Butyl Carbitol Acetate as an Ant Repellent on the Pecan Tree Trunk[1]

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Abstract 2 – (2 – butoxyethoxy) ethyl acetate (butyl carbitol acetate), an animal repellent, was found to repel red imported fire ants, *Solenopsis invicta* (Buren), in trail blocking, pickup, and trail to source bioassays. Butyl carbitol acetate effectively prevented worker ants from trailing up the trunk of pecan trees for 1 wk and reduced foraging for 2 wks after application. Butyl carbitol acetate and farnesol were more effective than neem extract, methyl myristate, methyl anthranilate, and Tanglefoot® (The Tanglefoot Co., Grand Rapids, MI) in restricting ants from crossing a trunk barrier. Also, application of the repellents dissolved in wax-slurry and applied directly to the trunk was more effective than application to a wax-covered Kraft paper (Food Services Direct, Hampton, VA) band. Wax-covered strings amended with the repellents and tied around the trunk were similar in effectiveness to the waxy slurry band.

Key Words Ant foraging, *Solenopsis invicta*, *Carya illinonensis*, ant trail blocking

Preventing red imported fire ants, *Solenopsis invicta* (Buren) (Hymenoptera: Formicidae), from foraging within the canopy of pecan trees [*Carya illinonensis* (Wangh.) K. Koch] prevents these ants from interfering with aphidophagous insects, thus disrupting naturally-occurring biological control of pecan aphids (Dutcher 1995). Commercial growers currently attempt to control fire ants with ant baits, mound drenches (Tedders 1985) or by treating the trunks with chlorpyrifos (Dutcher 2004). The latter approach conserves ants as primary predators of pest life stages on the orchard floor, such as pecan weevil, *Curculio caryae* (Horn) (Dutcher and Sheppard 1981) and southern green stink bug, *Nezara viridula* (L.) (Kryspin and Todd 1982).

The pecan tree trunk is an important refuge for aphidophaga (Mizell and Schiffhauer 1987); treatment with chlorpyrifos can be detrimental to these aphid predators. Research is needed to find a practical method of repelling fire ants without harming aphidophaga. Certain glycol ethers, including 2 – (2 – butoxyethoxy) ethyl acetate (butyl carbitol acetate) (CAS No. 124-17-4), are patented for use as inexpensive animal repellents (Saijo 1985). Trunk barriers consisting of strings treated with farnesol or methyl myristate disrupt "trail following" by Argentine ants, *Linepithema humilis* (Mayr), on citrus trees (Shorey et al. 1992) and offer evidence for a potentially

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successful approach involving strings soaked with animal repellents. The objective of the research reported herein was to determine the repellency of butyl carbitol acetate to red imported fire ants in laboratory bioassays and to evaluate its potential in the field as an alternative trunk treatment to chlorpyrifos. We also compared trunk bands treated with butyl carbitol acetate, farnesol, methyl myristate, neem extract, methyl anthranilate, and Tanglefoot-trap Coating® (The Tanglefoot Co., Grand Rapids, MI) for the ability to restrict ant foraging in pecan trees.

Materials and Methods

Red imported fire ant colonies were collected in the field by shoveling out the main portion of the colony with two opposed shovels in one scoop and placing it in a 20-L white plastic bucket (Banks et al. 1981). Ants were held in the buckets by treating the inner surface of the top 10 cm with a band of Fluon GP1® (Whitford Worldwide, Frazer, PA) applied as a liquid and dried before the ants were placed in the bucket. Ants were fed various foods ad libitum – dead frozen insects, dried pecan nuts, 5% sugar water, and tap water. Five ant colonies in buckets were used in the trials and each colony was placed on a laboratory bench. A sheet of glass (70 × 25 cm) was set up below and to the side of each colony on cement blocks in plastic buckets with tap water in the bottom to a depth of 20-30 cm. The short end of a Γ-shaped strip of wood was pushed into the ant colony, and the long end was placed on top of the glass surface so the ants could forage from the colony to the glass surface using the wood strip.

