Micronesica 37(1):37-48, 2004

Developing Insecticide Management for *Insnesia glabrascuta* (Caldwell) (Homoptera: Psyllidae) on Young Ifit Trees on Guam

Ross H. Miller

Agricultural Experiment Station
College of Natural & Applied Sciences
University of Guam
Mangilao, GU 96923
email: rmiller@uog9.uog.edu

Abstract—The effects of four pesticides on populations of the psyllid, *Insnesia glabrascuta* (Caldwell), were examined on ifit trees, *Intsia bijuga* (Colebr.) O. Kuntze. The pesticides tested were Cygon®, a commercial over-the-counter formulation of dimethoate; Avid®, a commercial formulation of avermectin; Actara®, a commercial formulation of thiamethoxam; and Conserve®, a commercial formulation of spinosad. All pesticides caused initial mortality to psyllids. However, psyllid populations rapidly rebounded to pre-treatment levels in the Cygon® spray and drench treatments, while densities remained below pre-treatment levels longest in the highest concentrations of Actara®, Conserve®, and Avid® spray treatments. Psyllid population suppression was probably linked to residual activity characteristic of the different compounds and to physiological changes in tree leaves induced by feeding psyllids. Implications for the use of these pesticides for psylla management on ifit trees in Guam's tropical insular environment are discussed.

Introduction

The ifit tree (also known as ifid or ifil), *Intsia bijuga* (Colebr.) O. Kuntze, is a hardwood with economic and cultural significance to Guam as well as to Southeast Asia and the Pacific Islands in general. Wood from ifit trees is highly sought after by builders and artisans throughout the Pacific region for use in construction of buildings, flooring, furniture, and artwork. The wood possesses high strength, dense grain structure and hardness and is resistant to fungi and insects (Hillis & Yazaki 1973; Stone 1970). Oils extracted from ifit trees repel insects and have insecticidal activity comparable to neem seed oils (Mohiuddin et al. 1987).

Traditionally, the durable wood from ifit trees was a critical ingredient in the construction of sea-going canoes among the Chamorro on Guam and among other Pacific island peoples (Banack & Cox 1987). The ifit tree has come to symbolize the cultural legacy of the Chamorro people throughout the Mariana Islands and was therefore designated the territorial tree of Guam in 1969 (Public Law 10-52).

A decline in ifit tree populations on Guam was noticed as early as 1905 (Safford, 1905) and active logging prior to 1970 on Guam reduced ifit tree populations to such an extent that mature trees are now rare on the island (Marler 1996). Large trees are primarily limited to restricted-access military bases and reserves. Wood for commercial purposes is limited to small pieces suitable only for carving. Although Guam law prohibits cutting live ifit trees, the great demand for ifit tree wood has lead to illegal harvesting of ifit trees and tree parts, even from restricted-access areas.

Ifit trees are currently propagated only by the Guam Department of Agriculture, Forestry Division that uses seeds imported from the Philippines. Local seeds are difficult to obtain because of the inaccessibility of pods on mature trees, and the general erratic seed pod production caused by wind damage during typhoons and psyllid feeding during flowering. Trees that are propagated are primarily used in ornamental and ceremonial plantings.

The ifit tree has been characterized as a slow growing species and exhibits the cycles of rapid stem tip extension followed by periods of no extension typical for tropical trees (Possingham 1986). However, Marler (1996) demonstrated that rapid growth is possible when seedlings are protected from biotic and abiotic stresses. Important abiotic stresses on Guam include defoliation caused by typhoon winds, flooding, and drought. The most serious biotic stresses on Guam are feeding by wild pigs and Philippine deer, and infestations of the psyllid, *Insnesia glabrascuta* (Caldwell). Feeding by *I. glabrascuta* results in stunting and occasional defoliation, likely resulting from salivary secretions injected into the tree during psyllid feeding.

Insect management on ifit trees on Guam must pose minimal impact to the environment and human safety while remaining compatible with such biorational pest management strategies as biological and cultural control that form the basis for integrated pest management. The objective of this project was to identify insecticides and formulate application methodologies appropriate for use against *I. glabrascuta* on young ifit trees in nurseries and in the field in Guam's tropical insular environment.

