IPM in Texas Citrus

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Texans have grown citrus since at least the mid 1800s, and pests have caused problems for growers from the beginning. Growers have tried to control those pests using a variety of methods, both chemical and biological. But because pests often become resistant to chemical suppression methods, pest management continues to be a major concern for citrus producers.

Using the principles of integrated pest management (IPM), growers can integrate environmentally compatible control tactics to achieve satisfactory long-range pest control. IPM tactics also allow producers to optimize net returns while preventing harm to people or the environment.

**Citrus History**

The earliest record of citrus in Texas dates back to 1849, when trees were grown from seed near Brazoria. The earliest citrus trees in the Lower Rio Grande Valley (LRGV) were planted in 1882, also grown from seed, on the Laguna Seca Ranch about 20 miles northwest of Edinburg.

By the early 1900s, the number of citrus trees in Texas totaled 883,406 trees, according to the U.S. crop report in 1910. Most of those trees were Satsumas in the Galveston-Houston area. However, by the 1920 report, Texas had only 123,951 bearing trees, primarily because of citrus canker and the freeze of 1917-18.

Since 1920, consistent citrus production has remained in areas that are less likely to experience severe freezes, such as in the Lower Rio Grande Valley. The early growers in the LRGV found that Satsumas were poorly adapted to their conditions. Oranges and grapefruit gave promising results, especially if they were grafted on sour orange rootstock.

Although the first successful commercial citrus orchards using sour orange rootstock were made in 1908 by Charles J. Volz, it was not until 1920 that the Lower Rio Grande Valley was recognized as an important citrus area.

The citrus industry expanded rapidly during the 1920s, and with this growth came the need for research-based information on citrus production and pest management. Organized meetings were held to disseminate this information to growers.

In 1932, the first Citrus Institute was held in Edinburg, sponsored by Edinburg College, now known as the University of Texas-Pan American. Participants discussed various aspects of citrus production, including arthropod and disease control as well as spray oils and spray mixtures. In 1935, producers formally requested that the Texas Agricultural Experiment Station at Weslaco investigate the importance of biological agents for armored scale control in Texas citrus.
Several more citrus institutes were held annually in Edinburg, but they were discontinued after World War II broke out. The institutes resumed in 1946 in conjunction with discussions of other horticultural crops.

The meetings were sponsored by the Rio Grande Horticultural Club and held in Weslaco. This Horticultural Institute continues to this day and is sponsored by the Rio Grande Valley Horticultural Society.

Today, the Texas citrus industry is located almost totally in the Lower Rio Grande Valley in Hidalgo, Cameron and Willacy counties. Of the 32,800 acres in citrus production, about 70 percent are grapefruit and the balance is mainly oranges. Hidalgo County has 83 percent of the total citrus acreage, followed by Cameron County with 15 percent.

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The seedless, colored (pink to red) grapefruit from Texas is world renowned for its deep red flesh. It is high in sugars and low in acids. These grapefruit either originated in the Lower Rio Grande Valley or were developed by the Texas A&M-Kingsville Citrus Center (formerly known as Texas A&I Citrus Center at Weslaco). Ruby Red originated as a bud mutation from a Pink Marsh in 1929, and Rio Red was developed from irradiated Ruby Red budwood in 1984.

The grapefruit acreage in Texas is now nearly all Rio Red, with a very small acreage of Star Ruby, which originated from irradiated Hudson seed. These two varieties have deep red flesh and peel. They are marketed as Rio Stars®; they make up 85 percent of the production.

The remaining production of colored grapefruit is mainly Ray Ruby and Henderson, both of which originated as bud mutations of Ruby Red. A few acres of Ruby Red also remain. Their flesh and peel color is not as red as the Rio Stars® and are marketed as Ruby Sweets®.

While not as cosmetically appealing as Texas grapefruit, Texas oranges are also well known for their low acidity and thin peel. Early and mid-season varieties comprise 87 percent of the total orange acreage, with the balance being late-season Valencia oranges. Marrs, the earliest maturing variety, originated as a bud mutation from a navel orange tree. Other early and mid-season orange varieties include navels (N-33, Everhard), Jaffa and Pineapple.

In 1983 and 1989, freezes not only reduced acreage significantly, but they also lowered market confidence and reliability. The 1983 freeze reduced the citrus acreage from 69,200 to about 22,000. The 1989 freeze reduced the 35,700 acres then in production to about 12,000. The Texas citrus industry is still rebuilding from those freezes.

Another result of those freezes is that problems arose from some pests that had previously been maintained at acceptable levels by naturally occurring predators and parasitoids. After the 1983 freeze, citrus blackfly populations became more widespread than before. After the 1989 freeze, California and Florida red scale became more widespread and devastating.

To alleviate the problem, parasitoids were introduced into orchards that had little to no parasitization, bringing these pests under an acceptable level of biological control.

All citrus in the Lower Rio Grande Valley is grown for the
fresh market, which requires that pesticides – whether synthetic or organic – be used to ensure yield and cosmetic appeal. Some pests are controlled by naturally occurring parasitoids and predators; others are controlled with pest-selective pesticides that are least destructive to these natural enemies.

However, all pesticides have some effect on the natural enemies of pests. To help prevent the pesticides from disrupting these natural enemies, researchers have developed action thresholds, which are specific levels of pest populations or disease incidences that signal impending economic damage to the crop or trees.

Growers must have sound information based on research and experience in order to develop a more effective integrated pest management program.

**Pest and Pesticide Challenges**

Changes and improvements in pest management approaches over the years have occurred primarily in response to pest outbreaks and pests that continue to be troublesome every year. Biological control – the use of living organisms to control insect pests and weeds – has been employed in Texas citrus as far back as 1929, when parasitoids and predators were used to reduce California red scale populations, in many instances, to tolerable levels for fresh fruit.

Until 1933, California red scale, *Aonidiella aurantii* (Maskell), was considered the most destructive citrus pest in the LRGV. Growers mostly used citrus spray oil to control it. In September 1933, a hurricane blew most of the fruit from the trees, and pest-control costs nearly reached zero for this pest.

After 1933, the citrus rust mite, *Phyllocoptruta oleivora* (Ashmead) was considered the most serious citrus pest, and today it is the most costly arthropod pest. Until the late 1950s, sulfur was used to control the citrus rust mite. However, the continued use of sulfur caused increases in populations of armored scales.

Zineb sprays came into use in 1958 and controlled citrus rust mites for longer periods than did sulfur. However, growers eventually discontinued using zineb because it had to be mixed with other miticides to provide a quick kill. Also, because zineb affects fungi, it was harming *Hirsutella thompsonii* Fisher, a fungus that attacks citrus rust mites.

In the 1960s, growers begin to realize the importance of pesticidal effects on secondary pests and their natural enemies. These effects in many cases were more important than the effects on the target pests. It became evident that various pesticides disrupted the populations of beneficial insects, causing secondary pest outbreaks.

Growers recognized that it is often more difficult and expensive to control secondary pests than the target pest, especially as the use of synthetic pesticides became more common. As different synthetic pesticides came into use, serious pest problems arose.

Several of these problems became evident in Texas citrus:

- Parathion drift from treated cotton produced major prob-

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**ORDERED RANKING OF CITRUS PESTS IN 1950**

1. Citrus rust mite
2. Texas citrus mite
3. California red scale
4. Purple scale
5. Glover scale
6. Mexican fruit fly
7. Chaff scale
8. Fire ant
9. Florida red scale
10. Leaf-footed bug
11. Southern green stinkbug
12. Melon aphid
13. Brown soft scale

Citrus pests in order of importance as provided in 1950 by S. W. Clark (TAES entomologist from 1927 to 1937).

**ORDERED RANKING OF CITRUS PESTS IN 2001**

1. Citrus rust mite
2. California red scale
3. Florida red scale
4. False spider mite
5. Citrus black fly
6. Mexican fruit fly
7. Brown soft scale
8. Texas leafcutting ant
9. Chaff scale
10. Root weevil
11. Fire ant
12. Texas citrus mite
13. Citrus leafminer

Citrus pests in order of importance as provided in 1950 by J. Victor French (TAMUK citrus entomologist from 1972 to present).
• 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 in the 1960s.

• In 1970, after organophosphate pesticides had been used continually, false spider mites and citrus mealybugs became major problems affecting grapefruit. Three of these pesticides – Guthion® (azinphosmethyl), Lorsban® (chlorpyrifos) and Supracide® (methidathion) – kill most beneficial insects and, after they are used, considerable time is required for the biological control agents to reestablish.

• Problems with Florida red scale have arisen after Supracide® and Lorsban® were used, even though these products initially achieved some control in the 1990s.

• When certain miticides were combined with Supracide® as well as with copper, populations of citrus rust mite increased in the 1980s.

Changes in the availability of pesticides also have affected pest control strategies. During the 1970s, Acaraben® (chlorobenzilate) and Kelthane® (dicofol) were used most widely against citrus rust mites. However, with re-registration and special review processes by the Environmental Protection Agency (EPA) that focus on preventing potential harm to people or the environment, many pesticides were canceled, including Acaraben®.

Another problem is that some pests can become resistant or tolerant to some pesticides because of their widespread use (such as Kelthane®). Therefore, resistance management continues to be an important reason for a sound integrated pest management program.

Many of the citrus rust mite products of today became widely used during the 1980s. By the 1990s, growers were reporting that some of these products failed to control citrus rust mite. Among the pesticides reported were Agrimek® (abamectin), Temik® (aldicarb), Vendex® (hexakis) and Vydate® (oxamyl).

Although the reasons for these failures have been as varied as the products themselves, growers will need to integrate all the control tactics for key pests such as the citrus rust mite in order to achieve control. Even as new products such as Nexter® (pyridaben) become labeled for citrus rust mites, the products will affect beneficial agents, and pests will develop resistance to the products. Therefore, sound research and experience will be needed to adjust integrated pest management programs.

Response and Successful IPM Implementation

Sound research and Extension programs have brought about several major changes in integrated pest management to aid the citrus industry:

• Extension personnel have given useful, research-based information to growers and pest control operators about the selective effects of pesticides against target species and their natural control agents.

Such information can help growers avoid creating new pest problems while increasing the residual effectiveness of pesticides.
against the target pests. Extension personnel begin to use and disseminate this information as soon as it is made available.

Citrus growers can better understand the citrus agroecosystem – including pests and their natural enemy complex – when this information is discussed with them by research and Extension personnel.

- **Research with oils has produced guidelines for the most effective pesticidal oils with the least adverse effects on trees.** Target species cannot develop resistance to oil, and it does not produce disruptive effects on natural enemies as do many organophosphate pesticides. Oil is the most selective scalecide available, but many years of research were needed to gather data on its safe use and effectiveness against specific pests.

- **Purple scale was reduced from the fourth most harmful pest of Texas citrus in 1950 to that of incidental occurrence status by the early 1970s.** Today, this pest is found widespread but is of no economic importance. It is unusual that the introduced parasitoid, *Aphytis lepidosaphes* Compere, was able to reestablish after certain adverse pesticidal applications and bring about biological control of purple scale. This is a classic example of biological control.

- **Florida red scale was reduced from the ninth most destructive pest of Texas citrus in 1950 to incidental pest status by 1972.** A parasitoid (*Aphytis holoxanthus* DeBach) introduced in 1959 reduced the economic importance of this pest. Certain pesticides, such as Supracide® and/or Lorsban®, allow the Florida red scale to become a problem because they kill this effective parasitoid.

  During the 1990s, problems with the Florida red scale recurred. However, after intensive efforts, it was brought under an acceptable level of biological control with augmentive releases of *A. holoxanthus* and twice-stabbed lady beetles (*Chilocorus stigma* Say).

  Reducing the pest status of this insect was a very important contribution to the Texas citrus industry.

- **Brown soft scale was determined to be a parathion-related problem on Texas citrus.** Nine natural parasitoids were identified and others were imported to provide more effective control of brown soft scale under a wide variety of conditions. Fruit blemishes attributed to this scale were reduced to less than 1 percent at the packing houses.

  The brown soft scale is now an occasional pest in isolated locations within infested orchards.

- **Citrus mealybug was determined to be a pesticide-related problem.** Results showed that the problem could be avoided or limited by selectively using certain pesticides. Biological control agents (both native and introduced) have provided effective biological control.

- **The early introduction of parasitoids to control citrus blackfly prevented this insect from becoming a major pest in Texas citrus in the early 1970s.**
Pesticides were found to be ineffective in controlling citrus blackfly. However, two effective parasitoids (Encarsia opulenta and Amitus hesperidum) were introduced from Mexico. They dropped this pest to an occasional problem until the 1983 freeze.

Outbreaks have occurred since 1983, but intense efforts to reestablish these biological agents have resulted in complete biological control.

- Pest-selective pesticides were integrated to allow native beneficial predators and parasitoids to maintain citrus leafminer populations to tolerable levels in mature orchard trees.

The citrus leafminer was first reported in the United States in 1993. By the fall of 1994, it had spread through the entire Texas citrus industry. Several native parasitoid and predator species were found attacking the citrus leafminer. Seven parasitoids were identified, the most abundant of which was Zagrammosoma multilineatum Asmcd. Exotic parasitoids were released but did not become established.

However, through the integration of pest-selective pesticides, the native beneficial complex has maintained citrus leafminer populations to tolerable levels in mature orchard trees. It is an occasional problem in young nursery trees.

**Grower IPM Program Guidelines**

The objective of an IPM program is to achieve satisfactory long-range pest control while integrating environmentally compatible tactics and optimizing net returns. Growers reach this goal by using various IPM strategies with an emphasis on preserving the natural biological control agents.

Ideally, IPM programs consider all available management options – including taking no action – to achieve minimum pesticide use. This approach promotes the preservation of natural biological control agents.

However, citrus IPM programs involving the Texas fresh fruit industry need to emphasize optimizing rather than minimizing pesticide use. When pest or disease incidence increases rapidly, growers may need to apply pesticides more often to protect fruit quality and crop investment.