Bioassays. The repellency of butyl carbitol acetate was measured in three laboratory bioassays. Air temperature in the laboratory ranged from 26° to 28°C and fluorescent lights over the bioassays ranged from 470-700 lux. Bioassays were run on the glass sheets. First, in the trail blocking bioassay, ants were allowed to trail to a food source of 5% honey water held in an open, cylindrical, shallow (6 mm deep) glass well (20 mm diam.) glued to a standard microscope slide (25 X 75 mm). Donut-shaped pieces of Whatman No. 2 filter paper were cut to fit loosely around the well (internal diam 21 mm, external diam 24 mm). Five concentrations of butyl carbitol acetate in pentane (0.01, 0.1, 1.0, 10.0, 100.0 μL/ml) were applied to the filter paper pieces by dipping the pieces in the solutions. The repellency of each concentration was measured by observing ant behavior after the pieces of paper were placed around the well. One treated slide and one untreated control slide were placed on each of the five glass sheets. Before each treatment ants were removed from the well by first blocking the trail with a piece of pine wood (30 by 3.8 cm and 6 mm thick) set on its edge and placed 60 cm from the well and brushing away the ants between the wood piece and the well. The pentane was evaporated from the paper before the paper was used for the bioassay. The treated pieces of paper were then placed over the well, and the ants were allowed to reform the trail to the well by removing the wood piece. Ants were observed for 15 min afterward; an ant was considered to be repelled if it did not completely cross the treated piece of paper to the edge of the well. Each treatment was replicated five times.

Second, a pick up bioassay was conducted in the laboratory where colonies of red imported fire ants were allowed to forage on pieces of a commercially prepared wheat germ that were treated with a series of concentrations of butyl carbitol acetate and placed in a grid. The grid was a plexiglass (6.6 mm thick) box (16 × 16 × 2.2 cm) with a removable lid. A paper treatment map was placed in the bottom covered with a plastic grid (14 × 14 cm) commonly used to cover fluorescent lighting with 100 cells (13 × 13 mm with 10 × 10 cells/grid). Concentrations of the repellent were prepared by mixing 0, 20, 40, 60 or 100 μL/g of butyl carbitol acetate in 1 ml of pentane and mixing in 1 g of wheat germ. The treated wheat germ pieces were selected for uniform size so that ants could easily carry them off of the grid. The selected pieces were placed singly in the cells of the grid over the treatment map. Treatments were assigned to cells at random and labeled on the map. The 20 replications (wheat germ pieces) of the 5 concentrations were arranged on a single grid. A grid was placed on each of the glass sheets previously described. Sixteen grids were observed with 320 wheat pieces per treatment.

Third, a trail to source bioassay was conducted for 48 h to determine the longevity of the repellency of butyl carbitol acetate. The food source was the same as in the trail blocking bioassay; the repellent was a 10% solution of butyl carbitol acetate in pentane applied to a donut shaped piece of filter paper as described above. Two food sources were placed 21 cm apart in each pair on the sheet glass (i.e., one with a repellent-treated piece of paper and one with a pentane-treated paper). Each sheet of glass had three pairs of food sources. One glass sheet was connected to each of three colonies for a total of nine pairs of food sources. Glass sheets were triple rinsed in tap water and finally rinsed in acetone between each type of bioassay to remove any traces of chemicals from the previous experiment. The treatments were set, and the ants were allowed to forage on the glass sheets by placing the Γ-shaped wooden strips to connect the colonies to the glass sheets. Ants were counted at the edge of the well of each food source at 1, 2, 3, 4, 5, 9, 12, 24, and 48 h. after the ants were connected to the bioassay. Between 24 and 48 h, ants from one of the colonies completely destroyed (shreaded and carried away) the paper pieces of the bioassay so that the readings at 48 h were based on six replications on two colonies. Data were statistically analyzed by ANOVA, LSD and linear regression (Hood 2004) to further describe the treatment effects.

