Damage to Young Citrus Trees by the Red Imported Fire Ant (Hymenoptera: Formicidae)

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ABSTRACT Surveys of 2,384 ha of young citrus groves in Florida in 1982 showed that red imported fire ants, *Solenopsis invicta* Buren, were abundant ($\bar{x}$ = 366.8 nests per ha). The ants built their mounds around or near the base of young citrus trees 1–4 yr old and fed on the bark and cambium to obtain sap, often girdling and killing the tree. In the spring, they also chewed off new growth at the tips of branches and fed on flowers or developing fruit. In central Florida, survival of citrus trees increased when the number of ants was reduced and maintained at low levels with insecticidal bait. Tree mortality was 5.5–6.6 times higher in the untreated than in the treated sections of grove. Replacement costs for dead trees were $214.65–$843.11 higher in untreated than in treated 1.0-ha test plots.

KEY WORDS Insecta, *Solenopsis invicta*, citrus, economic damage

REPORTS OF DAMAGE to young citrus trees by fire ants of the genus *Solenopsis* Westwood predate the introduction and subsequent widespread distribution of the red imported fire ant, *Solenopsis invicta* Buren, in the southern United States. Clark (1931) reported that the fire ant *Solenopsis geminata* (F.) severely damaged young citrus trees throughout the Rio Grande Valley of Texas. He also cited earlier reports by Essig (1930) of similar damage in Arizona, California, and Puerto Rico. Fire ants built their nests at the base of the young trees and fed on the bark and young tender flush, often killing the trees by girdling the trunk. Although Clark did not estimate the economic loss, he considered the ant to be the most important pest of young citrus and the third most important pest of all citrus in the region.

The first official report noting the presence of imported fire ants in the United States (Loding 1929) indicated that the black imported fire ant, *Solenopsis richteri* Forel, caused considerable damage to young Satsuma orchards and nursery stock in Alabama by girdling trees just above the graft union. Similar damage was attributed to the black and to the red imported fire ant in subsequent reports (Lyle & Fortune 1948, Eger 1985).

Although considerable crop damage was attributed to fire ants in early reports (Smith 1949, Wilson & Eads 1949), Hays & Hays (1959) identified insects as the primary food of red imported fire ant and suggested that the ants would resort to cannibalism rather than eat plant material. The Hays report led to the opinion in the 1960s and 1970s that red imported fire ants feed on plant tissue only in rare and extreme situations. By the mid- to late 1970s, however, additional reports of damage to a variety of crops, including citrus, appeared. Smittle et al. (1983, 1988) demonstrated in studies with radioisotopes (^{32}P) that, contrary to previous opinions, red imported fire ants fed readily on a number of plants including okra, corn, soybean, and citrus.

Lofgren & Adams (1982) suggested that the paucity of reports of imported fire ant damage to crops through the 1950s and 1960s was due to extensive use of the chlorinated hydrocarbon insecticides. These chemicals controlled imported fire ants very effectively (Eden & Arant 1949; Blake et al. 1959; Lofgren et al. 1964, 1965), and their wide-spread use in citrus and other crops likely kept populations at nondamaging levels. Fire ants became more abundant in fields and groves, however, as residues of these persistent pesticides disappeared from the soil after their registrations were cancelled by the Environmental Protection Agency in the early 1970s. We have found (unpublished data) that the red imported fire ant has largely displaced native ant species and has become the numerically dominant ant in many Florida citrus groves. The presence of red imported fire ants in young groves has evoked strong complaints from grove owners, who attribute the death of many young trees to the ant. Here we report infestation levels of red imported fire ants in citrus groves in central Florida and quantify damage to young citrus trees relative to the presence of this fire ant species. Data on the economic effect of the ant on the Florida citrus industry are also presented.

This paper reports the results of research only. Mention of a proprietary product or pesticide does not constitute an endorsement or a recommendation by USDA for its use.