IPM strategies are governed in large part by the relationships of pest and disease development with weather conditions, cultural practices, natural biological control agents and pesticide use. To manage citrus pests, three general approaches are available: cultural control, biological control and chemical control.

The first two approaches are preventive and may have more impact in the long term than in the short term. Chemical control is suppressive and may have more of a short-term effect. When integrated into a pest management strategy, these three approaches must be compatible with each other as well as with environmental and economic conditions.

The term “management” implies that a grower accepts that pests will be present in the orchard at some population level as components of the citrus production system. It is this concept of a pest population level or action threshold that is key in an
IPM program.

Action thresholds are specific levels of pest populations or disease incidences that signal impending economic damage to the crop or trees. This level is known as the economic threshold. Ideally, each action threshold value considers the pest’s life cycle, its potential for rapid population increases under existing or anticipated environmental conditions, orchard history, the type of damage likely to occur in proportion to the control costs, and other relevant factors.

Action threshold values have been established for the citrus rust mite, the major economic pest of Valley citrus. However, there are no standardized criteria for other citrus pests. Suggested thresholds on these other pests are based on guidelines developed in other citrus production states and on data accumulated by the local Texas Pest Management Association (TPMA) IPM program.

Action thresholds in any pest management program are flexible and subject to change. They should be altered to fit the orchard’s individual management conditions.

Growers can monitor for a single primary pest (such as the citrus rust mite) and for the environmental conditions that influence that pest’s behavior, or they may monitor for all major pests and beneficials. Monitoring systems in Texas focus primarily on estimating citrus rust mite populations and evaluating the other pests and diseases.

Monitoring Techniques

Field monitoring or scouting is the foundation for making decisions in an IPM program. When growers monitor on a systematic and quantitative basis (that is, regularly measure the extent of the infestation), they can more accurately detect changes in pest activity and disease incidence. This information enables growers to make better pest management decisions and therefore improve spray timing, increase the effectiveness of pesticide applications and improve record keeping.

Although monitoring techniques vary, depending on individual preferences and management intensity, they should provide a consistent, repeatable way for growers to measure pest activity. Below are guidelines for monitoring various citrus pests.

Citrus Mite Complex Guidelines

Citrus rust mite monitoring procedures and action thresholds are the backbone of IPM programs in Texas citrus. Growers should begin monitoring immediately after post-bloom (March or April) and continue until the crop is completely harvested. The date of complete harvest varies from orchard to orchard; it may not occur until January to May of the following year.

Monitoring programs for this pest often end at the beginning of winter (November), because average winter conditions do not cause citrus rust mite populations to increase. However, in mild winters, citrus rust mite populations increase, and rinds may be damaged.

Monitor your orchards for citrus rust mite every 2 weeks.
This monitoring frequency has been demonstrated by the TPMA IPM program to be satisfactory. It takes 2 weeks or more for rind damage to become visible when populations on fruit exceed 50 citrus rust mites per square centimeter (cm²). Also, under favorable conditions, citrus rust mite populations more than quadruple on infested fruit during a 2-week period.

To sample, check randomly selected trees that are dispersed enough to give a representative sampling of the entire orchard. You can do this by moving in a diagonal direction or Z-shaped pattern.

The sampling size should be one tree per 2 acres, with a minimum of 20 trees per orchard. Check for pests on the underside of young foliage as well as on one fruit per randomly selected tree. The fruit should be selected randomly from a shady area that is about an arm’s length.

To count citrus rust mites, use a 10X to 14X hand lens in at least four separate lens fields per fruit. The counts are expressed in numbers per cm². Because hand lenses come in different sizes, you need to calculate their area in order to determine these numbers per cm².

The action thresholds should vary according to irrigation schedules and weather outlook. Generally, take action when there is an average of more than 5 mites/cm² and/or when 20 percent of the sampled fruit are infested.

Growers should consider several factors when making control decisions about citrus rust mites, including weather outlook, time of year and orchard history.

The most favorable conditions for this pest to increase rapidly occur during the heaviest rainfall periods, which are May/June and August/September. Carefully evaluate citrus rust mite populations that are near the action threshold, because using ground applicators is difficult after prolonged rainfall. Aerial applications have been ineffective in controlling citrus rust mite populations.

Orchard history is important because certain orchards or areas within an orchard can consistently experience rapid reinfestation. Keep this information in mind when sampling or when evaluating action threshold guidelines.

Generally, natural enemies cannot maintain citrus rust mites below damaging levels under Texas conditions.

False spider mites can cause extensive fruit damage on grapefruit but rarely on oranges. Unlike citrus rust mites, fruit damage (qualitative criteria) is the basis for action instead of population count (quantitative criteria). These mites cause a “leprosis-like” spotting of the fruit. Initiate control – particularly on grapefruit – when you see this damage and/or find false spider mites on fruit from May through September.

When monitoring, it is easy to overlook early signs of infestation of false spider mites because of their color and behavior. Use the same sampling frequency, period and sample size as for citrus rust mite monitoring. However, take fruit samples from the lower skirts (bottom ⅓ of the tree) because false spider mites and damage are most often located on these fruit near the orchard floor.
Texas citrus mites do not require control action in most seasons if the trees are vigorous and are protected from other mite pests. Unlike citrus rust mites, Texas citrus mites damage leaves, causing defoliation. Qualitative criteria are the basis for action. If there are more than 10 adult mites per leaf over a period of 30 days, the crown leaves may be defoliated during the winter. However, initiate control when heavy feeding is sustained and when leaf loss occurs during October through February rather than by specific mite numbers.

Use the same sampling frequency, period and sample size as for citrus rust mite monitoring.

Citrus red mites generally are more troublesome in the Mid-Valley area. They do not require specific control action in most seasons if the trees are vigorous and are protected from other mite pests. Like Texas citrus mites, citrus red mites damage leaves, causing defoliation. Qualitative criteria are the basis for action. When citrus red mite populations build rapidly, trees may undergo sudden leaf death (firing) and twig dieback.

Initiate control not by specific mite numbers, but when heavy feeding is sustained and when you see this damage anytime during the year. Use the same sampling frequency, period and sample size as for citrus rust mites.

Armored Scale Complex Guidelines

During a survey in 1999, California red scale was found to be the most widely distributed and abundant armored scale in commercial Texas citrus orchards. California red scale can devastate trees and blemish fruit, especially if natural biological control is disrupted by any means, but especially by dusty conditions that may be found along roadsides.

Various methods have been used to measure California red scale populations, including pheromone traps for the adult males. Although several methods are used to estimate California red scale populations, no action thresholds have been established or they have been considered too intense for management decisions. Pheromone traps take too long to place, and monitoring is rather time intensive.

Adult scales produce an “armor” made of body secretions that helps protect them from spray applications. Immature stages, called crawlers, do not have this armor. They move about the tree searching for a suitable site on which to settle. Initiate control when you see crawlers on fruit between May through October.

Although several generations occur per year, the populations have distinct cycles that can be recognized with routine monitoring. For all armored scales, use the same sampling frequency, period and sample size as for citrus rust mites.

Oil has proven to be an effective scalecide for armored scales. It has minimal impact on biological control agents. However, you must consider the environmental conditions when using oil. Do not apply oils to moisture-stressed trees or
when humidity is below 30 percent and/or temperature exceeds 95 degrees F. Also, as a general rule, do not apply them after September 15, because the development of soluble solids is deterred after this time. Sugar development is delayed, and the fruit must be left on the tree longer.

The 1999 survey found that Florida red scale was the second most widely distributed and abundant armored scale in commercial citrus orchards. Florida red scale generally cause large yellow chlorotic spots when attacking leaves or fruit. They often prefer fruit over leaves and, because of their deep red color, it can easily look as if there are more Florida red scale without proper random sampling.

Like for California red scale, take action on the basis of qualitative criteria. Initiate control when you find crawlers on the fruit between May through October. Take orchard history into consideration because Florida red scale populations tend to reestablish themselves in the same orchard and at the same locations within an orchard.

It may be difficult to evaluate the biological control already present in an orchard. For help, submit samples to Extension or research personnel.

Chaff scale was found in 1999 to be the third most widely distributed and abundant armored scale in commercial citrus orchards. During the 1970s and 1980s, it was considered the most widely distributed armored scale.

Chaff scale can cause serious problems for the fruit because it prevents degreening of the rind when the color changes naturally or by degreening. Green spots are left where the scales once were, rendering the fruit unsuitable for fresh markets.

Its pest status, like that of another armored scale, purple scale, has declined so that generally it does not require specific control action in most seasons if fruit are protected from other armored scale pests. Initiate control when you see crawlers on the fruit or where orchard history indicates problems may arise.

**Other Arthropod Guidelines**

Brown soft scale reduce tree vigor by their feeding activities and by the sooty mold that develops on their honeydew excrement. Sooty mold is a nonparasitic black fungus that inhibits leaf photosynthesis.

Early signs of infestation can easily be overlooked during monitoring activities until blackening of leaves by sooty mold becomes noticeable. When you find localized infestations, spot treatment of trees may be appropriate to reduce costs and prevent possible harm to natural enemies.

Infestations of whiteflies – including citrus blackfly, citrus whitefly and several other whitefly species – can be troublesome in isolated situations. They also reduce tree vigor by their feeding activities and by the sooty mold that develops on their honeydew excrement.

Monitoring can reveal infestations on young leaves or
sprouts. Take action on the basis of qualitative criteria. Because biological control often maintains whiteflies at acceptable levels, evaluate the biological control present before taking any action.

Initiate control as needed, based on blackening of the leaves and the status of the biological control.

**Citrus mealybugs** interfere with fruit development and may cause the fruit to drop. Individuals are usually found under the calyx (the area where the stem meets the fruit) of fruit. They cause sooty mold. When monitoring, be sure to examine underneath the calyx of fruit for immature stages.

Qualitative criteria are the basis for action. Initiate control when you find immature stages and when fruit clusters indicate early signs of sooty mold or white wax secretions.

**Ants** can cause serious damage to citrus, particularly young trees. The tropical fire ant and the imported red fire ant can build mounds around trees. Fire ant feeding on the bark kills trees, most commonly on young trees with cold weather wraps.

Texas leaf cutting ants can cause severe defoliation and eventually kill young trees. In addition, all these ants can be a nuisance to pickers and other grove workers.

Monitoring should include finding the mounds and ant trails. Monitor during early morning or late evening, because above-ground activity ceases in direct sunlight. Initiate control as needed, based on damage.

**Disease Monitoring Guidelines**

Monitor for diseases using the same sampling frequency, sampling period and sample size as for citrus rust mite monitoring. Good disease management requires that you thoroughly understand how environmental conditions affect disease development.

Much of the decision-based criteria is often preventive and based on history of the orchard. If you monitor routinely, the qualitative information on disease incidence may be useful immediately, but often it will be helpful the next season to prevent potential problems.

**Melanose** is a disease caused by a fungus that produces dark blemishes on fruit and leaves. Make melanose control decisions immediately after postbloom (March or April) based on orchard history and the amount of deadwood present.

Initiate control when the citrus fruit is most susceptible to melanose infection, from post-bloom (April to June) to 3½ inches diameter in grapefruit and to 1½ inches in diameter for oranges. After this period, the fruit can better tolerate melanose infection.

Usually one application of a fungicide is satisfactory for most melanose situations. However, you may need to apply it twice for satisfactory control if the disease incidence is severe.

**Greasy spot** is a disease caused by a fungus that causes spotting of leaves and a rind blotch on fruit. Make control decisions about greasy spot before the spring flushes, based on orchard history and on the amount of leaf litter from greasy spot defoli-
ation from the previous season.

Initiate control from June to September, the period that has been shown to be the most cost effective for controlling this disease. Greasy spot spore releases reach a peak during August and September, especially after rains during this period.

Early summer sprays often control this disease adequately because the fungus grows on the surface of leaves and fruit. If oil is part of your summer spray program, you can achieve satisfactory control of greasy spot under most situations. However, if disease incidence is high, a fall application will be needed to protect the late flushes.

Average rainfall amounts and numbers of greasy spot spores trapped over a 3-year period. Spore releases reach a peak during August and September rains.
Mites of Texas Citrus

Mites are the most economically important group of Texas citrus pests. The citrus rust mite and the spider mite complex are responsible for most of the production losses and require most of the pesticides used on citrus in Texas.

For chemical control measures, see the Texas A&M University–Kingsville Citrus Center’s Pest Control Guide. For organic measures, refer to the Texas Department of Agriculture’s Organic Certification Program.

Citrus Rust Mite
Eriophyidae: *Phyllocoptruta oleivora* (Ashmead)

The citrus rust mite (CRM) is considered the single most important pest of Texas citrus. CRM are wedge shaped, lemon yellow and about 1/200 inch long. They can be seen only with the aid of a hand lens of 10X power or greater. They have only two pairs of anterior (front) legs that propel them worm-like across fruit and leaf surfaces.

CRM can reproduce at high rates, and small populations can quickly reach damaging levels. Favorable conditions for population development include warm weather, high rainfall and high relative humidity (more than 70 percent).

CRM females lay an average of 20 spherical, translucent eggs on fruit or leaf surfaces. The eggs can hatch in 2 days. The immature nymphal stages look like the adults, but the nymphs are smaller and pale yellow.

Because CRM avoid direct sunlight, the highest infestations are on fruit and leaves in the interior tree canopy.

CRM that are actively feeding can cause a broad spectrum of fruit blemishes and discolorations. On grapefruit in early season, CRM feeding causes the rind to become leathery, with a gray or silvered cast. This “shark skinned” fruit generally does not develop to normal size. Mid- and late-season mite attacks cause “russeted” or “bronzed” fruit; the damage may appear as brown blotches, bands or “tear stains.”

On oranges, the predominant damage is russetting, with similar injury patterns. Heavy mite feeding causes the fruit to lose water; the resulting concentration of sugar makes the fruit taste sweeter.

