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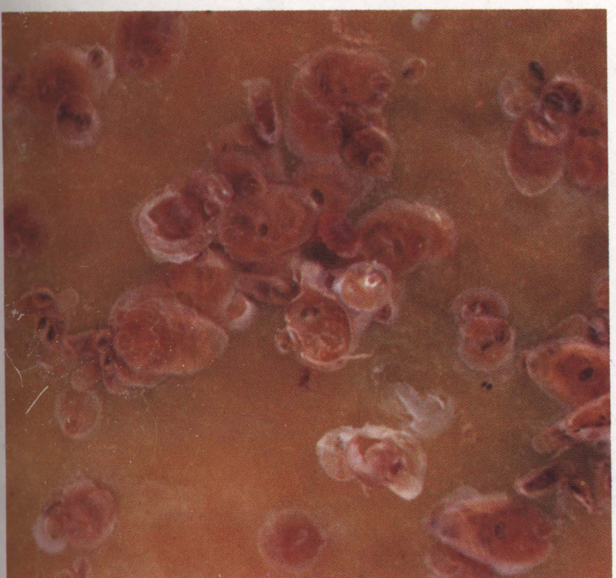
Development of Integrated Pest Management in Texas Citrus



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DEVELOPMENT OF INTEGRATED PEST MANAGEMENT IN TEXAS CITRUS

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SUMMARY

A short history of citrus in Texas is provided along with the changing citrus pest problems.

Data for over 25 years has been utilized for a better understanding of major pest problems. Some former major pests have become minor pests through introduction of effective parasites. Certain pesticide-related pest problems are discussed. The discussion of pests, pesticides, and beneficials are herein provided in order that the grower and pest control operator may develop a more valid and effective pest management program at minimal cost. Such has been accomplished through effective Research and Extension Service programs.

DEVELOPMENT OF INTEGRATED PEST MANAGEMENT IN TEXAS CITRUS

INTRODUCTION

The earliest record of citrus plantings in Texas dates back to 1849 when trees grown from seed were examined approximately 10 miles from Brazoria (50). Consistent citrus production was not possible in the region north of the Lower Rio Grande Valley (LRGV) because of recurrent freezes. The earliest seedling trees in the LRGV were planted in the 1880's, about 20 miles northwest of Edinburg (65). The first successful commercial citrus plantings utilizing sour orange rootstock (75) were made in 1908 by Charles J. Volz, but it was not until 1920 that the LRGV was recognized as an important citrus area. Market acceptance of Texas citrus has been favorable, particularly the red mutations of grapefruit that have been developed.

The Texas citrus area is comprised of 70,421 acres of which approximately 63 percent is grapefruit-planted and the balance mainly oranges. Hidalgo County has 83 percent of the total citrus acreage (61). The grapefruit acreage is comprised of 84 percent 'Ruby Red' and 10 percent 'Star Ruby', with the remainder being pink and white varieties. Future grapefruit plantings will probably be 'Ray Ruby' (49) and 'Henderson' Red (52), which originated as bud mutations of 'Ruby Red'. Their flesh and peel color is redder and more attractive.

Early and mid-season varieties comprise 60 percent of the orange acreage with the balance in late season 'Valencia' oranges. 'Marrs' is the earliest maturing variety and originated as a bud mutation from a 'Navel' orange tree (75). Some of the other orange varieties include 'Hamlin' and 'Pineapple'.

Fruit grown for the fresh market has generally required more use of pesticides. Certain pests are controlled by naturally occurring parasites and predators while other pests are controlled with the use of selective pesticides least destructive to natural enemies; thus, pests are maintained below economic population levels. If potential pests become major pests, additional personnel, equipment, and pesticides are required for their control. Knowledge from research and experience are provided herein to help the citrus grower to develop a more effective and less expensive pest management program.

HISTORY OF PEST PROBLEMS

California red scale, *Aonidiella aurantii* (Maskell), was the most destructive citrus pest in the LRGV until 1933 (7). Citrus spray oil was the principal scalecide used for its control. A hurricane in September 1933 blew most of the fruit from the trees and pest control costs nearly reached zero. Very little spraying of citrus was done from then until the late 1950's. Sulfur had continually been applied (mainly in dust form) as the controlling agent for citrus rust mite, *Phyllocoptruta oleivora* (Ashmead). However, the continued use of sulfur resulted in increased populations of armored scales (6, 30).

As far back as 1929, parasites and predators had reduced California red scale populations, in many instances, to tolerable levels for fresh fruit shipment (6). In 1935, growers made a formal request for Texas Agricultural Experiment Station at Weslaco (TAES W) to investigate the importance of biological agents for armored scale control on Texas citrus. Initial studies in 1937 showed several important natural enemies of scale insects.

The following list of citrus pests, in order of importance, was provided to Ebeling (1950) by S. W. Clark, entomologist (TAES W from 1927 to 1937):

1. Citrus rust mite
2. Texas citrus mite, *Eutetranychus banksi* (McGregor)
3. California red scale
4. Purple scale, *Lepidosaphes beckii* (Newman)
5. Glover scale, *Lepidosaphes gloveri* (Packard)
6. Mexican fruit fly, *Anastrepha ludens* (Loew)
7. Chaff scale, *Parlatoria pergandii* (Comstock)
8. Fire ant, *Solenopsis geminata* (F.)
9. Florida red scale, *Chrysomphalus aonidum* (L.)
10. Leaffooted bug, *Leptoglossus phyllopus* (L.)
11. Southern green stink bug, *Nezara viridula* (L.)
12. Cotton aphid/melon aphid, *Aphis gossypii* (Glover)
13. Brown soft scale, *Coccus hesperidum* (L.)

Zineb[1] sprays came into use in 1958 and provided longer residual control of citrus rust mites. In many instances, control lasted from 3 to 5 months in combination with oil (30). Other serious pest problems arose as different pesticides came into use.[2] Several of these pesticide-related problems became evident in the 1960's. Parathion drift from treated cotton produced a major problem with brown soft scale, (21, 44, 45). Sevin (carbaryl) was approved for control of brown soft scale, but caused increased populations of chaff scale, California red scale, purple scale, Florida red scale, and Texas citrus mites (22, 23). In 1970, following continued use of organophosphorus pesticides, false spider mites, *Brevipalpus* spp., and citrus mealybug, *Planococcus citri* (Risso) became major problems affecting grapefruit. (26, 21)

[1]Trade names of pesticides will be used throughout (Diathane® Z-78, zineb; Metacide, methyl parathion; and Nialate, ethion excepted) for the convenience of readers (4). Common names of insects and mites as approved by Entomological Society of America (68) will be used.