Materials and Methods

Counts of red imported fire ant mounds were made in 46 groves in six Florida counties over a 13-mo period (February 1982–March 1983) to determine the abundance of red imported fire ant in young citrus groves and to select groves for detailed ecological study. Because preliminary counts showed mounds to be about equally distributed between grassy and bare areas, we confined our counts to areas where the grower had suppressed vegetation with herbicide, making the mounds more visible. We counted all ant mounds within these areas (about 1.5 m on each side of the row of trees) along the entire length of randomly selected rows. The counts were used to calculate the number of mounds per hectare. Percentage trees infested by red imported fire ants was determined in two counties by examining all parts of the tree for the presence of foraging, feeding ants, or both.

Evidence of ants feeding on the trees was obtained by capturing foraging ants as they left the trees. The ants were taken to the laboratory and held at room temperature in Petri dishes lined with filter paper until they expelled the buccal pellet (the solid materials not ingested). The expelled pellets were analyzed by gas chromatography for the presence of limonene or were examined by phase microscopy for the presence of cuboidal cells characteristic of plant tissue.

Test with Orange Trees. Studies were conducted at two locations to assess the extent and effects of feeding by red imported fire ants on young citrus trees. The first site was a 12-ha grove near Scottsmoor in southern Volusia County, Fla., comprising equal areas of 'Navel' orange, 'Hamlin' orange, and pink grapefruit trees. Each tree was planted (6.1 by 6.7 m spacing) on a raised circular bed and encircled by an earthen ring for water retention. The trees were 1–2 yr old when studies were begun in the grove in October 1983; however, replacement of dead trees after severe freezes in December 1983 and January 1985 resulted in an age span of 1–4 yr.

We divided the trees of each type of fruit into four equal sub-blocks. Two sub-blocks were left untreated as controls; the other two sub-blocks were treated with semiannual applications of a chemical bait (Logic, Maag Agrochemicals, Vero Beach, Fla.) to reduce or maintain the ant populations at low levels so that effects of high and low numbers of red imported fire ant on the trees could be compared. The bait was broadcast with a tractor-mounted granular applicator (Williams et al. 1983) in October 1983, March and October 1984, and March 1985. No other insecticides were used in the grove during the study. All other routine cultivation and grove management practices were continued and were the same for all sub-blocks.

Foraging ants were captured with bait and pitfall traps in a sample area of 25 trees (5 by 5 trees) near the center of each sub-block during each month of the study as an indicator of the relative numbers present. Trapping was used to assess relative numbers because cultivation practices made the usual method of counting mounds to determine infestation levels inaccurate. Paired traps, one each baited with meat and honey–agar (Stringer et al. 1980), were placed at the center and four corner trees of each sample area. One bait of the pair was placed at the base of each test tree, and the other was placed at a random point on an imaginary circle drawn equidistant between the test tree and the next adjacent tree. Placement of the baits at the five trees in each sample area was alternated on a given collection date and was reversed for the subsequent month's collection. The baits were exposed for 1 h, collected and placed on dry ice, and taken to the laboratory for removal and identification of trapped ants. Pitfall traps (360-ml styrofoam cups containing 200 ml of 50:50 isopropanol/ethylene glycol) were placed about 1 m from the bait traps at the four corner trees in each sub-block. Pitfall traps were exposed for 72 h; collections were then placed in glass jars and transported to the laboratory for sorting and identification of specimens. The number of red imported fire ants captured monthly at each collection site was recorded for the 2-yr study period.

Randomly selected trees in each sub-block were examined monthly for the presence of foraging red imported fire ants, obvious recent feeding damage, or both. Dead trees were counted in October 1984 and October 1985.

