blocks treatment was by dip diffusion and sand drenching. This showed that 2 ml/l, 4 ml/l and 6 ml/l levels of concentrations for Fipronyl or termidor (10 ml/l) have equal impact on termites since there was no significant difference in weight loss in the treated timbers compared with untreated timbers that had weight loss. Fipronyl treatment is effective at different concentration. This was determined by assessing the magnitude of timber attack by subterranean termites under different treatment regimes. It is advisable for the user to use Fipronyl 200 g/l at medium concentration this is because too high concentration may kill termites faster than expected while at lower concentration may not supply a sufficient dose for contaminated termites to transfer a lethal dose to unexposed termites. Appropriate concentration of a termiticides should be applied to achieve a wide coverage.

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TABLE OF CONTENTS

LIST OF TABLES

LIST OF FIGURES

CHAPTER ONE

INTRODUCTION

1.1 Back ground of the study

The Formosan subterranean termite are social insects living in colonies, *Coptotermes formosanus* Shiraki (Isoptera: Rhinotermitidae), is one of the most economically important termite pests and with a widespread global distribution (Henderson 2008, Rust& Su 2012).Among them, the introduced Formosan subterranean termites. It was established that *Coptotermes formosanus* Shiraki, is the most damaging species (Song & Hu, 2006).Due to the *Macrotemes natalensis* (widely distributed in Kenya) extraordinary economic importance, intensive research has been centered on two main methods for subterranean termite control, based on bait technologies and liquid termiticides, have been widely used (Henderson 2001, Gautam& Henderson 2012, Rust & Su 2012).

According to Haagsma and Rust(2007), Saran and Rust (2007), Spomer *et al.*(2008) and Bagnères *et al.* (2009) they established that, there is growing evidence that at least some non -repellent termiticides can be transferred among individuals within colonies. However, it was established that termite baits have some obvious advantages in long-term termite control and structural protection for its low chemical expense and environmental friendliness (Thoms *et al.* 2009, Liu *et al.*, 2011, Gautam& Henderson 2012).Soil treatment with termiticides remains popular in termite control (Anonymous 2002, Su 2002). One of the recent termiticides is Fipronil a phenyl pyrazole. It was reported that phenyl pyrazole is a chemical that interferes with the function of the central nervous system(Cole *et al.* 1993).It was discovered that, fipronil can have activity on termite colonies beyond the immediate zone of treated soil (Potter and Hillery 2002, Osbrink and Lax 2003, Ripa *et al*. 2007, Parman and Vargo 2010), possibly resulting in colony elimination.

Fipronyl has a delayed action that allows the contaminated termites to maintain normal behaviour for an extended period so as to transfer its lethal effects activity on termite colonies beyond the immediate zone of treated soil (Ripa *et al*. 2007, Parman and Vargo 2010), fipronil usage has a greater impact on termite populations than Organochlorines cyclodienes and pyrethroids and can provide 100% control for more than 10 years (Hu and Hickman 2006).Vargo and Parman (2012) was working on Partial post construction treatments with the use of fipronil slow-acting and Non repellent insecticides.Vargo and Parman (2012) surrounded houses with monitors and examined the genetic colony identification of the termites, both before and after a treatment with fipronil. Their study showed that all colonies within 6 m of the treatments vanished and did not return during 3 yrs. of monitoring post termiticide application.

1.2 Statement of the problem

Subterranean termites are mostly living in warm and humid climatic conditions found in tropical and sub-tropical of African countries. They are called subterranean termites because most of them live in the soil habitat. These termites form tunnels in soil that can be several metres long and are used to forage and locate food and moisture resources such as wooden pieces. The Colonies of subterranean termites are composed of mature and immature individuals having soft and delicate bodies sensitive to desiccation and heat. These termites are responsible for damage to timber, in agricultural and urban areas. In recent years factors such as buildings costs and expanding urbanization have contributed to substantial increase in monetary expenditure due to termite damage and control. Insecticide application is an effective strategy for termite control.

1.3 Justification of the study

The severity of the risk posed to termites by Fipronyl200g/l on contact and feeding is primarily dependent upon the insecticide applied and their exposure to it and its residues. Fipronyl is an insecticide that blocks the γ -amino butyric acid (GABA)-gated chloride channel of insect nervous systems, it is a highly effective, broad-spectrum insecticide which degrades slowly and has a degradation product more toxic and persistent than the parent compound. Therefore, it is an effective insecticide to control termites hence helping in preventing economic loss due to the damage to timber in both developed and developing countries.

1.4 Objectives

1.4.1 Main objective

To assess the efficacy of Fipronyl at the rate of 200 g/l in controlling termites,when compared with *Termidor* a registered termiticides.

1.4.2 Specific objectives.

1. To evaluate the efficacy of *Termidor* and Fipronyl 200g/l commercial formulations at various treatment concentrations on treated timber.

2 To determine the efficacy of *Termidor* and Fipronyl 200g/l at various treatment concentrations on treated sand.

3. To assess the magnitude of timber attack by subterranean termites under different treatment regimes.

1.5 Hypotheses

H0: There is no difference in termite attack on treated and untreated timber with different concentrations of tested termiticides.

H1: There is difference in termite attack on treated and untreated timber with different concentrations of tested termicides.

H0: There is no difference in termite penetration on treated and untreated sand with different concentrations of tested termicides.

H1: There is difference in termite penetration on treated and untreated sand with different concentrations of tested termicides.

H0: there is no difference in termite attack on treated and untreated timber with tested insecticides basing on visual rating and weight loss.

H1: There is difference in termite attack on treated and untreated timber with tested termicides basing on visual rating and weight loss.

CHAPTER TWO

LITERATURE REVIEW

2.1 Localized treatments using commercial liquid formulations of fipronil against termites

Most part of Kenyan regions have warm climatic conditions with quite variable patterns of rainfall. It was established by (Rust and Su, 2012)that termites are some of the most economically important pests, with a widespread global distribution and therefore it causes significant economic damage to wooden structures in buildings in several areas of Kenya. When seasonal variations were studied for different species of termites, it was observed that *Heterotermes indicola* and *Microtermes spp* were more persistent (Manzoor and Mir, 2010). In recent years soil treatment with liquid termiticides has been the dominant method used in subterranean termite control programs (Anonymous, 2002).