Materials and Methods

A research orchard of 64 *I. bijuga* seedlings was established during the spring of 1998 at the University of Guam's Yigo Experiment Station in northern Guam. Seedlings planted in the test plot were obtained from field collections of *I. bijuga* seeds from Andersen Air Force Base in northern Guam, the Admiral Nimitz Golf Course in central Guam, and by the acquisition of potted seedlings from Guam's Department of Agriculture. Collected seeds were soaked in water, scarified, and germinated in pots containing a 2:1:1 mix of soil, sand, and peat moss. When approximately 0.5 m tall, seedlings were planted in the field in an 8 X 8 matrix with a 3 m spacing interval between trees. Drip irrigation was applied for four hours three times per week. Fertilizer (16:16:16 NPK) was applied at planting, after two months, and approximately every 6 months thereafter. The insecticide Cygon® was applied as needed to protect seedlings from *I. glabrascuta* until trees had attained 1 m in height and possessed sufficient foliage to allow experimental screening.

Insecticides were tested using a single tree randomized design with 16 replications. In testing insecticides, all trees in the plot were initially sprayed with Cygon® to relieve insect pressure on the trees and allow them to produce new growth. Experiments were then initiated when subsequent psyllid surveys revealed a consistent population of psyllids on trees, usually 6 to 8 weeks from the initial Cygon® spray. Prior to applying the test insecticides, a section of a branch from each tree of approximately equal area was marked with forester's tape and designated as the psyllid sampling site. All psyllids were counted on this portion of the tree 24 hr before applying insecticide treatments.

Insecticide treatments included a water control and 3 concentrations ranging from very dilute up to the maximum application rate indicated on the insecticide's label. Insecticide treatments were assigned to trees randomly. All sections of each tree were sprayed until dripping with the appropriate treatment concentration using a Solo® backpack sprayer equipped with a hand pressure pump and a standard fan nozzle.

An exception to the above spray treatment technique was made to compare a Cygon® soil drench on ifit tree psyllid populations to foliar applications of Cygon® and to an unsprayed control. In this test 24 randomly chosen trees were assigned to one of three Cygon® concentrations that were applied to the soil within the drip line of each tree. An additional eight randomly selected trees were irrigated according to the regularly established schedule but not sprayed with Cygon® or with water. The remaining 32 trees in the plot were treated with three concentrations of Cygon® or with a water-only control in randomly assigned groups of 8 trees.

Psyllids were counted from each designated section of each tree 24 hr following each test insecticide application and approximately every other day thereafter for nearly two weeks, and then at intervals of about 3 days until the experiment was terminated. Psyllid population responses to the treatments were expressed as the average percent of the pre-treatment population density from each sampling site on each tree. Psyllid counts were terminated when psyllid populations in treatments consistently exceeded pre-treatment levels, or when repetitive cyclic population cycles, were observed. When the experiments were terminated, all trees in the plot were treated with a Cygon® cover spray. Trees were irrigated and fertilized as described until they once again produced new and adequate foliage and supported a consistent psyllid population.

The Cygon® and Avid® trials reported here were conducted in May 1999 and July 1999, respectively, which coincided with the transition period from the dry season to the wet season. The Conserve® trial was conducted during September 2000 during the wet season. The Actara® trial was conducted during April 2001 during the dry season.

On occasion, heavy rains occurring within 24 hr of the spray applications appeared to wash most of the pesticide from the trees. When it became obvious that the experiment was compromised, the entire plot was treated with a Cygon® cover spray and the experiment repeated after tree foliage and psyllid densities had again increased and stabilized within the orchard. Data for aborted experiments are not reported.

Statistical analyses included 1-Way ANOVA using a general linear models procedure by NCSS (Hintze 2000) followed by a calculation of least significant difference (LSD) (Steel & Torrie 1980). Psyllid count data are presented as the mean percentages of pre-treatment psyllid density (Figs. 1-4).

