EFFICACY OF TRIFLUMURON DUST FOR ERADICATION OF SUBTERRANEAN TERMITE (ISOPTERA: RHINOTERMITIDAE) COLONIES

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Abstract - A dust containing 80% triflumuron, a chitin synthesis inhibitor, was tested for its efficacy in eradicating colonies of subterranean termites (*Coptotermes* spp.) in the Sydney-Newcastle area, Australia. Triflumuron is believed to act on a termite colony in the following way: first the queen stops laying fertile eggs and dies; secondly the early instar nymphs then the older instar nymphs die as they attempt to moult; thirdly the worker termites die leaving the soldiers which possibly starve in the absence of workers to feed them. Triflumuron dust was successful in eradicating six of seven termite colonies when 0.9-6.3 grams of dust were applied directly to tree nests of *Coptotermes* spp. Eradication took from 6 weeks to 12 months. Further studies investigated whether termites dusted in their workings, remote from the nest, would carry the triflumuron back to the nest and eradicate the colony. Aggregation devices (bait buckets) consisting of weathered timbers in a perforated container were placed on the ground, close to a known termite tree nest. Termites entered these bait buckets and were dusted. The nearby tree nest was monitored, using a temperature probe, to gauge colony health. Eradication of colonies took from three to 12 months. In three out of five nests more than one dust application was needed to achieve eradication, with one colony not.
Key words - *Coptotermes*, chitin synthesis inhibitor, dusting

INTRODUCTION

Termites species of the genus *Coptotermes* Wasmann cause considerable damage to houses and other structures in Australia (Gay and Calaby, 1970). *C. acinaciformis* (Froggatt) and *C. frenchi* Hill are characterised by their tendency to form nests in trees and stumps in southern Australia. When the nest can be located, it is possible to treat the nest and achieve eradication.

Control of active termite infestations currently relies on the application of chemical soil barriers to prevent termite entry. Arsenic trioxide dust is the principal chemical used in Australia for termite colony eradication. A direct injection of a few grams of arsenic dust into a nest normally achieves eradication within a week. Active termite workings can be dusted with the aim that treated termites carry the arsenic back to the nest where it passes around through mutual grooming and trophallaxis. Arsenic has a delayed reaction which allows it be passed around the colony before it acts as a stomach poison. Arsenic trioxide is a very toxic compound with a LD_{50} of 34-64 mg/kg, and it remains toxic for long periods (Hadlington and Gerozisis, 1995). Termite activity was usually treated with arsenic prior to an organochlorine soil treatment being applied two weeks later. When the house was inspected prior to soil treatment, the lack of activity was assumed to be due to the eradication of the colony rather than localised repellency. After the soil barrier was applied, termites were unlikely to attack the house for many years.

Triflumuron is a chitin synthesis inhibitor (CSI) from the benzoyl phenylurea chemical group which acts to disrupt the formation of new exoskeleton in developing insects. Following exposure to triflumuron, an insect nymph generally displays no symptoms until it attempts to moult. Death occurs because the new exoskeleton is incomplete. Triflumuron also interferes with egg eclosion following uptake of the compound by adult insects (Hamman and Sirrenberg, 1980). As triflumuron is slow acting, it is suitable as a termite eradicant which can be passed through the colony without any perceptible toxic effects over several weeks. Doppelreiter and Korioth (1981) examined the efficacy of diflubenzuron baits in the laboratory and first reported the activity of chitin synthesis inhibitors against termites. Su

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(1994) examined the use of hexaflumuron baits. Lenz *et al.* (1996b) examined the effect of hexaflumuron in termite colonies in Australia showing.

The termiticidal activity of triflumuron was first reported by Cymorek and Pospischil (1984) with the active ingredient incorporated into a bait. Lenz *et al.* (1996a, b) in both laboratory and field trials confirmed the similar activity and mode of action of triflumuron to hexaflumuron. Much of the work done with CSIs and termites has involved the active ingredient being incorporated into a bait matrix but to date, no work with a CSI formulated as a dust appears to have been carried out. A dust offers the advantage of being able to be applied directly to termite activity without the need to first aggregate termites into bait stations. However, the main advantage of the 80% triflumuron dust over arsenic is its safety profile. Triflumuron technical material has oral and dermal LD_{50} (rat) ratings of > 5000 mg/kg and, due to its mode of action, is relatively specific to insects.

This work examines the impact, and associated symptoms, of applications of triflumuron dust to termite colonies following direct application of small doses into the colony or by applying the dust to foraging workers in aggregation devices.