It has been observed that non-repellent and relatively slow-acting liquid termiticides represented by imidacloprid (e.g., Premise®), fipronil (e.g., Termidor®), chlorfenapyr (Phantom®), indoxacarb (Aperion™) and chlorantraniloprole (Altriset™) are soil termiticides widely used for the prevention and treatment of structural infestations of subterranean termites according to (Potter &Hillery, 2002; Ibrahim *et al*., 2003; Remmen& Su, 2005; Saran & Rust, 2007). Potter &Hillery (2002) suggested that treatment standards require a complete drench around the foundation of the structure and around pipes penetrating the slab to ensure that all potential areas of termite entry are blocked from infesting the building.

One important advantage of a non-repellent termiticides is the potential greater "coverage" as termites do not detect the chemical presence and do not die immediately after walking across the treatment (Thorne & Breisch, 2001), thus opening the door for possible alternative treatment methods to incorporate into integrated pest management strategies that reduce the amount of chemical applied. Localized (or soil) treatments using non-repellent, slow acting chemicals can be an alternative to complete soil drenching. However, the success of soil treatment is not free from doubt as it leaves numerous avenues of termite entry untreated. Some studies (Potter & Hillery, 2002; Reid *et al*., 2002; Waite *et al*., 2004; Hu & Hickman, 2006; Hu, 2011) have reported success in suppressing termite populations well beyond the treated areas, while others such as Osbrink *et al*. (2005), Su (2005) and Saran and Rust (2007) cast doubt on the long-distance coverage of these termiticides. Su (2005) and Osbrink *et al*. (2005) concluded that fipronil and imidacloprid could not fulfill the requirements for liquid bait models.

Despite differences in interpretations, it is established that, unlike repellent soil termiticides, non-repellent, delayed action termiticides have impacts beyond the treated area. Moreover, studies suggest that the active distance covered by non-repellent termiticides varies depending on termite species, termiticide class and the test protocol such as field trial (grave yard test) versus laboratory.

In this study, we aimed to understand the efficacy of fipronil at the rate of 200g/l, impacts of dip diffusion and soil treatment against the Formosan subterranean termite, *macrotemes natalensis*.This liquid formulation can be a potential candidate for successful localized treatments as previous studies have suggested that termiticidal dusts may be suitable for termite colony elimination according to Lin *et al*., (2011). Gautam *et al*., (2012) suggested that fipronil dust effectively killed termites and transferred well from treated to non-treated individuals. In this study, our objectives were to determine and compare the effectiveness of Fipronyl at rate of 200g/l with Termidor.

2.2 Historical termite management in other countries

In recent years there has been two main methods for subterranean termite control that are widely used: one is based on bait technologies and the other on liquid termiticides
(Gautam and Henderson 2012, Rust and Su 2012). In the United States, it was discovered that termite bait products account for approximately one third of the market share according to a 2002 survey (Rust and Su 2012). But the labor costs associated with bait placement and inspection have hampered sales of baits compared with liquids. But termite baits have some obvious advantages in long-term termite control and structural protection for its low chemical expense and its environmental friendliness (Thom's et al., 2009, Liu *et al*. ,2011, and Gautam & Henderson 2012).

A successful baiting system depends on understanding the foraging behavior of subterranean termites. A toxicant-laced cellulosic food material can be in introduced to the whole colony through direct feeding, trophallaxis, cannibalism, and mutual grooming (Bagne`res *et al.*, 2009, Gautam& Henderson2012). The two cellulosic food materials, wood and cardboard, have been commercially used in baiting systems. Maize (*Zea mays*) cob is another material that contains abundant cellulose.

2.3 Evaluation of Efficacy and Non-repellency of Fipronil and other termicides-Treated Soil at Various Concentrations and Thicknesses against Termites

Effectiveness of termiticides-treated soil against subterranean termites depends mainly on the toxicity and the mode of activity of the toxicant, as well as other factors such as termite susceptibility to the insecticide, soil properties (e.g., pH, soil group, particle size, organic matter, and compactness), application protocol, and formulation (Osbrink *et al*.2001). Non-repellent compounds like fipronil are preferred for soil treatment because they do not seem to disrupt termite foraging in the treated soil zone and have a delayed mode of action that may contribute to movement of the active ingredient in the colony through trophallaxis and social grooming (Kard, 2003).The changes in subterranean termite control technologies and the needs of the pest control industry, numerous studies have examined the efficacy of insecticides, new formulations, and new active ingredients intended for termite control (Shelton and Grace 2003).

The US Environmental Protection Agency (EPA) has developed Eco-toxicity classification based on LD50 and LC50 assessments (US EPA, 2012). They classify the acute toxicity of a given product on a particular species as practically nontoxic, slightly toxic, moderately toxic, highly toxic, or very highly toxic based on lethality dose ranges. One of the serious failings of current risk assessments is the underestimation of interspecies variation in insecticide susceptibility. Too few species are typically tested to derive the true variation in response from the vast array of exposed species in the wild Mineau and Palmer (2013).

2.5 The effect of soil and exposure duration on mortality and transfer of fipronil on termites

Despite recent advances in the treatment of subterranean termites by using bait technologies ,Two main methods for subterranean termite control, based on bait technologies and liquid termiticides, have been widely used (Gautam and Henderson 2012, Rust and Su 2012) Termite control largely depends on the use of soil termiticides for the prevention and treatment of structural infestations (Gahlhoff & Koehler 2001).

Soil termiticides are used to treat soil to establish a toxic zone against termite penetration (Saran & Rust, 2007). It is good idea to apply an appropriate concentration of a termiticide to achieve a wide coverage, too high concentration may kill termites faster than expected while at lower concentration may not supply a sufficient dose for contaminated termites to transfer a lethal dose to unexposed termites (Thorne & Breisch, 2001; Ibrahim *et al*., 2003; Shelton & Grace, 2003; Hu, 2005; Remmen & Su, 2005; Su, 2005; Rust & Saran, 2006; Saran & Rust, 2007; Gautam& Henderson, 2011b; Hu, 2011).