Results

There were differences observed in psyllid population decreases between the Cygon® drench and spray treatments (Fig. 1A&B). While psyllid populations initially rose above pre-treatment counts within a day or two in the water and unsprayed controls, populations in the spray treatment immediately decreased to near zero (Fig. 1A). Increases in psyllid density at all Cygon® spray concentrations were observed apart from day 5. Psyllid population increases were greatest in the

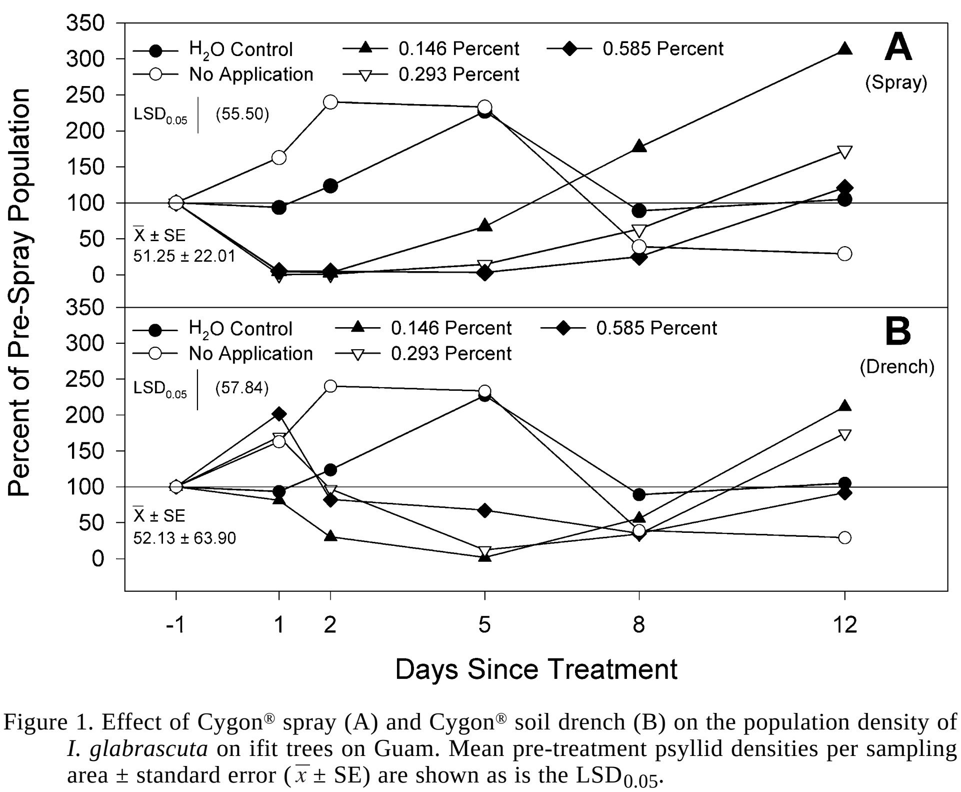

Figure 1. Effect of Cygon® spray (A) and Cygon® soil drench (B) on the population density of *I. glabrascuta* on ifit trees on Guam. Mean pre-treatment psyllid densities per sampling area ± standard error ($\bar{x}$ ± SE) are shown as is the $LSD_{0.05}$.

lowest Cygon® concentration and least in the highest Cygon® concentration, with the mid-level concentration giving rise to an intermediate population density. In contrast, psyllid densities in both the water and unsprayed controls peaked at about 225% of the pre-treatment density on day 5 and decreased below the pre-treatment level by day 8. Psyllid densities in the water control remained about equal to the pre-treatment levels through day 12 when the experiment was terminated, while densities in the unsprayed control decreased further.

Psyllid densities in the Cygon® drench experiment (Fig. 1B) either decreased slightly within 24 hr of application or increased. However, psyllid densities in all Cygon® treatments were below the pre-treatment control levels by day 2 and continued to decrease until day 5. After this time, densities in the two lowest concentrations began to rebound and had exceeded pre-treatment levels by day 12 when the experiment was terminated. Psyllid populations in the most concentrated dimethoate drench treatment also increased to near pre-treatment levels by day 12.

