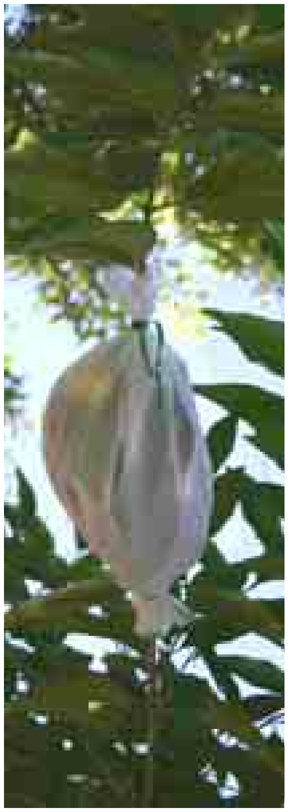
Insecticide control of *Aconophora compressa* on fiddlewood.



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Queensland Government
Department of Primary Industries and Fisheries

Executive Summary

Aconophora compressa (Hemiptera: Membracidae) (Aconophora), a sap sucking bug from Mexico, was released in Queensland and New South Wales as part of the biological control program against the weed *Lantana camara* (Verbenaceae*)*.

Aconophora spread from its intended host to infest fiddlewood, *Citharexylum spinosum* (Verbenaceae), a species native to the Caribbean and widely planted as an ornamental in south east Queensland in the 1970s and 80s.

Aconophora populations on fiddlewood were very high and caused leaf fall, branch death and loss of amenity due to heavy deposits of honeydew and sooty mould. Complaints were received from the public.

This study examined the efficacy and persistence of two systemic insecticides, dimethoate and imidacloprid, in controlling Aconophora on fiddlewood. The insecticides were tested in glasshouse and field situations.

Glasshouse trials tested imidacloprid and dimethoate as foliar sprays, and imidacloprid at two application rates as a soil drench. Insecticides were applied to trees approximately 2m tall in 12L pots.

Field trials tested imidacloprid at two application rates as a soil drench, and dimethoate at a single rate as a stem injection. The insecticides were tested on medium (6-12m height) and tall (12-18m in height) trees.

Efficacy and persistence of the insecticides were measured by recording the survival of late-instar Aconophora nymphs caged on treated branches, and by analysing foliage for insecticide residues.

Glasshouse trials showed that as foliar treatments both chemicals are effective, imidacloprid is the most persistent causing mortality up to 30 days post-treatment compared to 14 days post-treatment for dimethoate. Imidacloprid as a soil drench at both application rates still gave protection at 12 months post-treatment.

In field trials both imidacloprid (as soil injection) and dimethoate (as stem injection) were effective. Imidacloprid was the most persistent, at the highest dose it was still effective 6 to 9 months post-treatment compared to less than 6 months for dimethoate.

In garden applications, for example small shrubs and trees, the general public can apply Confidor® (active ingredient imidacloprid) as a foliar spray or soil drench at the recommended concentration.

Imidacloprid formulation for soil injection (probably needed annually), requires application of Merit® by a certified pesticide applicator, imposing a significant cost. Restricted access to root areas or proximity to water bodies can limit the use of this technique.

Ongoing research into stem-injectable formulations of imidacloprid should be monitored and considered further if and when available.

Background

Aconophora compressa (Hemiptera: Membracidae) (Aconophora) is a sap sucking bug introduced into Australia from Mexico as part of the biological control program against the weed *Lantana camara* (Verbenaceae*)*. Lantana is a major problem for grazing, forestry and conservation areas throughout the world. It is regarded as the principal exotic weed in southeast Queensland and currently infests more than 4 million hectares of land in Queensland and New South Wales (Batianoff and Butler 1992). Aconophora is the most recent of 29 agents introduced to control the weed in this country during the past 90 years (Julien and Griffiths 1998). Host testing of Aconophora was carried out by the Queensland Department of Natural Resources and Mines (NR&M), initially in Mexico and later at the Alan Fletcher Research Station (AFRS), Brisbane. Following testing, release approval was obtained and the first releases were made in Brisbane and Charters Towers in 1995.

Since its release Aconophora has established and spread throughout Brisbane and is also present at sites in north Queensland and New South Wales. The bug has been damaging to lantana in some areas, but has also been found to feed and develop on several other plant species in the Brisbane area, most notably on the related fiddlewood trees, *Citharexylum spinosum* (Verbenaceae). Aconophora has built up large populations on many fiddlewood trees resulting in defoliation and death of limbs. The production of copious amounts of honey dew has killed understorey plants, fouled buildings and structures, and restricted human access.

Aconophora is now permanently established on fiddlewood in the southern Queensland region and has rapidly become a serious problem. There are currently no proven control methods for the insect, particularly on larger trees. NR&M commissioned the authors to identify insecticides and application technologies to control the lantana bug. Control methods, chemicals and application techniques were required which are suitable for application to a wide range of tree sizes, and in a range of situations.

***Aconophora compressa*, Lantana bug – biology and life history**

Adult bugs are 0.6 cm long and pale brown in colour, with a distinctive projection on the front of the head. Nymphs are spiny, and the pre-adult stage has a T-shaped projection behind the head.

Females lay up to 65 eggs in a cluster on the host plant stem; the egg cluster is covered and protected with a thin layer of foam which hardens as it dries. Each female stays with her eggs and nymphs throughout their development, moving around the stem when disturbed but then returning to the nymphs. This behaviour is thought to protect the eggs and nymphs from parasites and predators. Eggs hatch in 2 - 3 weeks and nymphs go through five growth stages, becoming adults after 4-6 weeks (Palmer *et al.* 1996). The family group then disperses and the female may lay another egg batch. Adults live for up to 3 months. The insects often form aggregations, with several thousand clustered together on a stem.

Adults and nymphs suck sap from the stems of their host plant. The plants lose water and nutrients, leaves become pale and chlorotic, and leaves and stems may shrivel. The feeding behaviour causes puncture wounds, which stress the plant, and can be sites for entry of disease organisms. The insects excrete large volumes of honeydew, a viscous, sticky liquid with a high sugar content, which sticks to the host plant and rains on the area below. Sooty mould grows on the honeydew and spreads over the host and surrounding plants, interfering with photosynthesis and further stressing the plants.

***Citharexylum spinosum,* fiddlewood tree**

Fiddlewood, a native to the Caribbean (Mendez 2001), was widely planted as a garden and roadside tree in Brisbane and other Queensland centres during the 1970’s and 1980’s. The tree was particularly popular for shade and screening, with multiple stems often encouraged. It is a fast growing tree reaching 12-15 metres, and is semi-deciduous, with the crown changing colour before leaf fall. Trees produce white, pleasantly perfumed flowers, but do not produce seed in Australia. In recent years fiddlewood has lost popularity with home owners because of its invasive roots and deciduous nature. The species is now rarely planted, and is not recommended by the Brisbane City Council or Southeast Water (www.southeastwater.com.au). It is generally not available through nurseries, and is not included in Queensland Regional Floras as it has not naturalised. In some areas overseas where the species does produce seeds, including Hawaii and the Galapagos Islands, the species is considered an invasive weed.