[2]Reference should be made to the current Texas Guide for Controlling Pests and Diseases on Citrus, Tex. Agric. Ext. Serv. Bull. 1336 for recommended pesticides and rates.

Pesticidal effects on secondary pests and their natural enemies were more important considerations, in many cases, than the effects on the target pests. It was evident that the effects of various pesticides were disruptive to beneficial insect populations which resulted in secondary pest outbreaks. Control of the secondary pest is often more difficult and expensive than control of the target pest. Changes in the order of importance of the major pests since 1950 will be shown later in the text.

Integrated pest management investigations began in the 1950's and have continued to date.

FACTORS AFFECTING THE QUALITY AND QUANTITY OF FRESH AND PROCESS FRUIT

Blemished fruit are more prevalent in some years than others and must be sold for juice at reduced return to the grower. A survey of seven packinghouses in October 1980 showed that 26.6 percent (range: 14 to 50 percent) of their total fruit had to be sold for processing. Most rind blemishes do not affect internal juice quality, but the U.S. Grade Standards (72, 73) must be met for fresh fruit shipment. Based on packinghouse records for three to seven seasons, the leading causes for fruit blemishes with their respective average percentage and range were: citrus rust mite, 25 (7-35); windscar, 25 (8-35); undersize, 17 (9-25); melanose, *Diaporthe citri* (Faw.), 10 (5-17); armored scales, 8 (0-17); mealybug, 5 (0-15); misshapened, 4 (0-15); brown soft scale, 1 (0-6); and other, 5 (0-24).

Rust mite damages grapefruit more severely than it does oranges (76) and it is the most serious citrus pest in Texas. Rust mites can be effectively controlled by acaricides; however, growers can do little to reduce windscar, the second most widely occurring fruit blemish. Undersized fruit occurs more often with certain citrus varieties and is most prevalent during years of higher fruit yields. Misshapened fruit (sheepnose, etc.) were found in only two of the seven packinghouses surveyed.

Maturity of Texas citrus is determined by minimal soluble solids, soluble solids to acid ratios, and juice content (5). For oranges, the minimal 8.5 percent soluble solids and 10 to 1 soluble solids to acid ratios (according to the state citrus color-add law) often allows Marrs oranges to be shipped intrastate as early as September 15. At times, minimal juice is restrictive. Failure of acid percentages to be low enough to meet minimal soluble solids to acid ratios has been the principal restriction for intrastate movement of grapefruit. Minimal fruit sizes of 2-¼ and 3-9⁄16 inches in diameter for oranges and grapefruit, respectively, has prevented movement of small fruit to the fresh market (as authorized by Federal Marketing Order 906 to the Texas Valley Citrus Committee). Certain pesticides have been shown to delay maturity, and retard fruit degreening (32).

Pesticidal residues and spray coverage can cause problems when fruit is on the trees. Initial sprays are usually applied at postbloom in late March or April when some of the previous crop has not been harvested. Late fall spray applications, principally for mite control, may delay early fruit harvest. Growers are often confronted with a decision as to which operation must come first.

PRIMARY AND SECONDARY ARTHROPOD PESTS AND THEIR CONTROL

A list of Texas citrus pests and potential pests is shown in Table 1 with the relative importance for only the top four pests.

Primary Pests

The most important arthropod pests of Texas citrus in 1980 were citrus rust mite, chaff scale, California red scale, and Texas citrus mite. Control of citrus rust mite must be considered in every pesticidal application to citrus in the LRGV. Many growers apply an annual (summer) scalecide treatment for control of chaff and California red scales. Other growers wait until summer before making a decision whether to spray or rely on natural enemies to maintain control of scale insects. Texas citrus mites can cause significant damage to foliage in dry years. Control of this mite is needed most when dry weather conditions prevail following postbloom and during the fall periods.

Citrus rust mite (Figure 1) — This mite has a high reproductive potential and small populations may reach damaging levels in a short period of time. A generation may develop in 7 to 10 days during the warm season and as many as 29 eggs may be laid by a single female (76).

Adult female mites are wedge-shaped and approximately 1⁄200-inch in length. This small size makes detection difficult. A 10 to 14X hand lens is normally used for determination of mite infestations in the grove. In early season, undersides of leaves are checked (postbloom to May); thereafter, fruit are examined. An inspection may be required every 2 weeks during periods favorable for mite population increases. The greatest numbers of mites usually occur in the northeast quadrant of the tree (9). Russeted fruit (Figure 2) are most frequently found in the interior, top center, and skirt areas of the tree. This suggests lack of pesticidal coverage in these areas.

High relative humidity (RH) has been a factor most often related to increase of citrus rust mite populations. In the LRGV, RH usually stays above 50 percent. Rust mites increase very rapidly when RH exceeds 70 percent (8, 74). Abnormally high rainfall conditions are also followed by sharp increases in mites. Sharp reductions in populations are found when RH drops below 10 percent (8). In May 1972, an epiphytotic fungus, *Hirsutella thompsonii* (Fisher) developed following excessive rainfall during March and April (74) and live rust mites were difficult to find in May and June of that year. This fungus has provided the best potential control of rust mites of all biological control agents in the area.

Acaraben® (chlorobenzilate) and Kelthane® (dicofol) have been the most widely used acaricides for control of this mite. Residual control has been about the same for the two materials but in certain tests (15), repeated applications were required at shorter intervals with Acaraben than with Kelthane. Citrus rust mites were controlled for 3 months or longer with a significant reduction in mite-damaged fruit at harvest, with soil applications of the systemic pesticide, Temik® (aldicarb) (42). Vendex® (fenbutatinoxide) can provide longer residual control than Kelthane with adequate coverage (36, Dean unpublished). Vydate® (oxamyl) has provided 6 to 8 weeks suppression of this mite (34). Zineb can provide long residual control, particularly with oil; however, another acaricide must be added for initial quick kill when high populations are present (30). Zineb and copper treatments inhibit the development of the rust mite fungus, *H. thompsonii* (53).

Ethion and Trithion® (carbophenothion) provide good control, but residual control has been shorter with Trithion (Dean and Tannahill, unpublished). Carzol S.P. (formetanate hydrochloride) has provided longer residual control than sulfur. Guthion® (azinphosmethyl) did not provide sufficient rust mite control. The combination of Acaraben or Kelthane with Supracide (methidathion), as well as copper, has been associated with some population increase of this mite (15, 35).