Psyllid counts were continued beyond 12 days in the experiment testing Avid®, where 16 trees were included in each treatment instead of the 8 used per treatment in the Cygon® experiments, and where sprayed water constituted the control (Fig. 2). Psyllid densities in the control rapidly rose to about 450% of pre-treatment levels by day 6 post-treatment. They then rapidly decreased to near zero

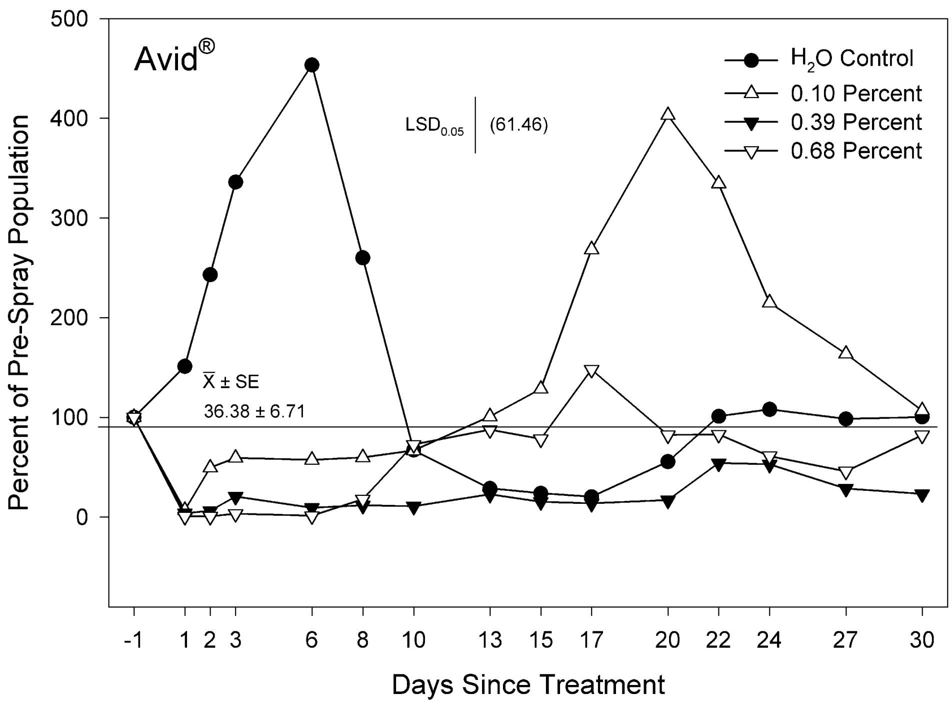

Figure 2. Effect of sprays of Avid® on populations of *I. glabrascuta* on ifit trees on Guam. Mean pre-treatment psyllid densities per sampling area ± standard error ($\bar{x}$ ± SE) are shown as is the $LSD_{0.05}$.

levels by day 13 and did not return to pre-treatment levels until day 22, where they remained until the experiment was terminated on day 30. Psyllid densities in all Avid® spray treatments decreased to near zero by day 1 post-treatment. Populations in the lowest concentration increased to about 50% of the pre-treatment level but didn't exceed it until day 15 when densities dramatically soared to about 400% of the pre-treatment count. Densities then rapidly decreased to pre-treatment levels by day 30. The intermediate Avid® concentration applied caused psyllid populations to decrease to near zero, where they remained until day 20. At this time they slightly increased to about 40% of pre-treatment levels before tapering off to near zero by day 30. In contrast, the greatest Avid® concentration resulted in psyllid densities near zero until day 6, at which time densities increased to about 80% of the pre-treatment levels on day 10. They then fluctuated approximately 40% above or below the pre-treatment levels until the end of the experiment.

Psyllid densities on trees treated with Conserve® decreased to near zero on sprayed trees immediately following treatment and remained below pre-treatment levels for eight days at which time psyllid densities in the most dilute treatment regained their original levels (Fig. 3). Psyllid densities in the highest Conserve® concentration remained below pre-treatment levels for 16 days, at

