Efficacy of Three Citrus Oil Formulations Against *Solenopsis invicta* Buren (Hymenoptera: Formicidae), the Red Imported Fire Ant[1,2]

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ABSTRACT Experiments were conducted in Alabama, Oklahoma, and Texas to assess efficacy of raw citrus peel extract (orange oil) and a commercial citrus oil formulation for control of *Solenopsis invicta* Buren, the red imported fire ant. A recipe containing orange oil (equal parts orange oil, cattlemen's molasses, and compost tea at 47 mL L^{-1} water), orange oil premixed with water to form an emulsion, and the commercial product all resulted in 80% or greater control when applied in 3.8 L of water as a mound drench. In most trials, the level of activity in mounds receiving citrus oil alternatives was statistically comparable with conventional diazinon formulations. Citrus oil alone presented mixing problems prior to application; some possible solutions are discussed. Citrus oil formulations and commercial products appear to be viable alternatives for people who do not wish to apply conventional insecticides against *S. invicta*.

KEY WORDS *Solenopsis invicta*, orange oil, organic, drench

Common methods for managing the red imported fire ant, *Solenopsis invicta* Buren, include broadcast and individual mound treatments with traditional contact insecticides or baits. These approaches may be used alone or in combination to meet specific goals in different areas (Drees et al. 2000). Generally, individual mound treatments provide more rapid, selective control than broadcast treat-

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[2]Mention of trade names or commercial products in this publication is solely for the purpose of providing specific information and does not imply recommendation or endorsement by Auburn University, Oklahoma State University, Texas A&M University, US Forest Service, or the US Department of Agriculture.

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ments but may not yield sufficient control of small, difficult-to-detect colonies. Treatment with contact insecticides yields faster control of individual mounds than bait treatments (e.g., Vogt & Appel 1996), but problems with colony relocation may occur (e.g., Francke 1983, Lemke & Kissam 1987).

Homeowners wishing to use "organic" materials for control of fire ants have limited options. With growing concern over groundwater contamination, nontarget species, and other environmental considerations, more consumers are turning to organic solutions for their pest problems. Despite this increasing interest, many materials purported to control fire ants lack credible scientific data to support claims of efficacy. Extension entomologists are frequently asked to provide "natural" or "organic" recommendations for the control of fire ants (W. A. Smith, Oklahoma Cooperative Extension Service, personal communication). However, relatively few studies of alternative treatment methods for fire ants have been conducted. Drees (2002) demonstrated mortality of fire ants exposed to several plant oil-containing products in the laboratory. Tschinkel & Howard (1980) determined that 3 gallons (11.4 L) of hot water, applied as a mound drench, effectively killed 60% of treated colonies. Drees & Lennon (1998) reviewed "organic" methods of fire ant control.

Orange oil (cold press extract) contains the monoterpenoid d-limonene. The mode of action of d-limonene is similar to that of pyrethrum, affecting sodium flux in the peripheral neurons (Ware 2000). Although "orange oil" and "citrus oil" do not appear specifically on the National List of Allowed and Prohibited Substances [National Organic Program (NOP), US Department of Agriculture, NOP Final Rule (12/21/00)], the rule allows for use of natural compounds that are not specifically excluded. Several insects are susceptible to d-limonene, including honeybee (*Apis mellifera* L.) (Ellis & Baxendale 1997), cat flea [*Ctenocephalides felis* (Bouché)] (Hink & Fee 1986), German cockroach [*Blattella germanica* (L.)], housefly (*Musca domestica* L.), and rice weevil [*Sitophilus oryzae* (L.)] (Karr & Coats 1988). Whole citrus peel extracts, of which d-limonene is the major ingredient, have also been tested against some insects. Lime peel oil is toxic to the cowpea weevil [*Callosobruchus maculatus* (F.)], the maize weevil (*Sitophilus zeamais* Motschulsky), and the hide beetle (*Dermestes maculatus* DeGeer) (Don-Pedro 1996).

The purpose of this study was to evaluate raw citrus peel extract, an organic recipe for fire ant control, and a commercial citrus oil product as mound drenches for control of *S. invicta*. Experiments were designed to (1) compare the organic recipe to its individual ingredients and an organophosphate check; (2) evaluate different rates of orange oil in water; and (3) test the commercial orange oil formulation. Trials were carried out in Alabama, Oklahoma, and Texas.