Chaff scale (Figure 3) — Chaff scale has been the most widely distributed and abundant armored scale in the commercal citrus area of Texas during the past 20 years. All life stages have been found during every month of the year, indicating reproduction occurs throughout the year. The insect attacks all parts of the tree aboveground, and may be particularly abundant under the calyx (button) of the fruit and in pits of the rind (24).

Aphytis hispanicus (Mercet) is the most common parasite of this scale, although *Prospaltella fasciata* Malenotti has been found quite numerous at times (11). *Aphytis lingnanensis* Compere and *Aphytis comperei* DeBach and Rosen have also been reared from this

TABLE 1. POTENTIAL ARTHROPOD PESTS OF CITRUS IN THE LOWER RIO GRANDE VALLEY, TEXAS

Class	Family	Species	Common Name[1]
Arachnida:			
	Eriophyoidae	*Phyllocoptruta oleivora* (Ashmead)[2]	citrus rust mite
	Tetranychidae	*Eutetranychus banksi* (McGregor)[5]	Texas citrus mite
		Panonychus citri (McGregor)	citrus red mite
	Tenuipalpidae	*Brevipalpus californicus* (Banks)	(false spider mite)
		B. phoenicis (Geijskes)	red and black flat mite
Insecta:			
	Diaspididae	*Parlatoria pergandii* (Comstock)[3]	chaff scale
		Aonidiella aurantii (Maskell)[4]	California red scale
		Chrysomphalus aonidum (L.)	Florida red scale
		Lepidosaphes beckii (Newman)	purple scale
		L. gloverii (Packard)	Glover scale
	Coccidae	*Coccus hesperidum* L.	brown soft scale
		Ceroplastes cirripediformis (Comstock)	barnacle scale
		Icerya purchasi (Maskell)	cottonycushion scale
		Saissetia miranda (Cockerell & Parrott)	Mexican black scale
	Aleyrodidae	*Dialeurodes citri* (Ashmead)	citrus whitefly
		D. citrifolii (Morgan)	cloudywinged whitefly
		Aleurocanthus woglumi (Ashby)	citrus blackfly
		Aleurothrixus floccosus (Maskell)	woolly whitefly
		Paraleyrodes citri (Bondar)	—
	Pseudococcidae	*Planococcus citri* (Risso)	citrus mealybug
		Pseudococcus longispinus (Targioni-Tozzetti)	longtailed mealybug
		Pseudococcus calceolaria (Maskell)	citrophilus mealybug
	Pentatomidae	*Loxa florida* (Van Duzee)	(stinkbug)
	Aphididae	*Aphis gossypii* (Glover)	cotton or melon aphid
		A. spiraecola (Patch)	spirea aphid
	Papilionidae	*Papilio cresphontes* (Cramer)	orangedog
	Curculionidae	*Compsus auricephalus* (Say)	(snout beetle)
		Epicaerus mexicanus (Sharp)	(snout beetle)
	Flatidae	*Metcalfa pruinosa* (Say)	(flatid planthopper)
	Coreidae	*Leptoglossus phyllopus* (L.)	leaffooted bug
	Formicidae	*Atta texana* (Buckley)	Texas leafcutting ant
		Solenopsis geminata (F.)	fire ant
		Crematogaster laevinscula clara Mayr.	—
		C. arizonensis (Wheeler)	—
	Tephritidae	*Anastrepha ludens* (Loew)	Mexican fruit fly

[1]Common names approved by Entomological Society of America, names in parenthesis only for information.
[2]through [5]: Order of economic importance of primary pests.

insect (Dean unpublished). Numbers of parasites are usually higher during September and October, although high numbers have been found in rainy spring months following warm winters (Dean unpublished). Drier weather conditions are usually more favorable for increase of chaff scales than their parasites.

California red scale (Figure 4) — This scale has three and possibly four generations each year (7). Greater numbers are usually found in those years when dry weather conditions prevail during the spring and summer when parasites are less abundant. Growers often mistake chaff scale for California red scale. In Texas, damage to twigs and young newly planted trees (32) can be greater from California red scale than from chaff scale.

A. lingnanensis has been the most effective parasite in Texas citrus, and has given economic and sustained control in many instances (29). Efforts to establish *Aphytis melinus* DeBach or *Aphytis africanus* Quednau in Texas have not been successful.

Texas citrus mite (Figure 5) — This mite was described in 1914 in collections from castor bean and velvet bean at Orlando, Florida (54). In the LRGV, the mite has been found predominantly on citrus. Most of the year numbers were greater in south quadrants of grapefruit trees (9). Peak populations usually occurred during May through September, although peaks have occurred in mid-March from large winter populations when warm temperatures prevailed during February and March (8, 16). Greater numbers were found on leaves in the tops of trees than in skirt or inside canopy areas (14) and greater populations also occurred on Marrs than on Hamlin, Pineapple, or Valencia orange leaves (16). Damage (Figure 6) has been principally to leaves, but it will feed on fruit. Leaf drop has been associated with high mite populations, particularly following dry weather conditions.

Longest residual mite control has been with Vendex and Kelthane (34, Dean unpublished). Effective control has been difficult to attain when populations are increasing rapidly, such as during April and May. Ethion, Trithion, Carzol S.P., and oil have not been as effective as the aforementioned acaricides. Some reduction in mite numbers have been noted following use of Acaraben or sulfur. Increased mite populations have followed the use of Zineb (30) or copper (15). This may be caused by the destruction of a mite fungus, *Entomophthora floridanus* Weiser and Muma. The fungus was first found in the LRGV in 1969 (51). Increases in mite populations have also been observed following use of Supracide or Sevin, even though effective acaricides were added (35, 15, 24).

Secondary Pests

Secondary pests are potential or minor pests normally held below the economic injury level by their natural enemies or weather conditions. Outbreaks of secondary pests result when their natural enemies are killed by pesticides applied for target pest control; by pesticidal drift from adjacent crop land; by improper timing, mixtures, or selection of pesticides; and by inadequate coverage. Some secondary pest outbreaks result from indirect causes. Methyl parathion stimulated reproduction of brown soft scale (46). Road dust from frequently traveled roads can settle on adjacent citrus trees and act as a drying agent thus causing eradication of natural enemies. A discussion of secondary pests, not necessarily in the order of importance, follows.