Test with Grapefruit. The second test site was a 100-ha grove of 1-yr-old pink grapefruit trees near Fellsmere in Indian River County, Fla. The trees were planted on continuous elevated beds (two rows per bed with 6.1- by 7.0-m tree spacing, 7.6 m between beds) with a drainage ditch between each bed. Four 1.0-ha test plots were established in a randomly selected 10-ha portion of grove. In each plot, five beds with 30 trees each (two rows with 15 trees each) were selected for a detailed study from October 1985 through October 1986. Each month, six randomly selected trees on each bed were examined for the presence of foraging ants, recent feeding damage, or both. Monthly pitfall and bait trap (paired meat and honey–agar baits) collections of ants were made. A single pitfall trap was placed 1.5 m north of each test tree. One bait of each pair was placed on the soil surface about 30 cm north and the other an equal distance south of each test tree. The position of the respective baits was reversed for the next month's collection. Ant populations on two plots were reduced with two broadcast applications (November 1985 and April 1986) of chemical bait (Logic). Dead trees in each plot were counted in October 1986.

The mean numbers of ants collected from paired treated and untreated sub-blocks of each fruit and the percentage of traps catching ants for the paired sub-blocks (data transformed by arcsine) were compared with Student's t test (SAS Institute 1985).

At both sites, the cost of replacing trees killed by red imported fire ant feeding was calculated using established guidelines (Muraro 1985).

Results and Discussion

The young citrus groves surveyed in the six counties were heavily infested with red imported fire ants, with a mean 366.8 (range, 181.5–631.5) queenright colonies per ha (Table 1). For this study, only colonies that contained abundant immatures and worker ants were considered queenright. We concentrated on young groves because complaints about tree mortality from red imported fire ant have been in newly planted to 3-yr-old trees. Although we have observed heavy infestation and ant-tending of scale insects and aphids in mature groves, we have not observed or been advised that the ants severely damage or cause mortality of mature trees. Our observations suggest that the effect of red imported fire ant becomes progressively less as trees age and that trees ≥4–5 or more years of age can survive attack. Inspection of trees for foraging red imported fire ant workers in two counties revealed that ants were present in 916 (38.3%) of 2,390 trees on 117 sites in Brevard County and in 1,296 (30.6%) of 4,237 trees on 89 sites in Indian River County.

The presence of limonene and plant cells in the buccal pellets of ants captured as they left the trees provided evidence that the ants feed on citrus trees and cause the type of damage that we observed on bark and cambium (Fig. 1), branches, fruit, and flowers of the trees. General observations in young groves showed that such feeding damage occurred wherever red imported fire ants were abundant.

We observed this type of feeding damage in the groves each month during the studies at Scottsmoor and Fellsmere. Soil encasement of the trunk and some of the lower branches of the citrus trees (Fig. 1A) was quite common. Actively foraging ants and feeding damage to the bark were observed when the soil was removed (Fig. 1 B and C). The feeding damage ranged from slight to severe, with complete girdling of the trunk or branches in some instances. Ant foraging and fresh feeding damage were evident in the untreated blocks throughout the study, with a monthly mean 37.5% (range, 6.25–71.9%) of the trees being affected. Ant activity and damage were initially relatively high in the treated blocks but steadily declined as the bait treatments reduced ant numbers. Throughout the study, actively foraging ants or fresh feeding damage was observed in a monthly mean of only 9.4% (range, 0–31.3%) of the trees in the treated blocks. Tree death generally showed a strong positive correlation with ant numbers and the foraging and feeding activity. Tree death was significantly lower in the treated blocks, where the monthly mean number of ants captured and the percentage of traps that caught ants were significantly lower (Table 2).

