Effect of Imidacloprid Granules on Subterranean Termite Populations (Isoptera: Rhinotermitidae)

by

T. Chris Keefer[1,2], Robert T. Puckett[1] & Roger E. Gold[1]

ABSTRACT

Efficacy data were gathered on imidacloprid (Premise® Granules) when; 1) broadcast over an open field site, 2) when used as a "spot treatment" around infested structures for control of subterranean termite populations. Commercial in-ground monitors were installed in the open field site prior to treatments to verify subterranean termite activity. Grids measuring 8.53 m x 7.32 m were marked off, in-ground commercial termite monitors were installed, and grids were treated with Premise® Granules. Untreated southern yellow pine surface boards were then placed in grids to determine if Premise® Granules would suppress foraging and feeding on surface boards. Premise® Granules suppressed surface feeding of *R. flavipes* for 9 months post-treatment, although termites were active throughout the study in in-ground commercial termite monitors. For the "spot treatment portion of this study, ten structures with active subterranean termites were utilized (5 treatments and 5 untreated controls). No termite activity was detected on any of the treated structures for 8 weeks post-treatment. However, by 48 weeks 60% of the structures were re-infested. These structures were inspected through 12 months post-treatment.

Key Words: imidacloprid granules, spot treatment, *Reticulitermes flavipes*

INTRODUCTION

Termites are in the insect order Isoptera (Haverty 1976). There are seven common genera of subterranean termites found in North America including: *Amitermes, Anoplotermes, Coptotermes, Gnathamitermes, Heterotermes, Reticulitermes* and *Tenuirostritermes. Reticulitermes* is the most widespread, with species found throughout North America. The genus *Reticulitermes* includes

[1]Texas A&M University, Center for Urban and Structural Entomology, College Station, TX 77845
[2]tckeefer@tamu.edu

R. flavipes (Kollar), *R. tibialis* Banks, *R. virginicus* (Banks), *R. hageni* Banks, *R. hesperus* Banks, *R. okanagenensis, R. malletei,* and *R. arenicola* Goellner. *Reticulitermes flavipes*, is known as the Eastern subterranean termite and is the dominant subterranean termite species found throughout the United States (Austin *et al.* 2005). It is responsible for most damage to structures done by this genus of subterranean termites.

Currently there are four documented species of *Reticulitermes* found in Texas including *R. flavipes, R. tibialis, R. virginicus*, and *R. hageni* (Howell *et al.* 1987). *Reticulitermes flavipes* are found throughout the state and are the dominant species in Texas (Austin *et al.* 2004). Their peak swarming times in Texas are from late February to early April depending on longitude and elevation (Furman & Gold 2002). The alates have dark brown to black bodies and their wings are approximately 10 mm in length and are translucent. The soldiers are characterized by a large rectangular-shaped head with large mandibles. These mandibles have no internal teeth and curve inward at the proximal tip (Messenger 2002).

In recent years, urban sprawl has contributed greatly to the economic impact of termites in the United States (Su & Scheffrahn 1990, 1998). The National Pest Management Association estimates the cost to control termites annually in the United States to be $5 billion (NPMA 2005). When the cost of building repair is included, cost estimates can be as high as $11 billion annually in the United States, and as much as $22 billion globally (Su 2002). Termite control measures include, but are not limited to, liquid sub-soil treatments, above and in-ground baiting systems, stainless steel mesh, diatomaceous earth, insecticide- impregnated polymer barriers, sand, salt, and post-construction applications of chemical made directly to wood (Mampe 1991, Grace & Yamamoto 1993, Robertson & Su 1995).

The strategy of establishing a complete chemical barrier to protect a structure, and the methods for application of such barriers are as pertinent and effective today as they were 50 years ago (Gold *et al.* 1994, Gold *et al.* 1996). The application of termiticides to soil to create this barrier continues to be the preferred method of control for subterranean termites. Termiticides used in this strategy should be effective against all castes to provide an effective barrier (Gatti & Henderson 1996), but subtle differences in susceptibility to termiticides by termites have been detected even within conspecifics. Also, significant changes have occurred in what chemicals can be used as barriers against termites, and the challenge of controlling these destructive pests remains enormous (Raina *et al.* 2001).