Materials and Methods

Efficacy of the organic recipe. The organic recipe consisted of equal parts cattlemen's molasses, compost tea (water in which manure has been allowed to steep for a week or more), and orange oil (Garrett 2001). The compost tea used in this and subsequent trials was prepared using primarily goat manure and obtained from a single manufacturer/distributor (Robert Pearson, Red River Organics, Durant, Oklahoma). The orange oil used in these trials was cold press citrus peel extract obtained from a single distributor (Erath Earth Orange Oil, Erath

Earth Holding Company, Erath, Texas). This initial experiment was designed to test the organic recipe (47 mL L^{-1} water; assuming individual ingredients to be 100% active ingredient, 3.8 L 4.7% finished drench) against a water-only control and a diazinon check [Hi-Yield® Imported Fire Ant Killer (12.6% diazinon), Hi-Yield Chemical Company, Bonham, Texas] for rapid reduction in ant activity. The diazinon check was applied per label instructions (7.8 mL L^{-1}; 3.8 L 0.1% finished drench). The study site was an airport in Bryan County, Oklahoma. The areas used for experiments were relatively flat and uniform in moisture and sunlight intensity.

We used a completely randomized design with each treatment replicated 15 times. Fire ant mounds were the experimental unit. Mounds were located, measured across their widest aspect, and marked using forestry flags. All mounds were a minimum of 3 m apart. Before treatment, each mound was evaluated for ant activity by creating a small (1-cm wide × 10-cm long × 2-cm deep) opening in the top with a sharp instrument, and estimating the number of ants appearing in 20 sec. Activity ratings were taken 1 day before treatment, and 1, 3, and 14 days after treatment (DAT). Mounds were sorted according to width before random drawing of treatments to ensure even distribution of treatments across mound sizes. Treatments were applied, and activity ratings taken, in mid-morning (between 0800 and 1000 h) when ants and brood were in the upper part of the mounds (J. T. Vogt, personal observation). All treatments were applied using a sprinkling can; liquid was applied beginning at the periphery of the mound and slowly working inward toward the center. Separate sprinkling cans were used for each treatment. Each mound received 3.8 L of the appropriate insecticide mixture. The organic recipe was premixed in 2-L containers by shaking vigorously before dilution. If a mound received an activity rating of 0, it was excavated and inspected for live or dead ants. The area around each mound was visually inspected for formation of satellite colonies following treatment; if a satellite colony appeared within a 1.5-m radius of a mound it was noted and marked, and sampling proceeded on the new mound. Data were analyzed using repeated measures analysis of variance followed by a Ryan-Einot-Gabriel-Welsch Q test (SAS Institute 1985) for mean separation.

Efficacy of the organic recipe and its individual ingredients. This trial was designed to test the individual ingredients of the organic recipe for activity against fire ants. We used a completely randomized design replicated 12 times, with fire ant mounds as the experimental units. Study site, marking of mounds, and activity ratings were all as described above. Activity ratings were taken 1 day before treatment, and 1, 3, 7, and 14 DAT. Treatments included: a water-only control, the organic recipe (47 mL L^{-1}), a diazinon check (as above), orange oil (15.7 mL L^{-1}), compost tea (15.7 mL L^{-1}), and cattlemen's molasses (15.7 mL L^{-1}). The concentrations used were chosen because they correspond with the concentration of each ingredient in the organic recipe; individual ingredients, assuming 100% active ingredient, were applied as 3.8 L of 1.6% finished drench. Mixing was done on-site by placing the measured amount of the appropriate ingredient into a standard sprinkler can, adding water to bring the volume to 3.8 L (1 gal), and stirring. A separate sprinkling can was used for each treatment. Data were analyzed as described above.

Efficacy of three rates and volumes of orange oil. Because there are no data upon which to base concentration or volume recommendations for orange oil treatments, we designed an experiment to test three rates and three volumes of orange oil. Mounds were arranged by width, as above, before assigning treatments by random drawing. Treatments were: a water only control, a diazinon check (as above), orange oil at 15.7 mL L^{-1} (1.9 L 1.6% finished drench), orange oil at 15.7 mL L^{-1} (3.8 L 1.6% finished drench), orange oil at 15.7 mL L^{-1} (7.6 L 1.6% finished drench), orange oil at 7.8 mL L^{-1} (3.8 L 0.8% finished drench), and orange oil at 31.2 mL L^{-1} (3.8 L 3.1% finished drench). Study site, marking of mounds, mixing of materials, activity ratings, and data analysis were all as described above.