CHAPTER THREE

MATERIALS AND METHODS

3.1 Study site

The research was carried out at the Forest Products Research Centre of the Kenya Forestry Research Institute (KEFRI) located at Karura Forest, Nairobi. The Kenya Forestry Research Institute headquarters is located at Muguga 23 km north-west of Nairobi, off the Nairobi – Nakuru highway. KEFRI has 5 regional research programmes with head offices in Kitui, Maseno, Gede, Muguga and Londiani. The treated and untreated wood samples were set up in a "grave yard" (in the field) at the Kibwezi KEFRI Sub-centre.

3.2Experimental design

3.2.1 Efficacy of Fipronyl at the rate of 200 g/l in controlling termites. When compared with termidor

The experimental research was carried out in September 2014 to July 2015 .The experiments were laid out in a randomised group design carried out in both laboratory– with five treatments and six replicates; and "graveyard" trial tests with five treatments and ten replicates. Testing was carried out on Fipronyl at the rate of 200g/l against an approved and registered chemical known as *Termidor*. Whereby *Termidor* was the experimental standard, The treated wood samples and controls was set up in a "grave yard" (in the field – at the KEFRI's Kibwezi Sub-centre) by following the "Protocols for assessment of wood preservatives; A production of the Australian wood preservation committee (2007 revision)".This was a wood preservation experiment whereby the main target was to use timber used in building; *Eucalyptus grandis* and *Grevillea robusta* treatments using Fipronyl 200g/concentrations at 2ml/l, 4ml/l and 6ml/l and *Termidor* concentration at 10 ml/l.

Plate 3.1 above shows graveyard trial test at KEFRI Kibwezi Sub-centre

(Source: Author.2015)

3.3 Study sample

The main objective during the research being studied was the determination of the efficacy of Fipronyl 200 g/l for controlling termites. Fipronyl was tested against an approved and registered chemical known as *Termidor*. During this field experiment the test chemical was Fipronyl200g/l whose recommended concentration was 4ml/l, In addition two concentrations were used one lower (2ml/l) and one higher (6ml/l).

Fipronyl 200g/l were tested against an approved and registered chemical known as Termidor that has a recommended concentration of 10ml/l.There field experiment also had control samples (no treatment applied). The “graveyard” trial was carried out by using *Eucalyptus grandis* and *Grevillia robusta* (commonly used as construction and furniture timber). These chemicals were applied in two ways - dip diffusion and also applying the chemical in the ground at test site (this is how these termiticides are applied normally).

3.4 Laboratory experimentation

Procedure

The *Eucalyptus grandis* and *Grevillia robusta* timber was sawn into cubes of about 1 cm^3 cubes. The cubes were labeled by giving each code number, weighed and recorded. The numbers of wooden blocks were 60 cubes for both - 30cubes from each species. After that the cubes was subjected into a temperature of 161°Cin oven for 24 hours. Then the weight was recorded. Samples were immersed for four days in Fipronyl 200g/l with concentrations of 2ml/l, 4ml/l and 6ml/l, *Termidor* concentration of 10 ml/l.The treatment mode of wood blocks was by dip diffusion. There were done in 6 replicates.After treatments each block was dried by air drying in the shade or the open for four days as outlined in the Protocols for assessment of wood preservatives; A production of the Australian wood preservation committee (2007 revision).

Sand was collected, washed and then sterilized in an oven for 24 hours at 161°C. This was put in 27 clear plastic test bottles of 300ml, with each being filled 1/3 full. Thirty millimetres of distilled water were sprinkled on to the sand till it was wet and kept for two hours .Then two blocks of the treated and untreated blocks measuring $1cm^3$ were put onto the sand in each of the bottles. Then subterranean termites of the species *natalensis* from a single colony comprising of 360 females and 40 males were introduced according to a procedure adapted from AWPA E1-97 standard (Standard method laboratory for evaluation to determine resistance to subterranean termites, 1997).The test bottles was then kept in an incubator at temperatures between 25-28 °C.Out of treated wood blocks, the samples that were exposed to termites were 6 at each concentration.

Plate 3.2 shows exposure of wood samples to termites in incubator

(Source: Author.2015)

3.5 Assessment of magnitude termite attack on timber under different treatment attacks

The blocks were inspected weekly for visual rating and after four weeks for weight loss techniques in the laboratory test and for field trials was after six months as per the protocol “Following the Protocols for assessment of wood preservatives; A production of the Australian wood preservation committee (2007 revision)”. During each inspection, the blocks were removed, cleaned by scrapping soil or sand off the blocks surface and intensity of termite attack assessed. The attack was rated visually and weight loss basis as indicated below.

Plate 3.3 Typical cube that have been damaged by termites.

(Source: Author.2015)

Table 1: Shows how the visual ratings for termite attack were rated, depending on magnitude of Timber attack.

Description of attack	**Rating**	**Percentage(attack)**
Sound	0	(0% attack)
Trace	1	(1-10% attack)
Slight	2	(11-30% attack)
Moderate	3	(31-50% attack)
Severe	4	(51-80 attack)
Fail	5	(81-100% attack)

3.6 Field trial graveyard test

Procedures

Eucalyptus and Grevillea timber measuring 4 by 2 inches were measured from the market then cut into 1metre length and their weights were recorded. Labelling was done by giving each sample a code. The samples were immersed for four days in Fipronyl 200g/l with concentrations of 2ml/l, 4ml/l and 6ml/l, and *Termidor* concentration of 10 ml/l. Some samples were not treated with the chemicals so as to serve as controls. After four days the samples were removed and the weights were measured and recorded. The colour changed from golden brown to black on *Eucalyptus grandis* and no colour change in *Grevillea robusta* when treated with *Termidor*. Slight change of colour to black but others no change of colour on *Grevillea robusta* when treated with Fipronyl 200g/l.The colour changed from golden brown to black on *Eucalyptus grandis.*

3.7 Field soil mixing

Holes were dug 20cm deep then 2 litres of the different solution strengths was prepared. Then the samples were placed into the hole and the sample was protected all round with plastic pipe of 30cm length.As per Following the Protocols for assessment of wood preservatives; A production of the Australian wood preservation committee (2007 revision).The moisture content (M.C) of the samples were determined by the following formulae

Moisture content= (initial weight/oven dry weight multiplied by 100).

The experiments were setup as shown in following plate.

