would be unaffected by any of the barrier devices developed in California for the Argentine ant.

On the other side of the coin, experiments in which egg masses of *Diaprepes* were placed in trees showed that while *Azteca* sp., *Crematogaster curvispinosa* Mayr, *Camponotus lucianus* Forel and *Camponotus sexguttatus* (Fabricius) would not harm the eggs, quick and thorough predation with strikes within 5 minutes of the start of observation occurred if other ants were present in the tree in the absence of the dominant arboreals. The species involved were *Monomorium floricola* Jerdon and *Monomorium ebininum* Forel, which could be arboreal nesters, and the ground nesting *Pheidole* sp. (*fallax* group) and *Ectatomma ruidum* Roger. Observations indicated that the most obvious method of trying to manipulate the ant ecology in Guadeloupe in favor of the predacious ants would be careful prunning of dead wood from the trees in order to remove nest harborage of the dominant arboreals while at the same time preserving moss growths on the trunks and lower branches as nest harborage for the *Monomorium* spp. Concerning the two ground nesters involved, *Pheidole fallax* needs bare ground while *Ectatomma ruidum* needs some plant cover. Providing adequate harborage for the nests of the beneficial ants while destroying harborage for the nests of the harmful ants seems the most logical initial step in efforts to manage the ant ecology of citriculture, but, due to the complex nature of this ecology, cannot be guaranteed *a priori* to have the effects desired.

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Proc. Int. Soc. Citriculture. 2:498-500. 1977.

CITRUS ROOT WEEVILS IN FLORIDA: IDENTIFICATION, BIOLOGY AND CONTROL[1,2]

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Additional index words. Pachnaeus litus, P. opalus, Artipus floridanus, and *Diaprepes abbreviatus.*

Abstract. **Five species of weevils attack Florida citrus:** Pantomorus cervinus **(Boheman),** Artipus floridanus **Horn,** Pachnaeous litus **(Germar),** P. opalus **(Oliver) and** Diaprepes abbreviatus **(L.). The so-called sugarcane rootstalk borer weevil,** D. abbreviatus, **is the most destructive. Therefore, biological and chemical control efforts have been directed at this recently introduced species. However, egg parasites introduced from Puerto Rico did not become established, and application of broad-spectrum insecticides to citrus have resulted in other insect problems. Selective chemicals and biological controls are needed for area control and possible total population suppression.**

Five species of weevils attack Florida citrus, Fuller rose beetle, *Pantomorus cervinus* (Boheman); the so-called little leaf notcher, *Artipus floridanus* Horn, the citrus root weevils, *Pachnaeus litus* (Germar), *P. opalus* (Oliver), and the so-called sugarcane rootstalk borer weevil, *Diaprepes abbreviatus* (L.), a relatively new pest of citrus and other host plants in central Florida. The biology of the 5 species is similar: Eggs are deposited in the canopy of the host tree. After hatching, neonate larvae enter the soil and feed on roots. Major injury to citrus results from larval feeding on roots (except for *A. floridanus*), which leads to host decline and subsequent reduced yield. The adult weevils are foliage feeders and cause a characteristic notching of leaves that is of secondary importance in the case of mature trees. *Diaprepes abbreviatus* is potentially the most destructive of the 5 species and is a major threat to citrus, sugarcane, and ornamental plant industries in Florida. Therefore, citrus weevil research at the U.S. Horticultural Research Laboratory at Orlando has been directed toward control of this species.

Diaprepes abbreviatus was first observed in central Florida in 1964. By 1968, a quarantine area of ca. 2000 ha had been established (15). The original quarantine area has since been extended 3 times. At present, it encompasses ca. 20,000 ha (1976). Attempts to eliminate *D. abbreviatus* from central Florida with insecticides were unsuccessful. At present, there are no recommended control methods for *D. abbreviatus* on citrus. Techniques for control, containment, and total weevil population suppression are needed.

Eggs of *D. abbreviatus* (ca. 100/mass) are deposited between mature citrus leaves. The leaves are cemented to

[1]This paper reports the results of research only. Mention of a pesticide in this paper does not constitute a recommendation for use by the U. S. Department of Agriculture, nor does it imply registration under FIFRA as amended. Also, mention of a proprietary product in this paper does not constitute an endorsement by the U. S. Department of Agriculture.

[2]Refer to Table 1—List of Common & Chemical Names.

ber by a gelatinous adhesive secreted by the female ing oviposition. After ca. 7 days, the eggs hatch, and the ate larvae drop to the ground. The larval period in to Rico was ca. 1 year, but the range was 8-18 months In Florida, adults were obtained from potted citrus to 268 days, also an indication of a variable develop- period (5).