Providing a dependable and effective termite control job is a complex duty. It requires knowledge in many areas including termite biology, different control tactics available, tools and equipment used, landscape and hydrology surrounding a structure, and building construction (Forschler & Jenkins 2000). In addition, one must be experienced in the identification of termites and common construction elements. Three other important factors to consider when planning a termite treatment are where food sources are found, suitable moisture levels occur, and which soil types are preferred for termite survival (Suiter *et al.* 2002). These specific factors are known as conducive conditions.

Several new chemical groups have been developed including; pyrethroids, phenylpyrazoles, chloronicotinoids and fiproles, to combat termites. A current list of registered active ingredients used in termiticides for soil treatments currently regulated by the United States Environmental Protection Agency include: bifenthrin, cypermethrin, permethrin, chlorfenapyr, acetamiprid, imidacloprid, and fipronil. Bifenthrin, cypermethrin, and permethrin all belong in the family of chemicals known as pyrethroids. Fipronil is the lone member of the fiproles (Ware & Whitacre 2004), chlorfenapyr is a phenylpyrazole (Valles & Koehler 1997) and acetamiprid and imidacloprid are chloronicotinyls (Abbink 1991, Gahlhoff & Koehler 2001).

The newer generations of chemicals have been developed since the demise of the chlorinated hydrocarbon insecticides, such as chlordane and lindane, which lasted up to 50 years. The use of chlorinated hydrocarbons as pesticides was phased out completely by the Environmental Protection Agency (EPA) in 1988, and the use of new chemical classes of termiticides began. These new classes of chemicals, which are not as persistent as the chlorinated hydrocarbons in the environment today, need to be explored more intensely.

Imidacloprid 1-[(6-chloro-3-pyridinyl)methyl]-N-nitro-2-imidazolidinimine (Fig 1.), is a systemic chloronicotinyl insecticide with a novel mode of action, that acts as an agonist of the nicotinyl receptor (Bai *et al.* 1991, Mullins 1993). Imidacloprid acts as both a contact and a stomach poison which attacks the insect's nervous system by attaching to acetylcholine binding sites, called nicotergenic receptors on the receiving nerve cells (Abbink 1991, Ramakrishnan *et al.* 2000). Once attachment occurs, and the ligand-gated Na^+ cation channel is opened, and the neuron continually fires with the result being death of the insect (Schroeder & Flattum 1984).

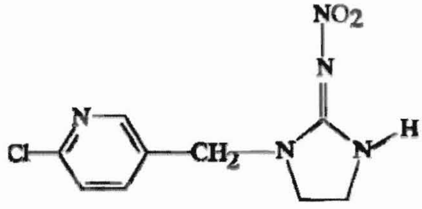

Fig. 1. The chemical structure of imidacloprid (adapted from Fernandez-Perez *et al.* 1998).

Imidacloprid ($C_9H_{10}Cl\ N_5O_2$) is sold under the trade name Premise® by Bayer Environmental Science (Research Triangle Park, NC). Imidacloprid is commonly used to control subterranean termites and is available in several formulations including: liquid (Premise® 0.5 SC, Premise® 2, Premise® Pro); wettable powder (Premise® 75WP); gel (Premise® Gel); foam (Premise® Foam), and a granule (Premise® Granules). All of these formulations are regulated as termiticides for the control of subterranean termites. Premise® is a non-repellent termiticide in the liquid and wettable powder formulations which, when applied as a soil barrier, allows the termites to contact the product.