MATERIALS AND METHODS

This work was conducted in the Sydney-Newcastle area, Australia. Colonies were identified according to Hadlington and Gerozisis (1995). A tree or stump with a suspected *Coptotermes* termite colony was drilled with a 12 mm diameter 400 mm auger bit and the centre of the nest located using a temperature probe (Amalgamated Instruments Company Australia, hand held digital thermocouple meter model HH4TC, 1 m long type K probe). Temperatures over 28 ºC are considered to indicate the presence of termite nests (Hadlington and Gerozisis, 1995). Triflumuron dust (80% active ingredient) was supplied by Bayer Australia Limited.

Direct dusting

Where possible the dust was applied into at least three holes using a hand puffer. The puffer was weighed before and after dusting to calculate the mass of dust used. The target dose used was between 2 and 5 grams per nest. The holes were then plugged using short lengths of dowel. Direct dusting was used at seven locations (Kangy Angy I, Kangy Angy II, Mona Vale, Neutral Bay, Tingira Heights, Turramurra and Waterfall.)

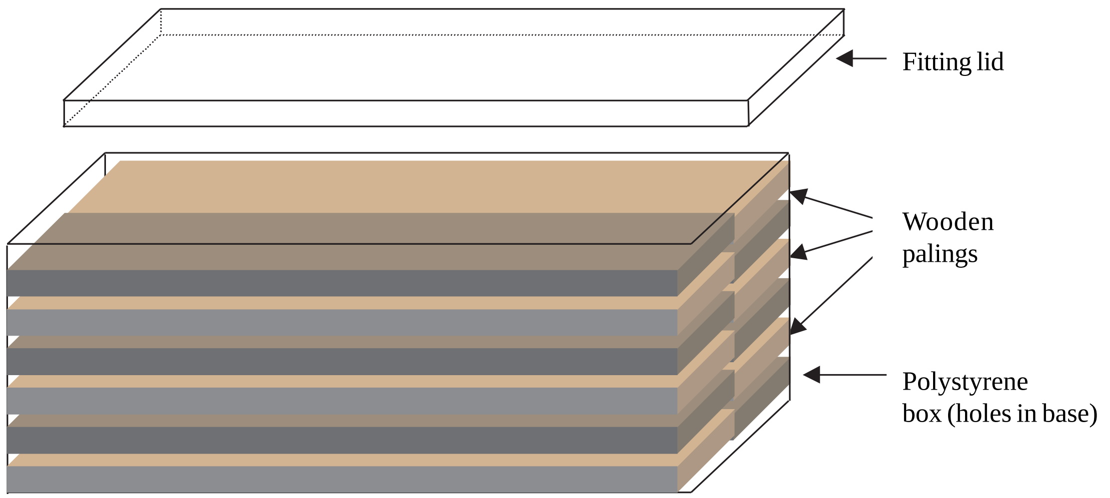

Figure 1. Diagram of the bait box aggregation device.

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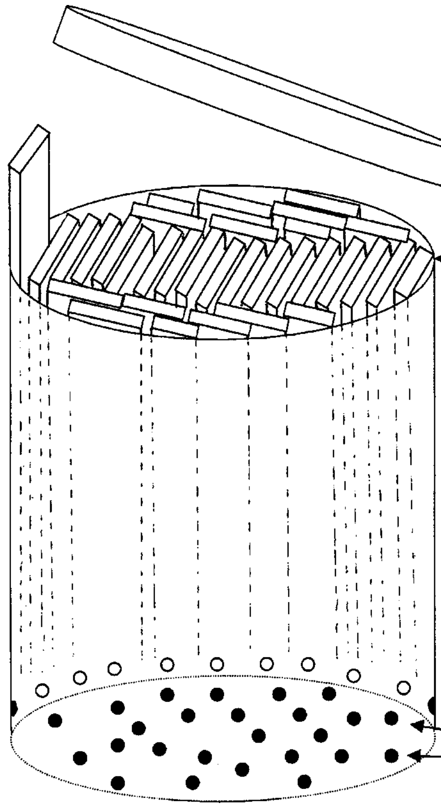

Figure 2. Diagram of the bait bucket aggregation device.

Remote dusting

Once a nest was located an aggregation device was placed within 5 m of the nest. This device took a number of forms: a bait box, similar to that described by French *et al.* (1995) (Fig. 1). A polystyrene box (60 cm long × 30 cm wide × 40 cm high) with a fitting lid and holes in the bottom and around the base was filled with weathered fence palings or other susceptible timbers cut to length. The box was dug about 10 cm into the ground near the termite nest. About 2 L of water was poured onto the wood in the box to make it more susceptible to termites. The termites took a week to six months to infest the box.