Citrus mealybug (Figure 7) — *Planococcus citri* (Risso) has three to four generations per year in South Texas and possesses a high reproductive potential (43). Under optimum conditions the mealybug can complete development in 30 days. Individuals of the first generation are usually found under the calyx of the young fruit in the spring. Preference for grapefruit was found in Texas over other plant parts and other varieties (55). The winged male is the only motile stage which does not feed. Following natural enemy destruction by pesticidal misuse, the populations will increase to high levels by the second or third generation. Sooty mold, *Capnodium citri* Berk. & Desm., develops in the excreted honeydew of this mealybug. White filamentous wax secretions produced by the egg-laying females and their body wax can cause the fruit to appear as white snowballs. Outbreaks in 1969 and 1970 in South Texas were associated with continued use of broad spectrum organophosphate pesticides (22). These pesticides were detrimental to beneficial insects (23, 63, 57). Sex pheromone traps were found to be effective for survey and indexing the population density of the citrus mealybug (43, 33). Oil, which controls only the youngest stages of the mealybug, was used successfully in an integrated pest management program because of minimal disruptive effects to the natural enemy complex (56). Insect growth regulators also appeared promising for citrus mealybug control (40). Parasites included *Pauridia peregrina* Timberlake, *Leptomastix dactylopii* Howard, and *Anagyrus* sp. near *sawadai* Ishii (59, 22). Predators were a brown lacewing, green lacewing species, and a predaceous beetle (22, 63). Vine control was important in controlling mealybugs in infested grapefruit groves (39).

Whiteflies (Aleyrodidae) — The citrus whitefly, *Dialeurodes citri* (Ashmead), and the cloudywinged whitefly, *Dialeurodes citrifolii* (Morgan) (Figure 8), are the only whiteflies of potential economic importance of the five species on citrus in Texas (60). These two species can become pest problems in early and late spring. They excrete copious amounts of honeydew. Although quite similar, the species can be differentiated by their eggs on the lower leaf surface: citrus whitefly eggs remain yellow during maturation and have a smooth surface while cloudywinged whitefly eggs change color from yellow to black and have a net-like surface. A darkened area at the tip of the forewing occurs only in cloudywinged whitefly adults. No parasites were found attacking either species in South Texas. A red fungus, *Aschersonia aleyrodes* Webber, was found infecting citrus whitefly while some occasional predation was observed.

(continued on page 9)

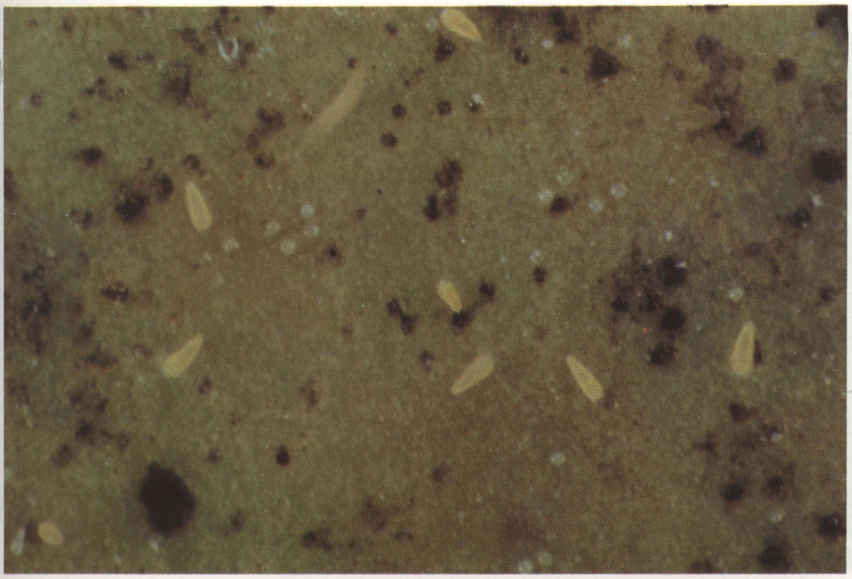

Figure 1.
Citrus rust mite.
Ca. 14X.

Figure 2.
Russeted grapefruit
by citrus rust mite.

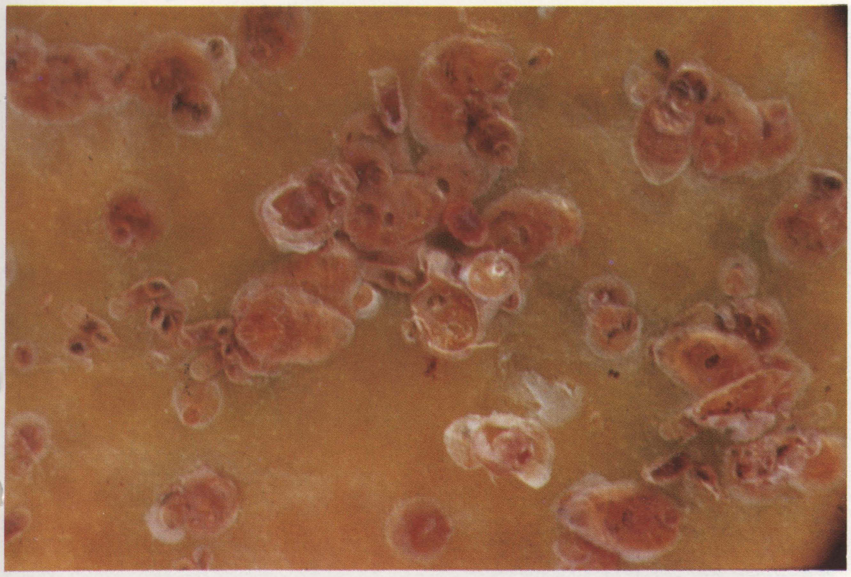

Figure 3.
Chaff scale.
Ca. 9X.