Table 1. Density of red imported fire ant mounds in young citrus groves in six counties in Florida, 1982

County	No. groves inspected	No. hectares	No. mounds/ha	
			Mean	Range
Indian River	12	720	447.0	296.8–563.3
St. Lucie	11	264	361.5	217.8–631.5
Brevard	4	240	364.3	256.3–470.5
Collier	2	280	333.8	181.5–503.3
Hendry	13	800	319.0	278.0–336.5
De Soto	4	80	374.5	196.0–501.0
Totals	46	2,384	366.8	181.5–631.5

Our data suggest a differential response of the different fruits to attack by red imported fire ants, with 'Hamlin' orange being most susceptible, followed by pink grapefruit and 'Navel' orange. However, although susceptibility may differ, we suspect that most of the variation in this study is attributable to differences in age of the trees. Reduced mortality may only reflect the ability of older trees to withstand ant attack better; e.g., fewer 'Navel' orange trees had to be replaced after the freezes in 1983 and 1985. Thus, fewer very young trees were subjected to ant attack. Additional studies will be required to determine whether one fruit is more tolerant to attack by red imported fire ants than another.

Differences between treated and untreated sections of grove were not as great at Fellsmere because the study was shorter-term and the baits did not have opportunity to reduce ant numbers sharply. Overall ant numbers were considerably higher and monthly mean numbers captured were significantly lower in only one of the treated sub-blocks. A lack of significant difference in percentage of traps with ants showed that ants remained widely dispersed in the treated blocks throughout the study (Table 3), a fact further reflected by a monthly mean 28.5% (range, 3.3–53.3%) of the trees having foraging ants or fresh feeding damage. By comparison, foraging ants or fresh feeding damage was evident in a monthly mean 58.8% (range, 45.0–79.2%) of the trees in the untreated blocks. Tree mortality in both treated and untreated blocks at Fellsmere reflected the higher ant numbers and feeding activity; however, significantly more trees were killed in the untreated than in the treated blocks.

The number of trees killed in the treated sections of a grove might have been even lower had the treatments been applied before tree planting. Substantial feeding damage by red imported fire ants was already evident on many young trees at both locations when our studies began. Ant activity and damage continued for several months while the baits reduced ant numbers. Our results suggest that treatment with an effective bait 3–6 mo before planting, with retreatments at intervals of about 6 mo, should keep ant numbers at sufficiently low levels to eliminate them as a cause of tree death.