Once a box was infested, the termites were treated with dust. The infested palings were lifted out, two at a time, and struck together to dislodge the termites into a large plastic basin. Excess mud was removed from the basin before the termites were poured into a measuring jug and the volume of termites recorded. The termites were then poured from the jug into a plastic bag. Dust was applied to the termites by adding a pre-measured 5g dose to the bag. The termites were gently rolled in the bag to coat them with dust. The treated termites were carefully poured back into the bottom of the bait box and allowed to return to their workings. The lid was placed on the box to protect the termites from the elements and predators. The remaining palings were returned to the box at the next visit, so that the bait box could be used to monitor the termite activity. Bait boxes were used at four locations (Kangy Angy III & IV, Lane Cove and Tingira.)

Another type of aggregation device, the bait bucket, was developed during these trials to minimise stress on the termites. A 20 L plastic bucket with lid was used. About 50 holes (10 mm diameter) were drilled in the bottom and around the circumference as shown in Figure 2. The bucket was filled with weathered fence palings cut to length. These were placed in the box vertically to create potential galleries for the termites. The bucket was dug 10 cm into the ground as close as practical to the termite nest. Water (2 L) was poured over the wood and the lid replaced. When the bucket was infested the lid was removed and holes were made in the termite mudding to expose the termite galleries. Dust was puffed

Direct dusting sites

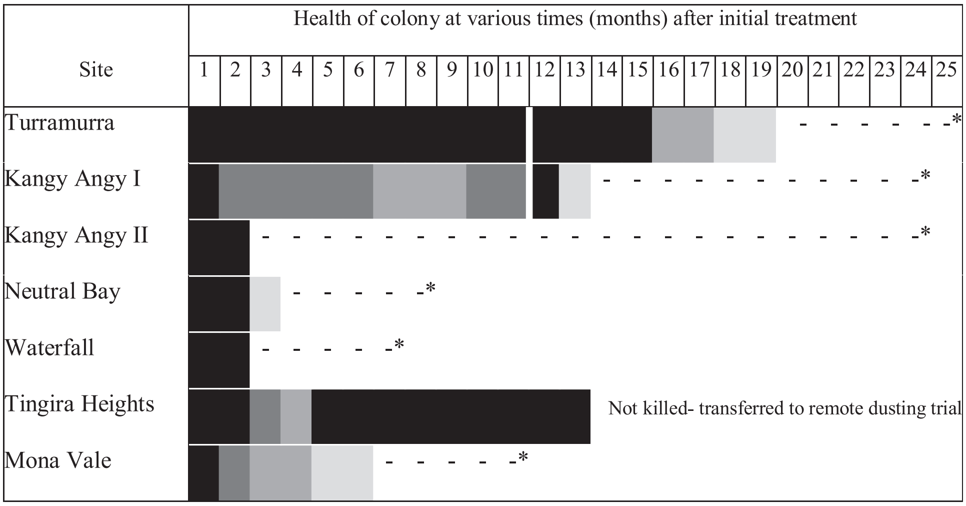

Table 1: colony condition rating of direct dusting sites over time.

Remote dusting sites

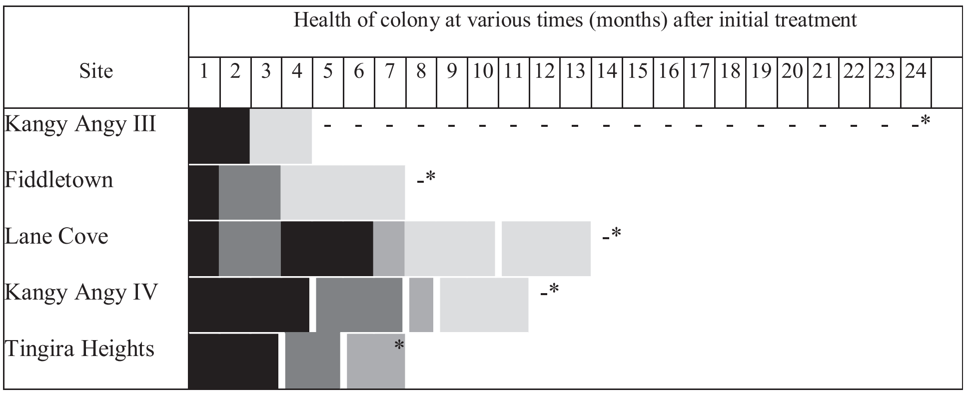

Table 2: colony condition rating of remote dusting sites over time.