(Plate3.4) shows how field soil mixing at KEFRI Kibwezi . (Source: Author.2015)

graveyard field trial test was set up in September 2014 at KEFRI Kibwezi as follows;

T1:2ml Fipronyl 200g/l in 1 litre water, T2:4ml Fipronyl 200g/l in 1litre water, T3:6ml Fipronyl 200g/l in 1litre water, T4:10 ml termidor in 1 litre water, T5: control, R1: treated timber, R2: treat soil.

Table 2: Map showing Randomized efficacy set up layout at KEFRI Kibwezi Sub-Centre

	1	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**	**10**
1	144	104	89	3	161	149	29	70	130	150
2	108	64	128	8	165	148	27	44	50	42
3	88	143	141	109	127	46	186	68	102	1
4	23	121	49	125	85	86	83	61	164	184
5	2	81	69	106	147	110	66	65	190	183
6	6	162	67	170	146	63	48	105	145	5
7	163	142	26	188	126	168	24	124	122	21
8	7	9	82	87	22	45	182	10	187	90
9	103	107	28	101	43	62	41	167	47	166
10	4	25	185	169	189	181	30	84	129	123
11	160	12	154	34	59	57	155	196	75	79
12	111	177	18	171	60	93	52	56	74	77
13	116	140	137	179	32	139	71	40	35	134
14	133	80	92	136	153	195	138	191	16	15
15	95	37	117	174	158	20	51	98	175	200
16	180	132	112	152	39	100	178	157	193	159
17	54	36	135	13	55	118	199	76	172	197
18	198	31	115	194	17	151	11	58	73	97
19	192	119	94	33	113	173	14	78	38	19
20	96	53	156	120	99	176	114	72	131	96

There is a distance of 1metre in between each sample. The samples were set up in four plots where by each plot had50 samples. In between each plot there is a break of 5 metres each indicated in bold lines in randomized efficacy set up shown above.

3.8 Data Analysis

Data analysis was performed using STATA version 13 special edition after the data had been entered in Excel package before being exported to STATA software. Categorical variables were summarized as frequencies and its corresponding percentages, while weight loss, the only continuous variable of interest, was positively skewed because of some weighted outlier, therefore it was summarized as median and it's corresponding inter quartile range (IQR). Two-way ANOVA was the only statistical technique which was used to find out if there was any difference in weight loss given that different concentration of treatments were applied using different modes of application in the field trial test or under laboratory test. Results were presented in form of tables and graphs.

CHAPTER FOUR

RESULTS

4.1.1: Magnitude of termites attack on treated and untreated timbers

There were a total of 60 and 200wood samples whose data from laboratory experiment and graveyard trial test respectively was included for analysis this represented 100% evaluation in each experimental trial. Both in the laboratory and graveyard trial test experiments, the number of wood samples in the control group 12(20%) and 40(20%) respectively were not equal to that of intervention 48(80%) and 160(80%) respectively. Data on weight loss by treatment captured during laboratory and graveyard trial experiments for both overall and group summary statistics like median, minimum, maximum and inter quartile range (IQR) were presented in Table3.

In the laboratory experiment, the median weight loss for Eucalyptus was 0(IQR: 0-0) grams and its minimum and maximum weight loss was 0 grams and 0.2 grams respectively, while the median weight loss 0(IQR: 0-0) grams for Grevillia and its minimum and maximum weight loss was 0 grams and 0.5 grams respectively. Likewise in the graveyard trial test, the median weight loss value for Eucalyptus was 0(IQR: 0-0) grams and its respective minimum and maximum weight loss were 0 gram and 1 gram, and Grevillia had a median 0(IQR:0-0) and its minimum value of 0 gram and a maximum value 0.9 gram. In the two experiments this variable (weight loss) was significant for the grouped factors median and IQR statistics which is a measure of variability in data. Majority of the wood samples in the laboratory test and grave yard trial test treated with either *Termidor* or Fipronyl did not have their weights changed from the weights after exposure to termites, representing 48(80%) and 160(80%). This showed that the treatment was so highly effective that it suppressed the termites from finding the "foods" and for those termites which tried to attack the wood samples treated with Fipronyl and *Termidor* died.

Table 3: Evaluation of Timber weight loss stratified by treatment and control group as compared with its total number of samples

Outcome variable	Experiment type	Grouping factor	Freq.(%)	min	max	IQR	Median
Weight loss	Laboratory	Control	12(20%)	0.1	0.5	0.2-0.3	0.2
		Treated	48(80%)	0	0	0-0	0
		overall	60(100%)	0	0.5	0-0	0
	Graver yard	Control	40(20%)	0	0	0.1-0.4	0.3
		Treated	160(80%)	0	0	0-0	0
		overall	200(100%)	0	1	0-0	0

Control wood samples which were under experimental test in the laboratory and had weight loss of approximately 0.2 grams represented 6(10%), control wood samples which lost their weight approximately to 0.3 grams represented 3(5%), those wood samples which lost weights approximately to 0.1 grams represented 2(3%) and other control wood samples 1(2%) lost approximately to 0.5 grams, (Figure1). While control wood samples which were under the field trial experiment and had a weight loss of approximately 0.1 were 4(4%), those with a weight loss of 0.2 represented 5(5%), with 0.3 grams loss in weight were 5(5%), with 0.4 grams change from initial weight before exposure to termites were 3(3%) while all those which had a weight loss of 0.5, 0.8 and 1 gram represented a total of 1(1%), (Figure 2). The median weight loss for controls and interaction timber were different, both in laboratory experiment and field trial experimentation.

Furthermore, the shape of distribution was assessed and was not similar. Also the treated group and the control group had different inter quartile ranges, (IQR: 0-0 grams) and (IQR: 0.2-0.3 grams) respectively for the laboratory experiment and in graveyard trial test treated group had IQR: 0-0 grams while the control group had (IQR: 0.1-0.4 grams).