Field trials. Two field trials were established to determine the residual action of four trunk treatments designed to repel ants from the tree crown with a trunk band. The bands were constructed in three ways: (1) Kraft paper (Food Services Direct, Hampton, VA) 15 cm wide, long enough to circumvent the tree trunk, was folded lengthwise at 5 and 10 cm to form a band 5 cm wide with three layers of paper; (2) strings cut from a hemp twine were treated, wrapped, and tied around the tree trunk; and, (3) wax treated with the repellent was spread directly onto the trunks. Paper bands and hemp twine strings were soaked in a mixture of hot waxes – 50% beeswax and 50% paraffin wax – drawn out of the wax and allowed to cool to room temperature. The beeswax gave the band or string sufficient flexibility to bend it around the tree trunk. Repellent chemicals were applied as pure chemical with a paint bush to the entire inner and outer surface of the bands (~3ml/band) and strings (~0.6 ml). Methyl anthranilate was mixed with Tween 60® (trademark registered to ICI Amerias, chemical source Aldrich Chemical Co. Milwaukee, WI, CAS No. 9,005-67-8) (0.1 ml Tween 60-3ml methyl anthranilate) before applying it to the wax surface so that this chemically polar compound would spread evenly across the surface. After removing the loose bark from around the area of the tree trunk to be banded, repellents were applied as follows. Band barriers were affixed by wrapping them tightly around the trunk, holding the ends of the bands with two thumb tacks, tying a string around the middle of the band and trunk, and removing the thumb tacks. String barriers were tied around the trunk and the excess string removed. The wax-slurry barrier was spread around the circumference of the tree trunk in a 5 cm wide band with a paint brush. Hot wax was blended with Tween 60 (50 ml beeswax: 50 ml paraffin wax: 4 ml Tween 60) to form the wax-slurry, and after cooling to room temperature, it was amended with 4 ml of the repellent treatment. Then each banding type was tested in a separate trial. Treatments for the string barriers were: control – wax coated string without a repellent; farnesol (CAS No. 4,602-80-0, 95% pure, Aldrich Chemical Co., Milwaukee, WI); methyl myristate (CAS No124-10-7, 99% pure, Aldrich Chemical Co., Milwaukee, WI); methyl anthranilate (CAS No134-20-3, 99% pure, Aldrich Chemical Co., Milwaukee, WI); butyl carbitol acetate (CAS No. 124-17-4, 97% pure Fluka Chemie AG, Basal, Switzerland); Trilogy® 70% neem extract (active ingredient azadirachtin (CAS No. 1141-17-6), Certis USA, Columbia, MD); Tangletrap-trap coating aerosol spray. Treatments for the band barrier were: control – wax band without a repellent compound, farnesol, methyl anthranilate, and butyl carbitol acetate. Treatments for the slurry barrier were: control – wax slurry only, farnesol, methyl anthranilate, and butyl carbitol acetate. In each trial, four single tree replications were treated in a completely randomized design in a 16-yr-old pecan orchard planted to the cultivar 'Desirable' with a tree density of 60 trees/ha. Ant behavior on the treated tree trunks was recorded at 1 d and 1 wk after the bands were applied. Different types of ant behaviors were observed for 25 ants per replication. The behavior types were: number of ants on the ground from the trunk and out 15 cm from the trunk, number of ants crawling below the barrier, number of ants crawling above the band, and number of ants crawling completely across the barrier.

Results and Discussion

The trail blocking bioassay (Table 1) indicated that a 10% (100µl/ml) solution of butyl carbitol acetate (97% pure) was sufficient to repel red imported fire ants from following a previously established trail to a food source. Only 2% of the ants crossed the repellent paper strip treated with a 1% (10µl/ml) solution, and continued to follow the trail. Ant repellency was significantly lower at lower concentrations of butyl carbitol

Table 1. Repellency of butyl carbitol acetate to red imported fire ant in a trail blocking bioassay

Concentration (C) (ppt, µl/ml)*	No. ants observed**	Percentage of ants repelled (R)
0	693	48.3
0.01	344	58.7
0.10	337	56.1
1.00	333	88.6
10.00	201	98.0
100.00	218	100.0

* µl of butyl carbitol acetate (100% pure solution) solute per ml of pentane solvent.