Efficacy of premixed orange oil and compost tea with molasses. We hypothesized that mixing problems observed during the above trials may have resulted in poor control, so an additional experiment was designed to test orange oil premixed with an equivalent amount of water and then shaken vigorously to form an emulsion prior to mixing in the field. We also determined whether the combination of compost tea and molasses (1:1) at 3.1 mL L^{-1} exhibited any control activity. To prepare the orange oil emulsion, equal parts orange oil and water were placed in 2-L containers and shaken for approximately 30 sec. The emulsion was placed in water at 31.2 mL L^{-1}, resulting in a 15.7 mL L^{-1} orange oil treatment (applied at 3.8 L $mound^{-1}$, 1.6% finished drench). Other treatments included a water-only control, the orange oil recipe (47 mL L^{-1}, 3.8 L 4.7% finished drench), and a diazinon check (as above). Study site, marking of mounds, mixing of materials, activity ratings, and data analysis were all as described above.

Efficacy and satellite mound formation. This trial was conducted in an open field in Lee County, Alabama, and combined mound activity and satellite mound formation into a scoring system to analyze effectiveness of the orange oil emulsion. The emulsion was prepared as described above. Treatments were: water-only control, a diazinon check (Ortho® Diazinon Ultra™; 22.4% diazinon; 3.8 L 0.18% finished drench), and orange oil at 7.8 mL L^{-1} (3.8 L 0.8% finished drench), 15.7 mL L^{-1} (3.8 L 1.6% finished drench), and 31.2 mL L^{-1} (3.8 L 3.1% finished drench). The experimental design was a completely randomized design replicated 12 times, with mounds as experimental units. Treatments were applied during morning hours, when ants and brood were nearest the tops of mounds (T. G. Shelton, personal observation). Mounds were scored according to the system summarized in Table 1. Mounds were scored at 1, 3, 5, 7, 14, 21, and 28 DAT. Data were subjected to repeated measures analysis of variance using the day of sampling and treatment as classification variables, followed by the Ryan-Einot-Gabriel-Welsh Q test for mean separation (SAS Institute 1985).

Efficacy of a commercial orange oil formulation. This trial was conducted in an open field at Dallas Fort Worth International Airport (Tarrant County, Texas) and was designed to quantify satellite mound formation and/or re-infestation of treated areas following mound drenches with a water only control, an untreated control, Garden–Ville Soil Conditioner (30% citrus oil; Garden-Ville, 7561 East Evans Rd., San Antonio, Texas; 47 mL L^{-1}; 1.4% citrus oil finished drench), and a diazinon check (Evict®, 56% diazinon; 6.6 mL L^{-1}; 0.37% finished drench). Plots (n = 16) [12.2 m wide, varying length (range = 8.5 to 89 m)], each containing 10–13 active *S. invicta* mounds, were established and blocked by size, resulting in a randomized complete block design replicated 4 times. All treatments were applied at a volume of 3.8 L $mound^{-1}$, with the exception of the untreated control. Mounds were scored according to a rating scale

Table 1. Scoring system used to evaluate *S. invicta* mounds in satellite mound study following drench treatments (water-only control, diazinon, citrus oil recipe).

Score[a]	Treated mound active?	Number of new mounds <1.5 m away
1	No	0
2	No	1
3	No	2
4	Yes	0
5	Yes	1
6	Yes	2

[a]No mound in the study ever scored a 6, and score 3 only occurred once.

modified from Lofgren & Williams (1982), where 1 = small mounds (<100 ants) and 5 = large mounds (>50,000 ants); colonies in which no ants were detected during sampling received a 0. Mounds were counted and scored 1 day prior to treatment, and 1, 3, 7, 14, and 28 DAT. Original mounds were marked with forestry flags at the beginning of the trial, and all mounds within a plot were counted thereafter. Additional mounds indicated satellite mound formation and/or immigration into the plots. Mound scores and number of mounds per lot were analyzed with sampling day treated as a split-block, using PROC MIXED in SAS followed by least squares means for mean separation (Littell et al. 1996).