The adult male is active for ca. 2 months and the female ca. 4 months. During this period, a single female can osit more than 5000 eggs (18). Adult *D. abbreviatus* are sent in Florida from May to November, but the greatest bers occur from August to October (6). In mild winters, ults can be found throughout the year.

One of the problems encountered in delimiting the area sted with *D. abbreviatus* was the inability to distinguish *abbreviatus* larvae from other weevil larvae found in area. A larval key was developed to overcome this acle (7).

Control

Tetrastichus haitiensis Gahan was reported as the major parasite of *D. abbreviatus* in Puerto Rico (19), and empts were made to establish this parasite in Florida (4, Weevil egg masses were recovered from release sites om 1970 through 1973, but only one parasitized egg mass as been recovered and that was shortly after the releases 1970. *Brachyufens osborni* (Dozier) also develops in eggs *D. abbreviatus* in Puerto Rico, but no attempts have en made to release or colonize this species since it has en reported from eggs of *Pachnaeus* sp. in Florida (1). A edacious mite, *Blattisocius keegani* Fox, has also been orted to attack *D. abbreviatus* egg masses in Florida (2). The green muscardine fungus, *Metarrhizium anisopliae* Metschnikoff) Sorokin, was found on all stages of *D. ab- reviatus* held in confinement in Puerto Rico (19). In the boratory, the fungus *Beauveria bassiana* (Balsamo) Vuil- min also attacked larvae and adults and may exhibit ntrol in the field (3). Other biotic agents such as ants, nds, and predacious insects are active against various ges of *D. abbreviatus*.

Table 1. Chemical and common names.

ticide designation	Chemical name
ephate	*O,S*-dimethyl acetylphosphoramidothioate
drin	1,2,3,4,10,10-hexachloro-1,4,4a,5,8,8a-hexahydro-1,4-*endo-exo*-5,8-dimethano-naphthalene
mphosmethyl	*O,O*-dimethyl *S*-[(4-oxo-1,2,3-benzotriazin-3(4*H*)-yl)methyl] phosphorodithioate
rbaryl	1-naphthyl methylcarbamate
bofuran	2,3-dihydro-2,2-dimethyl-7-benzofuranyl methylcarbamate
lorpyrifos	*O,O*-diethyl *O*-(3,5,6-trichloro-2-pyridyl) phosphorothioate
ldrin	1,2,3,4,10,10-hexachloro-6,7-epoxy-1,4,-4a,5,6,7,8,8a-octahydro-1,4-endo-exo-5,8-dimethanonaphthalene, 85% minimum
flubenzuron	*N*-[[(4-chlorophenyl)amino]carbonyl]-2,6-difluorobenzamide)
methoate	*O,O*-dimethyl *S*-(methylcarbamoylmethyl) phosphorodithioate
nsulfothion	*O,O*-diethyl *O*-[*p*-(methylsulfinyl)phenyl] phosphorothioate
ptachlor	1,4,5,6,7,8,8,-heptachloro-3a,4,7,7a-tetrahydro-4,7-methanoindene
lathion	diethyl mercaptosuccinate *S*-ester with *O,O*-dimethyl phosphorodithioate
rathion	*O,O*-diethyl *O*-(*p*-nitrophenyl) phosphorothioate
ophos	*O,O'*-(thiodi-4,1-phenylene) bis(*O,O*-dimethyl phosphorothioate

Control of neonate larvae was obtained with aldrin (20) and dieldrin (11) in the West Indies. These materials are not presently available. A series of insecticides was evaluated in the Florida laboratory (10, 12). None is presently approved for use. Heptachlor is temporarily approved for *D. abbreviatus* control as a soil mix to prevent larval establishment on potted plants.

Control of established larvae on citrus roots in the field has not been attempted. However, in 1973, 17 insecticides were tested as root-dip treatments for potted citrus (16). Hot water and fensulfothion gave 100% control, chlorpyrifos and temephos were effective in controlling large larvae in potted nursery plants (13). Use of these insecticides enabled growers to ship plants from the quarantine area.

An attempt was made to control the adult *D. abbreviatus* with insecticides in Florida (8). Of the 24 insecticides tested, 10 were capable of providing complete kill of adult *D. abbreviatus* within 72 hr when they were applied as dilute foliar sprays. Azinphosmethyl, dimethoate, parathion, and malathion were effective and are recommended for use on Florida citrus. However, multiple applications are required, a procedure with little economic appeal. In additional tests with 21 insecticides in Puerto Rico, Sevin®-4-oil, a formulation of carbaryl, gave 100% control for at least 26 days (21). Control of adults was also attempted with carbaryl plus Pinolene® (spreader-sticker) and a Sevin-4-oil formulation (22), but other insect problems, especially purple scale, *Lepidosaphes beckii* (Newman), developed in sprayed areas, and the program was discontinued. Acephate and carbofuran were also found to be effective for adult control (9).