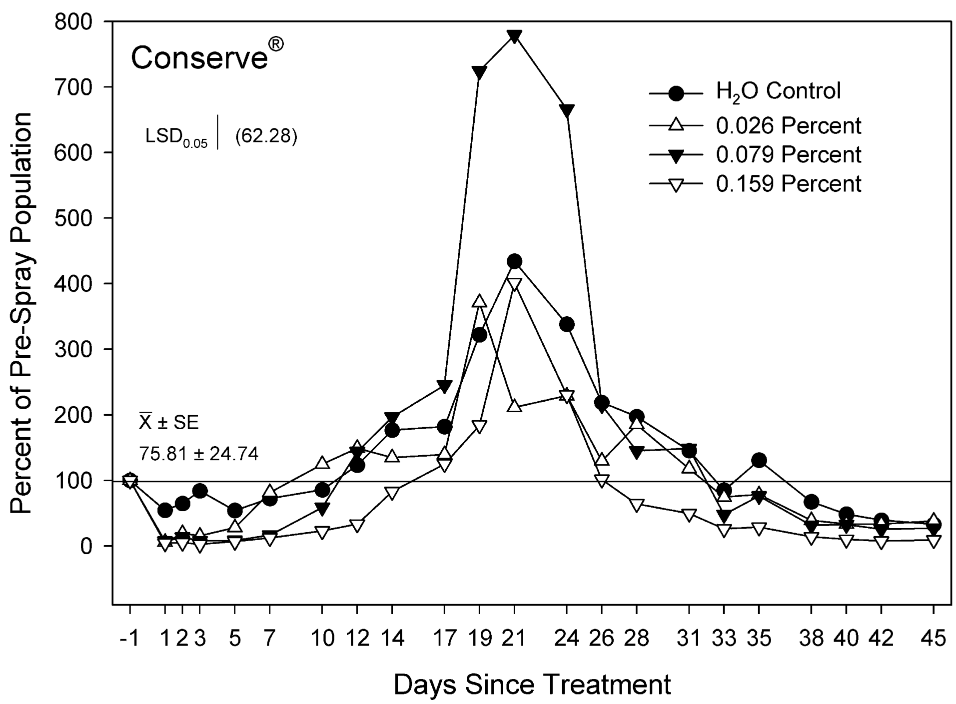

Figure 3. Effect of Conserve® on populations of *I. glabrascuta* on ifit trees on Guam. Mean pre-treatment psyllid densities per sampling area ± standard error ($\bar{x}$ ± SE are shown as is the $LSD_{0.05}$.

which time all spray treatments including the control exhibited synchronous rapid population growth continuing until about day 21 post-treatment. Psyllid densities on trees treated with the intermediate Conserve® concentration rose nearly 300% higher than those on trees treated with the other concentrations and with the water control. From their peak near day 21, psyllid population densities gradually decreased below pre-treatment levels by the time the experiment was terminated on day 45.

Psyllid densities on trees treated with Actara® decreased immediately to near zero following spray applications and remained low until day 25 post-treatment (Fig. 4). Psyllid densities treated with a water control fluctuated around the pre-treatment level and did not rapidly increase until about day 27 post-treatment. When psyllid densities on sprayed trees began to increase, they did so in a manner that was roughly inversely proportional to the concentration of the spray treatment. Psyllid densities in both the most dilute and the intermediate concentrations of Actara® eventually exceeded pre-treatment levels near the end of the experiment, while those on trees treated with the highest concentration never attained their previous levels and were observed to decrease slightly when the experiment was terminated on day 34.