Results

Efficacy of the recipe. One mound slated for diazinon treatment was accidentally driven over prior to treatment and was excluded from the experiment. Both the diazinon and orange oil recipe provided rapid control of colonies (Fig. 1), resulting in significantly lower ant activity in treated mounds (F = 21.9, df = 2, 41, $P < 0.0001$). Activity ratings were not different prior to treatment ($P > 0.05$), and diazinon- and recipe-treated mounds had statistically indistinguishable activity following treatment ($P > 0.05$). Two satellite mounds were noted during the experiment, one nearest a colony treated with diazinon and one nearest a colony treated with the recipe.

Efficacy of the organic recipe and its individual ingredients. Mound activity ratings were significantly reduced by orange oil, organic recipe, and diazinon treatments over the course of the experiment (F = 7.23, df = 5, 54, $P < 0.0001$; Fig. 2). Activity ratings for mounds treated with molasses and compost tea were not significantly different from control ratings at any time ($P > 0.05$). Some rebound in activity level was observed in the orange oil treated mounds. Two treatments (orange oil and organic recipe) each had two apparent mound relocations.

Efficacy of three rates and volumes of orange oil. Treatments significantly reduced mound activity during the course of the experiment (F = 7.9, df = 6, 72, $P < 0.0001$; Table 2). By the end of the trial (14 DAT), orange oil at 15.7 mL

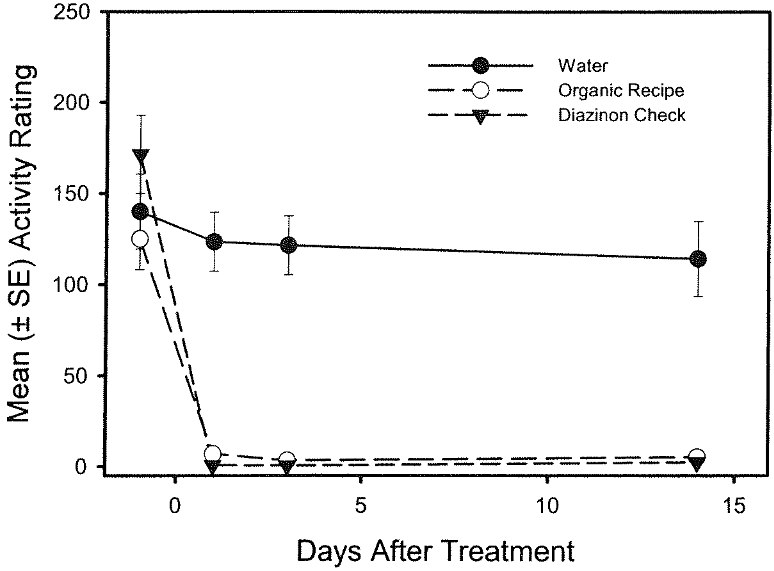

Fig. 1. Activity ratings (mean number of ants on surface 20 sec after disturbance) for *S. invicta* mounds drenched with water, an organic recipe, or a diazinon formulation.