Insecticides

In this study we undertook glasshouse and field trials to compare the efficacy of two insecticides in controlling Aconophora numbers, and to establish suitable application rates. The insecticides trialled were Rogor®, active ingredient (ai) 400g/L dimethoate, an organophosphate systemic insecticide and Confidor®,ai 200g/L imidacloprid, a chloronicotinyl systemic insecticide. Both insecticides have given effective control against tree pests in a range of situations. Imidacloprid has been effective in controlling a wide range of tree and shrub pests in the USA including Hemlock woolly adelgid (*Adelges tsugae* (Homoptera: Adelgidae)), elm scale (*Gossyparia spuria* (Homoptera: Eriococcidae), elm leaf aphid (*Tinoocallis ulmifolii* (Hemiptera: Aphidoidea) and Asian long horned beetle (*Anoplophora glabripennis*

(Coleoptera: Cerambycidae)) (Pais and Polster 2002, Sclar and Cranshaw 1996, Tattar et al. 1998, Webb et al. 2003, www.aphis.usda.gov). In Australia imidacloprid is registered for use against the elm leaf beetle *Pyrrhalta luteola* (Coleoptera: Chrysomelidae) in Victoria. Dimethoate is registered for use throughout Australia to control a range of insect pest species on ornamental, farm and forest trees.

Under glasshouse conditions both insecticides were trialled as foliar sprays, imidacloprid was also tested as a soil drench. During field trials separate methods of chemical application were tested as appropriate for each insecticide: soil injection of imidacloprid and stem injection of dimethoate. Application through soil or stem injection is most appropriate for larger trees, above approximately 2m in height, as it eliminates problems associated with foliar sprays, including spray drift and detrimental impact on foliage-inhabiting beneficial organisms.

Following soil injection the chemical is taken up by feeder roots of the infested tree and translocated through the vascular system to the stems and leaves, where it is ingested by herbivores. Overseas experience indicates that a single imidacloprid application annually or even every two years is effective in controlling many pests (Pais and Polster 2002, Sclar and Cranshaw 1996).

Methods

Trials were carried out in two stages. Initially glasshouse trials were undertaken to compare the efficacy, persistence and dose response of dimethoate and imidacloprid. These trials were also used to develop techniques for sampling Aconophora population levels in the field. The second stage involved testing of the insecticides and application methods in field situations.

Glasshouse trials

Glasshouse trials were conducted at the Department of Primary Industries and Fisheries Glasshouse Complex, Indooroopilly, Brisbane. These trials compared the efficacy of dimethoate and imidacloprid following foliar application, and determined the efficacy and persistence of imidacloprid as a soil drench applied at two different rates. Each trial included five trees arranged in two replicates within the glasshouse. Trials were conducted on trees at least 2m tall in 290mm diameter (12 litre capacity) pots.

Treatments

Foliar applications were made at the following rates as recommended by the chemical manufacturers on the product labels:

- Imidacloprid – 0.5ml Confidor/litre water, 0.5 L applied per tree (~0.05g ai/tree)
- Dimethoate – 1.0ml Rogor/litre water, 0.5 L applied per tree (~0.02g ai/tree)
- Control – water spray

The selected dose applied to the upper and lower foliar surfaces and sprayed to runoff.
Foliar sprays were applied on 10 September 2003

Soil drench applications were made at the following rates following consultation with Bayer staff; because of the height of the plants to be tested, the lower rate was set slightly higher than the 0.7g ai per pot recommended on the product label.

- Imidacloprid – 1g ai/pot
- Imidacloprid – 2g ai/pot
- Control – water drench

Prior to application of soil drench the pots were watered to saturation. The required dose of insecticide was diluted in 500ml water and added to the pot using a watering can.
Soil drenches were applied on 05 August 2003.

Assessment

Insecticide efficacy and persistence were assessed by confining late instar nymphs on the trees and recording survival. Gauze sleeves (15cm diameter and 25 cm length) were placed over the main tree stem and attached at one end. Ten field collected late instar nymphs were transferred into screw top vials (40ml capacity) and introduced into the sleeve, which was then sealed around the tree stem. The vial lid was unscrewed through the gauze, allowing the insects to escape into the closed sleeve. Sleeves were checked after two days, by which time the insects had left the vial and established on the tree, and daily thereafter until all nymphs were dead or had developed to adults. Assessments were made by opening the lower end of the sleeve and recording insect survival and development to adult.

Post-foliar application assays were conducted after 2 days, and then after 1, 2, 4, 8 and 20 weeks. Post-soil drench application assays were conducted after 2, 4, 12, 24, 36 and 52 weeks. After the 52 week assessment foliage samples were taken from all soil drenched trees and assayed for imidacloprid residues by Bayer Environmental at their Queensland University of Technology Laboratories, Gardens Point, Brisbane.

Field Trials

Based on the results from glasshouse trials both insecticides were further tested under field conditions, targeting a range of tree sizes and growing conditions. All trees were located on private property within the Brisbane area, with selections based on NR&M Call Centre records and Alan Fletcher Research Station staff recommendations. Selected trees had both single and multiple stems and were in reasonable health.

Imidacloprid,was applied through soil injection using a hand held soil probe. Chemical was premixed to the required quantities and diluted in 50L water before injection under pressure into the soil. Injections were made in a grid pattern at 50cm intervals extending to the drip line of the tree.

Dimethoate was applied by stem injection using a Chemjet® injector. The number of drill holes required was determined based on the number of stems present and their cumulative dbh to ensure even distribution through the canopy. We aimed for one drill hole for each 15-20 cm dbh, averaging 3-4 injection points per tree. The appropriate dose of chemical was then mixed and applied into the root flare region. An angled hole was drilled to depth of 5cm and material injected under pressure. Holes were not plugged after injection.

Application rates tested were based on those already recommended for similar treatments for the chemicals used. The appropriate dose of insecticide for application to individual trees was determined from the cumulative dbh of each multi-stemmed tree, calculated from the following formula:

$$\text{Cum dbh} = \sqrt{(d_1^2 + d_2^2 + \ldots\ldots d_n^2)}$$

Where $d_1, d_2 \ldots d_n$ are the diameters of stems taken at 1.3m above ground level
Dimethoate was mixed individually for each tree to ensure the correct dose.

Treatments for Trials 1 and 2 were applied between 10th and 16th December 2003. Landowners undertook to water the trees for a maximum of one hour per day for three days prior to treatment and seven days following treatment. This ensured good sap flow through the trees, enhancing chemical uptake. This was carried out at all except the two Rivetts sites, where watering was difficult for logistical reasons.

Trial 1 – Medium sized tress
The primary study compared five treatments comprising three different rates of imidacloprid applied through soil injection, a single rate of dimethoate applied through stem injection, and untreated control trees. Three trees were included in each treatment across three replicates.

Treatments used:

- Control - untreated
- Imidacloprid soil injection 6g ai/ tree (0.24 – 0.65g ai/cm dbh)
- Imidacloprid soil injection 12g ai/ tree (0.41 – 1.16g ai/cm dbh)
- Imidacloprid soil injection 24g ai/ tree (0.97 – 1.93g ai/cm dbh)
- Dimethoate stem injection (0.6g ai/cm dbh)

The study was conducted across three replicates, two of which were located on the Rivetts property:

- The Blowers site comprised a single avenue of 25 trees located along the northwest border of the property.
- The Rivetts sites comprised two avenues of between 40 and 60 trees located along the southern (Rivetts 1) and eastern (Rivetts 2) borders of the property.

In all three situations trees grew in close proximity with overlapping canopies and root systems, making it impossible to soil inject trees individually. Consequently we treated five trees in a row with a single dosage, and sampled only the central three trees. Stem injections were made on individual trees using the recommended application rate for dimethoate. All trees included in the trial ranged between 6 and 12 m in height with a cumulative dbh between 9.3cm and 36.9cm.