Imidacloprid was synthesized in 1985 and was registered in France as an agricultural pesticide used on sucking insects attacking sugar beets (Sur & Stork 2003). Imidacloprid is a systemic neonicotinoid insecticide carried in the tissues of the plants and thus makes the plant toxic to insects (Jeppson 1953, Carretero *et al.* 2003). Additionally, imidacloprid been introduced, and is being applied, in the urban sector of pest management. One of the benefits of this pesticide is that it may decrease the amount of chemical applied, which could lower exposure and cost in populated urban environments (Jeppson 1953).

In light of the need for more in depth research on imidacloprid termiticide as a control option for subterranean termites in Texas, the study described herein was performed. The primary goal of this research was to determine the effectiveness of a granular formulation of imidacloprid (Premise® Granules 0.50 % AI) for control of *R. flavipes* in structures and in open settings.

The use of granular formulations of imidacloprid for the control of subterranean termites is a new concept that offers a different formulation for such control. The granular product used in this study was "ready- to- use", required no mixing, and was transported by the pest control operators with ease. This particular product is labeled as a "kills only" product for several genera of termites including *Reticulitermes, Coptotermes, Heterotermes*, and *Zootermopsis.* A "spot treatment" technique was used to determine the effectiveness of Premise® Granules as a means for treating subterranean termite infestations in structures. A "spot treatment" as defined by the Texas Structural Pest Control Service in the Texas Administrative Code in Rule 7.174 is any treatment of a limited, defined area less than 10 linear feet (3.05 m) that is intended to protect a specific location or "spot" in which there are often times adjacent areas that are susceptible to termite infestation which are not treated (Texas Administrative Code 2009). It is stated on the label provided by the manufacturer that the product would kill termites, but there was no claim for protection of a treated structure. Imidacloprid was advertised as a non-repellent pesticide (Shelton & Grace 2003, Yeoh & Lee 2007), meaning that termites would reportedly not be able to detect the presence of the toxin, and that they would forage or tunnel into the product and "transfer" the active ingredient to nest mates via trophallaxis, grooming, and/or movement of "treated" soil which would result in the death of the colony (Tomalski & Vargo 2005, Parman & Vargo 2010).

MATERIAL AND METHODS

Grid treatments study of 0.5% imidacloprid granules

To determine the effectiveness of Premise® Granules (0.5% AI) for the control of subterranean termites, a series of urban field tests were conducted at a site located in Bryan, TX (GPS coordinates: 30° 37' 25. 27" N, 96° 22' 49.58" W). The field was dominated by grasses with, and surrounded by, predominately large Post Oak trees (*Quercus stellata*). This field was properly manicured and treated for *Solenopsis invicta* (Amdro®) prior to setup of the study. Amdro® was applied by laboratory personnel according to the manufacturer's label.

Twelve individual grids measuring 8.53 x 7.32 m (total of 62.44 m^2 each) were established at the study site. The corners of each grid were marked with survey flags. There was a minimum distance of 10 m between each grid. No trees or woody undergrowth were located in any of the grids. Six in-ground commercial termite monitors (Advance Termite Bait Station, BASF, St. Louis, MO) were evenly spaced in each grid to verify subterranean termite activity (Fig. 2). They were installed using an Ardisam Tecumseh TC II model 8900 gas powered auger (Cumberland, WI), with a 15.24 cm diameter Ardisam Earth Auger Bit model # EA6F. These in-ground commercial termite monitors were installed and each monitor was numbered in succession starting with 1 and ending with 72. The first inspection was 1 month after the installation, at which time seven grids were found to have active subterranean termite populations in them.