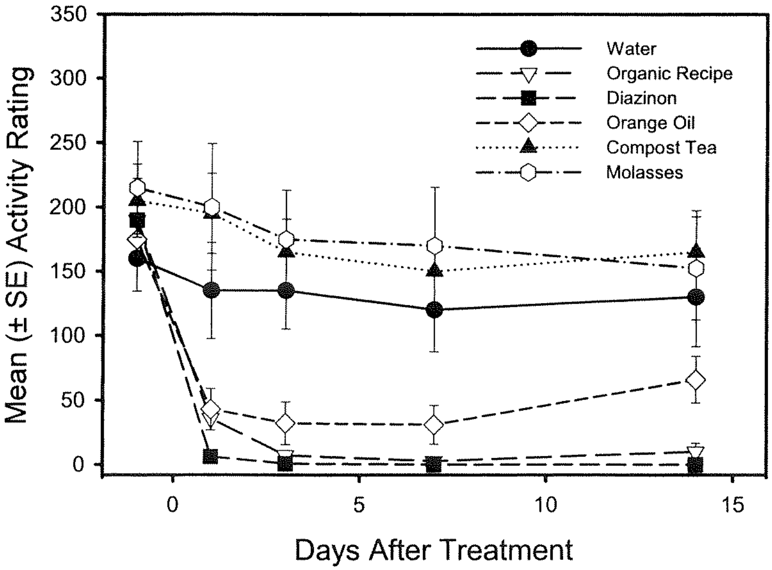

Fig. 2. Activity ratings (mean number of ants on surface 20 sec after disturbance) for *S. invicta* mounds drenched with an organic recipe, the recipe's individual ingredients, a diazinon check, or a water-only control.

Table 2. Effects a diazinon drench, three orange oil drench rates, and three orange oil drench volumes on *S. invicta* activity.

Treatment (volume, rate)	Mean (± SE) activity rating[a] at DAT[b]				
	−1[c]	1	3	7	14
Control (water only, 3.8 L)	335 ± 35a	230 ± 43a	213 ± 40a	225 ± 47a	175 ± 39a
Diazinon (3.8 L 7.8 mL L^{-1})	330 ± 43a	2 ± 2b	1 ± 1b	35 ± 25b	22 ± 13b
Orange oil (1.9 L 15.7 mL L^{-1})	295 ± 28a	24 ± 10b	68 ± 36b	106 ± 42b	82 ± 28ab
Orange oil (3.8 L 15.7 mL L^{-1})	338 ± 25a	19 ± 8b	17 ± 11b	77 ± 23b	74 ± 22ab
Orange oil (7.6 L 15.7 mL L^{-1})	305 ± 40a	4 ± 2b	56 ± 34b	59 ± 41b	40 ± 35b
Orange oil (3.8 L 7.8 mL L^{-1})	355 ± 38a	34 ± 15b	55 ± 29b	33 ± 20b	45 ± 23b
Orange oil (3.8 L 31.4 mL L^{-1})	305 ± 38a	20 ± 13b	11 ± 7b	0 ± 0b	8 ± 5b

[a]Mean number of ants appeairng on surface of mound 20 sec after disturbance.
[b]Means in a column followed by the same letter are not significantly different (Ryan-Einot-Gabriel-Welsch Q test, $P > 0.05$).
[c]Pretrial rating.

L^{-1} applied at volumes of 1.9 L and 3.8 L were statistically indistinguishable from the control ($P > 0.05$). A single mound with high levels of activity following treatment could skew the data; however, in this trial 45% of colonies treated with orange oil (total drench volume 3.8 L) at 15.7 mL L^{-1} survived by inhabiting the periphery of the treated mound or moving a short distance (<1 m) away. Diazinon eliminated ant activity in 70% of colonies, and orange oil (3.8 L) at 31.2 mL L^{-1} eliminated 80%.

Efficacy of premixed orange oil and compost tea with molasses. Treatments reduced ant activity ratings through the course of this trial ($F = 15.9$, df = 4, 44, $P < 0.0001$; Fig. 3). The molasses with compost tea treatment had an intermediate effect on ant activity, which was lower than control and higher than other treatments on every post-treatment sampling date but the last ($P < 0.05$). By 21 DAT, molasses with compost tea was indistinguishable from the control and other treatments; other products resulted in significantly less ant activity than the control ($P < 0.05$).

Efficacy and satellite mound formation. Mean (± SE) scores (Table 1) for all treatments appear in Fig. 4. Although there was no time by treatment interaction ($F = 1.25$, df = 4, 20, $P = 0.2115$), there were significant interactions for the treatment ($F = 1.73$, df = 5, 55, $P = 0.0023$) and for the time of treatment ($F = 6.35$, df = 5, 20, $P = 0.0001$). For time, only the first day was significantly different, indicating that the orange oil treatments were more similar to water than diazinon at 1 DAT (see Fig. 4). The remaining days were not significantly