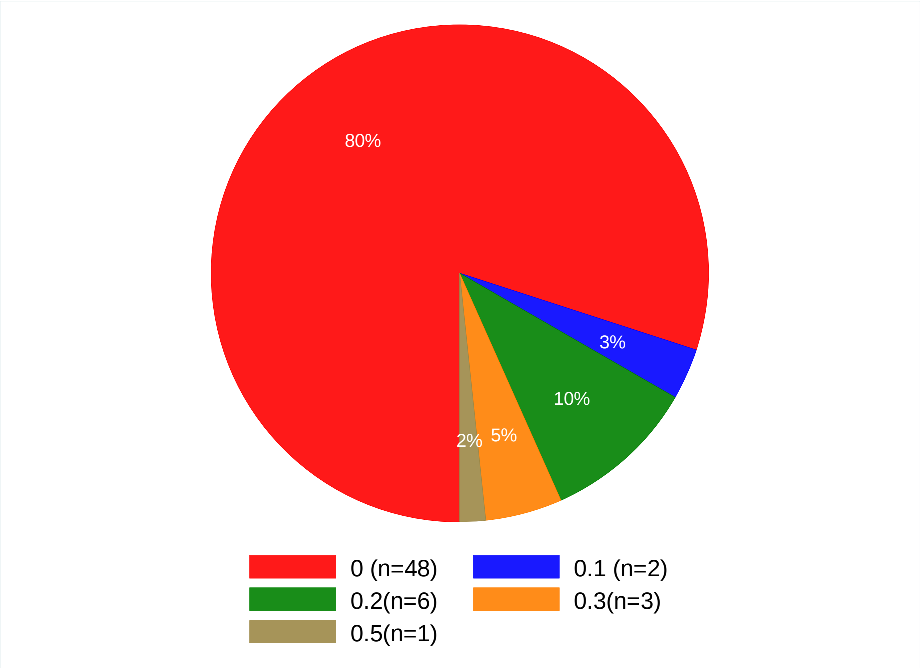

Figure 1: Distribution of wood samples weight loss in grams basing on laboratory experimentation.

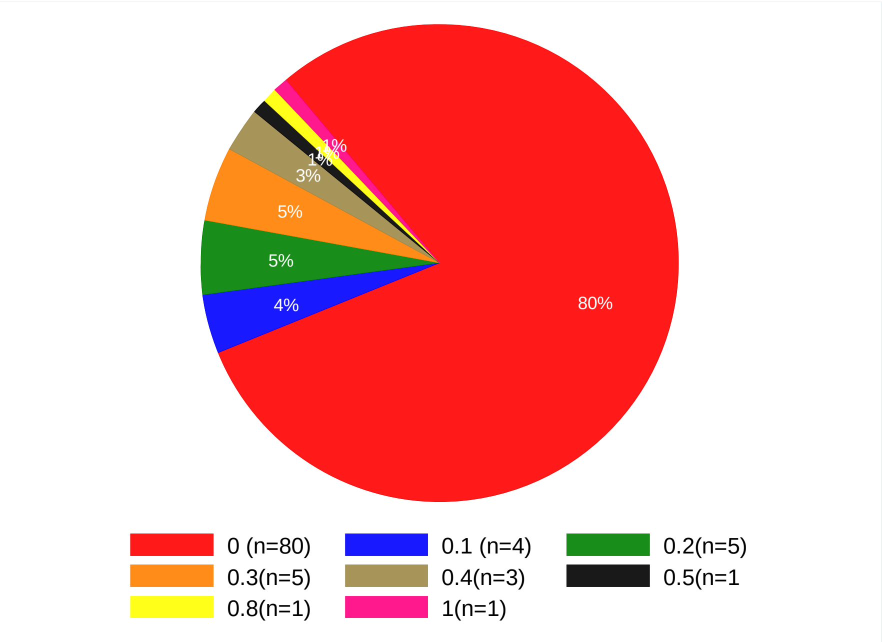

Figure 2: Distribution of wood samples weight loss in grams basing on laboratory experimentation.

Legend (n= numbers of wood samples, decimal units are weights in grams)

Different concentration of treatments applied to wood samples was coded as T1, T2, T3, and T4 and the only control allotment was coded as T5 in laboratory and field trial experiment. All wood samples which were subjected to different concentration of treatment and showed no change in their weight were in total 48(80%) during the laboratory test and 160(80%) during the field trial test, while timbers which were under control(T5) and were attacked by the termites showed different weight loss of (0.1, 0.2, 0.3, 0.5) grams and were in total 12(20%), (Figure 3) under laboratory trial test and (0.1, 0.2, 0.3,0.4, 0.5, 0.8 and 1)grams being in total 160(80%) under field trial test (Figure 4). The difference in weight loss between control and the treated timbers in the laboratory test indicated that there was a significant difference, p- value (0) with adjusted R-squared value of 39.2% for the explanatory variable. Table5.

Similarly, in the field trial test there was a significant difference in weight loss between control and treated timbers in their weight loss where mode of application of Fipronyl or *Termidor* was achieved through dip diffusion, p- value (0) and adjusted R-squared value (30.91%) of explanatory variable explaining the effect of treatment on termites among 100 treated timbers. That showed how effective the treatment (Fipronyl or *Termidor*) was in controlling termites from destroying timber.

