Drenches and Injections of Systemic Insecticides against the Invasive Erythrina Gall Wasp, *Quadrastichus erythrinae* Kim (Hymenoptera: Eulophidae), Attacking Erythrina Trees in Hawaii

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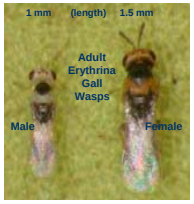


Abstract

Three systemic insecticides, imidacloprid, dinotefuran and abamectin, were applied to control the infestation of erythrina gall wasp (EGW), *Quadrastichus erythrinae* Kim, in *Erythrina* spp. trees. Imidacloprid was the most effective in controlling the wasp. Spatial and temporal distribution of imidacloprid in treated trees were monitored with an enzyme linked immunosorbent assay (ELISA) after injection with different formulations (Imicide via Mauget, Pointer via ArborSystems Wedgle, Merit 200 SL via Arborjet and IMA-jet via Arborjet) or after drenching (Merit 2F soil drench). All injection treatments were more effective in reducing wasp emergence as compared with the soil drench or the control. Imidacloprid concentration within injected trees showed a trend of decline with increasing distance from the trunk injection site, being higher in the lower canopy, and lower in the upper canopy. Less imidacloprid was detected in flowers than in leaves. A minimum concentration of approximately 4 ppm of imidacloprid in leaves is necessary for effective control of EGW. Trees injected with IMA-jet and Merit 200 SL via Arborjet had lower infestation severity ratings for the entire growing season than those injected with Imicide and Pointer via Mauget and Wedgle, respectively. Root drench efficacy was inconsistent and is recommended only for containerized or irrigated trees. Imidacloprid in IMA-jet and Merit 200 SL formulations delivered via Arborjet remained detectable one year after treatment and may be suitable for EGW management and control.

***Erythrina variegata* trees**
12 wk after injection with imidacloprid

Untreated | **12 WAT**
Trees injected with Arbor jet system using Merit 2000 or IMA-jet

Introduction

The erythrina gall wasp (EGW), *Quadrastichus erythrinae* Kim, is a newly described species first reported by Kim et al (2004) from specimens in Singapore, Mauritius and Reunion infesting *Erythrina variegata*, *E. fusca* and *E. indica*. Soon after, Taiwan reported infestations of EGW on *E. variegata, E. corallodendron, E. crista-galli, E. abyssinica and E. berteroana* (Yang et al. 2004). In April 2005, EGW was first detected in Hawaii (Heu et al 2005) and was suspected to have arrived a few months earlier. EGW very rapidly dispersed throughout the island of O'ahu, and by August 2005, reports established EGW on the islands of Oahu, Kauai, Molokai, Maui and Hawaii. EGW has proven to be a highly invasive and severely damaging pest of several *Erythrina* spp. used prominently in residential landscaping and agriculture for windbreaks due to their drought tolerance and rapid growth. Perhaps of greater concern is the ecological and cultural impact of EGW on the endemic species, *E. sandwicensis,* the key species in endemic dryland forests (Rock 1913). The extensive galling by EGW to all new terminal growth, flowers, and seed pods coupled with the impact of the wiliwili seed beetle, *Specularius impressithorax,* that renders seeds nonviable, will potentially alter the present ecology of dryland forests in Hawai'i.

Long term control of EGW in Hawaii will presumably be accomplished by classical biological control. Parasitic wasps have been found to attack EGW in Taiwan (Yang et al 2004) and reports from South Africa indicate that parasitic wasps do attack *Quadristichus* sp. (G. Prinsloo and M. Wright, per. com.); however, locating a suitable biological control agent has proven difficult since the specific origin of *Q. erythrinae* is unknown. Meanwhile, effective chemical management strategies are needed for immediate implementation to minimize damage by EGW. The objective of this study was to compare the efficacy and persistence of different formulations and applications of systemic insecticides on EGW infesting *Erythrina* sp. trees in Hawai'i.

Methods

Imidacloprid, dinotefuran and abamectin were evaluated to control EGW in two trials.

Experiment 1: (Aug 2005, Pearl City, HI, 58.4 cm annual rainfall) *E. variegata* trees with multiple vertical trunks (12.7 - 30.5 cm cumulative diam.; 6.1 - 7.6 m tall) were treated at labeled rates by root zone drench or trunk injection, or served as untreated controls (Table 1). Trees were heavily infested (severe galling, petiole distortion, leaf browning). Leaf samples (15 cm of growing tips from outer edge of canopy) were collected 1, 2, 2.5, 3, and 4 mo after treatment from at least four different locations.

Experiment 2: (June 2006, Hilo, HI, 305-457 cm annual rainfall) The persistence of imidacloprid as well as commercial injection equipment were evaluated on similar *E. variegata* trees (25.4- 30.5 cm cumulative diam., 7.6 - 10.7 m tall). Treatments were an untreated control and five imidacloprid treatments (4 trunk injections and 1 soil drench) applied at labeled rates using commercially available injection equipment (Table 2). The trees were heavily infested and nearly defoliated at the time of treatment. Leaf samples, as described above, were collected from all trees at 0, 3, 5, 10, 15 and 20 wk, 10 mo, and one yr after treatment.