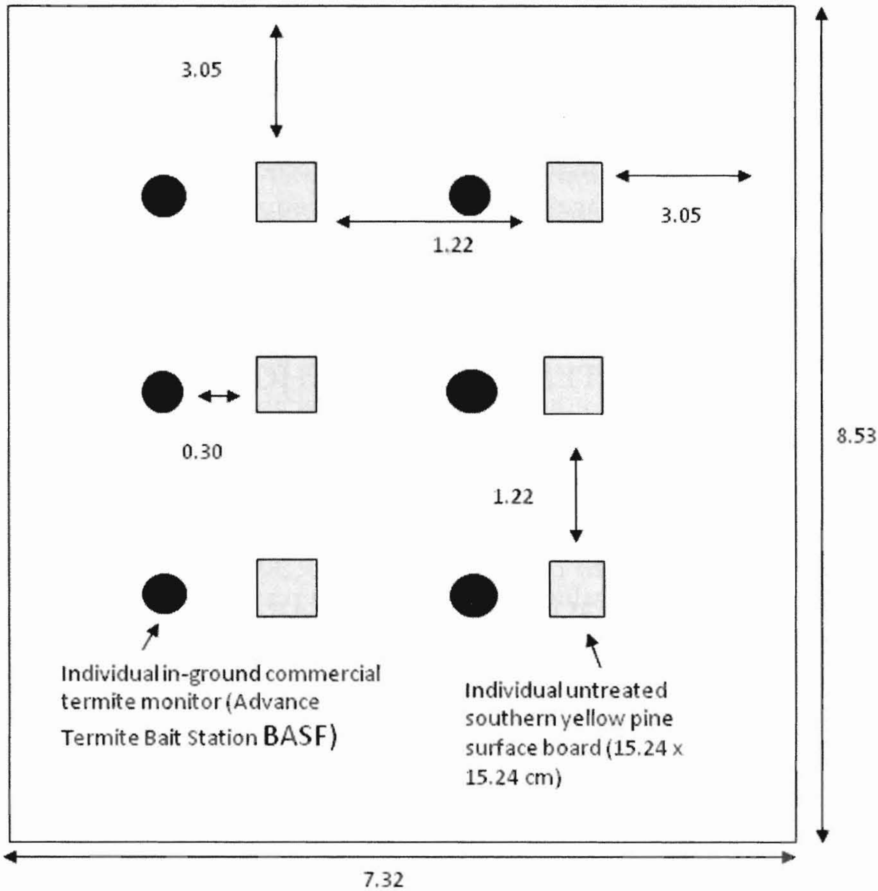

Fig. 2. Diagram of individual grid for Premise® Granule 0.5% AI study (all measurements are in meters).

Six grids were randomly selected and treated with the Premise® Granules (0.5% AI) at 8.86 g/m^2 as per the manufacturer's label directions. Six additional grids served as untreated controls. On the morning of the treatments, six plastic containers each received 552.81 g of Premise® Granules that were weighed out on an Ainsworth model XP-1500A scale (Chicago, IL). The Premise® Granules were dispersed evenly with a Scotts® Handy Green II (Cinnaminson, NJ) hand held rotary spreader (setting # 4). Each of the six treated grids received 552.81 g of Premise® Granule (0.5% AI). Each grid was treated by five passes at 6-7 seconds each, until all 552.81 g was evenly applied. After treatment, both treated and untreated grids had six untreated southern yellow pine boards (15 x 15 x 1.5 cm) placed on top of the soil and anchored with a brick. The southern yellow pine boards (surface boards) were placed a minimum of 3.05 m from the edges of the grid, a minimum of 1.22 m apart within the grid, and were 0.30 m to the right of the existing in-ground commercial termite monitors (Fig. 2). All surface boards were numbered in succession starting with 1 and ending with 72.

Inspections of both the in-ground monitors and surface boards were made at 1, 3, 6, 9, and 12 months post-treatment. Data were based on visual inspections that included the identification number of the surface board/in-ground monitor, and whether or not it had been attacked by termites (termite damage, but no termites present at time of inspection). In addition, if the surface board/in-ground monitor was found to be infested with termites (termites present at time of inspection), the location of each surface board/in-ground monitor (surface board #) and a rating of damage to each surface board/in-ground monitor was recorded using methods recommended by the American Society for Testing Materials (ASTM 1987, Link & De Groot 1989). If termites were present or damage was noted, a photo was taken of the surface board/in-ground monitor at each inspection. ASTM ratings on surface boards/in-ground monitors were cumulative throughout the duration of the study. The ASTM ratings for damage can be found in Table 1. If a surface board/in-ground-monitor insert was destroyed (rating of 0), it was replaced.