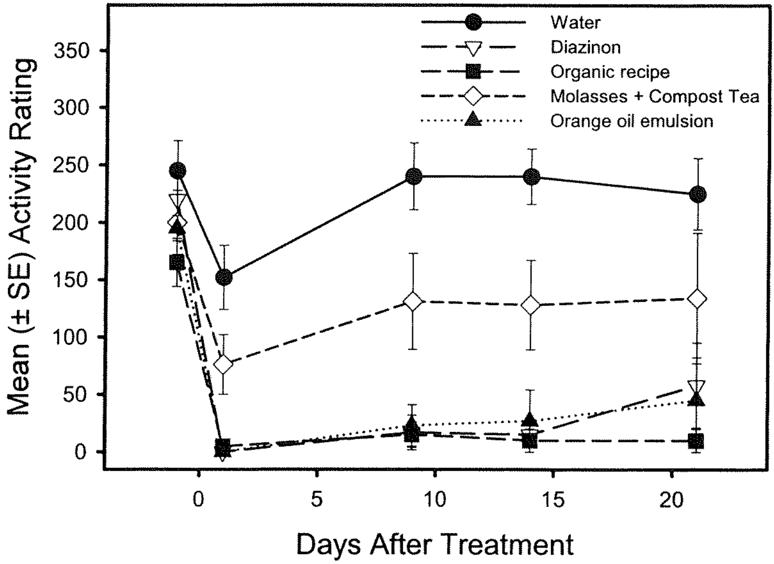

Fig. 3. Activity ratings (mean number of ants on surface 20 sec after disturbance) for *S. invicta* mounds drenched with an organic recipe, cattlemen's molasses with compost tea, an orange oil emulsion, or a diazinon check.

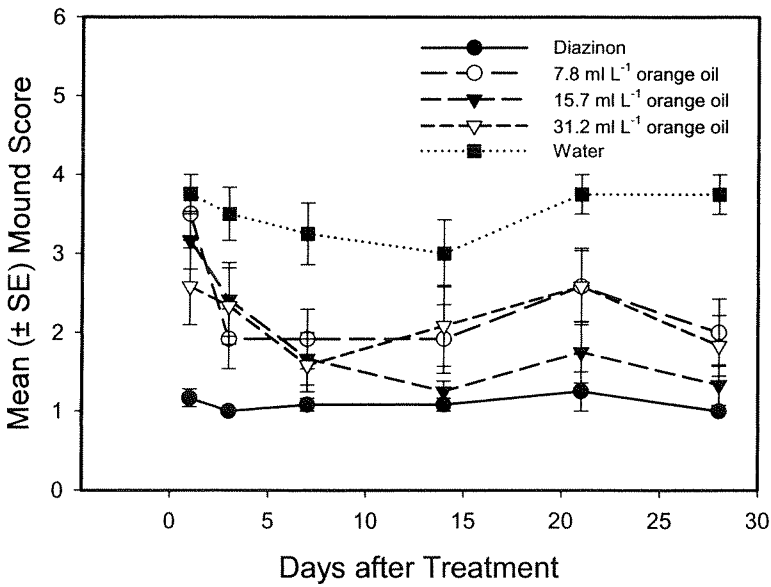

Fig. 4. Activity scores (see Table 1) for *S. invicta* mounds drenched with three different rates of orange oil, a diazinon check, and water-only control.

different, indicating that there is a time lag for the effects of orange oil on fire ant activity compared with diazinon.

Efficacy of the commercial orange oil formulation. For this experiment, a split block analysis was more efficient than repeated measures, based on a comparison of overall model fit with –2 Residual Log Likelihood. Mean (± SE) scores for all treatments appear in Fig. 5. Over the course of the experiment, the fixed effects of treatment ($F = 21.7$, df = 3, 10, $P = 0.002$), day ($F = 26.4$, df = 5, 15, $P < 0.001$), and treatment by day ($F = 5.5$, df = 15, 1,130, $P < 0.0001$) all contributed significantly to variability in the data. F-values for the treatment by day term changed with time and indicated the strongest effect at 3 DAT. This trend reflects activity level rebound in the diazinon treatment, as well as some decline in control ratings. Overall, diazinon provided slightly better control than Garden–Ville ($t = -2.51$, df = 9, $P = 0.033$), but Garden—Ville performed significantly better than no treatment ($t = 4.6$, df = 9, $P = 0.0013$) or water ($t = -4.1$, df = 9, $P = 0.0031$).