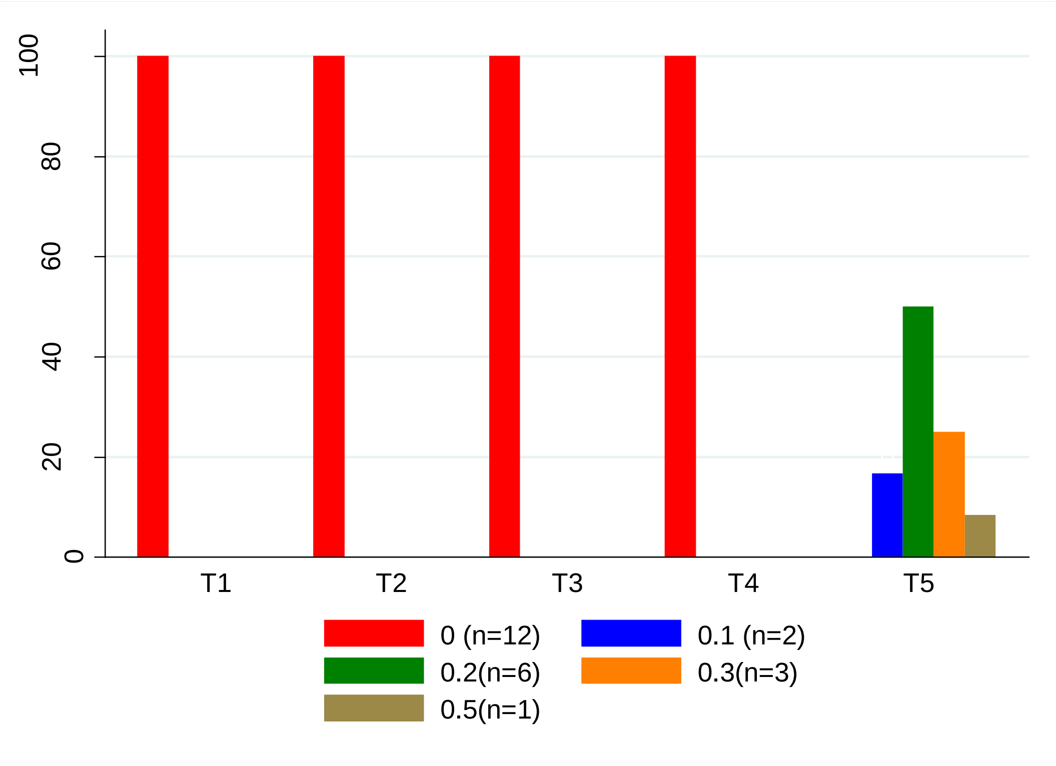

Figure 3: Distribution of Timber weight loss by Treatment under laboratory experimentation.

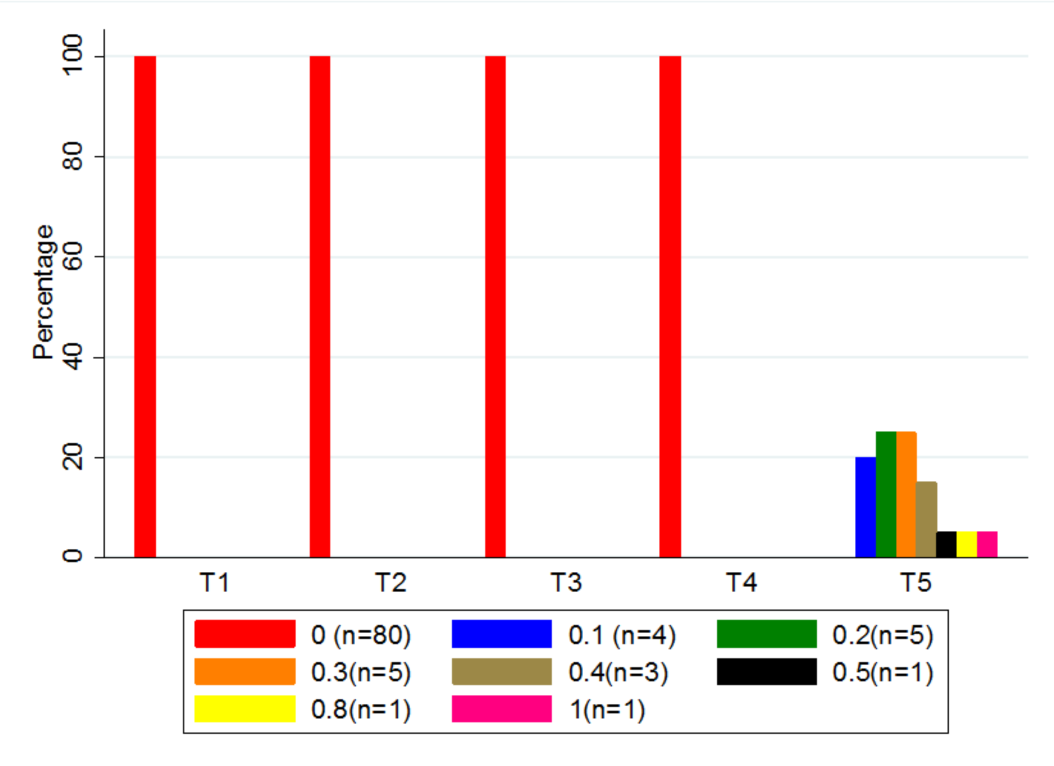

Figure 4: Distribution of Timber weight loss by treatment during field trial experiment

4.1.2 Magnitude of termite's attack on treated and untreated sand

When mode of application is only on sand the effect of Fipronyl or *Termidor* on termites is exactly the same as dip diffusion. Generally, weight loss, the only variable of interest in the field study had median value 0(IQR:0-0) and specifically, control group had minimum (0.1) and maximum value (1), (Table 4). It was clear from the results, that there was significant difference between timbers monitored under treated sand and those which were under control within the same field of study, p- value (0) with adj. R-squared value of 27.54% for the treatment which was an explanatory variable, (Table 6). That suggested a clear evident of the working effect of Fipronyl or *Termidor*.

Table 4: showing statistics on the loss weight of timbers

Variable	Mode of application	Sample size	Median	IQR
Weight loss	Dip diffusion(R1)	100	0	0-0
Weight loss	Sand treatment(R2)	100	0	0-0

Comparison of weight loss by mode of treatment application during field trial test

Considering the two modes of application, it was clear from the results in (Figure 5) that the two had equal effect in controlling termites from destroying timbers in the field. That is, 80% for the treated timber or sand were not attacked by the termites whereas the untreated ones which were control were differently attacked in the process, as shown in (Figure 5)