** Variation in the number of ants observed in four replications of each treatment was due to variability in ant activity between colonies. Repellency (R) was linearly and significantly (P = 0.0032, r^2 = 0.8200, df = 18) related to $\log_{10}$ of the concentration (log(C)).

Regression equation is: R = 0.1245 ($\log_{10}$(C)) +0.8028.

acetate. Butyl carbitol acetate repelled red imported fire ants from solid food particles at 0.1 ml repellent per gram of wheat germ (Table 2). Food particles treated with 0.06 ml repellent/gram of wheat germ or less did not prevent ants from picking up all the food particles. The 10% concentration repelled ants consistently for 48 h indoors (Table 3).

In the field trials, butyl carbitol acetate was the same or significantly better at repelling ants on the pecan tree trunk than the commonly used ant repellents. Strings treated with Tanglefoot, methyl anthranilate, methyl myristate and butyl carbitol acetate at the same concentrations were more repellent than the control at 1 wk post treatment (Table 4). All treatments, and the control, had similar ant abundance on the ground and on the trunk below the string. Ants were more abundant above the string on trunks treated with repellent-treated strings than in the control. Ants would not cross the strings treated with methyl anthranilate, methyl myristate and butyl carbitol acetate. A few ants were able to cross the Tanglefoot-treated string by crawling over ants previously stuck in the Tanglefoot. The formulation of the repellents as a wax-slurry band painted on the trunk was only repellent to the red imported fire ants when the repellent was butyl carbitol acetate. Repellency lasted at least 2 wks after treatment (Table 5). Ant abundance was significantly higher above the treated band in the farnesol and butyl carbitol acetate treated trees at 1 wk and 2 wk post treatment. Significantly fewer ants walked onto the treated band in the farnesol or methyl carbitol acetate than in the control or methyl myristate treated trees after 1 wk. Abundance was similar in the control, and all repellent treatments on the trunk below the treated band 1 wk and 2 wk after treatment. Significantly fewer ants walked completely across the treated band in the farnesol than in the control treated trees. Significantly fewer ants crossed the band. Significantly more ants would not walk onto the band treated with butyl carbitol acetate during 1 wk and 2 wk post treatment than any other treatment. Significantly fewer ants would walk onto the bands treated with farnesol and methyl myristate than the control during 1 wk and 2 wk post treatment. Application of all repellents tested (Table 6) on wax-covered Kraft paper bands was effective for 1 d after treatment, and significantly fewer ants crossed completely over the bands treated with Trilogy, butyl carbitol acetate and Tanglefoot than the untreated control band and bands treated with methyl myristate and methyl anthranilate at 7 days post

Table 2. Repellency of butyl carbitol acetate to red imported fire ant in a pickup bioassay

Concentration (µl/g)*	Particles picked up after 1 h of foraging (%)**
0	99
20	70
40	53
60	16
100	0

* µl of butyl carbitol acetate (100% pure solution) per gram of dried wheat germ.

** A piece of wheat germ (n = 320) was counted as 'picked up' if it was carried completely off the grid. Repellency (R) was linearly and significantly ($P = 0.0445$, $r^2 = 0.9130$, n = 16) related to concentration (C). Regression equation is: $R = -0.904(C) + 84.48$.