Both experiments used completely randomized designs with 4 single tree replicates. Trunk injections (30 psi) were administered according to manufacturer recommendations. Root zone drenches were applied in 37.85 l water within 1.5 m surrounding the base of each treated tree. All leaf samples were evaluated for severity of infestation on a six-point numerical rating system based on galls and emergence. Imidacloprid was extracted with acidic aqueous methanol and quantified by ELISA with 3 replicates (Xu et al, 2006). Differences in imidacloprid concentrations and severity ratings among treatments were tested by one-way ANOVA. Data of wasp emergence were log 10 (+1) transformed and severity and emergence ratings were subjected to angular transformation prior to ANOVA; mean emergence rates in experiment 1 were separated by Tukey's multiple comparison procedure with a family error rate of $P = 0.05$ and compared by Dunnett's test. For all statistical tests (Sigma Stat 3.5), significance was accepted at $P < 0.05$.

Table 1. Mode and rates of application of several systemic insecticides evaluated against the Erythrina gall wasp (Experiment 1)

Mode of Application	Treatment Trade (Common) Name	AI per inch diameter
Root Drench		
	Merit 2F (imidacloprid)	1.44 mg
	Safari 20 SG (dinotefuran)	5.15 mg
Injection Systems		
Maujet	Imicide 10% (imidacloprid)	0.17 mg
Maujet	Abacide 1% (abamectin)	.072 mg

Table 2. Mean emerged wasps per gram of gall tissue and imidacloprid concentration in leaves at 20 weeks after treatment (Experiment 2)

Treatment	AI (mg)/ Inch Diameter	Emerged Wasps per g Tissue	Imidacloprid Concentration µg/g
Untreated	-------	15 a	0.0 a
Imicide10% AI Mauget Capsules	0.17	3 b	0.5 a
Pointer 5% AI ArborSystems Wedgle	0.03	3 b	3.0 a
Merit 200 SL 17.1% AI Arborjet Tree IV	0.94	0.4 c	36.0 b
IMA-jet 5% AI Arborjet Tree IV	0.43	0.1c	235.0 c
Merit 2F 21% AI Root Drench	1.44	16 a	0.2 a

Means in the same column followed by different letters were different by Tukey's multiple comparison procedure (P<0.05).

Imidacloprid formulated as IMA-jet and Merit 200 SL delivered with Arborjet maintained adequate concentrations of imidacloprid (46 and 28 ppm, respectively) to control EGW for more than 52 weeks. Minimum of 4 ppm imidacloprid is needed in leaves for EGW control.

Figure 1. Efficacy of several systemic insecticides on erythrina gall wasp emergence

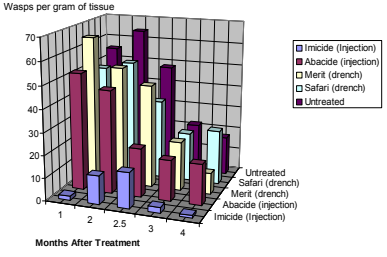
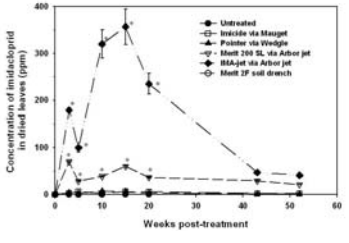


Figure 2. *Erythrina* spp. leaf concentration of imidacloprid formulations delivered by injection or soil drench over time



Results and Discussion

Experiment 1: Wasp emergence after injection with 10% imidacloprid (Imicide/Mauget) was lower ($P < 0.05$) than from other treatments or untreated control (Fig. 1). In general, the rate of EGW emergence from the untreated control and all treatments except Imicide/Mauget gradually decreased over the four month period due to unavailability of any ungalled leaves susceptible to EGW attack. Treatment was preventative and not curative because the development of galled plant tissues in response to EGW protected eggs and larvae from contact and systemic insecticides. Injection effectively delivered imidacloprid to *E. variegata* trees as compared with drenching. Evidently, the drench application of imidacloprid did not reach active functioning roots and/or was not effective due to inadequate soil moisture.

Experiment 2: Imidacloprid levels in leaf tissue after both Merit 200 SL and IMA-jet treatments via Arborjet injection were higher ($P < 0.05$) than those in untreated samples and the other imidacloprid formulations, which may be due to the ability of the Arborjet system to inject larger volume than the other systems (Table 2). Concentrations of imidacloprid in the trees treated with Imicide via Mauget or Pointer via Wedgle ranged from 2.9 to 6.2 ppm and 2.4 to 7.3 ppm, respectively, while trees injected by Arborjet averaged 235.0 and 36.0 ppm for IMA-jet and Merit 200 SL, respectively. In general, concentrations of imidacloprid gradually increased in the first 15 weeks after treatment followed by gradual decrease (Fig 2.). Twenty weeks after treatment, the trees began to naturally drop their leaves in the winter months and evaluations were discontinued until the spring flush (10 months after treatment). One year after treatment, leaf samples from trees treated with Merit 200 SL and IMA-jet still had imidacloprid concentrations of 28 and 46 ppm, respectively, which was well above the minimum 4 ppm necessary to control EGW, and the trees had low galling and emergence ratings. Treatments of Imicide via Mauget and Pointer via Wedgle at the tested rates, which were lower than Merit 200 SL and IMA-jet, require yearly application.

Conclusion

Among the three systemic insecticides tested, imidacloprid was the most effective insecticide to control gall wasps in *Erythrina* spp. trees. We found repeatable responses and efficacy from systemic trunk injections of imidacloprid as compared with root zone drenching. Through trunk injection, imidacloprid residues were detectable in the trees for at least one year and varied by dose and injection equipment used. Efficacy on EGW correlated with imidacloprid concentrations in leaf tissue throughout the sampling year. A minimum of 4 ppm imidacloprid was necessary for effective control of EGW. The IMA-jet and Merit 200 SL treatments effected higher concentrations of imidacloprid and lower infestation severity ratings than Imicide and Pointer treatments.

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