In field tests, Thompson-Hayward TH 6040, diflubenzuron, applied by air was effective in reducing the reproductive potential of *D. abbreviatus* (14). Egg hatch was reduced from 71 to 15% when weevils were continuously exposed to a 0- to 26-day-old residue. Spray oil, too, has an adverse effect, since it weakens the attachment of the weevil egg mass to foliage. The combined effect of diflubenzuron and spray oil might provide an acceptable method for weevil control.

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Proc. Int. Soc. Citriculture. 2:500-503. 1977.

ECOLOGICAL CHANGES IN FLORIDA CITRUS GROVES

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Additional index words. survey, pests, weather effects, growth, diseases.

Abstract. **A 16 year continuous ecological survey of 130 commercial citrus groves has been recorded on computer tape. These records have documented the invasion of groves by a mite pest** Eutetranychus banksi, **and the great and persisting reduction of 2 important scales** Lepidosaphes beckii **and** Chrysomphalus ficus **by new** Aphytis **parasites. Important increases and decreases of scale, mite and fungus pests are charted. Populations of 13 pest, predator and disease organisms decreased following extreme cold. Other organisms in the ecosystem were affected little if any by cold. Fluctuation in foliage growth, tree decline maladies and other points of horticultural interest are referenced.**

A citrus grove starts and continues in a man manipulated environment. In Florida, many of the 870,000 acres (354,000 hectares) of citrus are in adjoining tracts totaling a thousand or more acres. Thus we have a citrus monoculture with an ecosystem comprising insects, mites, nematodes, fungi, weeds and other organisms that can exist under the cultural practices necessary to produce a citrus crop.

Researchers and growers have attempted to manipulate the citrus ecology to their advantage by the use of biological agents, pesticides, plant nutrients, irrigation and other cultural procedures.

This paper will discuss important changes in the ecosystem during the 16 years from 1956 through 1971.

Methods

In 1951 the Agricultural Experiment Station of the University of Florida initiated a project to monitor the ecology in 130 commercial citrus groves throughout the principal citrus producing area of Florida. These groves, selected to represent the varieties, locations and cultural conditions, were examined by trained observers each month as described by Simanton (5).

The standardized procedure included inspection for 33 injurious insect and mite species, 18 parasites and predators, 10 foliage symptoms of diseases and nutritional disorders, 10 conditions of fruit and leaf injury and 9 cultural practices and growth conditions, plus any other ecosystem factors worthy of note. All pesticide and fertilizer applications and other treatments were recorded. Monthly evaluations of these parameters for the 16 years were recorded on 24,998 data cards and later transferred to computer tape.

The statewide data were summarized in several recent publications. One monograph (8) concerns the magnitude and fluctuation of populations of more than 72 species of insects and mites associated with Florida citrus. Another monograph (9) concerns the occurrence of injuries, diseases and abnormalities of fruit and foliage in Florida groves. Another publication dealt with the effect of spraying operations on pests, predators, and parasitism (6). In the above 3 publications and in this paper the magnitude of various parameters in the ecosystem is expressed in charts as the average percentage of monthly inspections (1560 each year) in which the organism or condition was present in the sample unit. The percentage of inspections in which the condition was sufficiently abundant to be of possible economic importance is also charted.

Results and Discussion

Weather factors exert an overwhelming influence on grove ecology. Man can slightly lessen the effects of cold in the minor percentage of groves where an effort is made to modify temperature. He also can augment rainfall by irrigation. Otherwise there is little he can do about weather except provide proper drainage and good cultural practices.

Weather influenced some pests directly as discussed later or indirectly by affecting the growth cycle of the tree as to time, magnitude and duration (7). In 1961 the spring flush of foliage started 2 weeks later than the 12 year average date, total new foliage for that year was 18.76% below the 12 year average, and tender foliage was present for only 3 weeks. In contrast, in 1958 subsequent to severe winter cold, new growth started earlier than average, total new foliage was near normal magnitude, and tender foliage was present for 17 weeks. In 1963, following the extreme cold of December 11-14 1962, new growth started early and for that year was 12.20% above average magnitude (7). Such variability influences severity of aphid, whitefly and mealynose attack which are associated with tender growth.

Simanton's charted data (8,9) revealed that the cold winters of 1957-58 and 1962-63 were followed by much reduced populations of black scale *Saissetia oleae* (Bernard), Florida red scale *Chrysomphalus ficus* (Ashmead), citrus mealybug *Planococcus citri* (Risso), Florida wax scale *Ceroplastes floridensis* Comstock, plant bugs (Hemiptera), orange dog *Papilio cresphontes* Cramer, pyriform scale