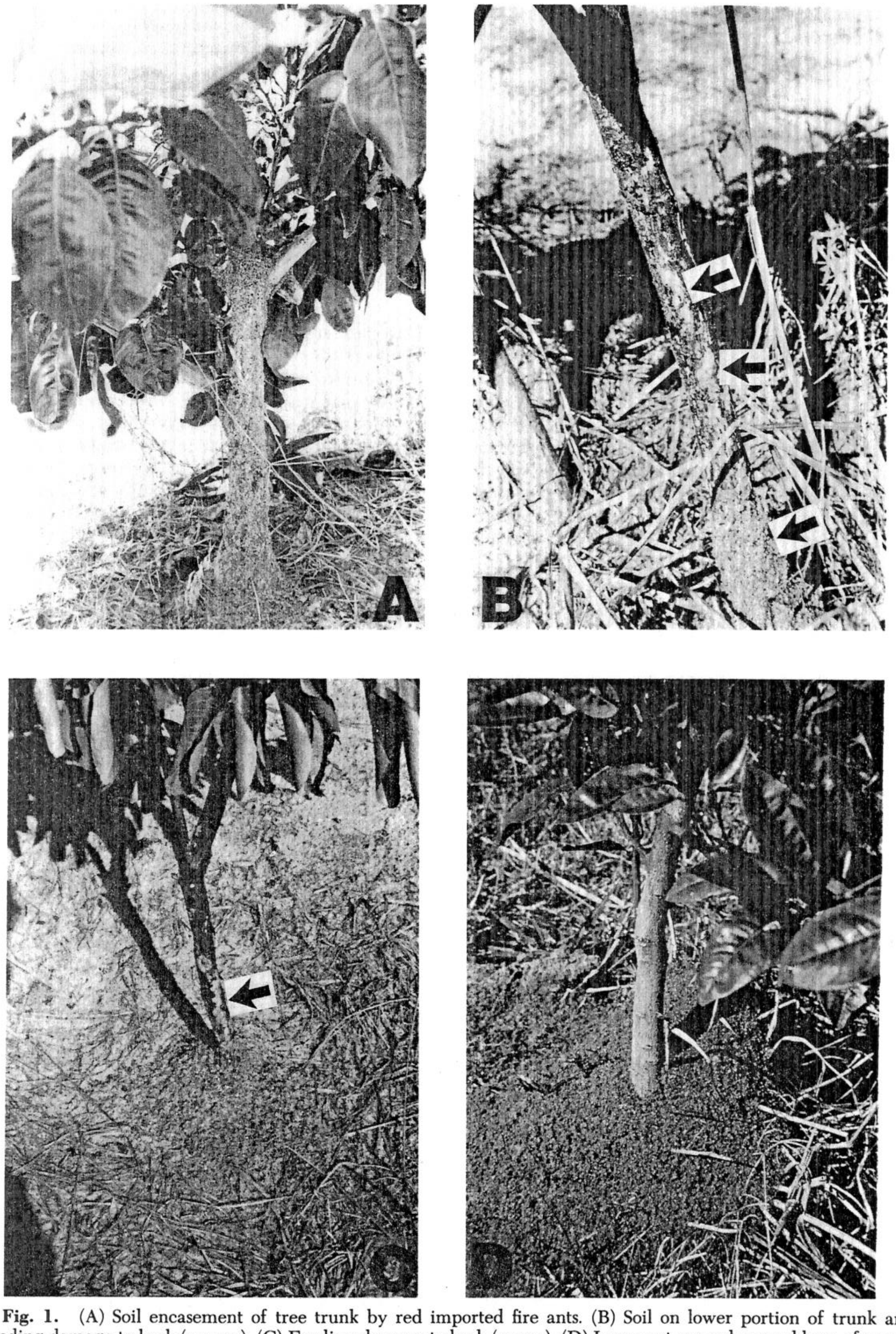

Fig. 1. (A) Soil encasement of tree trunk by red imported fire ants. (B) Soil on lower portion of trunk and feeding damage to bark (arrows). (C) Feeding damage to bark (arrow). (D) Large ant mound around base of young citrus tree.

Table 2. Mean numbers of red imported fire ants captured monthly in pitfall traps and bait traps in a citrus grove at Scottsmoor, Fla., with tree mortality and costs for replacement of trees killed by ants

Plot	Mean No. RIFA captured monthly[a]		Mean % traps with ants[b]		Total No. dead trees/cost of replacement during study[c]	
	Treated	Untreated	Treated	Untreated	Treated	Untreated
			'Navel' orange			
1	47.5	773.1	17.6	67.6	3/$76.35	15/$291.00
2	47.4	246.9	18.8	47.9	3/$76.35	18/$349.20
			'Hamlin' orange			
1	51.7	274.9	27.6	59.5	5/$127.25	33/$555.72
2	34.0	520.0	25.9	64.0	6/$136.14	40/$673.60
			Pink grapefruit			
1	28.9	598.6	24.3	71.9	11/$249.59	36/$606.24
2	146.5	637.0	50.0	73.8	5/$127.25	68/$970.36

[a] Data analyzed with Student's t test (SAS Institute 1985). For all plots, df = 20. Navel orange: Plot 1, $t = 6.5579$, $P = 0.0001$; Plot 2, $t = 3.4961$, $P = 0.0016$. Hamlin orange: Plot 1, $t = 5.3897$, $P = 0.0001$; Plot 2, $t = 3.0540$, $P = 0.0062$. Pink grapefruit: Plot 1, $t = 6.1649$, $P = 0.0001$; Plot 2, $t = 2.9216$, $P = 0.0079$.

[b] Arcsine transformation of percentage positive traps compared by Student's t test (SAS Institute 1985). For all plots, df = 20. Navel orange: Plot 1, $t = 9.3626$, $P = 0.0001$; Plot 2, $t = 5.4419$, $P = 0.0001$. Hamlin orange: Plot 1, $t = 6.6968$, $P = 0.0001$; Plot 2, $t = 6.7945$, $P = 0.0001$. Pink grapefruit: Plot 1, $t = 8.1816$, $P = 0.0001$; Plot 2, $t = 4.1004$, $P = 0.0002$.