Treatments significantly reduced number of mounds per plot over the course of the experiment ($F = 38.0$, df = 3, 9, $P < 0.0001$; Table 3). By day 28, the number of mounds in Garden-Ville plots was statistically indistinguishable from the number in plots assigned diazinon ($t = -1.4$, df = 37, $P = 0.17$).

Discussion

Premixed orange oil, the organic recipe, and Garden–Ville Soil Conditioner all effectively killed >70% of *S. invicta* colonies in these trials. If drenched mounds are considered separately from any satellite or immigrant mounds in these stud-

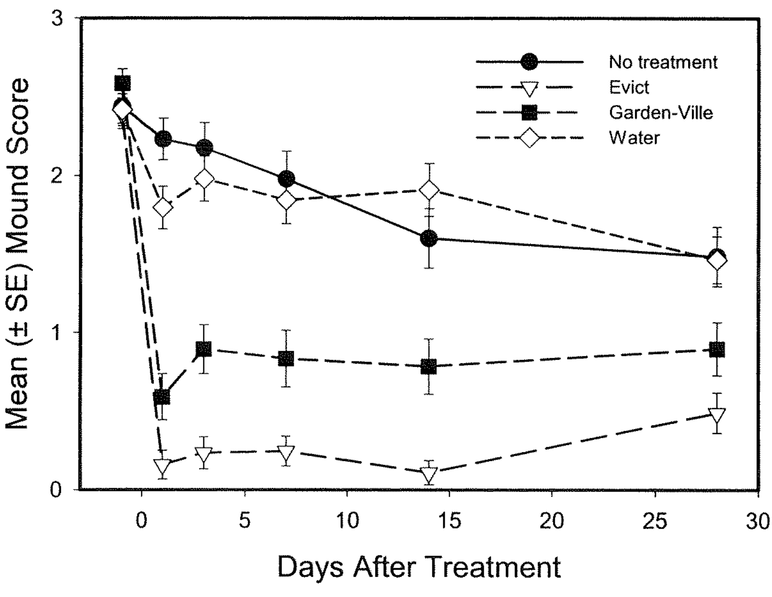

Fig. 5. Mean mound scores for *S. invicta* mounds drenched with Garden-Ville Soil Conditioner, Evict (diazinon), water only, or nothing.

Table 3. Mean number of active *S. invicta* mounds present in plots where mounds were drenched with water only, Evict® (diazinon), Garden–Ville Soil Conditioner (orange oil), or an untreated control.

	Mean (± SE) number of active mounds per plot at DAT[a]					
Treatment	−1[b]	1	3	7	14	28
No treatment	10.3 ± 0.3a	10.0 ± 0.4a	9.8 ± 0.6a	9.0 ± 1.5a	8.3 ± 1.7a	8.3 ± 1.3b
Water	10.8 ± 0.5a	11.3 ± 0.9a	10.8 ± 1.0a	10.3 ± 0.5a	10.5 ± 1.2a	11.0 ± 1.4a
Garden–Ville	10.3 ± 0.3a	3.8 ± 0.9b	5.3 ± 1.5b	4.0 ± 0.4b	4.0 ± 0.7b	5.3 ± 0.9c
Evict	10.3 ± 0.3a	0.8 ± 0.3c	1.5 ± 0.5c	1.8 ± 0.9b	0.5 ± 0.5c	3.5 ± 1.2c

[a]Means in a column followed by the same letter are not significantly different (Least Squares Means, $P > 0.05$).
[b]Pretrial rating.

ies, orange oil in water (stirred) eliminated ~30% of colonies at the lowest volume and rate versus ~80% at the highest volume and rate. Orange oil premixed in water as an emulsion eliminated ~80% of colonies. The organic recipe eliminated ~85% of colonies and the Garden–Ville product eliminated ~87% of colonies. Diazinon formulations resulted in ~75–100% control. Other individual mound control trials using various contact insecticides have yielded similar levels of control (e.g., Lemke & Kissam 1987, Morrill 1977). Decline in activity ratings for control mounds (Fig. 5) may have been due to colony decline during unseasonably hot and dry weather in 2000, or could be a result of ants becoming acclimated to repeated disturbance caused during sampling.