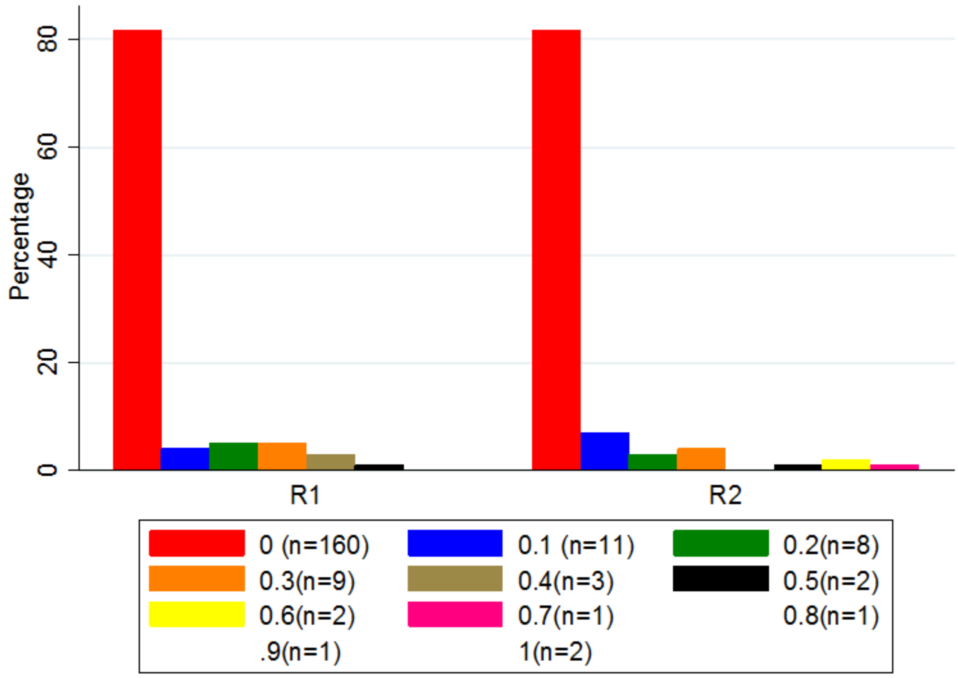

Figure 5: Comparison of weight loss of timbers by mode of application.

Distribution of timber by species

In laboratory experiment there were a total of 60(100%) consisting of two species, Eucalyptus 30(50%) and Grevillea 30(50%) timbers, while in the field trial the total number of timbers which were used were 200(100%), Eucalyptus 100(50%) and Grevillea 100(50%) timbers, were included in the studies. Among the Eucalyptus timbers in the laboratory experiment, 6(50%) timbers for each species were allotted or subjected to different concentration of treatment T1, or T2, or T3, or T4 and the remaining 12 timbers from each species (Eucalyptus and Grevillea timbers) were also under control (T5) in two plastic bottles. But under field trial test, every concentration of treatment was allotted equal number of timbers for each species 20(20%).

Table 5: Distribution of timbers by species and treatments applied under laboratory experiment and field trial test

	Treatment						
	Timber Species	T1	T2	T3	T4	T5	TOTAL
Laboratory exp	EU	6(50%)	6(50%)	6(50%)	6(50%)	6(50%)	30(50%)
	GR	6(50%)	6(50%)	6(50%)	6(50%)	6(50%)	30(50%)
Field trial exp	EU	20(20%)	20(20%)	20(20%)	20(20%)	20(20%)	100(50%)
	GR	20(20%)	20(20%)	20(20%)	20(20%)	20(20%)	100(50%)

T1-Standard recommended dosage **T2-** Higher dosage **T3-** Lower dosage **T4-**Termidor and **T5-** Control. **EU-***Eucalyptus grandis* and **GR**- *Grevillea robusta*

4.1.2 Difference of termites attack on timber basing on visual characteristics.

Those treated timbers which were not attacked by the termites and ranked visually as sound were 48(80%) under laboratory test while under graver yard experiment 160(80%) were ranked visually as sound, those which were attacked by termites slightly during laboratory experimental and ranked as slight were 10(17%) but 15(7.5%) was noticed under field trial test, those which were attacked moderately and ranked as moderate was 1(2%) during laboratory experimental while 8(4%) was visually noticed during field trial test and those which were severely attacked by termites and classified as severe was 1(2%) under laboratory test but 17(8.5%) was visually observed and classified as trace under graver yard trial test, (compare figure 8 and figure 9).

The test for difference in ranking visually of weight loss findings was significant, p- value (0) in both studies. The results from graver yard trial test experiment supports that the difference between the weight loss of the treated and untreated timbers basing on the visual ranking of the timbers after being exposed to termites was present. That was due to the fact that approximately 69% of the explanatory variable (different concentration of treatments) gave enough evidence of no destruction of timbers by the termites treated with either Fipronyl or termidor (Table 6).

Table 6: Showing the results of the analysis for the graver yard data set

Response variable	**Explanatory variable**	**Sample size**	**Adj. R-squared value**	**Prob. >F**
Weight loss	Visual ranking	60	0.9257	0.0000
Weight loss	Visual ranking	200	0.6859	0.0000
Weight loss	Treatment of timbers	60	0.392	0.0000
Weight loss	Treatment of timbers	100	0.3091	0.0000
Weight loss	Treatment of sand	100	0.2680	0.0000

Findings stratified by ranking weight loss were as given in the Figures 8&9.

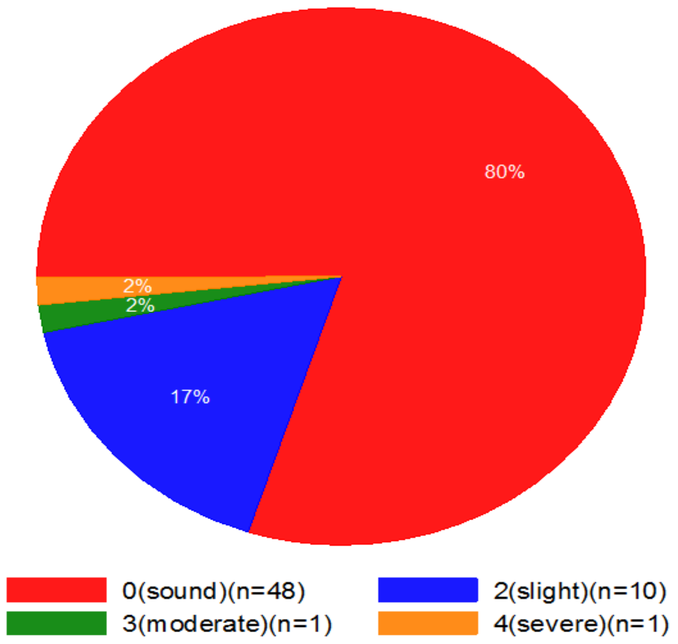

Figure 6: Distribution of timber weight loss during the laboratory experiment categorized by visual ranking