The factor most often related to increases of citrus rust mite populations has been high relative humidity (RH). In the Lower Rio Grande Valley, RH usually stays above 50 percent. Rust mites increase very rapidly when RH exceeds 70 percent. Mite popula-

Magnified image of citrus rust mites and their eggs. Adults are yellow and wedge shaped.

A citrus rust mite (shown stained and magnified) has two pairs of legs near the head; spider mites have four pairs of legs.

Fruit damaged by citrus rust mite. Early-season damage is known as “sharkskin” or “buckskin.” When this damage occurs, fruit size can be severely affected.
tions also increase after abnormally high rainfall. They plummet, however, when RH drops below 10 percent.

In May 1972, an epiphytotic fungus, *Hirsutella thompsonii* (Fisher), developed after excessive rainfall during March and April, and live rust mites were difficult to find in May and June of that year. Although this fungus has provided biological control of rust mites and once was marketed as a commercial product, under most Texas conditions all of the natural/biological control agents cannot maintain CRM populations below damaging levels.

Other natural enemies include predaceous mites in the family Phytoseiidae, small beetles and other small insect predators.

**Texas Citrus Mite**

*Tetranychidae: Eutetranychus banksi* (McGregor)

A long-established pest in Texas orchards, the Texas citrus mite (TCM) is readily visible with the unaided eye. The adult female and nymphal stages are oval and yellowish green and have irregular dark green spots along the side edges of their bodies. The bristles are short and inconspicuous on the rather shiny body. The adult male is smaller and more triangular shaped than the female; each has four pairs of long, tan-colored legs.

TCM prefer the upper leaf surface and are most numerous along the midrib and leaf margins. They tend to be found on leaves in the top and south side of the tree canopy.

The first indication of mite feeding injury is chlorotic spots that gradually coalesce (merge), giving the leaf a “silvered” appearance. Severe TCM infestations can cause defoliation, particularly in dry or water-stressed trees. Defoliation from TCM is generally most severe in late fall or early winter, particularly after drying north winds.

The TCM female deposits many flat, disk-like eggs along the midrib and lateral margins of leaves. Freshly deposited eggs are pale yellow, gradually turning reddish brown before hatching.

The life cycle consists of three distinct immature stages: the newly emerged larva, which has three pairs of legs; the protonymph, which has a fourth pair of legs acquired at molting; and the deutonymph, which also has four pairs of legs.

TCM develop best in low humidity and temperature above 85 degrees F. A generation is completed in about 3 weeks.

These mites are attacked by an entomogenous (insect-attacking) fungus, *Entomophthora floridanus* (Weiser and Muma). This fungus can be affected by copper sprays, creating increased mite populations. Other natural enemies include predaceous mites in the family Phytoseiidae, small beetles and other small insect predators. These predators cannot keep mite populations below damaging levels.

**Citrus Red Mite**

*Tetranychidae: Panonychus citri* (McGregor)

The citrus red mite (RdM) was first identified on Texas citrus in 1980. It has a velvet red body with long reddish bristles on prominent tubercles (knoblike growths). The female adult is globoid (shaped like a globe or ball); the male is smaller with a
more pointed abdomen. Both can be seen with the unaided eye. Immature RdM have the same general shape as the adults, but are a dull rust red.

RdM are most abundant on the upper surface of young leaves. The first signs of mite feeding injury are often yellow areas at the base of the leaf near the petiole (leafstalk). As RdM and their damage increase, whole leaves often wilt and drop, leaving many exposed twig terminals at the tops of trees. Defoliation is most severe in the fall and winter when trees are subject to drying north winds.

Each female lays from 20 to 50 eggs, mainly on the upper leaf surface along the midrib. The red eggs are onion shaped, each with a distinct vertical stalk and many fine threads that attach them to the leaf surface.

The life cycle and developmental stages are similar to that of the Texas citrus mite – including newly hatched larva with three pairs of legs, the protonymph and deutonymph (four pairs of legs) and adult. The entire life cycle can be completed in 3 weeks during the summer, but may take 5 or more weeks in winter.

These mites are also attacked by an entomogenous fungus, *Neozygites floridana* Weiser and Muma, which can affect RdM populations under certain environmental conditions. Other natural enemies include mites in the family Phytoseiidae. These predators cannot keep populations below damaging levels.

**False Spider Mite**

*Tenuipalpidae: Brevipalpus phoenicus* (Geijskes), *Brevipalpus californicus* (Banks) and *Brevipalpus obovatus* (Donnadieu)

The first two false spider mites (FSM) species are longstanding Texas citrus pests; *B. obovatus* was first identified on Texas citrus in 1996. Mature FSM are flat, pear shaped and dull to bright red. They lack conspicuous bristles and have four pairs of moderately long legs. They move slowly and are visible with the aid of a hand lens (about ½ inch long).

FSM are most numerous on fruit and leaves in the interior tree canopy. FSM feeding causes “leprosis-like” fruit spotting, also referred to as nail-head rust. The spots are brown, irregularly shaped pinpoints ranging to ½ inch in diameter. They often become raised when the fruit loses water.

Spotting is more prevalent on grapefruit than on oranges and occurs less often on leaf surfaces. Although FSM feeding causes bark scaling on twigs and branches in Florida, it has not been observed on Texas citrus.

Each female lays an average of 25 elliptical, bright red eggs, which are glued singly to the fruit or leaf surface. The eggs soon hatch into dull red, six-legged larvae. The eight-legged protonymph and deutonymph stages follow, each lasting from 6 to 8 days.

The development time from egg to adult takes about 4 weeks in the summer. Several FSM generations can occur in a single season.
Scale Insect Pests

Several species of armored and soft scale insects are important pests of Texas citrus. The armored and soft scales have many similarities and differences. Both secrete a protective covering, which in soft scale species remains attached to the insect's body and is called the "dem." In armored scale species, the protective covering "armor" is separate from the insect's body.

Both armored and soft scales have piercing-sucking mouthparts and extract plant sap from fruit and foliage. After feeding, the soft scales secrete honeydew, whereas the armored scale do not. The honeydew supports growth of black sooty mold fungus, which can seriously affect photosynthesis and tree productivity.

California Red Scale
Diaspididae: Aonidiella aurantii (Maskell)

A survey conducted in 1999 found that California red scale (CRS) was the most abundant and widely distributed armored scale in Texas citrus. The adult female CRS is legless, bright yellow and covered by a circular, rust red armor that has a distinct central nipple. The male's armored covering is more elongated.

California red scales use their piercing-sucking mouthparts to feed on fruit, leaves, twigs and branches. They damage the plant tissue by removing plant fluids and injecting toxic substances. California red scales may cause yellowing of leaves, leaf abscission (drop) and overall decreased tree growth. Feeding by these scales may kill young trees.

CRS do not lay eggs but are "viviparous," giving birth to active young nymphs. These "crawlers" are flat and lemon yellow and have three distinct pairs of legs. This is the only motile (able to move) stage other than the adult male.

When the crawlers settle and start feeding, they also begin to secrete the armor, which at first is a white waxy covering known as the "whitecap" stage. The second and third nymphal stages develop beneath the armor. They are yellow and legless.

The CRS male that emerges from under the armor is a weak-flying orange-yellow insect with two wings. Its sole purpose is to mate and fertilize the female. Several generations occur per year, each requiring about 60 days.

Natural enemies include the parasite Aphytis lingnanesis (Compere).

Florida Red Scale
Diaspididae: Chrysomphalus aonidum (L.)

The covering of the Florida red scale is dark brown or maroon with a central light brown nipple. The adult female's body under its armor is bright yellow. It lays eggs under this armor. The crawlers are oval, bright lemon yellow and very active, able to move quite far before settling on a host.

The life cycle of the Florida red scale can be completed in less than 6 weeks under warm conditions. Four to six genera-
Florida red scales generally cause yellow chlorotic spots on leaves. Yellow spots may also appear at the feeding sites on fruit. Because the scales apparently prefer fruit over leaves in the summer and fall, the fruit may be heavily infested while the nearby leaves are relatively free of Florida red scale. Unlike other armored scales on citrus, Florida red scales feed only on foliage and fruit and do not attack twigs or limbs.

Large populations of this scale may severely defoliate the tree and lower fruit production. Heavy scale infestations on the fruit will render it unmarketable as fresh fruit. In the 1999 survey, Florida red scale was the second most widely distributed and abundant armored scale.

A parasite wasp, *Aphytis holoxanthus* (DeBach), was introduced from Israel in 1959 to help control this pest. The wasp became established and is now the major biological control agent for Florida red scale on Texas citrus.

**Chaff Scale**
*Diaspididae: Parlatoria pergandii* (Comstock)

The chaff scale is the third most widely distributed and abundant armored scale. This pest can cause serious problems in the fruit. It injects a toxin that prevents degreening of the peel surrounding the scale when the fruit changes color naturally or when degreening is induced with ethylene oxide. The resultant green spots render the fruit unsuitable for fresh markets.

The armored covering of this insect is oblong or irregularly round and brown to gray. Scales are often located in depressions on fruit or along the mid-veins on leaves. The females, eggs and crawlers beneath the armor are all purple. The “chaff-like” appearance of the armor helps distinguish this scale from other scale species.

Natural enemies for chaff scale include two effective wasp parasites, *Aphytis hispanicus* (Mertect) and *Prospaltella fisciata* (Malenotti).

**Purple Scale**
*Diaspididae: Lepidosaphes beckii* (Newman)

The adult female's covering is brownish purple, elongated and usually shaped like a comma. The male's cover is similar in color to the female, but is much shorter and more slender. The crawlers are pearly white and very small, less than 0.25 mm. Three or more generations may occur each year.

Purple scales infest citrus leaves, fruit and bark, preferring shady or protected areas. The damage is like that caused by chaff scales: feeding results in chlorotic spots and then leaf and fruit drop. After degreening, green spots may remain on the fruit where scales were present, resulting in fruit quality downgrading or rejection.

In 1950, this scale was considered to be the fourth most harmful pest in Texas. The introduction of the parasitic wasp, *Aphytis lepidosaphes* (Compere), brought about complete biological control of purple scale. Today it is found incidentally and is of little or no economic importance.
Cottonycushion Scale
Margarodidae: *Icerya purchasi* (Maskell)

The cottonycushion scale gets its name from the female’s white fluted egg sacs. Females are about 1.2 mm long and are distinguished by a reddish plate in front of the cotton-looking egg sac. Young scales, or crawlers, have black legs and fairly long antennae.

The cottonycushion scale was controlled by the Vedalia beetle, which was the first successful use of classical biological control, in which a beneficial was introduced and complete control was achieved. Cottonycushion scale feeding can decrease tree vitality and ultimately influence fruit production. These scales secrete honeydew that will provide a medium for sooty mold.

Mature females are often found on younger plant parts and can lay 600 to 800 eggs. Heavily laden egg sacs may ultimately be several times larger than the female’s body. The eggs hatch in 2 days during warmer months but will incubate as long as 2 months in the winter. A crawler stage follows the egg and will undergo three instar levels of development. Males are present but are much smaller than the females.

Brown Soft Scale
Coccidae: *Coccus hesperidum* (L.)

The brown soft scale has a wide range of hosts. It is commonly found indoors and in greenhouses. Uncontrolled, the brown soft scale can totally cover some parts of infested plants. They are most noticeable on plant stems and branches, but also will settle on leaves.

These scales produce honeydew that can retard photosynthesis and attract other unwanted insects. Although the host plants are seldom killed, their strength and vigor are reduced significantly.

Brown soft scale eggs are retained in the female’s body until hatching. Females give birth to live crawlers that remain under the protective cover of the female’s body for several days. Once leaving their mother, the tiny crawlers find a feeding site where they remain until maturity.

Female crawlers molt twice and males four times. The males mature as winged adults and are so small that they are rarely seen. In warmer environments, crawlers are present throughout the year.

In Texas citrus, parasites generally hold the brown soft scale below damaging levels. These natural enemies of the scales *Coccophagus lycimnia* (Walker) and *Microterys flavus* (Howard) are highly susceptible to insecticides but will survive if applications are timed properly.

Barnacle Scale
Coccidae: *Ceroplastes cirripediformis* (Comstock)

The barnacle scale occurs incidentally in Texas citrus from July through October. Even though it is a minor pest, it can cause significant damage. Damage may be widespread; younger orchards are often damaged the most heavily.
The scales feed on twigs and on the upper surface of leaves near the mid-vein. As with other coccid scale species, their honeydew secretions and resultant sooty mold are a problem. They overwinter (spend the winter) as adult females. Large numbers of the oval, orangish eggs fill the inside of the female. Hatching starts in about 3 weeks and continues for 14 to 21 days.

First-stage (instar) nymphs, or crawlers, hatch from eggs and crawl to leaves, twigs and stems of the host plants. After settling, the nymph begins to secrete wax around its body, creating a star-like appearance. Soon after molting to the third stage (instar), the nymphs migrate from leaves to the woody tissue. There can be two or more generations per year.

Other Important Arthropod Pests

The arthropod pests listed below can cause damage but are normally held below damaging levels by their natural enemies or weather conditions. Outbreaks of these pests occur when their natural enemies are killed by pesticide applications or from indirect causes such as weather or other disruptive conditions.

A classic example of pesticide-induced outbreaks occurs when organophosphate insecticides are applied and citrus mealybug populations increase. An example of indirect cause of an outbreak is when road dust settles on adjacent citrus trees and acts as a drying agent, thus disrupting the natural enemies of armored scales.

Citrus blackfly
Aleyrodidae: *Aleurocanthus woglumi* (Ashby)

Citrus blackfly adult males and females are 2 to 3 mm long and have slate-blue wings with a white band in the middle. The abdomen and head are bright red with white legs and antennae. The yellowish brown eggs are laid in a distinct spiral pattern (30 to 50 eggs per spiral) on the leaf undersurface.

A blackfly female typically lays three spirals of eggs and lives for about 10 days. The nymph newly emerged from the egg is white and gradually turns dusky brown. It has two long dorsal (near the back) spines and many shorter spines. This is the only motile stage other than the adult. There are two additional sessile nymphal stages, both of which are black and covered with many spines. The pupa is ovate, shiny black and spiny with a prominent layer of white wax around the margin. It is in this stage that the nymph transforms to the adult blackfly. The emerging adult makes a distinct “T-shaped” hole in the pupa. There are several generations per season, each requiring about 60 days to complete.