We are aware of three ways that proponents of organic pest control explain the rationale for application of compost tea and molasses. One explanation is that "fire ants hate molasses." This seems to contradict what is known about pesticide efficacy and the possible disadvantages of repellence. The second is the idea that microbes in the compost tea will be more effective at infecting and killing the fire ants if molasses is present for them to feed on. No data exist characterizing microbes in compost tea and whether those microbes are capable of infecting fire ants. Finally, molasses may have some surfactant effect. Compost tea is difficult to characterize and standardize; however, for the purposes of our experiments, a single provider was used who is consistent in his preparation of the material (Robert Pearson, Red River Organics, Durant, Oklahoma, personal communication). The Garden–Ville product, although not a registered pesticide, is sold as a soil conditioner with fire ant control properties.

Individual mound treatments for *S. invicta* can provide rapid control of colonies, but are not suitable for longer-term control over large areas. Re-infestation of treated areas or rebound of some treated colonies can be seen in Figs. 2, 3, and 5 for various materials tested. For the most part, the organic recipe and orange oil formulations provided levels of control that were statistically indistinguishable from diazinon formulations, though in many cases activity was numerically higher and control was somewhat slower in orange oil treatments. Caution should be used when considering citrus oil alternatives, as they can be toxic to cats (Hooser 1990) and the major component, d-limonene, is a neurotoxin. A rate of 15.7 mL L^{-1} appears to be sufficient, so long as the orange oil is premixed to form an emulsion prior to dilution. A teaspoon of dishwashing liquid has been suggested as a possible emulsifying agent to add to orange oil drenches, but efficacy data are not currently available.

Mound movement and satellite mound formation following treatment could be caused by the treatments themselves or the method used to rate mounds. *S. invicta* colonies periodically relocate and/or form satellite mounds under natural conditions as well (Hays et al. 1982); even under the best conditions, it is difficult to separate natural movement from relocation induced by various stimuli. Data on possible repellence of the compounds tested are not available for ants; however, emigration to the mound periphery as noted in one trial may be due to repellent effects of the materials used.

Costs of the products used in these studies are provided in Table 4. Cost of raw orange oil and citrus products is generally higher than the cost of conventional insecticides. For example, Garden–Ville (946 mL) costs almost six times more than Evict® (946 mL) on a per-mound basis; however, some homeowners are willing to pay more for alternative means of controlling fire ants (W. A. Smith, personal communication). The data presented herein indicate that viable alternatives are available in the form of citrus oil products. The same care should be taken to time applications for maximum effect (e.g., drenching mounds on cool, sunny mornings) as when applying conventional insecticides. Safety considerations include eye protection, non-absorbent rubber gloves, long-sleeved shirt and long pants. Orange oil was observed to react with a plastic measuring cup used in some of these trials, so care should be taken not to spill it on plastic surfaces, and a metal or glass-measuring device should be used.

Table 4. Cost analysis of products used for *S. invicta* mound drenches.

Product	Cost[a]	Size	Number of mounds treated	Cost per mound
Erath Earth Orange Oil	\$18.95	0.95 L	16 at 15.7 mL L^{-1}	\$1.18[b]
Erath Earth Orange Oil	\$52.99	3.8 L	64 at 15.7 mL L^{-1}	\$0.83
Cattlemen's Molasses	\$6.00	3.8 L	64 at 15.7 mL L^{-1}	\$0.09
Compost Tea	\$3.00	3.8 L	64 at 15.7 mL L^{-1}	\$0.05
Garden–Ville Soil Conditioner	\$11.95	0.95 L	5.3 at 47.1 mL L^{-1}[c]	\$2.25
Garden–Ville Soil Conditioner	\$16.95	3.8 L	21 at 47.1 mL L^{-1}	\$0.80
Evict® (diazinon)	\$14.19	0.95 L	37 at 6.6 mL L^{-1}	\$0.38
Evict® (diazinon)	\$43.61	3.8 L	151 at 6.6 mL L^{-1}	\$0.29
Ortho® Diazinon Ultra™	\$13.95	0.95 L	32 at 7.8 mL L^{-1}	\$0.44
Hi-Yield® (diazinon)	\$17.14	0.95 L	32 at 7.8 mL L^{-1}	\$0.53

[a]Price at time of purchase.
[b]Cost when applied with molasses and compost tea = \$1.32 per mound.
[c]A 23.6 mL L^{-1} rate is also recommended by retailer, reported as tested.

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