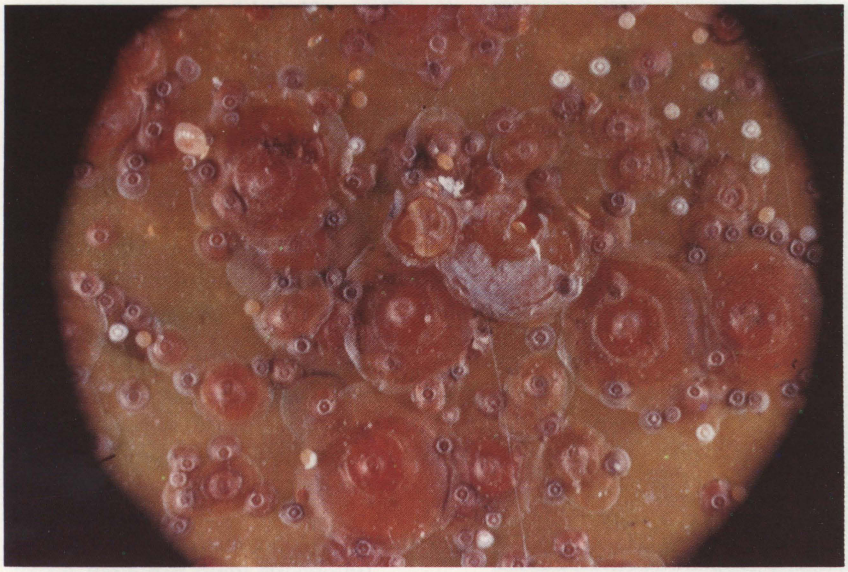

*Figure 4.
California red scale.
Ca. 9X.*

*Figure 5.
Texas citrus mites.
Ca. 13X.*

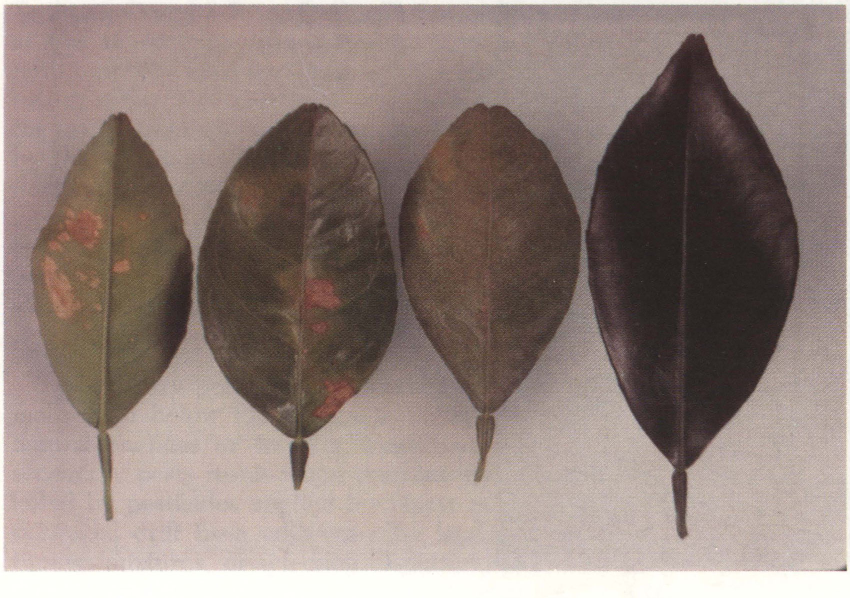

*Figure 6.
Texas citrus mite damage to citrus leaves.*

Figure 7.
Citrus mealybug.
Ca. 4X.

Figures 8 a & b.

a. Cloudywinged whitefly adult. Ca. 3X.

b. Citrus whitefly nymph. Ca. 3X.

Figure 9.
Purple scale and its controlling parasite.
Ca. 8X.

*Figure 10.
Brown soft scale.
Ca. 5X.*

*Figure 11.
Florida red scale
on orange.*

*Figure 12.
Sandy melanose
on grapefruit.*

The citrus blackfly, *Aleurocanthus woglumi* Ashby, became well established in the LRGV despite eradication attempts in 1971. Yellow traps became an effective tool for surveying and indexing the population density of this species (47). Adults have a red abdomen and grey-blue wings. Eggs are laid in a typical spiral pattern on the lower leaf surface. Nymphs and pupae are black with conspicuous spines, and pupae have a white wax band around their margin. Complete biological control was evident after the introduction of two parasites: *Amitus hesperidum* Silvestri (Platygasteridae) and *Prospaltella opulenta* Silvestri (Encyrtidae) (67).

The woolly whitefly species, *Aleurothrixus floccosus* (Maskell) and *Paraleyrodes citri* Bondar, are both under complete biological control in the LRGV (60). The former is attacked by three species of parasites: *Eretmocerus* sp., *Amitus* sp., and a *Prospaltella* sp.; *P. citri* is attacked by a single *Prospaltella* sp. A coccinellid predator, *Delphastus pusillus* (Le Conte) attacks both whitefly species while the coccinellid, *Nephaspis amnicola* Wingo, has been observed feeding only on *P. citri*. The woolly whitefly lays eggs in a typical circle configuration and nymphs and pupae are covered with a secretion of white wool-like wax filaments. *P. citri* lay eggs singly and nymphs and pupae are transparent with long cascading wax rods.

Brown soft scale — *Coccus hesperidum* L. (Figure 10) is a flat, ovate soft scale yellowish brown in color. Its life cycle is completed in approximately 60 days. Copious amounts of honeydew often result in heavy encrustations of black sooty mold. The insect became a major pest in 1959 (21) when natural enemies were killed by parathion drift from adjacent cotton fields (45). Methyl parathion caused increased fecundity of this insect (46). In the absence of methyl parathion treatments in cotton, the brown soft scale is no longer a major pest problem in Texas. It is believed to be under complete biological control by two dominant parasites: *Coccophagus lycimnia* (Walker) and *Microterys flavus* (Howard) (44).

Cottonycushion scale — *Icerya purchasi* Maskell is a soft scale which can secrete copious amounts of honeydew. The female is characterized by the grooved, white waxy egg sac which is 2 to 2-½ times the length of her body (32). There are three generations per year with a life cycle ranging from 96 to 144 days (62). The vedalia beetle, *Rodolia cardinalis* (Mulsant), provides complete biological control in the LRGV. Sporadic infestations may result from misuse of pesticides which kill the vedalia beetle.

Florida red scale — This scale insect (Figure 11, on fruit) attacks the fruit, leaves, and occasionally the green twigs. Today, it is only a minor pest due to the introduced parasite, *Aphytis holoxanthus* DeBach, in 1959 (2, 17). Two other parasites, *Pseudhomalopoda prima* Girault and *Prospaltella aurantii* (Howard) are present only in small numbers in the presence of *A. holoxanthus*. Pesticide-induced outbreaks occur following use of Supracide, Sevin, and sulfur (17).

Purple scale — This scale insect (Figure 9) was the fourth most harmful pest of Texas citrus in 1950 (32). Very little parasitization of this scale insect was found before the introduction of *Aphytis lepidosaphes* Compere in July 1952 (10). Sulfur was used primarily in dust form for control of citrus rust mite at that time, and even though *A. lepidosaphes* was found quite commonly (10), purple scale population densities were not sharply reduced until other pesticides less toxic to the beneficial insects were used beginning in 1960. Complete biological control was found by 1975 (13).