Citrus blackflies feed and develop on the leaf undersurface of all citrus varieties, slightly preferring oranges and lemons. The nymphs use their sucking mouthparts to extract sap from leaf tissues. They secrete large amounts of honeydew, which serves as a growth medium for the sooty mold fungus that blackens leaves and fruit. The combined effects of blackfly feeding and the associated sooty mold can seriously reduce fruit.
Blackfly has been biologically controlled through the release of two parasitic wasp species, *Amitus hesperidum* (Silvestri) and *Encarsia opulenta* (Silvestri).

**Whiteflies**

**Aleyrodidae:** *Aleurothrixus floccosus* (Maskell); *Paraleyrodes citri* (Bondar); *Dialeurodes citri* (Ashmead); *Dialeurodes citrifolii* (Morgan); and *Bemisia tabaci* (Gennadius)

Of the five species of whitefly that occur on citrus in Texas, the ones of potential economic importance are the citrus whitefly, *Dialeurodes citri* (Ashmead), and the cloudywinged whitefly, *Dialeurodes citrifolii* (Morgan). These two species can become pest problems in early and late spring. They excrete large amounts of honeydew.

Although they are quite similar, the species can be differentiated by their eggs on the lower leaf surface. Citrus whitefly eggs are smooth and remain yellow during maturation; cloudywinged whitefly eggs have a net-like surface and change from yellow to black. Only the cloudywinged whitefly adults have a distinct darkened area at the tip of the forewings.

The wooly whitefly, *Aleurothrixus floccosus* (Maskell), occurs occasionally in orchards. Its name is derived from the waxy filaments secreted by the nymphs.

Some parasitic wasp species are specific and selective for the different whitefly species and provide effective biological control.

**Citrus mealybug**

**Pseudococcidae:** *Planococcus citri* (Risso)

Citrus mealybug has three to four generations per year in South Texas and can reproduce at high rates. Under optimal conditions, the mealybug can complete development in 30 days.

Individuals of the first generation are usually found under the calyx of the young developing fruit in the spring. They prefer grapefruit over other varieties. The winged male is the only stage that does not feed.

After their natural enemies are destroyed by excessive pesticide use, mealybug populations can increase to high levels by the second or third generation. This mealybug secretes honeydew, on which sooty mold develops. The egg-laying females secrete white filamentous wax, which can make the fruit look like a snowball.

Outbreaks occurred in 1969 and 1970 in South Texas after continual use of broad-spectrum organophosphate pesticides. These pesticides harmed the beneficial insects.

Sex pheromone traps were found to be effective for surveying and testing the population density of citrus mealybugs. Oil, which controls only the youngest stages of the mealybug, was used successfully in an integrated pest management program because it did not greatly disrupt the natural enemy complex.

Parasites include *Pauridia peregrina* (Timberlake), *Leptomastix dactylopii* (Howard) and *Anagyrus* sp. (Ishii).
Predatory insects include a brown lacewing, green lacewing species and ladybird beetles. Vine control is important in controlling mealybugs in infested grapefruit groves.

**Aphids**
Aphididae: *Aphis gossypii* (Glover); *Aphis spiraecola* (Patch); and *Toxoptera aurantii* (Fonscolombe)

Aphids are small, pear-shaped, soft-bodied insects usually found in colonies. Most aphids in these colonies are wingless, but winged forms do occur, which enables them to disperse. Aphid infestations are usually found on new-growth flushes.

Aphids suck sap from leaves and stems, resulting in curled, distorted foliage that can retard tree growth and cause blossom and fruit loss. Aphids also produce large amounts of honeydew, which promotes the growth of sooty mold and consequently may reduce photosynthesis. Aphids can also transmit plant viruses.

Low to moderate infestations of aphids can be considered beneficial to the citrus ecosystem by providing food early in the season for natural enemies such as lacewings and ladybird beetles.

Two aphid species, the spirea aphid, *Aphis spiraecola* (Patch) and the melon or cotton aphid, *Aphis gossypii* (Glover), are the most common aphids on citrus in Texas. The black citrus aphid, *Toxoptera aurantii* (Fonscolombe), is also found occasionally.

The brown citrus aphid, *Toxoptera citricida* (Kirkaldy), is found in Florida but not in Texas. This aphid is considered to be the most efficient vector (transmitter) of the *citrus tristeza virus*.

Aphids reproduce asexually, with females giving birth to young nymphs. Within a week of their birth, the females mature sexually and can produce offspring. Because of this rapid reproduction rate, large infestations can develop quickly. Many generations can occur per year on citrus before the winged aphids migrate to other hosts.

Natural mortality factors, especially predatory and parasitic insects, are usually highly effective in limiting aphid populations. The wasp parasite, *Aphidius testaceipes* (Cresson), is a commonly found beneficial.

**Asian citrus psyllid**
Psyllidae: *Diaphorina citri* (Kuwayama)

The Asian citrus psyllid was first identified on Texas citrus in September 2001. It was found on nursery citrus seedlings and on orange jessamine, *Murraya paniculata* (L.). Psyllid infestations have since spread to orchards of grapefruit and orange varieties.

Psyllid adults are winged and 2 to 3 mm long. The adult holds its mottled brown body at a peculiar 30 degree angle to the leaf surface. Adults congregate on the leaf undersurface; when disturbed, they jump and fly — hence the common name “jumping plant lice.”

The females lay almond-shaped eggs on new shoots. The eggs hatch in 2 to 4 days. The nymphs are flat, yellowish orange and 1 to 2 mm long. They have distinct red “eye spots” and short black antennae. Their developing wing pads are obvious.
on the later-stage nymphs.

There are five nymphal stages, and the life cycle is completed in 2 to 6 weeks. Several generations can occur in a single season.

Psyllids target new, flush growth. They use their sucking-type mouthparts to draw large amounts of sap from citrus trees. Heavy infestations can curl the leaves and kill new shoots.

The Asian psyllid is feared primarily because it can efficiently transmit the bacterial pathogen (*Liberibacter* sp.) that causes greening disease or Huanglongbing (HLB) in Asia and Africa. Greening is a serious disease of citrus in the world, reducing fruit production and killing trees. The disease is not known to occur in Texas or Florida.

**Planthopper**

Flatidae: *Metcalfa pruinosa* (Say)

The planthopper is grayish white and about 10 mm long. It occasionally develops in localized outbreaks in Texas citrus.

The flatid planthopper completes only one generation per year, with adults surviving until September in most years. Immature planthoppers hatch from overwintering eggs in March and feed on twigs, often near fruit. Although the cottony secretions and honeydew produced by this planthopper resemble those of the citrus mealybug, the insect is easily distinguishable by its active jumping behavior when disturbed.

Planthoppers appear to favor grapefruit trees over oranges, but pesticidal control is usually not required. Parasitization by small wasps may be quite high in some years.

The planthopper overwinters in the egg stage. During the winter, the eggs may be found in the bark of dead citrus twigs. Hackberry (*Celtis laevigata* Willd.) and anaqua (*Ehretia anacua* Teran and Berl.) trees near citrus groves often serve as hosts.

**Snout beetles**

Curculionidae: *Compsus auricepsalus* (Say), *Epicaerus mexicanus* (Sharp) and *Diaprepes abbreviatus* (L.)

The most common species of snout beetle on Texas citrus is the golden headed weevil, *Compsus auricepsalus* (Say). The adult weevil is greenish gray and about 11 mm, but the length varies considerably. It has a distinct broad snout.

The adult of another, less common species, *Epicaerus mexicanus* (Sharp), is brownish black and about the same length as the golden headed weevil. A third species recently identified in Texas is the sugarcane rootstalk borer weevil, *Diaprepes abbreviatus* (L.). The adults are black and range from 15 to 20 mm long. The wings (elytra) are overlaid with yellow and reddish orange scales. The scales rub off, which makes the elytra appear to have distinctive black stripes.

The adults of all three weevils feed on new flush growth, causing a distinct notching along the leaf margins. The size of the notches reflects the size of the adults, with *D. abbreviatus* causing the most extensive notching. Leaf notching injury does not appear to affect fruit yield on mature citrus trees.
Weevil larvae are found in the soil, where they feed on citrus roots. The larvae are white and legless. *D. abbreviatus* larvae grow to about 24 mm long.

The weevils consume the outer bark tissue, channeling through lateral and major roots of mature trees. This type of injury provides entry points for soil-borne pathogens such as *Phytophthora* spp. The interaction between root weevil feeding and soil-borne fungal pathogens of the roots results in one of the most severe decline syndromes affecting citrus.

**Mexican fruit fly**
Tephritidae: *Anastrepha ludens* (Loew)

The Mexican fruit fly is native to northern Mexico and infests many citrus and wild plant host species. It migrates northward, where it is a recurring threat to citrus in the LRGV as well as other fruit areas.

This fly was first recorded in the LRGV in 1927. Since then, the U.S. Department of Agriculture (USDA) has conducted a rigorous survey and detection program for it. The Mexican fruit fly has been caught in fly traps as early in the production season as October, with peak populations in the period of March through May.

Fruit fly larvae feed and develop within the fruit. Infested fruit can be accidentally shipped and marketed because there may be no evidence of rind injury. To ensure against this possibility, quarantines and regulatory fumigation with methyl bromide were established.

The Mexican fruit fly is bivoltine, meaning that two broods are developed each year. Broods develop in the spring and fall. The native host in Mexico is the wild citrus called yellow chapote, *Sargentia greggi* (Wats.).

In Mexico, the conditions favoring high population growth include mild winters and rainfall during the breeding season. In the LRGV, flies are generally not trapped until spring. The USDA releases millions of sterile fruit flies to suppress populations and minimize the need to fumigate fruit for shipment.

**Citrus leafminer**
Lepidoptera: *Phyllocnistis citrella* (Gracillariidae)

The citrus leafminer (CLM) is a pest of citrus and other Rutaceae in many parts of the world. CLM larvae tunnel mines predominantly in new flush leaves, but also in succulent stems and sometimes fruit. The larvae bore through the leaf epidermis, ingesting the sap and producing chlorotic leaf patches.

CLM may prevent young leaves from expanding, causing them to become twisted and curled. After the CLM have finished feeding, other insects such as aphids and mealybugs often invade and continue feeding in the damaged area. The total generation time for CLM ranges from 13 to 52 days, depending on the temperature.

The adult CLM is a moth about 2 mm long with a wingspan of about 4 mm. It has silvery and white iridescent forewings with brown and white markings and a distinct black spot on each wing tip.
The adults mate 14 to 24 hours after emergence. Eggs are laid soon afterward. A single female may lay about 50 eggs during her lifetime.

The larvae undergo four instars; total development time is from 5 to 20 days. First-instar larvae begin feeding immediately, forming nearly invisible mines. The larvae are 1 to 2 mm long, light green and difficult to detect. As the larvae develop, the mines become more visible and the larval excrement forms a darker central trail within the mine.

**Texas leafcutting ant**
Formicidae: *Atta texana* (Buckley)

The Texas leafcutting ant is a serious pest of Texas citrus. Also known as “town ants,” “cut ants” or “parasol ants,” the workers are reddish brown with a series of stout spines arising from behind the enlarged head and from the thorax region (middle section) of the body.

Worker ants cut leaf tissue from citrus trees and take it underground to culture fungus that is consumed by the ant colony. Over time, colonies may excavate large areas of the orchard floor and create problems for grove machinery. These large colonies also can remove many leaves. The defoliation of young trees may slow their growth or even kill the trees.

Texas leafcutting ants nest in well-drained sandy loam soils. If not disturbed, the colonies may exist for years and become quite extensive, covering almost an acre and containing several million worker ants.

The ants make crater-shaped mounds 1/2 to 1 foot high and about 1 foot in diameter. Each mound surrounds a center entrance hole that leads to an underground nest. The underground nests often reach depths of 10 to 20 feet, with tunnels extending laterally for more than 100 yards.

As these ants will travel far to find food, damage often occurs where no colony is apparent. Control is often difficult as the active colony may be located on another property.

Texas leafcutting ant castes include the winged-reproductive or alates (female queens and male drones) and workers. Many colonies have five or more fertilized queens. Most of the eggs develop into sterile female workers.

The workers (2 million or more) vary considerably in form and range from ⅛ to ⅜ inch long. Generally, large workers or soldiers protect the nest; medium-sized workers forage for plant material and build tunnels and chambers; and tiny workers maintain fungal gardens and care for brood ants.

**Fire Ants**
Formicidae: *Solenopsis geminata* (Fabricius.); *Solenopsis invicta* (Buren); *Solenopsis richteri* (Forel)

Tropical fire ants, *Solenopsis geminata* (Fabricius), are generally considered to be minor pests of citrus. Workers are reddish brown and about ⅛ to ⅜ inch long.

The nests generally occur in areas that are least likely to be submerged or penetrated by water, such as irrigation borders. They appear as small mounds of fine soil usually no more than
12 inches in diameter and 2 to 4 inches tall.

The ants affect young trees when they damage bark beneath freeze-protection tree wraps and provide a point of entry for *Phytophthora* fungi. The damage to older trees is indirect; the ants tend to harbor sucking insect pests such as aphids and mealybugs, which produce honeydew and its associated sooty mold problems. The ants protect these pests against predatory and parasitic insects in order to “harvest” their honeydew.

The two species of imported fire ants, *S. invicta* (Buren) and *S. richteri* (Forel), and their hybrid are nuisance insects whose stings can cause serious medical problems. The winged-reproductive live in the mound until their mating flight, which occurs after a rainy period.

The average colony contains 100,000 to 500,000 workers and up to several hundred winged forms. Queen ants can live for 7 years or more; worker ants live for about 5 weeks.

There are two kinds of fire ant colonies: single-queen and multiple-queen colonies. Workers in single-queen colonies are territorial; those from multiple-queen colonies move freely from one mound to another. This movement dramatically increases the number of mounds per acre with multiple-queen colonies.