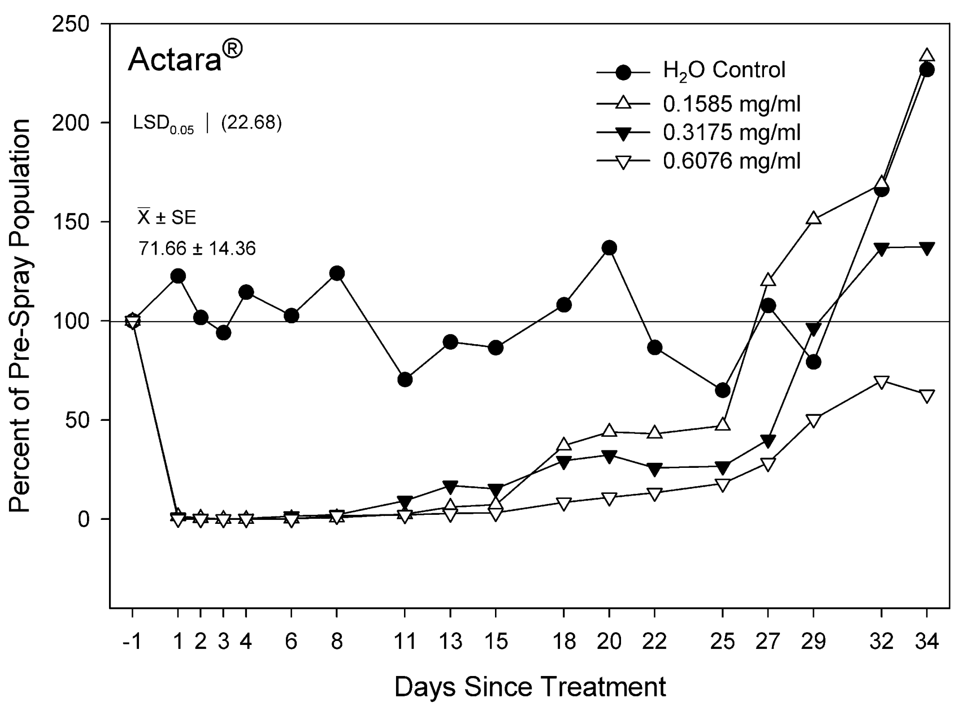

Figure 4. Effect of Actara® on populations of *I. glabrascuta* on ifit trees on Guam. Mean pre-treatment psyllid densities per sampling area ± standard error ($\bar{x}$ ± SE) are shown as is the $LSD_{0.05}$.

Table 1. Interval required for sprayed *I. glabrascuta* populations to attain pre-treatment densities.

	Treatment	Approximate Number of Days to Attain Pre-Treatment Density
Actara®	H_2O spray	-
	0.1585 mg/ml	26
	0.3175 mg/ml	29
	0.6076 mg/ml	34+
Avid®	H_2O spray	-
	0.100 %	13
	0.390 %	30+
	0.680%	15
Conserve®	H_2O spray	11
	0.026 %	8
	0.079 %	11
	0.159 %	15
Cygon® (Spray)	No Treatment	-
	H_2O spray	1
	0.146 %	6
	0.293 %	9
	0.585 %	11
Cygon® (Drench)	No Treatment	-
	H_2O spray	1
	0.146 %	9
	0.293 %	10
	0.585 %	12+

Discussion

While all four insecticides tested reduced psyllid populations immediately after application, there were differences in the time required for psyllid populations to return to pre-treatment levels (Table 1). Differences observed in the response of the psyllid population to different concentrations of insecticide may be linked to residual activity of the various insecticides and to the interaction between feeding psyllids and plant growth. Guam's climate has a distinct wet and dry season. Rainfall in the transition periods between the wet and dry seasons typically occurs in short, intense events that cover localized areas of the island (Lander 1994). Effects of heavy rainfall events within two to three days of insecticide application resulted in there being no observed psyllid mortality in any of the spray treatments, and appeared to wash insecticide from leaves and branches.

Rainfall events occurring later than one week during the experiment did not appear to appreciably affect psyllid densities in any of the treatments.

Trees protected from psyllids quickly produced new growth which in turn induced psyllid population growth. This interaction became apparent in all tests of where observations were extended more than two weeks from insecticide application. It is likely that oscillations in psyllid density, especially in the water control, would have also been observed had the sampling period been extended beyond 12 days for the Cygon® spray and soil drench.

More difficult to explain is the within-treatment synchronicity of psyllid population increase on trees treated with Conserve® (Fig. 3). This contrasts with the asynchronicity observed in the Avid® treatment where psyllid densities in the water control rapidly increased, while densities in the other treatments did not begin to rise until over a week later. This asynchronicity, as well as the decrease in psyllids in water controls observed in other treatments, may have resulted in part from degradation of the food source induced by heavy and sustained feeding by psyllid nymphs.

The chemical formulation of the different sprays, and their mode of application, may have also played a role in pattern of recovery of psyllid populations in the various treatments. Dimethoate is a broad-spectrum organophosphate that exhibits systemic action when applied as a soil drench. The 5+ day interval required before psyllid density decreased to their lowest point in the dimethoate drench treatment probably corresponded to the time required for the trees to translocate the active ingredient from the roots to the leaves where psyllids were located. It is unclear why the highest concentration (0.585 %) required 8 days, versus 5 days for psyllid populations receiving lower insecticide concentrations, to bottom out, and why there was an apparent inverse dose-response relationship with regards to mortality.