Trial 2: - Tall trees

The second study assessed the effectiveness of the insecticides on larger trees, ranging between 12 and 18 m in height with a cumulative dbh between 15.1cm and 46.2cm dbh. Treatments involved a single rate of imidacloprid applied through soil injection, and a single rate of dimethoate applied by stem injection at each site. Trees were well spaced, and each was treated separately at the recommended application rate.

Treatments used:

- Control
- Imidacloprid soil injection (0.6g ai/cm dbh)
- Dimethoate stem injection (0.6g ai/cm dbh)

Initially seven replicates across four sites were treated, with a single tree in each treatment, a total of 21 trees. However during the course of the study trees were removed from one site, leaving six replicates on three properties for assessment.

Assessment

Several methods were used to assess the efficacy and persistence of the different treatments.

Insect population census

The initial intention was to estimate the population of Aconophora on each of the treated and control trees at 1, 3, 6 and 9 and 12 months post-treatment by counting the number of individuals of each life stage (eggs, nymphs, adults) on a 40 cm length of shoot for 12 shoots in the outer canopy. Medium trees were to be sampled from the ground, and large trees climbed for accurate sampling.

The one month post-treatment census took place as planned.

After this census the insect population crashed due to unfavourable weather conditions. In January and February 2004 temperature extremes above 40º C were experienced in south east Queensland (Figure 1). In the western suburbs of Brisbane, (the location of our sites), where daytime temperatures are normally 3-4 degrees higher than in the east, all the lantana bugs died, with householders reporting a thick carpet of dead insects below their fiddlewoods. The populations in the eastern suburbs of Brisbane were reduced, but survived in low numbers until the next heat wave in February, when temperatures close to 42º C effectively eliminated Aconophora from the Brisbane area.

Inspections for lantana bugs were made during all subsequent collections of foliage for analysis, no insects were detected on trees at the experimental sites for the remainder of the study.

Containment of insects (Trial 1 only)

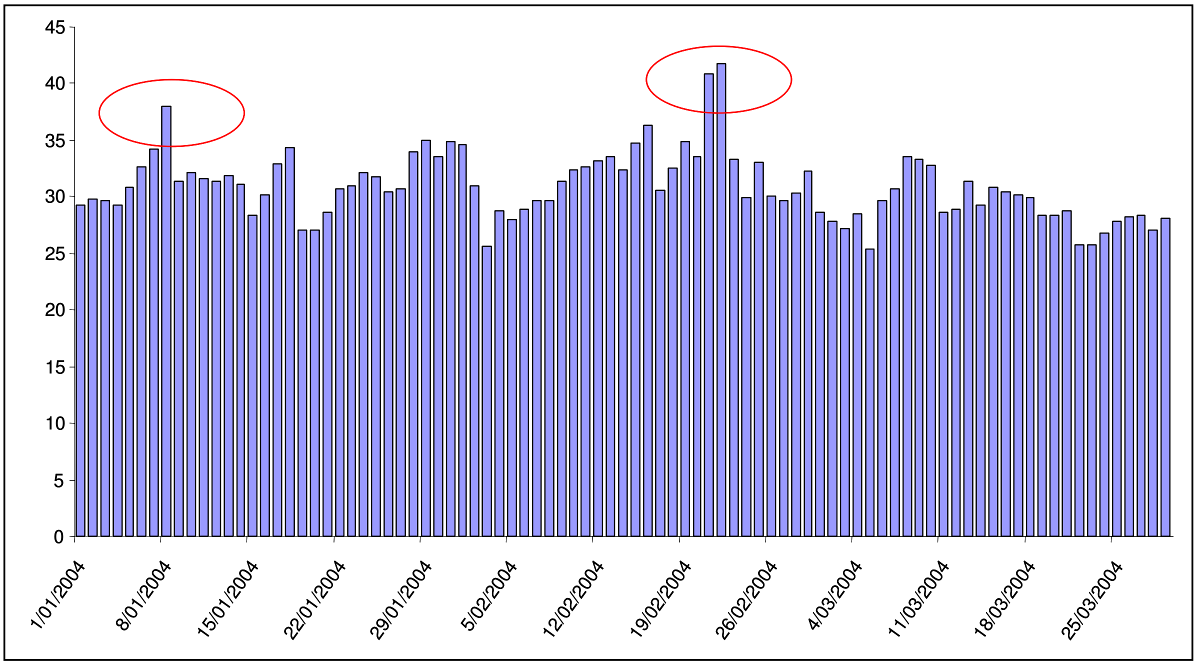
Direct counting of Aconophora *in situ* had to be abandoned. For the remaining assessments lantana bugs were collected from the hinterland at Springbrook and Mt Tamborine, where temperatures were lower than on the coastal plain and where they survived the summer.

Late instar nymphs were bagged onto young branches (diameter ~1cm) at four points around the crown of each tree, as described above for glasshouse trials. After two weeks the stem was cut from the tree, the sleeve was removed and the survival and development of the lantana bugs recorded.

- 6 months
- 9 months
- 12 months (high dose samples only)

For practical reasons this method was only used for the medium-sized trees.

Figure 1: Maximum daily temperatures (^{o}C) in the Brisbane area from January to March 2004, indicating periods when extreme temperatures resulted in the deaths of large numbers of Aconophora. (Data from Bureau of Meteorology).



Foliage residue analysis
Foliage was collected for analysis of imidacloprid chemical residue for all imidacloprid treatments in Trials 1 and 2. Foliage (400g per tree) was collected from the middle and upper crown, placed in plastic bags and immediately placed on dry ice, then stored in a freezer prior to analysis in January 2005. Analysis was carried out by Bayer Environmental Science at their Queensland University of Technology Laboratories, Gardens Point, Brisbane.
Samples were collected at:

- 3 months
- 6 months
- 9 months (high dose samples only) post-treatment.

Results

Glasshouse Trials

Foliar spray
Both imidacloprid and dimethoate applied as a foliar spray significantly decreased survival of Aconophora nymphs within two days of treatment (Figure 2). The effectiveness of dimethoate decreased rapidly and by 14 days post-treatment survival was not significantly different from that of untreated trees. Imidacloprid as a foliar spray remained effective for at least 30 days after treatment, but was no longer effective by 60 days post-treatment.

Soil drench
Imidacloprid soil drench at both concentrations showed significant activity against Aconophora nymphs throughout the trial, from as early as two weeks post-treatment until at least 12 months after application (Figure 3). At all times nymphal survival on treated trees was significantly lower than that on controls. After 12 months the percent survival four days after exposure was similar to that observed within the first month of treatment. Mortality was consistently higher on trees treated with the higher application rate of 2g ai per tree, than on those treated with 1g active ingredient, although this difference was not always significant.

The percent survival after four days exposure was lowest at the six month assessment for all treatments. This reflects the overall condition of the trees at this time, most of which had dropped their leaves, making them less suitable for Aconophora feeding.

Foliar residue analysis indicated the imidacloprid levels present in the foliage at 12 months post-treatment ranged from 0.43 to 1.35ppm (average 0.81ppm) at the lower application rate, and from 1.60 to 3.51ppm (average 2.62) for the higher rate (Figure 4). At this time survival of nymphs was similar for the two different treatment levels, suggesting no advantage at this stage to the use of higher doses.