Key to tables (colony condition rating)

(black)	1	high temperature (> 28 °C), termite activity obvious and widespread (extent established by inspection when nest first located)
(dark grey)	2	some drop in temperature, first signs of reduced termite activity away from nest
(grey)	3	lower temperature, clearly reduced termite activity in nest, some mottled termites, less resistance to drill/probe of nest or carton material
(light grey)	4	temperature near ambient, fungal smell, wet mud in nest, few termites – mostly mottled
- -	5	temperature at or below ambient, no termites coming from drill holes
(split black block)		Time of repeat treatment
*		Time of most recent assessment

into these galleries. Disturbance of the termites was minimised allowing the termites to continue feeding in the galleries, which helped increase their exposure to triflumuron. Bait buckets were used at Fiddletown and for the subsequent applications at Tingira.

Temperature monitoring

At the time of treatment the temperature of the nest was measured and the holes blocked with lengths of stick. At intervals after treatment the sticks were removed and any termite mudding was drilled-out and the temperature probe inserted. The ambient temperature was also recorded by placing the tip of the temperature probe on the soil surface at the base of the tree in the shade. The presence and relative number of termites and their appearance was also noted. As triflumuron is slow acting, assessments were usually carried out at monthly or greater intervals. When the peak temperature of the nest fell below the ambient temperature or no termites were found the nest was considered to be dead. Where possible the tree was felled to examine the nest area.

RESULTS

As the trial progressed, a pattern of colony decline became evident and is the basis of a 1-5 rating system used here to simplify the description of colony health. Results are summarised in Tables 1 and 2, according to the colony health rating.

Direct dusting sites

Four of seven colonies were eradicated following a single application, three of these within four months. Two colonies required additional applications as one part of the colony survived the initial treatment. The seventh colony declined and then recovered.

All colonies, with the exception of Turramurra, showed a similar response to the initial dusting. Within three months the nest temperature had declined by ten degrees or more. The termite activity in the vicinity of the nest was reduced. At Turramurra the initial application was unsatisfactory due to insufficient dust being applied to the only available drill hole. After 12 months the colony was still healthy so the nest was re-treated after drilling additional holes. After re-treatment, decline in this colony followed the pattern of the earlier successes. At two sites a remnant of the colony survived beyond four months. One colony (Mona Vale) died without further treatment after six months but the other (Kangy Angy I) had to be re-treated and was eradicated shortly afterwards. The colony at Tingira, after an initial decline in temperature, had recovered by the following summer. Instead of directly re-treating, the site was used for a remote dusting trial. At Neutral Bay, where the colony was eradicated within three months, the tree was cut down revealing only decaying nest material in the former nest area.

Remote dusting sites

Termite colonies were successfully eradicated in four of five sites following dust application to termites in aggregation devices. Two colonies were eradicated following a single treatment while the other two required additional treatments. The colony at Tingira Heights has not yet been eradicated.

Termites were initially treated at Kangy Angy III, Lane Cove, Tingira Heights and Kangy Angy IV using the bait box method. This proved successful at Kangy Angy III. At Lane Cove the temperature had declined more than ten degrees by the seventh month but some termites re-infested the box. These were observed for a further three months before re-treatment by direct application of dust to the galleries in the bait box, not the removal method as before. Thirteen months after the initial treatment this tree was felled to reveal only dead termites and fungi in the nest area. At Kangy Angy IV the termites were initially treated using the bait box method but as activity did not decline after four months a second bait box was treated. At the same time termite activity in timbers in a nearby fence and log was also treated. Following this treatment the colony declined and was eradicated after a further three months. In the last weeks before eradication the termites showed symptoms of mottling.

At Fiddletown the termites were dusted in a bait bucket. The nest temperature declined after two months and all activity ceased after seven months. The termites exhibited severe mottling and there was a predominance of soldiers in the weeks before eradication. At Tingira the colony showed only a slight decline three months after the treatment of the termites from the bait box. Termites were then treated in a bait bucket. There was a subsequent decline in activity in nearby trees but the activity in the nest persisted.

DISCUSSION

Direct nest dusting

The results demonstrate that a single dose of triflumuron dust applied directly to the nest can eliminate the colony in less than three months. Larger or more extensive nests may require subsequent applications. Application thoroughly into the nest (three clear drill holes > 28 ºC) gives the most effective result.

Remote nest dusting

Results confirm that colonies can be eliminated by dusting termites remote from the colony. The success seems to depend upon the number of termites treated relative to the size and complexity of the colony. More than one application may be required.