Fire ants nest in almost any type of soil but prefer open, sunny areas.
Diseases of citrus that affect the entire tree can be classified into two general categories:

- **Biotic diseases**, which are caused by living entities such as fungi, bacteria, viruses/viroids (a viroid is like a virus but does not have a protein coat), mycoplasmas/spiroplasmas and nematodes. Some biotic agents are restricted to certain parts of the plant, such as the root, trunk or fruit; others may affect several or all parts of the plant.

- **Abiotic diseases**, which are physiological disorders caused by excesses or deficiencies of certain nutrients or by unfavorable environmental conditions. Some of the most common abiotic diseases of citrus in Texas are iron chlorosis, micronutrient mottle leaf, salt injury and water table injury. In addition to the economic losses, these physiological disorders often predispose the tree to attack by disease-causing organisms.

The diseases discussed below are those present in or potentially devastating to the Texas citrus industry. For chemical control measures, see the Texas A&M University–Kingsville Citrus Center’s Pest Control Guide. For organic measures, refer to the Texas Department of Agriculture’s Organic Certification Program.

**Fungal Diseases**

**Melanose**

Melanose is a fungal disease of citrus caused by *Diaporthe citri* Wolf (also known as *Phomopsis citri* Fawc). It produces pustules (small bumps) of various sizes on the fruit. A light infection on small to relatively large fruit produces small, discrete pustules. In a heavy infestation, the pustules are larger and may coalesce, often causing the tissue to crack and produce a stage called mudcake melanose.

Melanose disease is directly associated with the presence of dead twigs, especially recently killed ones. Dead twigs often harbor the fungus, which produces several dark, egg-shaped structures called pycnidia that contain many spores.

The spores are released from these structures when they become wet. Rainwater washes the spores onto the young fruit, leaves and twigs. The spores that land on young tissue initiate the infection process.

Grapefruit is most sensitive to melanose infection. Although infected fruit become less marketable as fresh fruit, the internal quality is unaffected.

Some growers are confused by melanose and rust mite symptoms. The following tips may help you identify melanose symptoms:

- Melanose symptoms are found on leaves, stems and fruit.
• The presence of dead wood in the tree canopy may be a sign of possible infection.
• Grapefruit trees show more symptoms than other cultivars.
• Raised pimplies appear on the fruit and leaves.
• When rubbed with fingers, the pustules feel like sandpaper.
• The size and number of pustules on the fruit may vary with the stage of infection.
• The pustules may be small or large, a few or many coalesced.
• The fruit may be cracked and/or coalesced.
• If fruit is washed with spore-laden water, the effect will show as tear streaks.
• Rust mite blemishes are smoother than the rough pustules of melanose.

The melanose fungus can also cause a serious post-harvest disease called *Phomopsis* stem end rot. Both orange and grapefruit cultivars are susceptible to this disease, in which the infected tissue at the stem end part of the fruit shrinks.

A prominent feature of *Phomopsis* stem end rot is a clear demarcation line visible between the infected and the noninfected part of the fruit. In contrast, another type of postharvest stem end rot caused by the fungus *Diplodia* develops a characteristic finger-like projection of diseased tissue.

If the citrus tree is exposed to hours of below-freezing temperatures, the fungus could cause leaf drop, twig die back and, in a few cases, tree death.

The most important strategy for both melanose and stem end rot disease control is good cultural practice. Remove dead twigs from the tree by pruning, hedging or topping. Timely application of fungicides in the orchard can also reduce melanose infection.

**Greasy Spot**

Greasy spot (GS) is an important disease of citrus caused by the fungus *Mycosphaerella citri* Whiteside. It is becoming more severe in the LRGV – within the past 3 years, trees in many orchards have been heavily defoliated. Many growers have had greasy spot-infected fruit.

GS reduces tree vigor and thereby fruit size. GS-infected fruit also tend to regreen; such fruit are culled for fresh-market fruit.

To be able to manage the disease, growers need to understand the three stages of the GS life cycle: the epiphytic, the saprophytic and the parasitic stages.

In the epiphytic stage, the GS fungus grows on the lower surface of leaves for a long period before it enters the stomata (air pores) to begin infection. In this stage, which can last for several weeks, asexual spores or conidia are produced. The hyphal tips (threadlike parts) growing on the undersurface of the leaves can function as a germ tube and begin the infection process.

The most important factor involved in the fungal spread of GS is the ascospores, which are the sexual spores developed in
special fruiting bodies called perithecia. Perithecia are developed in decaying infected leaves on the ground.

The ideal conditions for ascospore germination and epiphytic (surrounding the leaf surface) growth of the fungus include the presence of water or relative humidity near 100 percent and temperatures between 77 to 86 degrees F.

The saprophytic stage of the fungus is the period when the perithecia develop and mature in decaying fallen leaves. Water from rain or irrigation enhances the release of ascospores into the air, and air currents carry the spores to the young growth flushes.

The major factors influencing greasy spot infection and disease severity are the number of infected leaves on the ground, the relative humidity, temperature, insect exudations (discharges), the amount of epiphytic growth and the physiological condition of the trees.

In the parasitic stage, the fungal filaments growing on the leaf surface enter the stomatal openings. The fungal growth causes the underside of the leaf surface to swell. This swelling is the first visible symptom of a new GS infection. The next sign is yellow spots, which develop into dark brown blisters resembling oil spots.

The most effective control material is citrus spray oil. Oil may help the cells resist the fungus. Fungicides will destroy the epiphytic growth of the fungus on the leaf surface. They provide protection for several weeks, which prevents the fungus from recolonizing.

The major source of ascospores for the new cycle of infection is infected leaf litter on the ground. If defoliation is severe, the leaf litter must be destroyed.

Florida citrus trees normally are defoliated more heavily than Texas trees. Florida’s rainy season starts in the summer, whereas our rainy season starts in the fall. Spray chemicals after the rainy season.

The epiphytic stage of trees on a microjet irrigation system may have different timing. In Texas, researchers are studying the epiphytic growth of GS fungus in young leaves of Rio Red grapefruit trees.

To destroy the fallen leaves, you can use a combination of blowing, raking and burning, but it is expensive.

**Anthracnose**

Anthracnose is a plant disease that causes black blisters or lesions. These lesions are caused by a fungus that produces spores in an acervulus, which is a saucer-shaped fruiting body (plural: acervuli). Anthracnose diseases occur worldwide, but the most severe losses are in the tropics and subtropics.

The major anthracnose diseases are caused by four members of the ascomycetes:

- **Diplocarpon**, which causes black spot of rose
- **Elsinoe**, which causes scab of citrus
- **Glomerella**, which causes bitter rot of apple
- **Gnomonia**, which causes anthracnose of oak

Anthracnose diseases are also caused by three members of the imperfect fungi:
• *Colletotrichum*, which causes anthracnose of citrus, fig, olive and avocado
• *Coryneum*, which causes shot hole of peach
• *Melanconium*, which causes bitter rot of grapes

Anthracnose in citrus is normally a postharvest disease of grapefruit, navel oranges and tangerines. It requires ethylene degreening.

The causal organism, *Colletotrichum gloeosporioides* Penz., is common in LRGV citrus orchards. It grows well and produces many spores in acervuli on deadwood. Rainwater may carry spores onto the fruit surface and often produces tear stains. Normally, the spores germinate, developing a swollen tip, but they remain inactive at this stage. Ethylene treatment for degreening the fruit breaks the dormancy and stimulates the spores to grow.

Anthracnose does not spread from infected fruit to healthy fruit in the packinghouse or in storage. To prevent anthracnose during degreening, keep the degreening process to the minimum amount of time, limit the ethylene concentration to less than 10 ppm, and store packed fruit at 50 degrees F.

Orchard practices that minimize deadwood of the tree canopy are very important in managing anthracnose. A pre-harvest fungicide spray or a post-harvest treatment with a fungicide are effective chemical controls.

In recent years, LRGV citrus growers and packers observed unusual blemishes on grapefruit and navel oranges after degreening. The rind of the affected fruit was firm and silvery gray, and some of the fruit showed tear staining. Eventually, the rind turned brown and developed soft rot.

When examined under a microscope, the fruit surface showed many black spores with swollen tips, especially in the tear-stained areas. The problem was more pronounced in grapefruit than in oranges. Also, the blemish problem was apparently connected to the use of a high concentration of ethylene for degreening.

Researchers isolated the cause of the blemishes to be a fungus, *Colletotrichum*.

**Phytophthora diseases**

The commonly known fungus *Phytophthora* has more than 50 different species; most are plant parasites and some species have seriously affected human and plant populations. An important example of *Phytophthora*-induced disease and destruction is the European potato famine of the mid-19th century as a result of potato late blight caused by *Phytophthora infestans*.

In citrus, *Phytophthora* causes foot rot of the trunk, gummosis, feeder root rot, brown rot of fruit and blight disease of leaves and stem. In Texas, foot rot and root rot diseases are more prevalent than is brown rot.

In the Valley, foot rot and gummosis diseases are common, both in commercial orchards and in dooryard citrus. Although it is not unusual to see citrus trees die of *Phytophthora*, the percentage of infection and tree mortality can vary with the incidence of *Phytophthora* distribution and with the conditions that favor growth and establishment of the fungus in citrus trees.
The *Phytophthora* fungus causes three major diseases in mature citrus trees: foot rot and gummosis; feeder root rot; and brown rot of fruit, which is a postharvest problem. It can also cause damping-off, which is the infection and eventual death of emerging seedlings in nurseries. Recent studies have shown that *Phytophthora* is also associated with a root weevil, *Diaprepes abbreviatus*, which causes tree decline in the Valley.

In the field, the most important disease of *Phytophthora* is **foot rot and associated gummosis**. Foot rot affects the bark of the main trunk or roots at the ground surface. The fungus *Phytophthora* is normally present in natural soil, mainly in the form of resting spores, which have characteristic thick walls. The thick walls allow these resting spores to survive in dry soils for long periods. Researchers have recovered *Phytophthora* from soil that has been air dried for more than 2 months and also after 3 to 4 months storage at -5 bars.

The resting spores germinate in moist soil, producing germ tubes that may end up in a structure called a sporangium, which is the next level of structural development in the distribution of *Phytophthora* in the field. The sporangium and its spores (sporangiospores) are less resistant to adverse environmental conditions. However, they can also survive some degree of heat, cold and dryness.

The sporangiospores are distributed in water, especially in flood-irrigated orchards. Each sporangiospore can begin an infection process, especially in young tissue. Infection occurs through wounds or natural cracks on the bark. The fungus grows in the bark, killing the bark tissue. The infected bark becomes discolored because the tissue has died. Although a symptom of foot rot may be abundant gum exudation, the gum can be washed off in heavy rains.

Affected trees may look “pale” and have yellow veins and leaves. The infection may extend downward into the crown root (the main root) and can completely girdle the tree. Once the bark has been damaged substantially, the tree starts to wilt, sheds leaves and experiences twig die back. The fruit may hang on a dead tree for some time.

**Feeder root rot**, as the name implies, occurs in the feeder roots where the bark (cortex) sloughs off. In susceptible rootstocks, the initial symptoms are limited to the roots. However, as the disease progresses, the trees show substantial decline and yield loss. The trunk does not show symptoms as in foot rot.

Trees under stress from chemical, water, soil type and other horticultural conditions can weaken the feeder roots and predispose them to the easy access of the fungus that causes feeder root rot.

**Brown rot** is a fruit disease that starts as a light brown discoloration induced by *Phytophthora*. Under humid conditions, the fruit may develop a white mycelium on the surface. The disease is initiated on fruit in the branches closer to soil through inoculum introduced via water splashing.

**Phytophthora-Diaprepes root weevil complex**

In several LRGV citrus orchards, orange trees have declined rapidly and died. The affected trees first showed leaf wilt, yellowing and defoliation, then died within 4 to 5 weeks.
Researchers have been trying to identify the cause(s) of this serious problem since August 2000.

Many of the affected trees were removed and the roots washed with a handgun sprayer. The roots showed extensive insect feeding injury (channeling) and symptoms of severe Phytophthora root rot. The channels varied from 1.25 to more than 30 cm long and up to 1.25 cm wide.

Scientists identified the white larvae (grubs) found in the soil as the blue-green citrus root weevil, *Pachnaeus* spp., and the sugarcane root stalk borer weevil, *Diaprepes abbreviatus*. Adult *D. abbreviatus* were captured in “Tedders traps” placed in the orchard. Also, larvae of *D. abbreviatus* were collected from the soil near affected trees.

Soil and root analysis have confirmed the presence of the *Phytophthora* fungus. Thus far, *D. abbreviatus* has been found in two LRGV orchards and surrounding dooryard properties. However, this type of tree damage exists in several locations.

In these other locations, 4.1 percent of the 1,768 trees surveyed were either dead or declining. One grower pushed out more than 145 dead trees; in another orchard, 20 percent of the trees died, but *D. abbreviatus* was not confirmed as the cause.

Studies to identify the cause(s) of tree death found that the problem was associated with a complex of *Phytophthora*- *Diaprepes* root weevil interaction. *Diaprepes abbreviatus*, a root weevil introduced into Florida in 1964, is now considered the worst long-lasting threat to the citrus industry in that state. This is the first report of this serious new root weevil-Phytophthora disease complex in Texas citrus. The affected area is under quarantine by the Texas Department of Agriculture.

**Viral Diseases**

*Citrus tristeza virus* (CTV)

Citrus tristeza disease is the most important citrus disease in the world. A major CTV disaster was reported in 1930 in the province of Corrientes, Argentina. In 1937, the disease was named tristeza – the sadness disease – in Brazil, where about 30 million citrus trees on sour orange rootstock were lost to CTV infection.