[c] Replacement costs based on information derived from Muraro (1985). The per-tree costs of replacement decrease as the number of trees replaced increases because of certain startup costs that remain relatively constant.

Profitable citriculture requires replacement of dead or unproductive trees in a grove with new trees. Calculated costs (Muraro 1985) for replacing trees killed by the ants in the untreated sub-blocks of 'Navel' orange, 'Hamlin' orange, and pink grapefruit at Scottsmoor ranged from $291.00 to $970.36 versus $76.35 to $249.59 for the sub-blocks where numbers of red imported fire ants were reduced by bait treatment (Table 2). Replacement costs for the untreated pink grapefruit at Fellsmere were $505.20–$730.85 versus $271.60–$368.60 for the treated blocks (Table 3). In groves with an average planting of 250 trees/ha, comparable losses would be equivalent to average annual replacement costs per hectare of $204.21 for 'Navel' orange, $407.40 for 'Hamlin' orange, and $637.55 for pink grapefruit. These are economic losses directly attributable to damage to the trees by the red imported fire ant. They do not reflect losses in yield due to the delay in trees reaching full bearing age.

Factors that influence feeding by red imported fire ants on young citrus trees are not well understood at this time. Presumably, such behavior is prompted by nutritional needs within the colony that are not being met from other sources of food. Red imported fire ants need and use carbohydrates (Petralia & Vinson 1978, Williams et al. 1980, Porter 1989) and show a preference for carbohydrate baits in colder weather (Stein 1987). We observed that the heaviest foraging on the tree and feeding on the sap oozing from the limbs and trunk occurred during mid- to late winter and early spring. Although we were unable to obtain information on the composition of citrus sap, we speculate that carbohydrates that the ant could use for colony survival and activity during the winter are present. Carbohydrates may also serve as a food resource for brood production in the early spring.

Our studies substantiate the reports that red imported fire ants are a serious pest of young citrus. In a recent survey (Jackson et al. 1988), 308 Florida citrus growers ranked ants as the second most important pest insect in their groves. Red imported fire ants are now found throughout Florida and are the dominant ant species in many citrus groves. Most pest problems associated with ants are due to

Table 3. Mean numbers of red imported fire ants captured monthly in pitfall traps and bait traps in a pink grapefruit grove at Fellsmere, Fla., with tree mortality and costs for replacement of trees killed by ants

Plot	Mean No. RIFA captured monthly[a]		Mean % traps with ants[b]		Total No. dead trees/cost of replacement during study[c]	
	Treated	Untreated	Treated	Untreated	Treated	Untreated
1	1,512.2	2,676.1	52.6	67.2	19/$368.60	47/$730.85
2	1,318.4	3,242.9	50.7	66.6	14/$271.60	30/$505.20

[a] Data analyzed with Student's t test (SAS Institute 1985). For both plots, df = 8. Plot 1: $t = 1.8888$, $P = 0.0772$; Plot 2: $t = 2.2664$, $P = 0.0376$.

[b] Arcsine transformation of percentage positive traps compared by Student's t test (SAS Institute 1985). For both plots, df = 8. Plot 1: $t = 2.0953$, $P = 0.0694$; Plot 2: $t = 1.8340$, $P = 0.0853$.

[c] Replacement costs based on figures derived from Muraro (1985). The per-tree costs of replacement decrease as the number of trees replaced increases because of certain startup costs that remain relatively constant.

red imported fire ants. The polygynous form of this species is becoming more widespread in Florida, and preliminary evidence suggests that it may be a more serious crop pest than the monogynous form (Glancey et al. 1987). All of these factors suggest that effective control measures will be necessary to prevent continuing serious economic losses from red imported fire ants in young citrus groves.

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