Glover scale — This scale insect has been an economic pest problem only in a few isolated groves during the past 27 years. *Prospaltella elongata* Dozier has been the principal parasite collected most often from this scale insect, while *Aphytis* sp., has been collected on numerous occasions. When found, Glover scale is usually associated with purple scale, with which it is confused. The adult Glover scale covering is narrow and its body under the cover varies in coloration from white to purple. The purple scale body is a chalky white color and the scale is "comma-shaped."

Citrus red mite — *Panonychus citri* (McGregor) was first found in commercial grapefruit and orange groves in Texas near Combes in January 1980 (37). The mite has been found in groves south and eastward toward the Gulf since that time (38). Heavy infestations were found on Ruby Red and Star Ruby grapefruit; 'Orlando' tangelo; and on 'Joppa', Navel, and Valencia oranges.

Somewhat larger than the Texas citrus mite, citrus red mite is recognized by the velvet red body which has prominent tubercles with long, reddish bristles. Eggs are round and bright red, and have a central stalk with threads radiating from the top to the leaf surface like a maypole. Eggs are generally laid alongside the midrib on the upper leaf surface.

Foliar applications of Vendex or oil as well as soil-applied Temik have produced good control (36).

False spider mites — *Brevipalpus phoenicis* (Geijskes) and *B. californicus* (Banks) become potential problems when organophosphorus pesticides are used for control of other pests. *B. phoenicis* is the most common of the two species. These mites are associated with a "leprosis-like" spotting of fruit, particularly on grapefruit. Increases in mite populations were observed on inside fruit and leaves in June followed by high populations in August and September (26). In general, these mites have not reached pest status where Kelthane, Acaraben, sulfur, or oil have been used.

Mexican fruit fly — This fruit fly is indigenous to northeastern Mexico and infests numerous citrus, deciduous, and wild host species. Northward migration of this fruit fly is a potential pest for citrus in the LRGV and other citrus as well as deciduous fruit areas from the migration spread. The first record of this fly in the LRGV was in 1927 (3). Since that date, a rigorous survey and detection program was established by USDA. Fly traps showed this fruit fly as early as October, with peak populations in the March through May period. Fly larvae feed and develop within the fruit. Infested fruit can possibly be shipped since there may be no evidence of rind injury. Quarantines and regulatory fumigation with EDB (ethylene dibromide) have been established to insure against this possibility.

A flatid planthopper — *Metcalfa pruinosa* (Say) usually hatches in mid-March with adults appearing in late April or May. Only one generation per year occurs in South Texas, but adults may be found as late as September. Honeydew is abundantly secreted during very dry spring months by the nymphs which have a cottony appearance and are sometimes mistaken for citrus mealybug. Grapefruit trees are preferred over oranges. Pesticidal control is usually not required. A dryinid parasite, *Psilodryinus typhlocybae* (Ashmead), has caused heavy parasitization in some years (20).

Barnacle scale — *Ceroplastes cirripediformis* Comstock is an oddity on Texas citrus. A 'Meyer' lemon tree, infested with a mild strain of tristeza virus, was caged with fine-mesh plastic screen at TAES W in 1955. Barnacle scale increased rapidly in numbers, but almost disappeared a short time after the cage was removed and numerous natural enemies were present.

Early in 1975, infestations of this scale insect were found in the eastern and western sections of the LRGV (41). A complex of parasites were important in biological control of barnacle scale as it was difficult to find this scale insect in 1977 (27). Thus, barnacle scale is controlled by its natural enemies unless the latter are killed by pesticides or hyperparasites become numerous and prevent parasites from maintaining control.

Aphids — Aphid species most frequently found on the LRGV citrus are the spirea aphid, *Aphis citricola* Van der Goot, and the cotton or melon aphid, *Aphis gossypii* Glover. Aphids can cause severe leaf curl of new growth. Pesticidal control is usually not necessary because of effective control by natural enemies. According to identification records, *Aphidius testaceipes* (Cresson) has been the most common parasite. Both aphids are inefficient vectors of tristeza virus (28). This disease has never been a problem in the LRGV even though more than 95 percent of the citrus is planted on susceptible sour orange rootstock.

Snout beetles — *Compsus auricephalus* Say is the most common in the area. The adult weevil is approximately 11 mm long and greenish-gray in color, has a broad snout, and feeds on foliage, while the larvae are root feeders. The adult of another less common species, *Epicaerus mexicanus* Sharp, is blackish-brown in color and about the same length as the *C. auricephalus*. Most species produce only one generation a year.

Ants — Ants may cause direct injury to the trees or may interfere with natural control of pests by their parasites and predators. The most common ant is the fire ant, *Solenopsis geminata* (F.), which may feed on the bark, often girdling and causing death of young citrus trees (66). Fire ants will nurse honeydew secreting insects such as aphids, mealybugs, and brown soft scale. They can also be a nuisance to pickers and other grove workers.

Acrobat ants will nest in foliage of the tree, in holes of wood boring insects, or at the base of the trees. They also feed on honeydew and interfere with biological control agents. The two particular species identified are *Crematogaster laevinscula clara* Mayr. and *C. arizonensis* Wheeler. The former is reddish-orange, while the latter is entirely black.

The Texas leafcutting ant, *Atta texana* (Buckley), can cause citrus defoliation (64).

MAJOR CHANGES IN PEST COMPLEXES THROUGH RESEARCH

A. Information on the selective effects of pesticides against target species and their natural control agents is of immense value to the grower and pest control operator. Such information can help them avoid the creation of new pest problems as well as increase the residual effectiveness of pesticides against the target pests. Extension Service personnel began to use this information as soon as it was made available. The citrus agroecosystem of pests and their natural enemy complex can be better understood by citrus growers when this information is discussed with them by research and extension personnel.

B. Purple scale was reduced from the fourth most harmful pest of Texas citrus in 1950 to that of incidental occurrence status by the early 1970's. The ability of the introduced parasite, *Aphytis lepidosaphes* Compere, to re-enter after certain adverse pesticidal applications and bring about control is very unusual (10). Control of purple scale by this parasite is more effective than the pesticidal control formerly used. This is a classic example of biological control (13).

C. Research with oils has produced specifications which provide guidelines for most-effective pesticidal oils with the least adverse tree effects (19). Target species cannot develop resistance to oil and it does not produce the disruptive effect on the natural enemies as do many of the organophosphorus pesticides (58). Oil is the most selective scalecide available, but many years of research were necessary to gather data on its proper use and efficacy against specific pests.