The term CTV covers different virus strains that produce at least five distinct biological reactions in citrus, depending on the cultivar and the environment:

The **mild** type isolates produce no noticeable symptoms on most commercial scion-rootstock combinations. However, they may cause slight stem pitting, vein clearing and flecking on
Mexican lime plants kept in a cool greenhouse. The **seedling yellows** (SY) type isolates may cause severe chlorosis and dwarfing of sour orange, lemon and grapefruit maintained in a greenhouse. SY type reaction is normally found in greenhouse-grown trees or in field trees top-worked with a susceptible cultivar.

The **sour orange decline** type isolates produce tree decline symptoms of sweet orange on sour orange rootstock. Grapefruit and tangerine cultivars are also commonly affected. Field symptoms include a gradual or quick decline of trees on sour orange rootstock. Infected trees show leaf yellowing, wilting, defoliation and fruit hanging on dead trees. The bud union area may show needlelike pegs in the wood and pinholes in the bark. They may also show a brown line at the bud union.

The **stem pitting on grapefruit** type isolates produce chlorosis, stunting and stem pitting on the stems. In the field, grapefruit and pummelo may show large longitudinal ridges or ropes, and the fruit on infected trees are rather small.

The **stem pitting on sweet orange** type isolates produce chlorosis, stunting and stem pitting. In the field, sweet orange trees also produce small fruit that are not marketable as fresh, and the twigs may become brittle and break easily.

The presence of CTV isolates in general can be detected by enzyme linked immunosorbent assay (ELISA), which is a laboratory test that can detect disease-causing agents. CTV in the field is naturally transmitted by aphids, especially the brown citrus aphid. In addition to aphids, people transmit CTV and other viruses and viroids in nature. The inadvertent use of budwood from CTV-infected but symptomless trees to propagate new trees would increase the incidence of CTV in the field.

The most efficient insect vector of CTV is the brown citrus aphid (BrCA). It originated in China and moved to several countries, including the United States. It probably reached South America in the 1930s or before, spread naturally northward to the Caribbean Basin and arrived in Florida in 1995. In Belize, its presence was confirmed in 1996; it was detected in southern Mexico in 2000.

It is possible that it will soon reach Texas either from Florida or Mexico. The BrCA efficiently transmits CTV in many parts of the world, contributing to the decline of several million citrus trees grown on sour orange rootstock.

The rate of BrCA-related tree loss can be best illustrated by the case study reported from Venezuela. BrCA entered Venezuela in 1976 through the southeast (Colombia) and southwest (Brazil) borders. The aphid was well established by 1978 and resulted in the death of more than 6 million trees on sour orange rootstock.

CTV was detected in noncommercial citrus cultivars in the 1950s in the Lower Rio Grande Valley. Later surveys in the 1990s using ELISA detected the virus in commercial orchards, nurseries and dooryard plantings. CTV has been also found in East Texas.

CTV was detected in noncommercial samples collected since 1994 in the LRGV and from areas northeast of the Valley. CTV transmission studies done with local aphids have shown that the spirea aphid, *Aphis spiraecola*, transmitted CTV isolates in the LRGV.
Psorosis disease of citrus has been reported to be spread in Texas orchards planted with nucellar, virus-free trees. Psorosis symptoms have also been reported in virus-free Rio Red grapefruit trees, which suggests that this virus may be transmitted naturally in Texas. It is our hypothesis that had it not been for the four tree-killing freezes in the past 50 years, the psorosis incidence in Texas would have been higher.

Psorosis disease of citrus has been known since 1896 and its viral etiology since 1933. The term “psorosis” has been used to describe several diseases that are transmissible through grafts and that produce leaf flecking in indicator plants. However, some have been characterized as being caused by different viruses.

It is the oldest citrus virus that is known and historically led to the establishment of a virus-free budwood programs in several citrus-producing states. The disease is caused by *citrus psorosis virus* (CPsV), with the genus name *Ophiovirus*.

The disease produces bark scaling that is different from that caused by fungus *Phytophthora* or Rio Grande gummosis diseases. This disease may also cause ring spots on leaves and fruit. However, many trees may grow in the field as symptomless carriers.

Reports from Argentina and Texas on the increase in the incidence of psorosis symptoms suggest that this virus may be transmitted naturally. Specifically, in Texas, the incidence of psorosis symptoms in nucellar, virus-free orchards increased from 0 to 11 trees within 7 years (1971-78). The percentage of psorosis disease increased from 0.7 to 2.0 in five orchards totaling about 3,400 trees. Vector transmission of psorosis has been suspected but not yet confirmed.

The Texas citrus industry in the LRGV dates back to the fruiting season of 1919-20, with a production of 12,000 boxes of fruit. The acreage and fruit production continued to increase for many years.

However, between January 1951 and December 1989, four tree-killing freezes occurred in Texas. These freezes crippled the acreage to as low as 12,000, but production has always been reestablished. Among the three or four grapefruit cultivars, Rio Red is planted in more than 70 percent of the area.

The tree-killing freezes drastically reduced the citrus acreage in the LRGV. This natural calamity probably helped reduce the incidence of prososis symptoms in commercial orchards.

In addition, the development and commercial success of a new (psorosis-free) grapefruit cultivar, Rio Red, through a mutation breeding also helped to reduce the overall impact of psorosis disease in Texas.

But in the past 6 years, field symptoms of psorosis have been found in new plantations (post-1989), old plantations (trees pruned after the 1983 freeze), dooryard trees (post 1983) and nucellar trees. Psorosis symptoms have been detected in Rio Red orchards that originated from a single source of psorosis-free trees, which implies that natural transmission is possible.

In a 2001 survey on citrus root weevil (*Diaprepes abbreviatus*) and fungus *Phytophthora* distribution in orchards, psorosis inci-
dence was found up to 13.6 percent in a mixed planting of two old-line grapefruit cultivars and a navel orange. In another orchard that had *D. abbreviatus*, *Phytophthora* and poor soil conditions, though the psorosis incidence was low, the trees exhibited a compounding effect.

The incidence of psorosis in nucellar trees (from the 1970s to present) and in Rio Red grapefruit plants (current) in Texas suggests that the virus may be transmitted naturally. We believe that the incidence of psorosis in Texas would have been higher if not for the tree-killing freezes. A new virus-free program will help reduce the incidence of graft-transmissible psorosis.

*Citrus tatter leaf virus (CTLV)*

*Citrus tatter leaf virus* (CTLV) was first discovered in California in 1962 on Meyer lemon trees introduced from China. This disease was also reported from other places in the 1960s and ’70s. In Texas, CTLV-like symptoms were discovered in indicator plants inoculated with tissue from Meyer lemon.

Most citrus species and commercial cultivars are symptomless carriers of this virus. A bud-union crease (with or without fluting of the stem) may develop when infected scions are grafted to trifoliate orange or its hybrids. When the bud-union crease is severe, the tops may shear off at the union in high winds.

*Citrus tatter leaf virus* is an important disease that growers should take into consideration when replacing sour orange with rootstocks of trifoliate orange or its hybrids. Always use virus-free plants for propagation. CTLV-free Meyer lemon is already available in Texas, and nurseries are encouraged to use only virus-free budwood.

The presence of CTLV is generally detected based on reactions of indicator plants such as *Citrus excelsa* and citranges. The common symptoms of CTLV infection are tattering of young leaves, chlorosis and asymmetric leaf distortion.

**Viroid Diseases**

*Citrus exocortis viroid* (CEVd)

Exocortis is a rootstock disease caused by the *citrus exocortis viroid* (CEVd). It is found in all citrus-producing areas.

Field symptoms are rare among commercial citrus trees in Texas. This is because the common rootstock, sour orange, is tolerant to CEVd. However, commercial citrus on tolerant rootstock can be stunted to some degree.

Susceptible rootstocks that show field symptoms include trifoliate orange and its hybrids. These rootstocks show bark scaling and tree dwarfing.

In the 1990s, several samples suspected to have CEVd were collected from commercial plantings. The presence of CEVd was tested by indexing on to ‘Etrog’ citron indicator plants. Of 45 suspected samples, 16 were found to carry CEVd based on the reaction of Etrog citron indicator plants for CEVd.
Cachexia

*Cachexia* (also called xyloporosis) is another viroid disease of citrus. Unlike exocortis, it affects the scion part of mandarins, tangelos and Palestine sweet lime trees. *Cachexia* produces wood pitting and gumming in the bark and distorted leaves in mature trees. Although this viroid is present in many citrus-producing areas, the disease symptoms are more prevalent in some of the Mediterranean countries.

Citrus Nematode

Citrus nematode, *Tylenchulus semipenetrans* Cobb, is an important pest in the LRGV. It feeds on young root tissue, using a spear or stylet (a slender probe) protruding from the “head.”

Feeding by an inconceivably large number of nematodes often results in the general decline of tree health and the production of fewer and smaller fruit. Affected trees do not die from citrus nematode infection alone. The effect of citrus nematode is often referred to as “slow decline.”

Sour orange, the predominant rootstock used in the Valley, is susceptible to attack by citrus nematodes. The greatest concentration of nematodes is in the upper 1 foot of soil.

A typical life cycle of citrus nematode can take 1 to 2 months. Eggs that are destined to be males do not develop a stylet and therefore cannot feed on root tissue.

Female juvenile larvae feed on root surface cells, each larva often embedding ¼ of its anterior body into root tissue (this is about 4 to 5 cells deep). Adult females penetrate deep into roots. Thus, a typical feeding nematode becomes a sedentary pest that feeds and develops a comparatively larger body (the posterior part) outside the root tissue. Females excrete gelatin and deposit many eggs into it.

Nematode populations are influenced by such factors as climate, soil type and root mass. Peaks in citrus nematode population in soil and roots are often associated with new growth of roots. Therefore, spring is an ideal time to have soil samples tested for nematodes.

The best strategy to control citrus nematode is prevention. Start with buying and planting trees grown in nematode-free soil. Unfortunately, most nurseries in the Valley have no programs to eliminate nematodes or to plant trees in nematode-free nursery plots.

In soils heavily infested with nematodes, the preferred control method is to fumigate the orchard site before planting. In dooryard situations, nematode populations can be managed by solarizing the soil with plastic mulch before planting.

When managing nematode problems, remember:

- Plant trees that are free of nematodes, other pests and diseases.
- When sampling, collect as many soil and root samples as possible.
- Before planting, have the soil tested to assess the nematode levels. The test can help you decide whether to fumigate the soil.
- To collect a soil sample, scrape off the top 1 inch of soil and collect the upper 8 to 10 inches along with many feeder roots.
• Collect soil samples in the spring or fall.
• Keep the samples at room temperature or in a cooler; avoid direct sunlight before shipping them to a laboratory.

Improving Disease Management
In recent years, the ability to manage diseases in citrus has been improved by new techniques and approaches such as:
• Shoot-tip grafting
• Laboratory tests that can confirm that no viruses or viroids are present
• A foundation block planting of virus-free plants to be used as a source of clean budwood
• The mandatory Citrus Budwood Certification Program
• A task force to advise on and help manage tristeza/BrCA
• Regulatory tools of the Texas Department of Agriculture
• High-density planting
These advances have enabled citrus growers to decrease losses from diseases.

Shoot-tip grafting (STG)
Shoot-tip grafting is a precise separation of the growing shoot tip from the tissue below, which may be contaminated with a pathogen that can be transmitted through the graft. This technique has been used successfully to produce virus-free citrus plants.

In this propagation technique, a tiny (0.17 mm) shoot tip cut with a fine blade is placed inside an inverted “T” on a decapitated rootstock. The rootstock, preferably a trifoliate, is grown in a sterile agar medium and kept in the dark until used. The grafted rootstock is then placed in a test tube containing an artificial liquid growing medium and kept under light for several weeks for growth.

Our success rate for this operation was about 15 percent. Plants grown this way were transplanted into 4-inch pots and kept in a greenhouse.

Indexing
Indexing here refers to a series of tests performed on plants developed by STG technique. These tests can confirm that there are no graft-transmissible viruses and viroids in a newly developed plant.

The most reliable of these tests is a comprehensive biological index using several citrus indicator plants. Inoculated plants are kept in a cool or warm section of a greenhouse for several weeks and symptoms are recorded.

Other indexing methods include the enzyme linked immunosorbent assay (ELISA) and nucleic acid analysis by poly-acrylamide gel electrophoresis (PAGE).

The ELISA test is used routinely to detect the organisms that cause plant and animal diseases, including CTV. The PAGE test can detect plant viroids even when the plants have only mild symptoms or none at all. It is an excellent tool for confirming that there are no viroids in shoot tip-grafted plants showing no symptoms from previous tests.

These tests are conducted at the Citrus Center in Weslaco. The budwood coordinator there is in charge of testing and mul-
tiplying the cultivars. This position is funded by the Texas Citrus Producers Board.

Foundation block

In spring 1998, the virus-free plants obtained through shoot-tip grafting and indexing were planted in a foundation block at the Citrus Center in Weslaco. These plants are the source of clean budwood for future bud multiplication. The foundation block trees are tested periodically for viruses and viroids.

The trees were planted in an 8-acre tract at the Citrus Center in Weslaco. The first phase of planting was Rio Red and Star Ruby grapefruits and Marrs, N-33 navel, Pineapple and Valencia oranges on Troyer and Carrizo citranges and sour orange rootstocks.

An increase block was planted next to the foundation block for the sale of buds; the revenue from those sales will be used to partially support the virus-free budwood program.

Many different cultivars have been shoot-tip grafted since 1994. Most of them have been completely tested and are undergoing mass propagation.

Other virus-free citrus plants that are needed for noncommercial or “dooryard” plantings will continue to be imported from the Citrus Clonal Protection Program in California.

Mandatory Citrus Budwood Certification Program

In 1997, the Texas Legislature passed House Bill 2807 to amend the existing citrus budwood program and law. This law is aimed at protecting the Texas citrus industry from the citrus tristeza virus through the use of budwood that is free of viruses and viroids.

The amended legislation eliminated an exclusion for ornamental nurseries that bud citrus trees for dooryard use. The legislation now applies to all nurseries and growers in Texas that have their own citrus trees.