Of the four materials tested, Actara® gave the best long term results (Table 1), although all four insecticides provided initial high knockdown. The active ingredient of Actara® is thiamethoxam, a neonicotinoid of compound low toxicity to mammals and an oral LD_{50} in rats > 5000 mg/kg body weight. It is toxic to fish and aquatic invertebrates and has high potential to contaminate surface water through runoff several months after application if not handled properly (Syngenta 2001). The establishment of vegetative buffers between areas sprayed with this product and bodies of water that could be potentially contaminated is recommended. On Guam the use of this product would require that it not be applied when winds were sufficient to cause significant drift, or when heavy rainfall was expected on poorly drained soils of southern Guam that might lead to runoff into rivers and streams and ultimately onto Guam's shelf reef. Similarly, heavy rainfall in northern Guam where soils and the limestone under layer are porous would allow percolation of insecticide contaminated water into the freshwater lens of northern Guam. Actara® would perhaps be most appropriate for use in nursery situations where runoff and wind could be stringently controlled with minimal chance of environmental exposure.

Avid® and Conserve® may be used as alternatives to Actara®, especially in a nursery setting on seedlings. Avid® contains abamectin, a mixture of avermectins which causes death by stimulating the pre-synaptic release of the inhibitory neurotransmitter gamma-aminobutyric acid (GABA) (Mellin et al. 1983, Babu 1988, Lasota & Dybas 1991). Abamectin causes insects to cease feeding through paralysis and ultimately results in the insects' death. The effectiveness of abamectin is greatest when the insect ingests the chemical, although contact activity has also been documented. Insect paralysis may be observed within hours of application, but maximum mortality usually requires 3 to 4 days. Although surface residues of abamectin degrade rapidly in sunlight, some of the active ingredient normally penetrates the leaf where it provides residual mortality. This may account for the prolonged and relatively low psyllid densities observed in the two higher concentrations of Avid® applied in this study. Such activity would ensure that only pests feeding on the trees are affected and while not affecting natural enemies also present on the trees. Degradation in sunlight would also lessen its chances for environmental contamination on Guam. Abamectin resistance has been documented in mites exposed to repetitive doses of abamectin (Hoy & Ouyang 1989, Hoy & Conley 1987), though this would likely not pose a problem for Guam growers given the large reservoir of untreated psyllid-infested trees.

Conserve® is a mixture of the isomers of spinosad (spinosyn A and spinosyn B), and is currently registered for use on turf and ornamental plants pests including various lepidopteran pests, sawflies, beetles and flies (Dow AgroSciences 2000). Spinosad is derived as a secondary metabolite in aerobic fermentation on artificial media of the soil actinomycete *Saccharopolyspora spinosa* Mertz & Yao. Spinosad causes death through over stimulation of the insects' nervous system. Spinosad normally has a soil half life of 9-10 days, is degraded by sunlight, and has low mammalian toxicity and low to moderate toxicity to aquatic invertebrates and fish. While Conserve® would constitute an environmentally friendly ifit tree treatment in the field, its relatively short residual activity and high price, coupled with a need to frequently reapply, render it less desirable than Avid® or Actara®.

Cygon®, a popular and effective systemic aphicide and broad-spectrum foliar spray for a variety of Guam's crop pests, is perhaps least suited for controlling psyllids on ifit trees on Guam due to the rapid resurgence of psyllids on Cygon®-treated ifit trees. Dimethoate, Cygon®'s active ingredient, is a widely used broad-spectrum organophosphate insecticide with documented systemic activity in a variety of plants. Formulated as a liquid emulsifiable concentrate in this experiment, dimethoate presents low hazard to applicators when labeled instructions are followed. The federal registration of dimethoate, along with many other commonly used organophosphates, is currently under extensive review as part of the provisions of the Food Quality Protection Act (USEPA 2000). At present, Cygon® is no longer sold on Guam in the gardening sections of local retail hardware and department stores. It may still be obtained from farm chemical suppliers, although these firms usually sell it in bulk quantities beyond the financial and practical means of home gardeners and backyard farmers that constitute the majority of Guam's agricultural community.