Differences in the behaviour of the Aconophora nymphs were observed on the imidacloprid treated trees following soil drenching. *Aconophora compressa* are naturally gregarious and subsocial, with nymphs aggregating together under the protection of the adult female throughout their development (Palmer *et al.* 1996). When disturbed, such as occurred during collection and release of nymphs during this study, nymphs tend to aggregate together again on the plant stems. However treatment with imidacloprid disrupted this behaviour. Nymphs released onto treated trees failed to establish into groups but instead rested individually on the stem and gauze sleeve. This behaviour was apparent for several days prior to death.

Figure 2: Survival by day four of *Aconophora compressa* released on fiddlewood trees following foliar spray treatment.

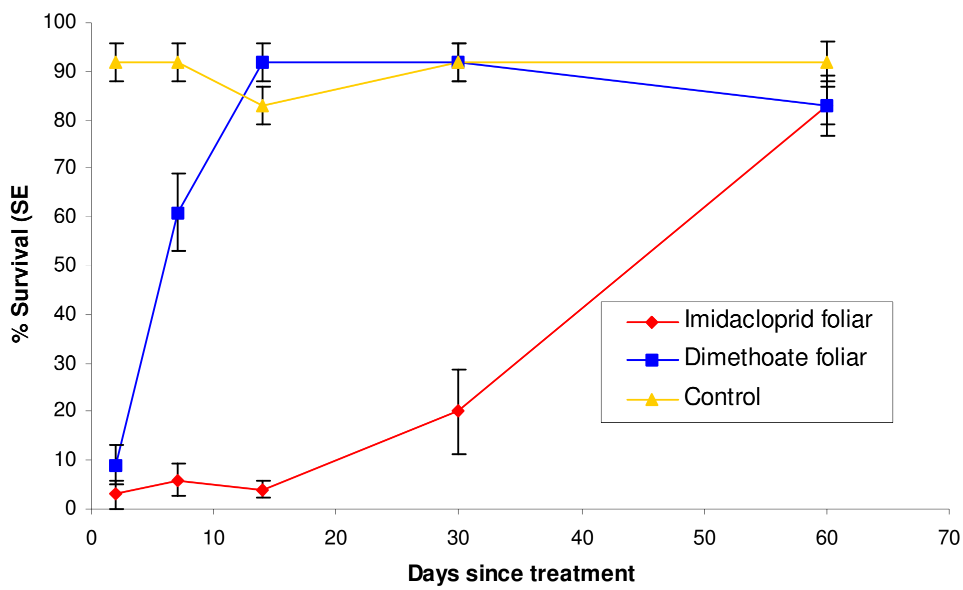


Figure 3: Survival by day four of *Aconophora compressa* released on fiddlewood trees following soil drench treatment .

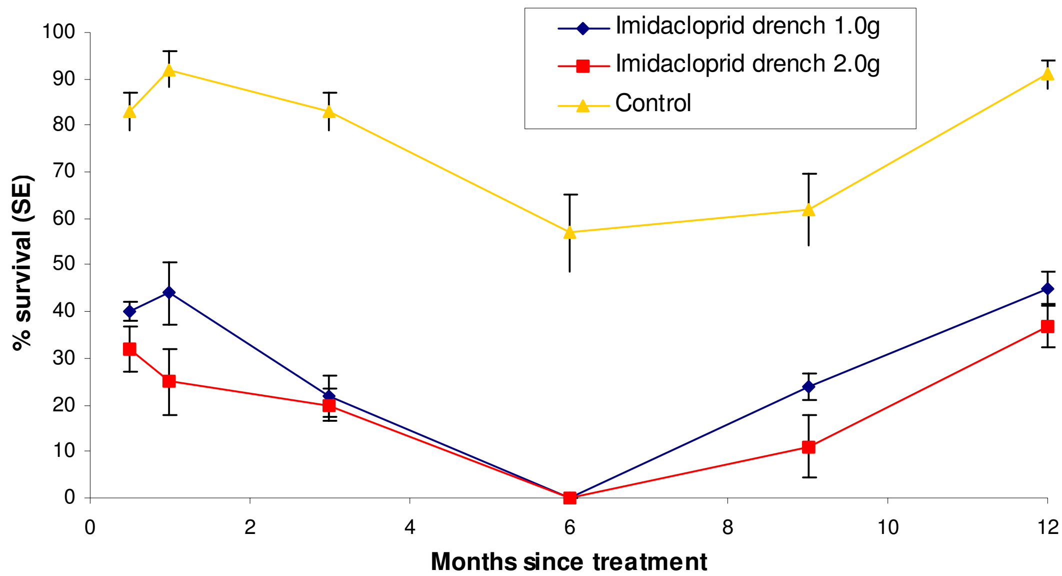
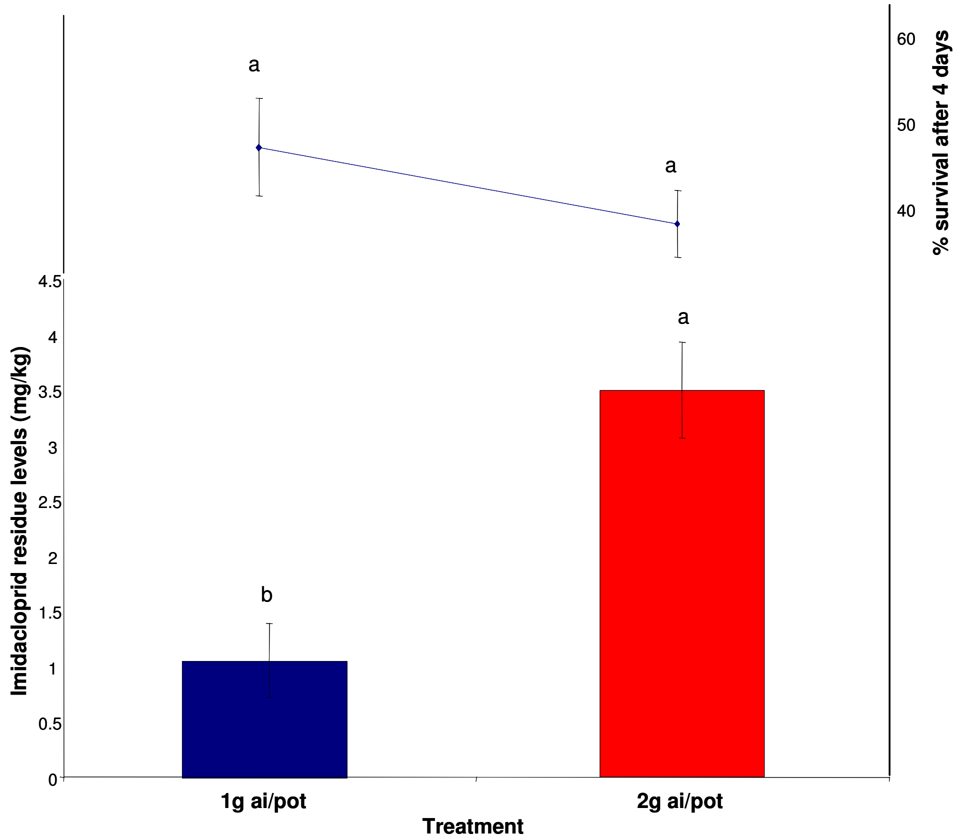


Figure 4: Survival of *Aconophora compressa* nymphs by day four and remaining levels of imidacloprid in fiddlewood foliage 12 months after treatment by soil drench. Within each dataset, means with the same letter are not significantly different (p<0.05).