Before the 1997 amendments, the program was strictly voluntary. The law now gives the Commissioner of Agriculture the authority to adopt rules that make the program mandatory.

The most likely way the program will be made mandatory is by the availability of virus-free budwood type. When an adequate supply of a given cultivar—for example, Rio Red—is available, the Agriculture Commissioner can adopt a rule specifying that citrus rootstocks cannot be budded with Rio Red unless the budwood is virus-free.

Industry support

The Texas citrus industry created a tristeza/BrCA task force to advise on and help manage this disease and its vector problem. The task force developed a management plan for CTV/BrCA. The plan outlines the importance and the risk of CTV/BrCA and describes the role and responsibility of each agency involved with this disease.

The most important aspect of this plan is the risk assessment procedure to be used when the BrCA or a severe strain of CTV is detected in the Valley.

The Texas Tristeza Task Force has also formed an education
committee that will develop a plan to inform the public about the rules and regulations restricting the importation of plant materials and to enlist the public’s help in identifying the BrCA and severe strains of CTV.

Such educational programs will help prevent infected citrus material from moving illegally into Texas. Another part of the education program will be to update all segments of the industry and Extension personnel about changes in the status of BrCA and CTV.

**Role of the Texas Department of Agriculture (TDA)**

The TDA has the statutory authority to take action to limit the spread of the BrCA or CTV. The Risk Assessment Group of the Texas Tristeza Task Force will recommend needed action.

Regulatory tools that could be used by TDA include quarantines to regulate the movement of the BrCA or CTV and the authority to remove citrus trees infected with severe types of CTV.

The Agriculture Commissioner has appointed a seven-member citrus budwood advisory council to advise the commissioner on issues related to BrCA and CTV.

**Reducing Disease Costs with High-Density Planting**

Several factors have contributed to reduced income from citrus in the Lower Rio Grande Valley:

- Four freezes in the LRGV over the past 50 years have killed thousands of citrus trees.
- Citrus production is limited by the scarcity of irrigation water because of drought, especially in flood-irrigated orchards in some water districts.
- Because of the population growth in the Valley, several citrus orchards have been converted into more lucrative residential subdivisions.
- Fruit prices in the past several years have been unpredictable, which is a disincentive for growers, especially for the younger generation of citrus growers.

These factors prompted us to investigate the possibilities of making cultural changes in citrus production to allow a rapid and better economic return for the growers, especially in the early years of an orchard. One change is to plant high-density orchards.

A few citrus growers in California have been very successful in growing ultra-high-density citrus blocks on a dwarfing rootstock. However, the initial cost of planting an orchard at ultra high density is high.

Preliminary studies conducted at the Citrus Center have shown that a microbudding procedure developed here may be useful in developing budded trees at a lower cost. All previous studies on the efficiency of high-density plants have been based on plants developed through conventional budding. Microbudding opens up an opportunity to plant more trees per acre at a substantially lower cost.

Microbudding as referred to here is a novel technique to produce grafted citrus trees inexpensively. The procedure is based on budding rootstocks that are about 4 months old, using small scion buds and no taping to keep the bud in place.
This technique speeds the production of budded plants and lowers the cost. It requires less space than the conventional system of citrus budding. Under greenhouse conditions, the procedure works on several scion rootstock combinations throughout the year. Scion buds sliced for this technique can be refrigerated for a week without significant loss in bud take. A nursery phase can be bypassed and these newly developed trees may be planted in the field with a month or two after bud growth.

In June 1997, several hundred microbudded citrus trees were planted at a 3-foot by 6-inch spacing in an ultra high density block. The plot was 54 by 408 feet, for a total area of 22,032 square feet. The planting continued monthly until December 16, 1997.

The block now has 983 microbudded trees, most of them Marrs orange. There are also 121 Rio Red grapefruit, four Meyer lemons, three tangerines and one Ponderosa lemon.

Fruit production depends on the amount of sunlight intercepted by the trees. Previous studies showed that during the first 5 to 7 years, trees spaced more closely produced more fruit per area of soil occupied than did widely spaced trees.

An ultra-high-density planting of inexpensive, microbudded trees offers the possibility for better economic returns in the early years. The field performance of microbudded trees planted between June and December 1997 show that such a possibility is very realistic.

Two questions were asked in our field study:
- Will the small, microbudded trees survive in the field?
- Will the trees grow normally?

The answers were yes, they survived, and yes, the trees grew very well in the field. Most important, the trees produced a sizable number of fruit in less than 2 years.

In December 1999, the Marrs orange trees planted in spring 1997 averaged 59.7 inches tall; trees planted in fall 1997 averaged 44.7 inches. The average height of Rio Red grapefruit trees planted in fall 1997 was 59.6 inches. No Rio Red were planted in spring 1997.

The number of fruit per tree varied between one and 71 in the first year of production. One Marrs orange tree had 70 fruit, a Meyer lemon had 71, a Rio Red had 19 and a Ponderosa lemon had four fruit. Although only less than 5 percent of the trees had fruit, the number of trees with fruit represented about 25 to 33 percent of trees in a standard planting density.

The fruit set in 2000 was very good, and it was excellent in 2001 and 2002. High yield from a lesser space with reduced cost is a better strategy to counter losses from diseases and insects.
Broadleaf weeds, grasses and vines in an orchard compete with the citrus trees for light, plant nutrients and available and applied water. Weeds can interfere with irrigation and harvest operations. Some weeds may contribute to pest management problems; others may host beneficial arthropods that can aid pest management. On the orchard floor, weeds can increase the potential cold damage to fruit and trees.

Young citrus trees do not compete well with other vegetation. For optimal growth and development of the trees, weeds must be controlled completely around the young trees throughout the orchard-establishment years.

Mature trees aid orchard floor management by shading the ground beneath the trees, which restricts the germination of seeds of many weed species.

Management Systems

In general, the orchard floor is managed by tillage, by herbicides, or by a combination of the two. When total economic costs of equipment and labor are considered, the most costly program is tillage. Tillage is the least expensive in terms of cash costs. Conversely, total herbicidal weed management is the least costly from the perspective of total economic costs, but has the highest cash costs.

Tillage implements include disks, cultivators, tree hoes and rotovators. Although all are still in use, the predominant choice in tilled orchards in Texas is disks.

Many disadvantages are associated with tillage:
- Tillage damages feeder roots, low-hanging fruit and the outer skirts of the tree.
- In turning the soil, tillage contributes to more rapid soil moisture loss and exposes new weed seeds that will germinate.
- Under tillage operations, weeds are usually allowed to germinate before tillage, thereby permitting some loss of moisture and nutrients that could have been used by the tree.
- Tillage must be practiced after each irrigation or significant rainfall.
- Repeated tillage operations usually increase soil compaction below the tilled soil. Loose soil resulting from tillage slows irrigation water movement, thereby increasing irrigation run times and total water application.

The disadvantages of herbicide use include:
- Occasionally, phytotoxicity can damage tree skirts after some herbicides are applied through nonshielded booms. However, herbicides are generally not phytotoxic to the tree when used in accordance with label directions.
- Because the roots of some weed species penetrate deep into the soil, removing those weeds will make the soil less...
porous and/or change the soil structure. However, the trade-off is that the soil surface is firm, which permits faster irrigation and provides improved cold protection.

• In some cases, wind erosion may reach undesirable levels.

Some growers practice a combination of herbicides under the tree canopies and either tillage or mowing of the orchard middles. There is some evidence that sod middles result in a smoother, thinner rind, primarily because the vegetation uses excess plant nutrients (which frequently results from over fertilization).

The competition by weedy middles is believed to be offset by reduced wind erosion and reduced soil compaction as afforded by deeply rooted weeds. Weedy middles reduce dust, thereby enhancing the pest management program.

Some species of weeds, particularly broadleaf weeds, may host a number of beneficial arthropods that can help growers manage citrus pests. Unfortunately, mowing usually favors the establishment of perennial grasses to the exclusion of broadleaf weeds, thereby negating this advantage over time. Conversely, some weed species may host some citrus pests.

Vegetative middles may make it easier for harvest equipment to enter after rainy weather. However, vegetative middles slow the forward movement of irrigation water, and they are colder than bare ground.

Because of differences in total economic costs and the actual cash costs of weed management options, the choice of program may be influenced by the cash flow of a particular orchard management operation. Aside from economics, however, the most significant determining factor is the type of irrigation system within the orchard.

A flood irrigation system with permanent valves essentially dictates the use of permanent borders, thereby favoring full herbicidal orchard floor management. Conversely, flood-irrigated orchards without permanent valves are more likely to be subjected to tillage in the middles because of the need to build (and then knock down) the temporary borders and ditches used to control water flow during irrigation.

With drip or microsprayer irrigation, the use of herbicides under the trees is essential. Weed control in the middles is usually much easier because little, if any, applied water extends beyond the tree canopy. Consequently, growers may choose to manage the middles by applying herbicides, by tilling or by mowing (either mechanical or mechanical plus chemical mowing).

The choice of a middles management program involves trade-offs that the grower must evaluate. Ideally, growers would encourage native weed cover in the middles from early spring to early fall, then eliminate it to provide the maximum warmth of a bare, firm soil surface during the winter.

Properly selected and applied herbicides should adequately control most weed problems. However, because no herbicide is effective against all weed species, resistant weeds will quickly proliferate in the orchard. Growers should identify such weeds so they can incorporate a herbicide that does control them into the next application to complement the existing herbicide.
Special Weed Problems

Four species of perennial vines in Texas citrus are especially hard to control: morning glory, goat's beard, milkweed vine and possum grape. These vines have very little treatable leaf area beneath the tree canopy and they are not very susceptible to available herbicides. Indeed, few herbicide labels even list any of these vines, and then only as partial suppression.

Although the overall herbicide program can reduce the problem, complete suppression does not appear to be possible now.

Possum grape is especially onerous because it produces aerial roots several feet above ground — these roots descend to the soil and soon give rise to more growth. Too, possum grape has a large underground storage organ similar to a sweet potato that can regenerate new tops for years.

Once the vines become established, about the only recourse is to cut them off below the canopy and pull them out of the tree by hand. Growers have applied undiluted systemic herbicides directly to the cut-off stems with some success; others have resorted to grubbing them out by the root. The latter approach is more easily performed when the soil is quite wet, as the major roots will come out without breaking off.

Intensive efforts are required to eradicate rhizome Johnson grass, Bermuda grass and guinea grass. Generally, treatment with systemic herbicide at the maximum labeled rate is most effective when applied a week or so after the weeds have been mowed or cut. Complete control often requires retreatment.

Because guinea grass is often located near the tree trunk, it usually grows up through the canopy. It is usually ineffective to apply systemic herbicides to the base of the clump – the grass must either be cut off below the tree canopy, after which the regrowth can be treated, or it must be pulled out of the canopy and laid flat in order to effectively spray the leaves.

Both methods are labor intensive, so use the maximum rate of herbicides and completely wet the foliage to reduce the need for retreatment.

Herbicidal Mode of Action

Herbicides are normally classified according to their principal mode of action. Pre-emergence herbicides must be incorporated into the soil to be effective, so they are applied before an irrigation to allow the water to move the material into the soil. Weed seedlings absorb the herbicide soon after germination and are killed before they can emerge from the soil.

Post-emergence herbicides control existing weeds either by desiccation (drying out) or by systemic translocation (movement through the plant) to all growing points. You must apply enough to thoroughly wet the weeds. Because most post-emergence herbicides are nonselective, take care to control drift and to avoid contact with fruit or foliage.

Desiccants simply burn vegetation on contact, which limits their use to small annual weeds and young weed seedlings. Because larger, established weeds – especially perennials – can

Citrus tree covered with goat’s beard vine.

Mature seed of goat’s beard vine.

Mature and immature flowers of goat’s beard, with typical trifoliate leaves in the background.
quickly regrow new tops, the desiccants are not very effective on them.

Systemic herbicides are moved throughout the plant to suppress all growing points, including the roots, thereby killing the plant entirely. Weeds respond to desiccants within hours; the reaction to systemic herbicides is apparent only after several days to a couple of weeks.

If you use a surfactant, some pre-emergence herbicides also provide post-emergence activity. However, the amount of material used in post-emergence activity is unavailable for pre-emergence control, so overall control may be less effective when these materials are applied over existing vegetation.

It is a grower’s responsibility to read and follow all directions on the product label.

**Factors Affecting Herbicidal Weed Control**

Existing weeds, leaf litter and other debris on the orchard floor interfere with uniform distribution of pre-emergence herbicides, thereby making them less effective. The same is true of a rough, cloddy soil surface. In time, however, the leaf litter beneath the trees will help prevent the germination of many weed seeds.

In heavier soils that tend to develop surface cracks as the soil dries, weeds emerge that should have been controlled by the applied herbicide. Because the herbicide is usually absorbed on the surface layer of soil, weed seeds below this surface layer can and do germinate in the soil cracks and emerge through them without having come into contact with the herbicide layer. This problem usually decreases over time as residual herbicides infiltrate such areas.

Because the various pre-emergence herbicides differ in solubility, some work for longer periods than others, depending on the soil type, the frequency and amount of rainfall, and the type and frequency of irrigation. On lighter soils, use the less-soluble herbicides because these soils do not bind the herbicide as well as do heavier soils.

With drip and microsprayer irrigation, water is applied frequently to a limited area of the soil surface, thereby increasing leaching loss in the wetted area, which reduces weed control. Fortunately, some of the least soluble herbicides can be applied through the irrigation system, thereby reducing this problem.

Apply systemic herbicides only to actively growing weeds, as absorption decreases greatly in weeds that are under drought stress or are otherwise not growing vigorously. Also, during the fall, many perennial weeds typically undergo greater translocation to the roots and underground storage organs, so control can be more effective then.

**Herbicide Applications**

Generally, most growers apply pre-emergence herbicides twice a year, commonly in early spring and late summer or early fall. Depending on weed pressure at the time of application, a post-emergence herbicide may be included to control existing
weeds. Both escaped weeds and established perennials are spot-treated with post-emergence herbicides as needed through the season.