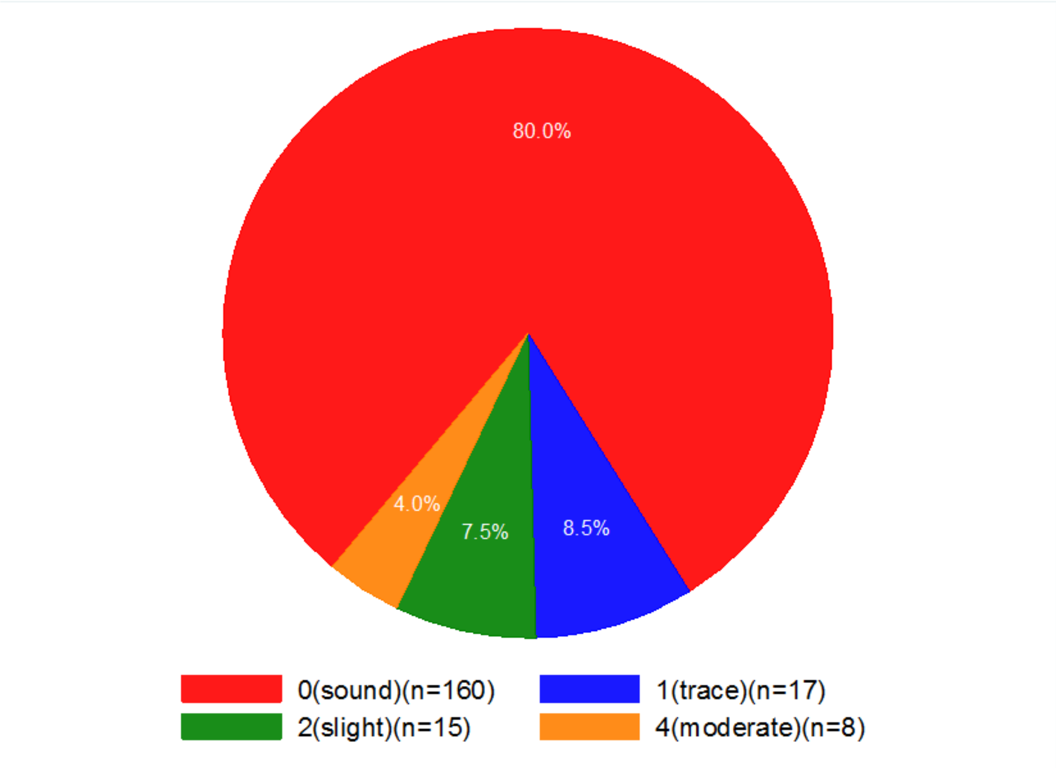

Figure 7: Distribution of timber weight loss categorized by visual during field trial test

CHAPTER FIVE

DISCUSSIONS

There was no difference in termite attack on timbers treated with different levels of concentration of either Fipronyl or *Termidor*, the standard product. This study found out that different levels of concentrations of 2, 3 and 6 ml of Fipronyl or *Termidor* (10 ml) have equal impact on termites since there was no significant difference in weight loss in the treated timbers, while the untreated timbers had a weight loss of varying values, of 0.2 to 0.5 gm under the laboratory test. Similarly, the results from the grave yard experiment supported the fact that Fipronyl and *Termidor* were more effective in controlling termites at different rates, a recent field study carried out by the investigator in Kibwezi (2014-2015), the median weight loss for the treated timbers of sand was 0 grams while the control group varied from 0.1-0.4 grams. Termite's prevalence in Eucalyptus and Grevillia wood was noted to vary.

The Grevillia wood species had more termite attack compared with the Eucalyptus wood. These findings showed that all levels of concentrations for the termiticides were equally effective when applied on timber. These findings are concurrent with Rust and Su (2012) who discovered that termite bait products account for approximately one third of the market share according to a 2002 survey. It also agree with Hu and Hickman (2011) that have reported the success in suppressing termite populations well beyond the treated areas. Although the availability of *Termidor* termiticides still remains a challenge in many developing countries like in Kenya, Fipronyl as an alternative could still be used for termites control with fairly accurate results in areas where *Termidor* is not readily available or have environmental effects. Although the termites under the laboratory experiment were within a restricted environment of clear plastic test bottles in the incubator with timbers treated with either Fipronyl or *Termidor* showed same results where all the termites with the treated wood samples died. Only one termite exposed to untreated timber of *Eucalyptus grandis* and three termites exposed to untreated timber of *Grevillia robusta* survived for 28 days. Termite galleries were evident after 28 days on untreated blocks. The galleries increased with increase in blocks exposure time.

From the results of this study it is clear that there is sufficient support for significant difference in termite attack between untreated and treated timbers with termiticides basing on visual and weight loss rating of termite's attack, p-value (0) in both the laboratory and graveyard studies. The study found out that the difference was from untreated wood samples which lost their weights after exposure to termites. Therefore Fipronyl is highly effective against a variety of termites. It disagrees with Su (2005) who found that Fipronil did not meet the criteria for liquid termiticide baits.

Result from this study shows that Fipronyl treatment was effective just as *Termidor* treatment on timber which is consistent with Saran and Rust, (2007), Gautam and Henderson, (2011b) and Hu, (2011) studies which showed that too high Fipronyl concentration may kill termites faster than expected while at lower concentration may not supply a sufficient dose for contaminated termites to transfer a lethal dose to unexposed termites.

CHAPTER SIX

CONCLUSION AND RECOMMENDATION

6.1 Conclusions

Termite galleries were evident after 28 days on untreated blocks in laboratory test and also termite galleries were evident after 10 months on untreated timber in the grave yard trial test, which showed that they were attacked. Termites generally did not get in contact with treated block samples or treated timbers. Therefore it gives a reasonable conclusion that Fipronyl is an effective termicides at the rates of 2, 3 and 6 ml/l and *Termidor* as the experimental standard. Significant difference in termites attack between untreated and treated timbers with termiticides can be based on visual and weight loss where treated wood block samples was ranked as sound indicating that it was not attacked and untreated wood block samples were ranked slight, moderate, trace and severe to give clear indication of magnitude of attack.

6.2 Recommendations

Further exposure time of wood samples to termites is advisable to give a clear difference in termite attack on treated timber under different levels of concentrations. Fipronyl treatment is effective at different concentration. It is advisable for the user to use Fipronyl concentration at 4ml per litre according to recommendation by manufacturer. It is a medium concentration and therefore it is effective. This is because too high concentration may kill termites faster than expected while at lower concentration may not supply a sufficient dose for contaminated termites to transfer a lethal dose to unexposed termites. So it is good idea to apply an appropriate concentration of a termiticide to achieve a wide coverage.It was suggested that Treatment standards for soil treatment require a complete drench around the foundation of the structure and around pipes penetrating the slab to ensure that all potential areas of termite entry are prevented from attacking the building.

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