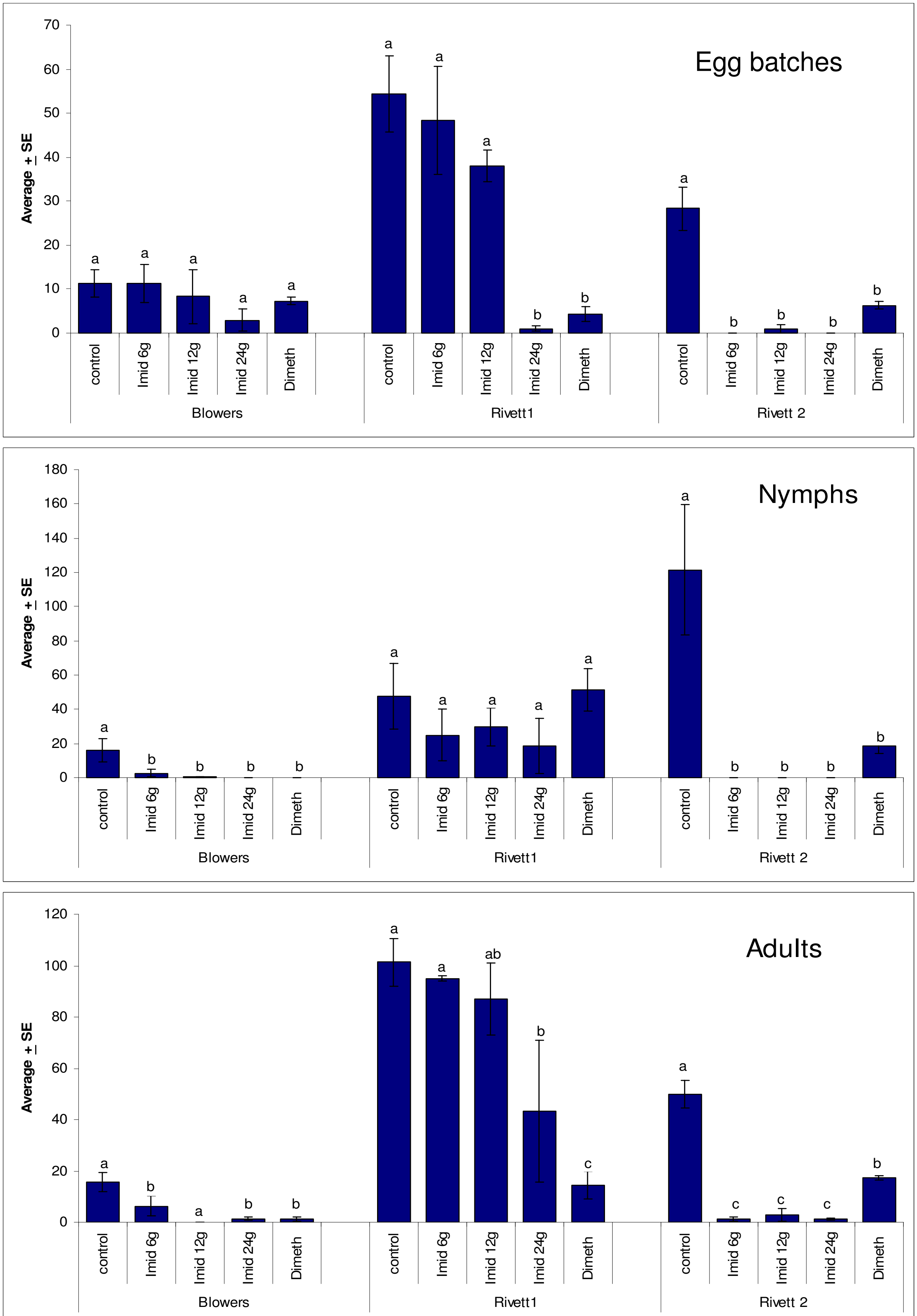


Field trials

Trial 1:

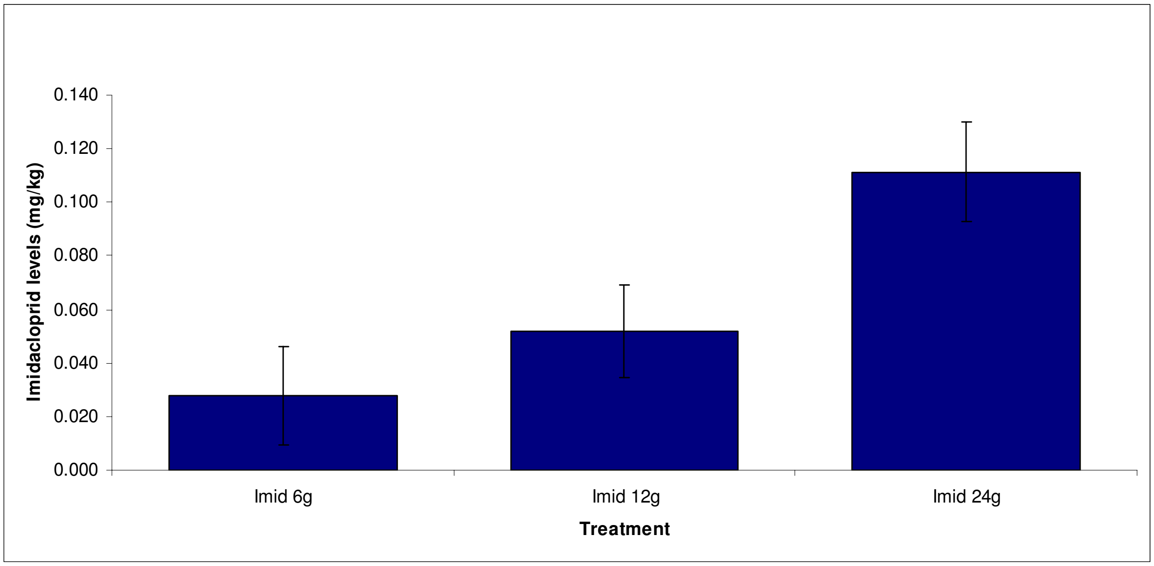
Four weeks post-treatment
Insect counts showed wide variability between populations across the three sites (F=5.572 P=0.0002), requiring that each site be considered separately (Figure 5). On most occasions untreated control trees had significantly more eggs, nymphs, adults and infested branches than trees stem-injected with dimethoate and those soil-injected with the highest dose (24g ai/tree) of imidacloprid. The only situations where this did not apply were for the number of eggs at the Blowers site (F=0.885, p=0.5072), and the number of nymphs at the Rivett1 site (F=0.901, p=0.4989) where the results followed the trend but the differences were not significant (Figure 5). The lower soil injection rates of Imidacloprid were more variable in their effectiveness at this time. Treatment resulted in a significantly reduced number of eggs at one site, and nymphs and adults at two sites.

Figure 5: Number of Aconophora egg batches, nymphs and adults collected from fiddlewood trees at three sites one month post-treatment with Imidacloprid at three rates (Imid) or Dimethoate (Dimeth). Means with the same letter within each site are not significantly different (p<0.05).