D. Florida red scale was reduced from the ninth most destructive pest of Texas citrus in 1950 to incidental pest status by 1972. An introduced parasite (*Aphytis holoxanthus* DeBach) in 1959 reduced the economic importance of this pest when adverse pesticides were not used (17). By killing this effective parasite with the use of Supracide and/or Sevin, Florida red scale will become a problem. Reduction of the pest status of this insect was a very important contribution to the Texas citrus industry.

E. Brown soft scale was determined to be a parathion-related problem on Texas citrus (46). Nine natural parasites were identified and others were imported to provide more effective control under a wide variety of conditions. Fruit blemishes attributed to brown soft scales were reduced to less than 1 percent at the packinghouses.

F. Citrus mealybug was determined to be a pesticide-related problem and caused by the particular pesticides applied to the trees (22). Results showed the problem could be avoided, or limited, by selective use of certain pesticides (40). Biological control agents (both native and introduced) have provided effective control (59).

G. The early introduction of parasites for control of citrus blackfly prevented this insect from becoming a possible major pest to Texas citrus. After establishment in the early 1970's and eradication attempts were unsuccessful, two effective parasites were introduced from Mexico and distributed throughout the infested areas. Complete biological control was the result (67).

GROWER PEST CONTROL PROGRAMS AS AFFECTED BY INTEGRATED PEST MANAGEMENT INVESTIGATIONS

Selective effects of various pesticides against various pests and certain natural enemies are provided in Table 2.

The first pesticidal application of the year is generally made at postbloom (when three-fourths of the petals have fallen) or soon thereafter. At that time, citrus rust mite can move onto young fruit and cause considerable damage. An unusually heavy increase of rust mites can occur early in the year when the last treatment for control was made during the prior August to September period and weather thereafter was favorable for rust mites to increase during the fall and winter (15). Damaging levels of rust mites were found in January and prebloom treatment was justified (15). Every grower should consider citrus rust mite control at this time.

The greatest increase of Texas citrus mites during the year generally occurs during the April to June period, and because of the importance and potential damage of this pest, control at this time is considered necessary (16). Generally, populations of Texas citrus mites are lowest in February, but usually increase rapidly with the warm weather. These mites may also increase rapidly during favorable fall weather conditions.

Armored scales usually increase after the postbloom period with warming weather. Parasites are often at their lowest level of the year during February and March, particularly following cold winters (11, 17). Consideration of armored scale control at postbloom is questionable. Coverage of all parts of the tree is necessary if satisfactory scale control is to result. Since complete air displacement is essential, the necessary volume of liquid to accomplish control is greater than many growers realize. Complete coverage cannot be accomplished with 25 to 125 gallons per acre in this area.

All commercial varieties of citrus may be attacked

TABLE 2. EFFECTS OF VARIOUS PESTICIDES AGAINST CERTAIN TEXAS CITRUS PESTS AND NATURAL ENEMIES

CITRUS PESTS:	Acaraben®	Kelthane®	Vendex®	Zineb®	Ethion	Trithion®	Sulfur	Carzol S.P.	Oil	Supracide	Guthion®	Sevin	Copper	Temik®	Comite®	Torak®	Vydate®
Citrus rust mite	4	4	4	3-4	4	3-4	2-3	3	1	a	1	—	a	4	3-4	2-3	3
Texas citrus mite	1-2	4	4	0	3-4	3-4	1-2	3-4	3-4	d	2-3	d	a	3	3	—	1
Citrus red mite	1	4	4	—	—	—	—	2-3	3-4	c-d	—	—	—	3	3	—	1
False spider mites	4	4	—	0	c	c	3	—	3	—	d	—	—	—	—	—	—
Chaff scale	N	N	N	N	a	b	b-c	c	4	4	4	d	a	1-2	—	—	—
California red scale	N	N	N	N	N	a	b-c	c	3-4	3-4	3-4	d	a	1-2	—	—	—
Purple scale	N	N	N	N	N	a	c	—	4	4	3-4	d	a	—	—	—	—
Florida red scale	N	N	N	N	—	—	c	c	4	c-d	—	d	a	1-2	—	—	—
Brown soft scale	N	N	—	—	1-2	3	—	a	3	4	4	4	—	3	—	3	—
Citrus mealybug	N	N	—	N	a-b	a-b	—	—	1-2	3-4	2	—	—	3	—	1-2	3
Whiteflies	N	N	N	—	—	—	—	—	2-3	3-4	3	—	—	3-4	—	2-3	3
PARASITES:																	
Ext. chaff scale	N	N	N	N	b	c	b-d	c-d	a	c-d	c-d	d	a	—	—	—	—
Int. chaff scale	N	N	N	N	b	c	b-d	c-d	a	c-d	c-d	b	a	—	—	—	—
Ext. CA red scale	N	N	N	N	c	c	b-c	d	a	b-c	d	d	a	—	—	—	—
Ext. purple scale	N	N	N	N	c	c	b-c	—	a	—	d	d	a	—	—	—	—
Ext. FL red scale	N	N	—	—	c	c-d	c-d	c-d	a	c-d	d	d	a	—	—	—	—
Int. brown soft scale	—	—	—	—	—	—	d	—	a	—	d	d	—	—	—	—	—
PREDATORS:																	
Lady beetles	N	N	N	—	a	a-b	—	—	a	c-d	c-d	d	—	—	—	—	—
Brown lacewing	N	2	N	—	a	b	—	—	a-b	d	d	d	—	—	—	—	—

Numbers: 0 to 4 = degree of kill by pesticide. Letters: a lowest to d highest = degree of increase of insects or mites, or degree of reduction of parasites found. N = no effect noted. (–) = no information. (Ext.) and (Int.) = external and internal parasites.

by melanose (Figure 12), but grapefruit seems more susceptible (1). The disease is more prevalent in the area from Mercedes eastward. Infection of fruit is more pronounced when fruit is less than three-fourths of an inch in diameter and in groves when wet weather prevails during this period or in groves where greater infection has occurred. Late melanose infection can occur in the June to July period when proper weather and other conditions prevail. Copper is the principal ingredient of the fungicides used in melanose control. Coverage of twigs, leaves, and fruit is necessary to accomplish effective control. However, residual control of citrus rust mite and Texas citrus mite is reduced when Acaraben or Kelthane is mixed with copper (15). The most important biological control agent of citrus rust mite in our area is the fungus, *Hirsutella thompsonii* Fisher, which copper kills (53). Copper also kills an important fungus of the Texas citrus mite, *Entomophthora floridana* Weiser and Muma. Indiscriminate use of copper is to be discouraged.