Table 1. ASTM ratings used in the study.

No. Rating	Description
10.0	No Damage
9.0	Trace Damage
7.0	Moderate Damage
4.0	Heavy Damage
0.0	Destroyed

A one-way analysis of variance (ANOVA) (SPSS 16.0 for windows Chicago, IL) was used to compare damage differences on in-ground monitors and surface boards between treated, untreated grids. Tukey's Honest Significant Difference test was used to separate means.

Structural treatments study of 0.5% imidacloprid granules

In this study initial pre-treatment inspections were done on subterranean termite-infested structures 1 week prior to actual treatment. During pre-treatment inspections, live termites were collected, preserved in 100% ethanol as voucher specimens, and every termite mud tube was marked and the distance was measured to a permanent benchmark (e.g., distance from corner of structure). Ten structures (5 treatments and 5 untreated controls) with active subterranean termites on the exterior of the structure were located in a single apartment complex in Houston, TX (GPS coordinates: 29° 36' 36.07" N, 95° 13' 32.48" W). All structures were built on monolithic concrete slabs, were of the same construction type, and were of the same age. All "spot treatments" were conducted according to the label provided by Bayer Environmental Science (Research Triangle Park, NC), which called for 283.33 g of granules per meter.

On the day of treatment five separate containers of 340.19 g of Premise® Granule formulation (0.5% AI) were weighed out on an Ainsworth model XP-1500A scale to ensure proper volume and weight of the treatments. At the point of infestation, a trench measuring approximately 15.24 cm wide and 15.24 cm deep was dug 1.22 m through, and on either side of, each active subterranean termite mud tube, which was in the center of the trench. All termite mud tubes on the treated or untreated controls were "knocked down" and scraped clean prior to treatment, and at each post-treatment inspection. This was done so that, at post-treatment inspections, if a termite mud tube was re-built in the "spot treatment" area, it verified that there were still active subterranean termites present. Each trench in the treatment set received 340.19 g of Premise® Granule. After treatment, the trench was back filled, and a thin layer (1.0 g/1.22m) of granules was applied to the top of the soil. There was a minimum distance of 15.24 m between all treatments and untreated controls (Kard 1998, Peterson *et al.* 2007). Post-treatment inspections were made at 1 and 2 weeks, and then monthly for 12 months post-treatment. Data included whether or not there were active subterranean termites in the "spot treatment" zone at the time of each post-treatment inspection was recorded.

A one-way analysis of variance (ANOVA) (SPSS 16.0 for windows Chicago, IL) was used to compare the number of active termite tube differences between treated and untreated structures in this study. Tukey's Honest Significant Difference test was used to separate means.

RESULTS

Grid treatments study of 0.5% imidacloprid granules

Pre-trial monitoring verified subterranean termite activity in 7 (58%) of the 12 grids. The following grids had confirmed activity prior to treatment with imidacloprid granules, 1, 2, 3, 4, 5, 10 and 11. Within those grids were a total of 8 monitors that had subterranean termite activity.

The following grids were selected at random and received Premise® Granules as treatments: 1, 3, 5, 7, 9, and 12. The remaining grids: (2, 4, 6, 8, 10, and 11) were sampled as untreated controls. At the 1, 3, 6, 9, and 12 month inspections, treatment Grid 3 had active termites in at least one in-ground commercial monitor, with damage ranging from trace feeding (9.0) to heavy (4.0). In this grid, no surface boards had any activity or damage through 12 months. At the 12 month inspection, treatment Grid 5 had activity and damage on one monitor and two surface boards with damage ratings of moderate (7.0). Treatment Grid 7 had active termites and moderate damage in one surface board at the 12 month inspection (Fig. 3). The mean number of monitors attacked at each inspection in the treatment grids was 2.8 with a mean ASTM damage rating of 5.7. The mean ASTM rating for the surface boards in the treatment grids was 9.4, with the only damage occurring between the 9 and 12 month inspections. Subterranean termites were active in the untreated control grids throughout the study; untreated control Grids 4 and 8 had subterranean termite activity at all inspection dates (Fig. 3). The mean ASTM damage ratings for surface boards and in-ground commercial termite monitors, in the untreated control grids at the 12 month post-treatment inspection, were 9.2 and 8.8, respectively (Fig. 4).