Three months post-treatment
No insects were located in any of the trees assessed, following high temperatures in the Brisbane area. Analysis of chemical residue levels revealed that 10 of the 27 imidacloprid-treated trees showed levels of imidacloprid below 0.04 mg/kg, this being the lowest level at which a successful response can be determined. All trees treated at the highest rate retained measurable levels of imidacloprid at this time, compared with six trees (66%) treated at the intermediate rate and only two trees (22%) treated at the lowest rate (Figure 6). Because the trees were treated with a predetermined quantity of insecticide per tree we looked at the relationship between insecticide application rate per mm dbh and residue levels at three months. This showed a positive but weak relationship (R^2=0.2487) indicating factors other than tree diameter were influencing the uptake and retention of the chemical. Results from this time indicated that only trees with application rates above approx. 1g ai/cm dbh retained any level of imidcaloprid by three months.

Figure 6: Imidacloprid residue levels remaining in Fiddlewood foliage three months post-treatment.



Six months post treatment
Insects were still not located at any site. Foliage samples at this time indicated that only six trees had imidacloprid residue levels above the 0.04 mg/kg minimum level for quantification, all from the highest application rate (Figure 7). Insects were bagged on the trees and survival assessed after two weeks (Figure 8). Supporting the residue results, there were no significant differences in survival between the control, dimethoate and two lower dose imidacloprid treatments. However survival was significantly lower on trees treated at the highest imidacloprid application rate.

Figure 7: Imidacloprid residue levels remaining in Fiddlewood foliage six months post-treatment..

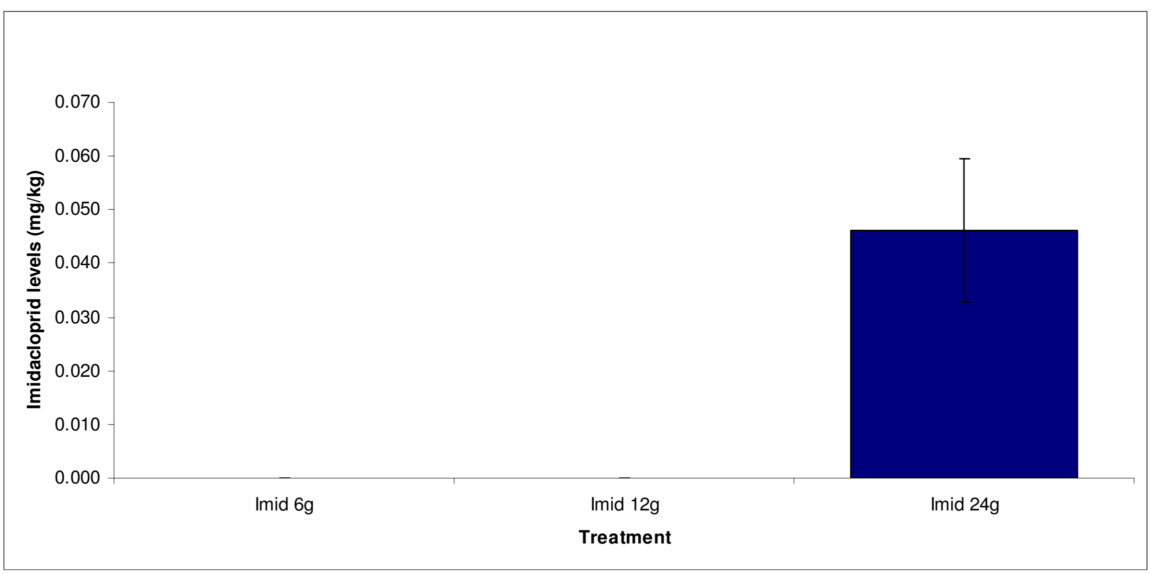
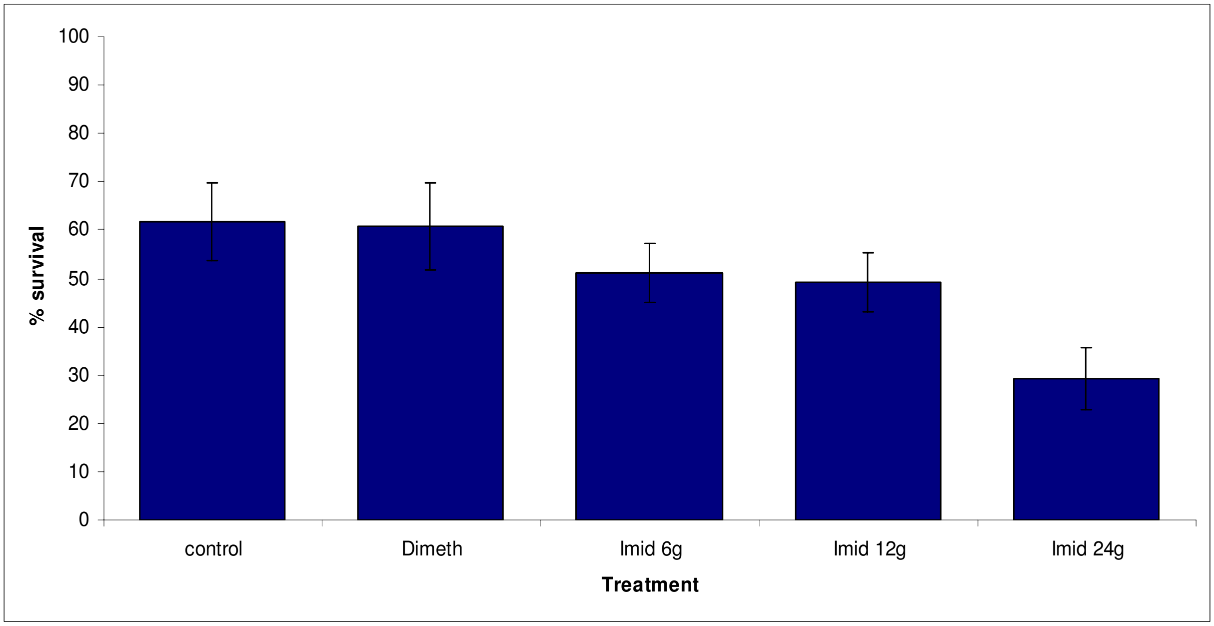


Figure 8: Survival of insects bagged onto Fiddlewood trees six months post-treatment. Survival was assessed two weeks after placement.