The citrus nematode, *Tylenchulus semipenetrans* Cobb, is a serious pest of citrus with approximately 90 percent of the orchards infested in the LRGV (48). Nematodes are wormlike, invisible to the unaided eye, and attack the root system causing general tree decline. A nematicide for control is generally applied prebloom or just after bloom. DBCP (dibromochloropropane), a highly effective nematicide applied in the irrigation water, is no longer approved for use. An alternative systemic nematicide-acaricide receiving increased grower use is Temik® (aldicarb). Granular Temik is chiseled 1 to 2 inches into the soil at the drip line of the tree and activated by irrigation water. Temik applications in a 'Marrs' Early Orange orchard at 33 and 67 lb/acre significantly reduced nematode populations in each of the three seasons of testing and significantly increased yield in 1 of 3 years (71). Temik activity against whiteflies, brown soft scale, Texas citrus mites, and mealybugs has been found in current research (French unpublished).

Vydate® (oxamyl) is a nematicide-acaricide recently registered for use on Texas citrus. Applied as a foliar spray, Vydate translocates systemically downward to the roots. Nematode control and fruit yield improvement has been less consistent with this material than with DBCP or Temik (69, 70, 71).

Pesticide selection at postbloom can directly affect pest problems throughout the season. Many growers that have used concoctions of various pesticides to control mites and avoid problems with other potential pests have learned this is not a valid approach to minimize pest problems. Postbloom applications are primarily for control of citrus rust mite and Texas citrus mite. However, control of scale insects is sometimes necessary at postbloom, and careful selection of scalecides is necessary to avoid reduction or knockout of parasite populations that could result in a sharper increase of armored scales, or other potential pests by early summer. Delaying postbloom application 1 to 3 weeks, if practical, can provide additional time for scale parasites to increase.

The decision for a pesticidal application following postbloom should be determined by grove surveys for pest populations. Generally, increase of citrus rust mite and armored scale populations are reasons for a second pesticidal application. Scalecide applications, when necessary, are usually applied during the June through September period. According to a study by Clark and Friend (1932) and later investigations by the authors, a full coverage scalecide application in early to midsummer will usually provide control for the balance of the season. Only three scalecides have been successfully used in this area: oil, Guthion, and Supracide. Each of these scalecides have their limitations.

In Texas, properly applied oil has been a very useful and selective pesticide for armored scale and Texas citrus mite control. Scales are killed with oil by suffocation (31), and this phenomenon does not offer a ready mechanism for the development of resistance. The use of oil has been preferred over certain organophosphorus pesticides for scale control because of other pest problems that have developed following applications of the latter (26, 23, 17). Oil undoubtedly kills some adult parasites. Immature parasites have protection under the scale coverings, and residual oil having soaked into the plant tissues, does not kill the emerging parasites as found with residues of organophosphorus pesticides. Chaff scale parasites were usually found with a smaller scale population at an earlier date after oil application than after certain organophosphorus pesticides. This was an advantage of oil (25).

Specifications for citrus oils (19) are still valid today. Oils developed for use on citrus in the 1960's produce only minimal tree reaction when properly used. Soil moisture should be at a maximum when applications are made. Lack of coverage reduces pest control efficiency with any scalecide when volumes of less than 500 gallons/acre are used. Certain other restrictions also must be observed with oil applications: use after September 15 deters the development of soluble solids of grapefruit and the meeting of minimum maturity standards for early fruit shipment; increased cold susceptibility of citrus when applied late; and delay in coloring of fruit for 30 days in the packing sheds for fresh fruit shipments. Oil is not suggested when RH is below 30 percent, which occurs infrequently.

The organophosphorus pesticides Guthion and Supracide kill most beneficial insects and considerable time is required for biological control agents to re-establish after their use. A problem with Florida red scale can be expected after the use of Supracide even though some control results (16, 15). Numerous studies have shown that the Texas citrus mite can increase in importance in a relatively short time period after application of these pesticides (12, 15). False spider mites become an economic pest when organophosphorus pesticides are used and no Kelthane, Acaraben, sulfur, or oil are applied during the May to September period (26). Moreover, the use of organophosphorus pesticides requires much greater personnel protection for the applicator safety. In addition, total tree coverage is absolutely necessary if satisfactory control is to result.

Greasy spot, *Mycosphaerella horii* (Harii), is a fungus disease which causes a "greasy-like" spotting of the undersides of leaves, particularly with grapefruit. Where control is necessary, oil or copper applied during the summer usually provides adequate control.

The last pesticidal application of the year is usually made during the fall. This application is to provide citrus rust mite control until the following postbloom season. Texas citrus mites can increase in populations in conjunction with dry, hot, and windy weather in October and November. Heavy infestation can result in considerable loss of leaves. Pesticidal control of armored scale insects during this period is considered too late to be effective. Armored scale parasites are numerous at this time, and if their numbers are reduced or eliminated, armored scales can increase thereafter without biological control assistance.

The number of pesticidal applications each year varies from grove to grove depending on location, weather conditions, and variations in pest to natural enemy ratios. One grove may require only two pesticidal applications a year, while another may need five or more. Some growers who have been ill-advised may apply excessive sprays during the year. The foregoing discussion is certainly <u>not</u> intended to endorse a calendar spray schedule and this is not recommended. Information is provided to develop a knowledgeable approach to the grower pest management program. The reduction of one or two applications per year may require extra effort. Pesticidal decisions based on careful monitoring of groves for pests and their biological control agents will result in less expensive pesticide bills. Other benefits include utilization of natural enemies, fewer major pest problems, and a less complicated pest control program.

INTEGRATED PEST MANAGEMENT IN ACTION

The Texas Agricultural Extension Service has utilized research data on various citrus pests and their natural control agents down through the years. Greater emphasis was considered in the control of target pests with pesticides in earlier work. A greater variety of pesticides became available for use on citrus in the 1960's. Additional problems with minor pests developed after continued use of many of these pesticides.

The effects of certain pesticides against various pests and their natural enemies were summarized in 1977 (23). The Extension Service began use of these pest management considerations immediately after release of the information. A better understanding of the citrus ecosystem and potential factors for possible changes or upsets were provided. Such information was reproduced for distribution as a guide in development of more valid and economical pest management programs for the growers as part of the Texas Guide for Controlling Pests and Diseases on Citrus, 1979. A revised edition of this information is provided in Table 2.

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