Acknowledgements

Technical assistance provided by Ms. N. Dumaliang, H. Osada and O. Idechiil of the College of Agriculture and Life Sciences, University of Guam, is gratefully acknowledged. Dow AgroScience, Syngenta Crop Protection, Inc. and Novartis AG provided samples of products used in this study. Drs. Lee Yudin, James McConnell and R. Schlub, University of Guam College of Agriculture and Life Sciences, provided reviews of the manuscript. Funding for this project was provided by a grant through the USDA McIntire-Stennis Program to the University of Guam Agricultural Experiment Station.

References

Babu, J.R. 1988. Avermectins: biological and pesticidal activities. *In* Biologically Active Natural Products-Potential Use in Agriculture. American Chemical Society Series No. 380. pp. 91–108. American Chemical Society. Washington DC.

Banack, S. A. & P.A. Cox 1987. Ethnobotany of ocean-going canoes in Lay, Fiji. Economic Botany 41: 148–162.

Dow AgroSciences. 2000. MSDS and specimen label for Conserve SC. Crop Protection Reference. Chemical and Pharmaceutical Press. 4 pp. http://www.greenbook.net

Hillis, W.E. & Y. Yazaki. 1973. Polyphenols of *Intsia* heartwoods. Phytochemistry 12: 2491–2495.

Hintze, J.L. 2000. NCSS 2000 User's Guide – I. NCSS, Kaysville, Utah, USA. 557 pp.

Hoy, M.A. & J. Conley. 1987. Selections for abamectin resistance in *Tetranychus urticae* and *T. pacificus* (Acari-tetranychidae). Journal of Economic Entomology 80: 221–225.

Hoy, M.A. & Y.L. Ouyang. 1989. Selection of the western predatory mite, *Metaseiulus occidentalis* (Acari: Phytoseiidae) for resistance to abamectin. Journal of Economic Entomology 82: 35–40.

Lasota, J.A. & R.A. Dybas. 1991. Avermectins, a novel class of compounds: implications for use in arthropod pest control. Annual Review of Entomology 36: 91–117.

Lander, M.A. 1994. Meteorological factors associated with drought on Guam. WERI Tech. Rep. No. 75. University of Guam, Mangilao, Guam 96923.

Marler, T.E. 1996. Protecting Guam's cultural and biological resource – the ifit tree. Legacy resource management program final report. University of Guam, Mangilao, Guam 96923. 37 pp.

Mellin, T.N., R.D. Busch & C.C. Wang. 1983. Post synaptic inhibition of invertebrate neuromuscular transmission of avermectin BQ_{1a}. Neuropharmacology 22: 89–96.

Mohiuddin, S., R.A. Qureshi, A. Khan, M.K.A. Nasir, L.M. Khoatri & S.A. Qureshi. 1987. Laboratory investigations on the repellency of some plant oils to red flour beetle, *Tribolium castaneum* Herbst. Pakistan Journal of Scientific and Industrial Research 30: 754–756.

Possingham, J.V. 1986. Impact of physiological research on the productivity of tropical and subtropical fruit trees. Acta Horticulturae 175: 17–25.

Safford, W.E. 1905. The useful plants of the island of Guam with an introductory account of the physical features and natural history of the island, of the character and history of its people, and of their agriculture. Government Printing Office, Washington DC. 416 pp.

Steel, R.G.D. & J.E. Torrie. 1980. Principles and procedures of statistics, 2nd ed. McGraw-Hill, New York. 633 pp.

Stone, B.C. 1970. The flora of Guam. Micronesica 6: 1–659.

Syngenta. 2001. MSDS and specimen label for Actara™ insecticide. Crop Protection Reference. Chemical and Pharmaceutical Press. 7 pp. http://www.greenbook.net

USEPA. 2000. Food Quality Protection Act (FQPA) of 1996. USEPA website updated April 13, 2000. http://www.epa.glv/appfead/fqpa.

Received 24 Sep 2002, revised April 2003