Total rainfall for the 12 month period was 132.38 cm, with a mean for each month of 11.02 cm. This is in contrast to the mean annual rainfall in

Bryan, TX of 99.06 cm. Rainfall data were taken from Easterwood Airport, which was approximately 3.42 km south of the study site.

Structural treatments study of 0.5% imidacloprid granules

Termite mud tubes had been re-built in all five untreated control structures by the end of the first week post-treatment. These mud tubes continued to be active with subterranean termites through the 12 month post-treatment period. There was no activity in any of the treated structures at 1 or 2 weeks post-application. At the 4 week inspection, Treatment Structure 2 had a new mud tube rebuilt 30.48 cm outside of the treatment zone (not noted as a failure). Treatment Structure 5 had a new mud tube rebuilt inside of the treatment zone, but it was inactive at the time of inspection. At the 8 week inspection, Treatment Structure 3 had an active mud tube rebuilt in the treatment zone that remained active until the end of the study. At the 8 week inspection Treatment Structure 5, again had a new mud tube rebuilt in the treatment

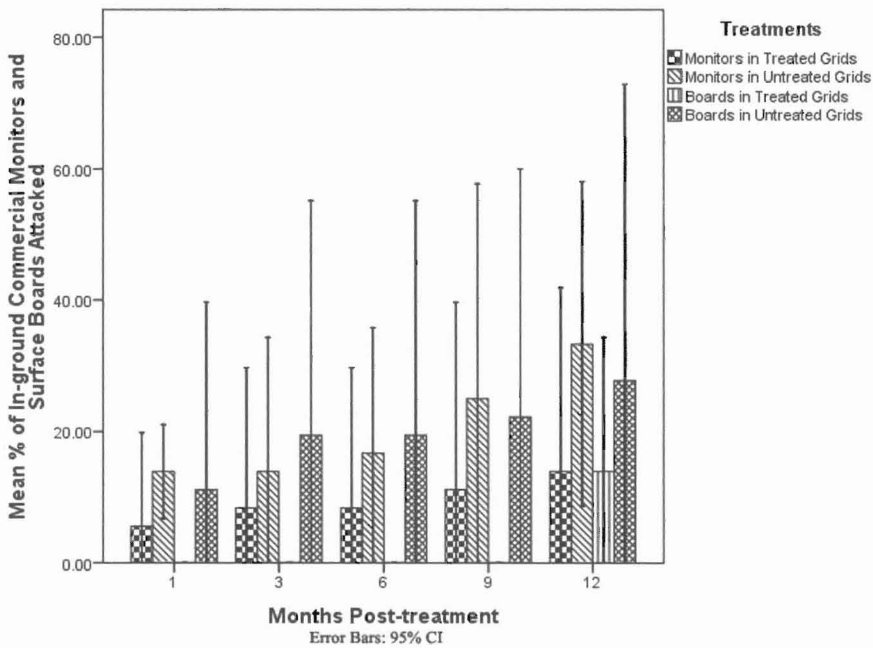

Fig. 3. Mean % of in-ground commercial monitors and surface boards attacked by *Reticulitermes flavipes* subterranean termites in grids treated with Premise Granules 0.5% AI and in untreated grids through 12 months post-treatment.

zone, but it was inactive. At the 12 week inspection, Treatment Structure 5 had an active mud tube re-built in the treatment zone, and it remained active for the duration of the study. At the 28 week inspection, Treatment Structure 1 had an active mud tube, and it remained active throughout the study. By the 28 week inspection, three (60%) of the five treated structures had subterranean termite activity within the treated zone (Fig. 5). There were no significant differences (p=0.05) in the termite activity between the treatment and the untreated controls starting at week 12 (Fig. 5) through 52 weeks post-treatment.