Growers must know the specific label requirements. Some pre-emergence herbicides can be applied only once a year; others have maximum rate limitations. A few herbicides can be injected via chemigation through drip or microsprayer irrigation systems, which is very specifically described on the product label.

Weed control may be improved by making three rather than two applications where control has been problematic, either because of orchard establishment or because of higher weed pressure in the wetted zone of orchards under drip or microsprayer irrigation.

A single application of pre-emergence herbicides that will provide year-round control has generally been unsuccessful, although it has been tried in some orchards with well-established herbicide programs. Even then, one or two treatments with post-emergence herbicides had to be used to maintain the floor management program.

**Herbicide Application Equipment**

Although manufactured machines are available, most growers build their own herbicide applicator rigs to suit their particular use and preferences. Components include a tank trailer, centrifugal pump (PTO or hydraulic), appropriate valves, controls and pressure regulators, and either single or double booms and a center boom.

Companies that manufacture spray components provide detailed plumbing diagrams as well as specifications for spray nozzles. For more information, see [http://aggie-horticulture.tamu.edu/citrus/l2318.htm](http://aggie-horticulture.tamu.edu/citrus/l2318.htm).

Herbicide booms are typically built with hydraulic cylinders to regulate boom height and to raise or fold the booms for travel. Either the entire boom or the boom tip is designed with breakaway features to prevent serious damage to trees or equipment.

Breakaway tips commonly operate on spring tension, though both hydraulic and air shocks are useful. The major advantage of air shocks is their slower return to the fully extended position as compared to the quick snapback characteristic of hydraulic shocks and springs.

Booms should include adequate shielding so that they will slide under low-hanging limbs and fruit. Shielding should extend sufficiently forward, backward and downward to facilitate coverage and to limit drift.

Because the operating height of a herbicide boom is limited by the low-hanging canopies of the orchard, select the nozzle type and spacing that will provide adequate overlap coverage at the designed boom operating height.

For example, 80-inch flat nozzles must be spaced closer together than 110-inch flat nozzles, which must be closer than flood nozzles (whether mounted to spray downward or horizontally). At a height of 10 inches, 80-inch nozzles must be spaced
at 12 inches, 110-inch nozzles at 20 inches and flood nozzles at 52 inches to achieve theoretical coverage with 33 percent overlap. For 50 percent overlap coverage, the same nozzles must be spaced at 8, 13 and 35 inches, respectively.

Because actual coverage is most likely less than theoretical coverage, space the nozzles somewhat closer. Moreover, they must be even closer to adequately cover standing vegetation.

The application volume per acre depends on ground speed, operating pressure, nozzle size, nozzle type and nozzle spacing. Generally, a system is designed for an acceptable ground speed and operating pressure (20 to 30 psi), with a fixed nozzle spacing.

Growers can make only minor adjustments to speed or pressure to change the application volume per acre (major changes in speed are not possible because of low-hanging branches and fruit). Therefore, the selection of nozzle type and size has the greatest effect on volume.

At a given pressure, a TK1 flood nozzle delivers twice as much output as an 11001 or 8001 flat nozzle, the same output as an 11002 or 8002 flat nozzle, and half the output of a TK2 flood nozzle. Thus, with all other factors being equal, 11001 or 8001 nozzles cover twice as much acreage per tank as do either TK1 or 11002 and 8002 nozzles and four times as much as TK2 nozzles.

On the other hand, TK1 flood nozzles spaced 24 inches apart will deliver the same output as two 11001 or 8001 flat nozzles spaced 12 inches apart. The same is true for TK2 versus 11002 or 8002 nozzles.

Because many of the post-emergence herbicides are applied as a percentage of total solution rather than as a fixed rate per acre, it is more economical to use smaller nozzles. Liquid herbicides are well suited for small nozzles; powders, granules and suspensions require larger nozzles to prevent clogging, even with good agitation within the tank.

**Chemical Mowing**

In orchards with vegetative middles, chemical mowing can effectively limit the vegetation growth and thereby reduce the number of mechanical mowings required. In chemical mowing, systemic post-emergence herbicides are applied at sublethal rates to stunt the vegetation without killing it. They also stunt seed development.

These herbicides are applied with small nozzles (TK1 or 11001) on a center-mounted, shielded boom at somewhat faster ground speeds. The application should be targeted to about 25 to 35 percent of the usual volume per acre. You will need to calculate ground speed, nozzle output and nozzle spacing to deliver the desired volume.

The duration of chemical mowing depends primarily on the level of moisture in the soil. For example, under microsprayer irrigation and in the absence of rainfall, chemical mowing lasted nearly 3 months in tests in Valley orchards. However, mechanical mowing had to be employed about 3 weeks after a significant rainfall to prevent seeding within the chemically mowed middles.

A commercial, self-propelled, self-contained herbicide rig with rear-mounted, fixed booms that cover a swath width of 14 feet.
**Floor Management Specifically for IPM**

In managing the orchard floor to support integrated pest management in Texas citrus orchards, there is no question that a variety of broadleaf weed species in the orchard middles can support both useful populations of beneficial species of arthropods and alternative prey and/or hosts for those beneficials.

On the negative side, such weed cover may also attract and support certain citrus pests. Moreover, maintaining weedy middles throughout the growing season, especially in the flat or drive (that is, non-bordered) middles, can significantly reduce the amount of dust in the orchard. Dust is well known to favor increased populations of certain citrus pests and to harm beneficials.

There is, however, only limited research information that identifies specific weed species with relation to specific pests, alternative prey or hosts or beneficial species. It is conceivable that one or a mix of weed and nonweed species, perhaps legumes, could be cultivated advantageously in alternate middles to provide maximum support to the IPM program.

However, much research will be needed to identify these potentials. Meanwhile, given the limited knowledge available, growers might consider allowing native weeds to grow from late winter to early fall in alternate middles of the orchard. To encourage those weeds, allow them to flower and seed before cutting and/or destroying them.

At the end of the growing season (and primary pest management period), the weedy middles must be fully destroyed in order to have a bare, clean and firm soil surface for maximum cold protection during the critical winter months.

You may need to apply either a desiccant or systemic herbicide to kill the weeds, and then mow the middle closely.

Finally, incorporate residue into the soil by shallow cultivation. A rotary cultivator may provide the best incorporation with the least damage to tree roots, as you can closely regulate the depth to which the machine disturbs the soil, unlike with disks or field cultivators.

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### Currently¹ Labeled Herbicides for Texas Citrus

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<tr>
<th>Bearing and Nonbearing Citrus</th>
<th>Post-Emergence</th>
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<td><strong>PRE-EMERGENCE</strong></td>
<td><strong>POST-EMERGENCE</strong></td>
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<tr>
<td>Eptam®²</td>
<td>MSMA®</td>
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<td>Hyvar®</td>
<td>Paraquat®</td>
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<tr>
<td>Karmex®</td>
<td>Roundup® (Rattler)</td>
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<td>Krovar®</td>
<td>Torpedo® (Poast)</td>
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<td>Simazine®</td>
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<td>Solicam®³</td>
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<td>Surflan®³</td>
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<tr>
<th><strong>Nonbearing Citrus Only</strong></th>
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<tr>
<td>Goal®</td>
<td>DSMA®</td>
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<tr>
<td>Prowl®</td>
<td>Fusilade®</td>
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¹ Labels and usages change frequently so the grower must consult the product label, for complete instructions before using any product.

² Use only via flood irrigation.

³ May be injected via drip or microsprayer irrigation.
Pest management strategies have been used for years in Texas citrus, and time-tested techniques have helped the industry improve yields while protecting human health and the environment.


However, new regulations have altered pest control options and integration. Growers must take those regulations into consideration when forming their pest management strategies. For the best results, they also must integrate all the tools – cultural, biological and chemical – and continue to acquire and use pest-management information to implement their strategies.

Pest Management Strategies

The first line of defense in a pest management program is often some form of chemical pest control. Regulations – through label changes or product cancellation – can limit or alter the availability of certain pest management tools and seriously affect the prevailing pest management strategy.

The contemporary approach to pesticide regulation is for the regulatory community to pay very close attention to pest control needs in the field and thus ensure that alternatives are in place as regulations are developed. This approach to pesticide regulation necessitates that the regulatory community thoroughly understand the day-to-day field-level pest problems. Communication among regulators, producers, commodity groups and research and agricultural education organizations is extremely important.

The purpose of a pest management program is to achieve satisfactory long-range pest control by integrating the techniques that will maximize net profit to growers in a socially acceptable and environmentally compatible manner. In the early developmental phases of a sound pest management program, growers need to have a general understanding of a respective pest/host/crop interaction, be able to identify pests and beneficial insects, and know the status of the pests in the orchard.

Then growers should integrate the various pest management tools, generally emphasizing preventive methods and the preservation of natural control agents.

Ideally, this objective is achieved with a minimum use of chemicals. However, rapid increases in pest or disease incidence sometimes require that growers apply pesticides more often to
protect fruit quality and crop investment.

We hope that as more is learned about the biology of a specific pest organism, we can minimize its population outbreaks. However, for the time being, organized services (such as the Texas Pest Management Association) scout fields and provide information to growers to help them keep pests at tolerable levels.

Pest management strategies have always depended on having certain chemicals available for pest control as the need arises. A part of basic pest management research involves specific pesticide controls. Through research, chemicals are discovered that provide a specific level of control for each given pest. When pest counts reached treatable levels, those pesticides provide a level of control for a certain period.

As different pesticides come on the market, research is needed to determine the level and duration of control that could be expected for each respective chemical. Additional research is needed to determine the effects on nontarget organisms such as parasites and predators. These effects on natural controls can alter pest management strategies.

The Food Quality Protection Act (FQPA) was enacted in August 1996 to better protect the American public from dietary and nondietary exposure to pesticides. Provisions included single, health-based standards for food, explicit language on children's exposure to residues in food, and the concept of aggregate exposure or a single “risk cup.” The U.S. Environmental Protection Agency (EPA) was given the responsibility of implementing this law.

After the law was enacted, the EPA established new pesticide registration standards. Among these actions was the ruling that certain classes of pesticides may pose unnecessary hazards to the public. These targeted pesticides included the organophosphate and carbamate insecticides and certain other types of agriculture chemicals, mostly fungicides. Many of the chemicals currently used in citrus are directly affected by the FQPA regulatory actions.

**Pest Management Tools**

**Cultural Control**

Cultural control is the use of horticultural production techniques to prevent pest problems. Although these techniques can be used in all phases of production, they should be a major consideration when establishing the orchard.

The goal is to create an environment that is as unsuitable as possible for potential pests but that is the best possible for citrus production. Cultural management options include selection of a rootstock with pest tolerance, orchard site selection and planting schemes.

**Biological Control**

Most of the citrus biological control research has involved insects. Researchers have studied weeds as biological control agents for other crops, and such opportunities exist in citrus.

Successful biological control efforts include the control of St. John's wort in rangeland using a beetle, *Chrysolina quadrigemina,*
and the control of strangler vine (*Morrenia odorata*) in citrus using a fungus, *Phytophthora palmivora*. Classic examples of biocontrol include the success achieved in controlling a citrus insect such as the cottony cushion scale during the late 1800s in California.

Predators and diseases are the most notable biocontrol agents of mites in Texas citrus. However, based on current understanding, entomophagous diseases are probably the most important biocontrol agents during times of high humidity.

Because of parasites and predatory insects, chemical treatments are generally unnecessary for Florida red scale, purple scale, glover scale and citrus mealybug. Satisfactory biological control exists – but often to a lesser extent – for California red scale, chaff scale and brown soft scale, which can rise to pest status after a broad-spectrum insecticide application.

The prospects for sustainable biological control in citrus are better than ever before because of the variety of citrus pests that are either partially or completely controlled by biological means and because of the development of newer narrow-spectrum products.

Researchers should place new emphasis on this type of control by taking a close look at the effects of newer chemistries and their subsequent influence on citrus biological control.

**Chemical Control**

Agricultural chemicals have been the mainstay of modern agricultural pest control. As technology has advanced, the availability of effective and economical pesticides has helped produce the abundance of food and fiber that society has come to enjoy and expect. It does not appear that this will change anytime soon.

Products continue to be developed and their effectiveness against citrus pests will be explored. Products will become more socially acceptable because they will offer new levels of safety for people and other nontarget organisms.

The screening of pesticide products for use against citrus pests will continue to be a major part of any citrus pest management strategy. Although the need for new citrus pesticides may be argued in some circles, it is important that we understand not only their effectiveness against pests, but also the role and effect each pesticide compound will have on the citrus ecosystem.

**Education**

A key component of any pest management strategy is to provide pest management information to producers. For such strategies to be implemented successfully, field-level scouting must be conducted and the results communicated to the respective grower.

Decision makers must have accurate and timely information on field-level pest situations so that they can implement pest management strategies. If they know the severity of a particular pest's infestation, they can use pesticides more judiciously, which will ultimately lead to minimal environmental disruptions, including the impact on nontarget organisms.
Key Components of a Pest Management Strategy

- Knowledgeable individual(s) available who can study, analyze and react to citrus pest management needs.

- An organized system of crop managers who keep pace with day-to-day field-level crop/pest dynamics.

- Research on the impact of insecticide applications on non-target organisms with emphasis on recently discovered chemistries with novel and often selective modes of action.

- A knowledge base available to citrus pest management practitioners that is an instant source of information on citrus pest management tools and techniques.

- State-of-the-art communication capabilities between citrus production personnel and citrus pest management experts.

- A system that can respond to regulatory issues that could potentially affect citrus pest management implementation.

- Annual citrus production educational programs that discuss the latest industry trends and research developments.

- A citrus industry that is progressive and strives to keep pace with citrus market needs.

- The recognition that a pest management strategy may be crop specific but must contain strategies (substrategies) for each organism (pest) harming the crop while continuously responding to the needs and demands of a modern society.

- Funding for nonchemical pest management research strategies, such as biocontrol programs (predators, parasites, pathogens and biocontrol materials), habitats of beneficials, mating disruption and resistant varieties.
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