Survival of nest remnants

On several occasions survival of a remnant of the colony was seen after the majority of activity had been eradicated. This occurred at two of the directly dusted, and two of the remotely dusted nests. The remnants were located at the periphery of the nest, not at the previous centre. Subsequent dustings eradicated the remnants.

At Kangy Angy I the dust worked effectively at the bottom of the tree where the highest temperatures were recorded but at the higher point the activity survived indicating that insufficient dust was applied to this part. Very young workers were found at this hole indicating a secondary reproductive was present. A second application to this hole resulted in the rapid decline of all termite activity. A similar situation was seen at Mona Vale where a remnant of activity survived above the main part of the nest for seven months. Most activity was gone from the lower, hotter part of the nest in the first two months. All activity ceased at this site after seven months without further treatment. This could have been due to only soldiers and workers surviving without a secondary reproductive. This work has also found that a population of workers and soldiers may exist for some time outside the nest after the colony is effectively dead (no reproductives). According to Lenz *et al.* (1996b), colony recovery of *Coptotermes* without reproductives is impossible if only old workers and soldiers are left, so the lingering presence of a few of these termites around the colony is to be expected and is not necessarily a sign of treatment failure.

Aggregation devices

Of the two main methods used, the bait bucket method appeared to be more successful. Both the bait box and the bait bucket aggregated termites equally but the ease of treatment favoured the bait bucket. Dusting according to French *et al.* (1995) caused the termites a lot of disturbance and termites, when returned to the box, tended to abandon it. On the other hand, the bait bucket allowed the termites to be treated *in situ* with a minimum of disturbance. Termites generally continued to feed in the bucket, allowing the triflumuron to be taken up over a longer period of time. This facilitated continuous monitoring of colony activity and provided a site for further dust application.

The main difficulty with any aggregation system is getting the termites to occupy it. Dry weather appeared to increase the length of time required for the termites to infest either the box or bucket. Regular addition of water to the devices may reduce the time required for infestation but may encourage the growth of fungi. Treating extensive termite activity in their galleries in building structures is probably very similar to treatment in the bait bucket. In practice dusting existing activity, such as this, avoids the long periods required for termites to infest aggregation devices.

Symptoms of colony decline

One of the benefits of this work was to observe the symptoms of a termite colony that was in decline and to relate this to the situation within the colony. In many cases a PCO cannot find the nest and so has to rely on the appearance of the termites or the lack of activity to know that the product is working. The principal sign of the effect of triflumuron on a colony is the reduction of termite activity in the area of the infestation. Termites appeared to withdraw from the points furthest from the nest first, until finally the only detectable activity was either in the nest or just outside. Another sign of colony decline is the absence of smaller workers amongst the foragers. As the greatest impact of triflumuron is on the early worker instars it is likely that they will die earlier than the fully grown workers. The changing ratio of workers to soldiers is also a sign of decline. According to Gay (1970) soldiers normally make up less than 15% of a colony's termites. At several sites it was observed that in the later stages of the colony decline, the numbers of workers were reduced relative to the soldiers and the ratio moved closer to 1:1. The soldiers appear to be least affected by triflumuron and tend to be the last surviving termites. As they are incapable of feeding themselves, they are unable to survive for long after the worker caste has disappeared. Mottled abdomens, especially in the worker caste, are a frequent symptom which may become apparent six months after treatment. This is believed to be a sign of a colony in decline.

Use in conjunction with soil treatments

The length of time triflumuron dust takes to eradicate a colony (3-12 months) may not be acceptable to many clients. In addition, there may be more than one colony attacking the building, and there is no guarantee against future colonies becoming established. Therefore it is recommended that triflumuron dust be used in combination with a soil treatment e.g. Premise (imidacloprid). Active termite galleries should be dusted two weeks before a soil treatment is applied and aggregation devices should be placed outside the treated perimeter. These devices can be used to monitor future termite activity and treat with triflumuron dust if necessary.

CONCLUSIONS

Triflumuron dust can eradicate *Coptotermes* colonies via direct dusting of nests or remotely, if sufficient termites are treated. Colony eradication can occur as quickly as six weeks but may require 12 months. Part of the colony may survive the initial treatment, either within the nest or outside. Additional dustings may be necessary to completely eliminate the colony. Failure to control is apparent within 3-6 months or conversely, colony eradication is likely if colony condition rating is 4 or greater at six months. The bait bucket method, where minimal stress to termites occurs during application and which may result in continued feeding, is preferred. This is probably equivalent to treating extensive termite activity in galleries. Use of triflumuron dust in conjunction with a soil treatment is compatible and recommended.

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