DISCUSSION

There was evidence of effectiveness of Premise® Granules for termite control in the grid tests, but there were no indications that the treatments "killed" the termite colony. This was evident because in-ground commercial termite monitors in the treated grids continued to be attacked by termites throughout the

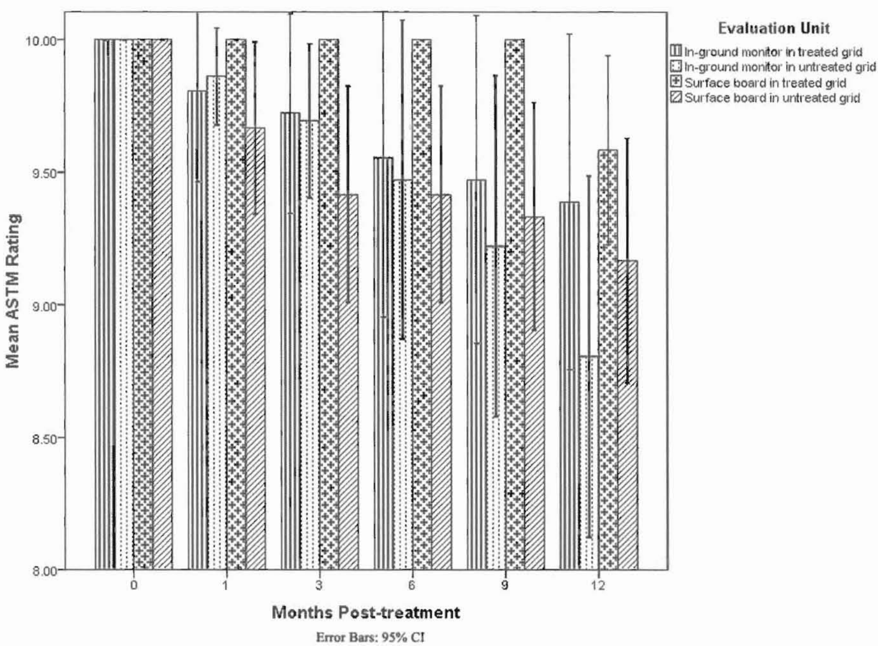

Fig. 4. Mean ASTM damage rating of in-ground monitors and surface boards attacked by *Reticulitermes flavipes* in test and control grids used in Premise Granule study

grid treatment study (Fig. 4); however, no damage was noted on the surface boards in the treated grids through the 9 month inspection. This is in contrast to results in a similar study (Hu *et al.* 2007) with Premise® Granules that had damage in surface boards as early as 7 months post-treatment. In the current study, the treatments suppressed termite foraging just below the soil surface which had a deleterious effect on termite feeding and, which was sufficient to protect the surface boards for up to 9 months post-treatment. The rate of 8.86 g/m^2 of Premise® Granules appeared to have repelled the subterranean termite foragers. A lower rate may need to be studied to determine if it will still protect the surface boards, but not repel the termites.

In the study of structures treated with granular imidacloprid, despite its reported non-repellency, there were several instances where subterranean termites simply moved outside the treatment zone, and re-built mud tubes on a structure. Premise® Granules are labeled as a "kills only" product. Based