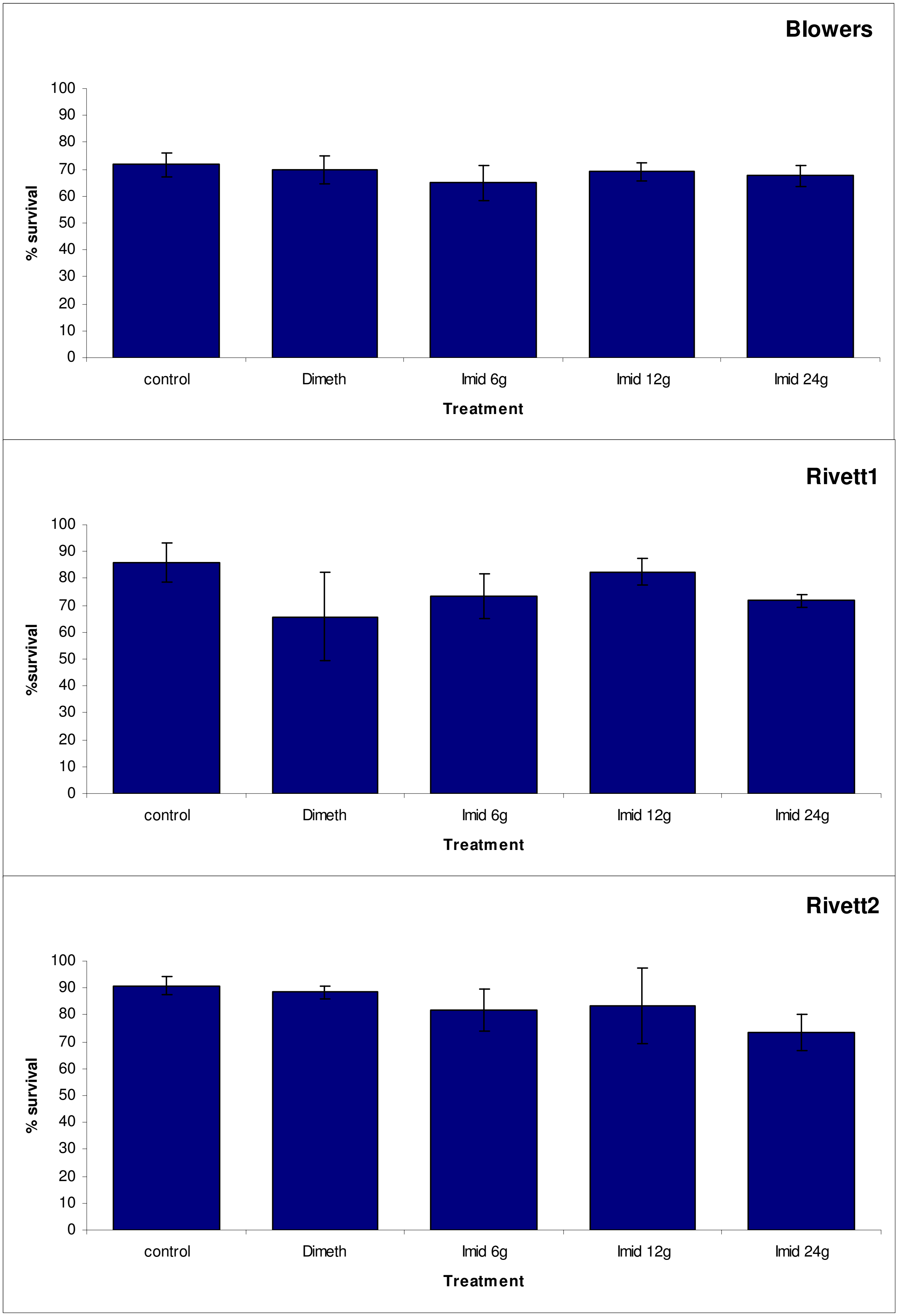
Nine months post treatment

Insects were again bagged onto the treated trees. Differences in survival between sites had become significant (F=1.035, P= 0.43) requiring sites be considered separately (Figure 9) :

- At the two Rivetts sites the highest imidacloprid application rate remained significantly different from the control treatment.
- At the Blowers site there was no longer any effect of treatment.

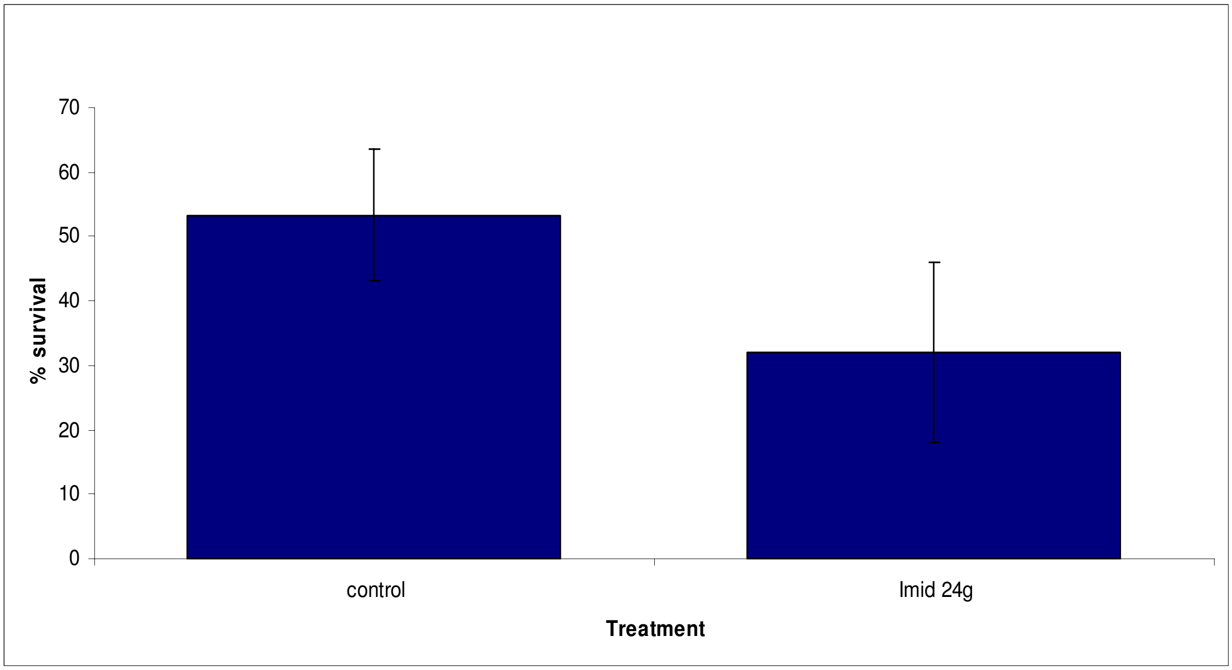
At this time residue analysis was assessed for only those trees which had scored imidacloprid residue levels above the 0.04 mg/kg minimum level of quantification at the six month sample. These results are not yet available from the Bayer laboratory.

Figure 9: Survival of insects bagged onto Fiddlewood trees nine months post-treatment. Survival was assessed two weeks after placement.



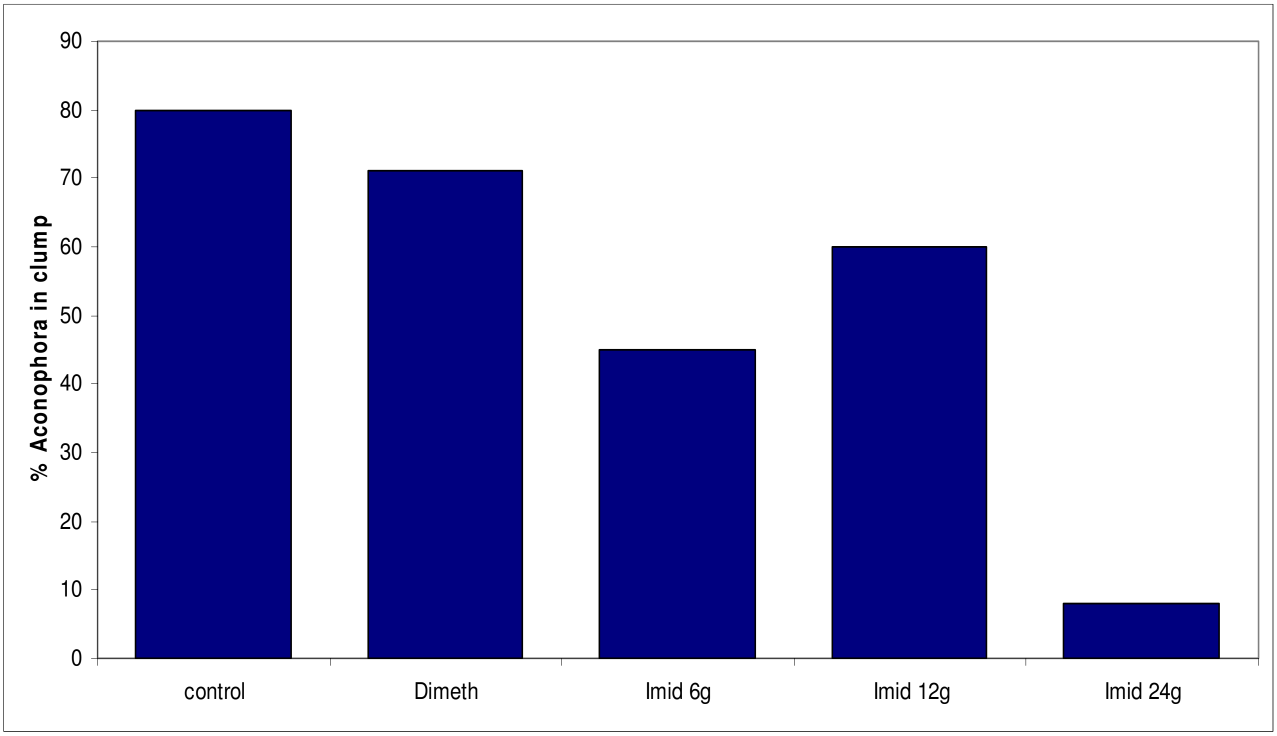
12 months post-treatment
Insects were bagged only onto those trees treated at the highest application rate and the controls. On one treated tree all bags were infested by ants during the course of the trial, consuming many Aconophora. This was the only mortality due to external factors recorded during the course of the bagging experiments. Results from this tree were therefore excluded from subsequent analysis. Although there were fewer insects alive on the treated trees compared with the control trees, the differences were not significant ($F=3.142$, $p=0.11$, Figure 10)).