Table 3. Repellency of butyl carbitol acetate to red imported fire ant in a trail to source bioassay

Time (hr)	Treatment	Feeding ants (Number)	Temperature (°C)	Light (lux)
1	Control	21	28	550-700
	Butyl carbitol acetate (10%)	0		
2	Control	11	28	500-700
	Butyl carbitol acetate (10%)	0		
3	Control	16	28	550-700
	Butyl carbitol acetate (10%)	0		
4	Control	20	27	600-700
	Butyl carbitol acetate (10%)	0		
5	Control	39	28	550-700
	Butyl carbitol acetate (10%)	0		
9	Control	29	26	520-700
	Butyl carbitol acetate (10%)	0		
12	Control	33	26	470-550
	Butyl carbitol acetate (10%)	1		
22	Control	9	27	500-650
	Butyl carbitol acetate (10%)	0		
24	Control	21	27	550-700
	Butyl carbitol acetate (10%)	0		
48	Control	17*	28	540-680
	Butyl carbitol aetate (10%)	0		

* Based on six of nine replications. Ants destroyed the integrity of three replications.

Table 4. Timed observation of ant behavior on and near the trunks of pecan trees treated with a string soaked in the indicated repellent 1 week after treatment

	Number of ants exhibiting indicated behavior in two min.			
Treatment	On ground	Below band	Above band	Crossing band
Control	22 a	6 a	5 b	9 a
Tanglefoot®	28 a	8 a	15 a	2 b
Methyl myristate	23 a	9 a	16 a	0 b
Butyl carbitol acetate	20 a	6 a	19 a	0 b
Methyl anthranilate	21 a	6 a	18 a	0 b

Means in the same column and followed by the same letter are not significantly different (ANOVA, LSD Test $P < 0.05$).

treatment. At 14 d post treatment, none of the band-type repellent treatments repelled ants.

A wax-slurry of butyl carbitol acetate painted around the trunk or a wax coated string treated with methyl myristate, methyl anthranilate or butyl carbitol acetate tied

Table 5. Red imported fire ant activity on pecan trees treated with ant repellent compounds mixed with a slurry of wax then painted in a band onto the trunk

		Number ants observed in 2 min*					
Time	Treatment	Above	On	Below	Crossing	On/Off	Not on
1 wk	Control	21 b	20 a	26 a	29 a	19 a	0.0 c
	Farnesol	35 a	12 b	32 a	11 b	12 a	3.7 b
	Methyl myristate	24 b	21 a	30 a	18 ab	15 a	3.5 b
	Butyl carbitol acetate	35 a	3.4 b	42 a	1.1 c	11 a	9.5 a
2 wk	Control	21 b	19 a	26 a	29 a	17 a	0.0 c
	Farnesol	37 a	33 a	35 a	11 b	11 ab	3.4 b
	Methyl myristate	22 b	22 a	32 a	17 ab	19 a	3.6 b
	Butyl carbitol acetate	40 a	34 a	47 a	1.3 c	3.3 b	9.2 a

* Means in the same column and followed by the same letter are not significantly different (ANOVA, LSD Test, $P < 0.05$).

Table 6. Red imported fire behavior across repellent treated wax covered Kraft paper bands 1, 7, and 14 days after banding

	Number ants crossing barrier at indicated days after treatment*		
Treatment	1 d	7 d	14 d
Control	21 a	64 a	92 a
Trilogy®	3 b	16 b	48 b
Methyl myristate	5 b	55 a	56 b
Methyl anthranilate	1 b	68 a	68 b
Butyl carbitol acetate	1 b	13 b	53 b
Tanglefoot®	0 b	17 b	67 b

* Means in the same column and followed by the same letter are not significantly different (ANOVA, LSD Test, $P < 0.05$). Ants crossing barrier over a 2 min. period.

around the trunk of pecan trees effectively repelled red imported fire ants and reduced ant foraging above the treated band of the tree. Ants walking down the trunk also were significantly repelled by these treated bands or strings and remained walking above the band. These results indicate that repellents, such as butyl carbitol acetate, may be an inexpensive alternative to insecticide sprays to the trunk for the purpose of partitioning the foraging behavior of red imported fire ants. The chlorpyrifos treatment restricts ants from the tree canopy for at least one year, whereas, the best repellent only lasted for 2 wks. Research is continuing to find methods to increase the residual activity of butyl carbitol acetate and to determine its toxicity relative to the standard chlorpyrifos trunk spray to aphidophagous insects that reside on the trunk.

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