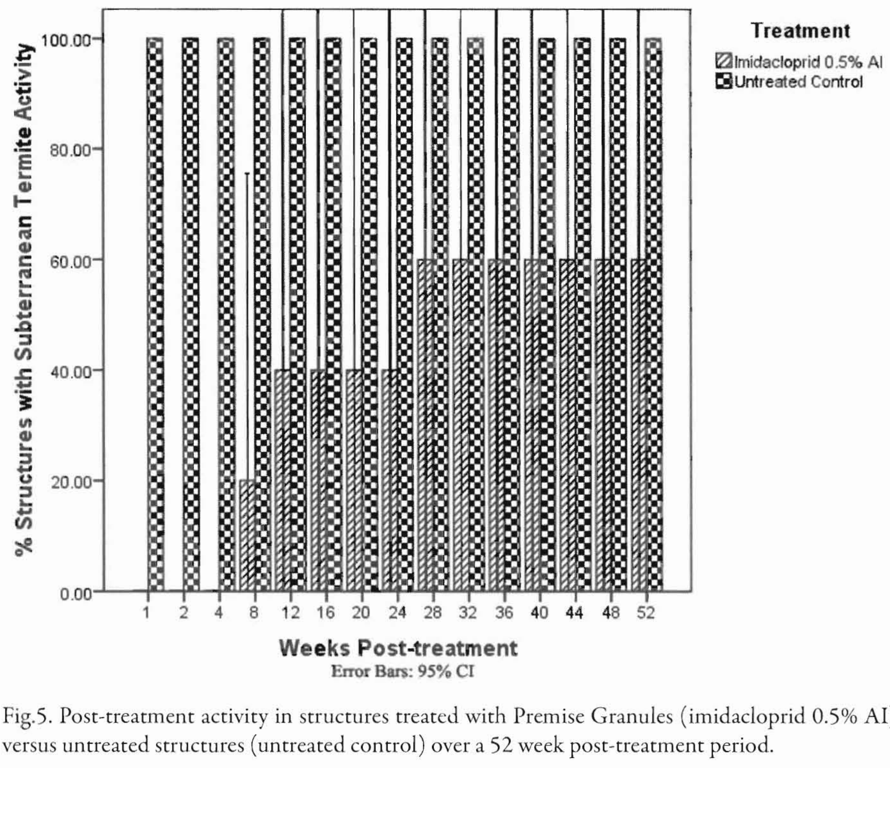

Fig.5. Post-treatment activity in structures treated with Premise Granules (imidacloprid 0.5% AI) versus untreated structures (untreated control) over a 52 week post-treatment period.

on the results from this study, Premise® Granules appeared to offer a relatively short term solution to the problem of subterranean termites infesting structures. Premise® Granules were effective as a post-construction treatment for remedial control of subterranean termites, but only for a period of 8 weeks. The concept of short term control of subterranean termites is new to the pest control industry, which, in the past, relied on liquid treatments that do offer long term control of termites and protected structures. It was shown from the current research that Premise® Granules did not "kill" the termite colonies, as evidenced by active termites in both the grid and structure experiments. This product does, however, offer some advantages to the industry including; 1) it is a ready-to-use product, and 2) it does offer some short term control. This can be an advantage, if arrangements cannot be made to offer a more conventional type of subterranean termite treatment due to extenuating circumstances on the part of the client. In this regard, according to regulations in Texas, a key element to the decision-making process by the client may be that a termite treatment may only be done if one of the following conditions exist: 1) evidence of live termites are present, 2) there is no evidence of a previous treatment, 3) the soil of a previous treatment has been disturbed, 4) it is proven that the concentration of a previous treatment is below the minimum inhibitory concentration, and/or 5) it has been more than five years since the last subterranean termite treatment (M. Kelley, Texas Department of Agriculture-Structural Pest Control Service, personal communication 2010).

In the structure treatments with granular imidacloprid, it is recommended that the zone of treatment should be expanded from 0.61 m either side of the active mud tube to at least 1.52 m either side of the mud tube. This would still be a "spot treatment", as defined by the Texas Department of Agriculture Structural Pest Control Service, and the time required to expand the treatment zone would be minimal to a pest management professional. Research needs to be performed to find the optimal treatment zone length for this product to provide better overall short term control of termites foraging on a structure.

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