Figure 10: Survival of insects bagged onto Fiddlewood trees nine months post-treatment. Survival was assessed two weeks after placement.



At the six month assessment we also compared the incidence of clumping within the bags at the time of assessment and the number of deformed adults present in each bag. The clumping behaviour of the insects differed significantly between treatments ($\chi^2 = 29.718$, $p = 0.0002$), due largely to a low incidence of clumping in the highest imidacloprid treatment (Figure 11). The total number of adults failing to emerge successfully was relatively low (0.06%) and showed no significant difference between the different treatments ($\chi^2 = 3.23$, $p = 0.52$).

Figure 11: Percentage of Aconophora nymphs aggregated in a clump following bagging on fiddlewood trees six months after treatment with insecticides. Assessments were made one week following placement of insects.



Trial 2:

By three months post-treatment only two of the six imidacloprid treated trees had foliage residue levels above the 0.04 mg/kg minimum level of quantification, and by six months none were above this level.

Conclusions

The results of these trials indicate that both dimethoate and imidacloprid have the potential to provide control of Aconophora on fiddlewood trees.

As foliar treatments both insecticides are effective, and cause substantial mortality of nymphs feeding on the tree within a few days of application. Of the two chemicals, imidacloprid remained effective over a longer duration than dimethoate, still causing nymphal deaths up to 30 days after treatment compared with less than 14 days effectiveness for dimethoate. Beyond this time trees will be reinfested from nearby, untreated trees. Canopy spraying allows only limited movement of chemical through the vascular system of the plant and so the residual effects are limited. Spraying requires the use of large amounts of insecticide and can be logistically difficult for larger trees. This form of treatment will be most useful on smaller, relatively isolated trees where quick action is required.

Both insecticides were also effective following either soil (imidacloprid) or stem (dimethoate) injection. Uptake of both chemicals was relatively rapid, providing effective control by one month post-treatment. This was more rapid than observed for a number of other tree species, (Tattar et al. 1998), where between 2 and 5 months were required to reach lethal concentrations. As with foliar application, imidacloprid provided the greater longevity of the two insecticides, still being effective six to nine months after treatment at the highest doses, compared with less than six months for dimethoate.

The effectiveness of all treatments in the field trials may have been modified by the severe drought conditions and heat waves experienced in south east Queensalnd during the trials.These conditions limited the availability of soil moisture and could have affected the uptake of the insecticides. Although most trees were watered immediately pre and post treatment they were not watered regularly during the trials. In contrast in the glasshouse trials, where the trees were watered regularly, imidacloprid was detectable and effective 12 months post-treatment.

In addition to the effects of imidacloprid on insect survival, impacts on behaviour were observed. During bagging trials insects on treated trees did not remain in the feeding groups usually observed, but rested individually on the shoots or on the bag itself. Aggregation behaviour is thought to offer protection for the developmental stages. Although many of the natural enemies of Aconophora may not be present in Australia, a number of generalist predators have been observed feeding on the insects or were present in infested trees, including assassin bugs (Hemiptera: Reduviidae) and ladybirds (Coleoptera: Coccinellidae). Disruption of the characteristic aggregation behaviour may make nymphs more susceptible to these predators and environmental factors and further increase mortality rates beyond those observed.

Imidacloprid applied through soil injection proved more effective than dimethoate applied by stem injection at the rates trialled, and provides the greatest potential for management of Aconophora on fiddlewood trees. It is a low toxicity, systemic insecticide having minimal environmental impact or phytotoxic effect. Application through soil injection guarantees minimal damage to the tree itself, and no long term effects on soil micro-organisms, earthworm populations or foliage-inhabiting beneficial organisms. In an urban environment, soil injection also ensures the chemical is well separated from children and pets.

Treatment with imidacloprid was consistently effective for extended durations only at the highest application rate (24g ai/tree or between 1 and 2 g ai/cm dbh). At these rates trees will require treatment on an annual basis. These results are considerably poorer than those recorded for several other situations, where trees remain protected for at least one year and up to two years post treatment following application rates of 0.6g ai/cm dbh (Sclar and Cranshaw 1996, www.elmsavers.com.au).

Soil treatment should ideally be applied only during the growing season of the tree to encourage uptake by the root system. The effectiveness and speed of uptake will be improved if the soil is damp at the time of application, possibly requiring additional watering in many situations. Treatment should be most beneficial in early summer, and in some years will be assisted by the impact of high summer temperatures eliminating or at least dramatically reducing Aconophora populations. Following such events trees should be monitored for the return of insects and treated as insect numbers start to increase and their impact on the tree becomes evident

In garden applications the general public can apply Confidor as a foliar spray, or a soil drench for small shrubs, in the recommended concentrations. Effective soil injection of Imidacloprid would require application by a trained pesticide applicator, increasing the cost of such treatments. Application through soil injection would be best carried out using Merit® (ai 200g/litre Imidacloprid) rather than Confidor. Merit® can be purchased in larger volumes for commercial operations. Not all trees are suitable for treatment through soil injection, either because of restricted access around roots or proximity to water bodies. Imidacloprid is highly toxic to aquatic invertebrates and should not be applied directly to water or in areas where surface water is present or groundwater is shallow. In these situations alternative treatments need to be considered. Canopy spraying can be successful but with the restrictions outlined above. Ongoing research into stem injectable formulations of imidacloprid should be monitored and considered further if and when available.

Aconophora will almost certainly be an on-going problem to fiddlewood trees in the Brisbane area. In light of the undesirable qualities of the tree, removal and replacement with alternatives is likely to be the best option in some situations. Treatment using imidacloprid applied through soil injection provides a method of control for valued trees in some situations. Ongoing research into the biology, host relations and natural enemies of Aconophora may provide further control options in the future.

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