Crop Profile for Satsuma Mandarin in Alabama

Prepared August 2007

Production Facts

Satsuma mandarin (*Citrus unshiu* Marc.) has been grown for over a century along the Gulf Coast in Alabama and neighboring states (English and Turnipseed, 1940), but growth and expansion of the industry has been hampered by periodic freezes, which until recently, have been severely devastating to the crop (Winberg, 1948; Campbell et al., 2004). Since the early 1990s, there has been an increase in the production of Satsuma mandarin in southern Alabama. Renewed interest in Satsuma production by Alabama growers is fueled by recent availability of new cold-hardy rootstocks coupled with improved methods for tree protection from temperature variations that occur in the region. Strong industry and state support are also promoting industry growth with much effort being made to develop new markets (Campbell et al., 2004).

Currently, Satsuma mandarin is a minor citrus crop in the U.S. produced commercially in the states of Alabama, California, Florida, Louisiana, Mississippi and Texas. California has the highest state production of Satsumas with approximately 3,000 acres planted, and Louisiana is second with about 300 acres (Boudreaux and Vaughn, 2006). Alabama is the third leading state for Satsuma production in the U.S. with over 100 acres. Twenty-five percent of Alabama's acreage is presently non-bearing trees that are one to two years old. An additional twenty-five percent of the planted acreage is from three to six years old, and are increasing in annual production. The remaining 50% is mature, bearing citrus. The USDA currently has no production statistics for Satsumas in Alabama. Based on acreage of mature trees in Alabama and production studies, Alabama's current level of production should be from 1.4 to 1.8 million pounds, and could increase to twice that level in three to four years.

The Satsuma mandarins grown in Alabama are marketed entirely for fresh consumption. The public school system in Alabama is a major market for Satsumas; about one-third of the local Satsuma mandarin crop has been sold annually to the Alabama public school system since 2003. Growers also market fruit to produce brokers and to fresh produce market vendors. A significant percentage of the Satsumas grown in Alabama are direct marketed to consumers at the farm gate. Wholesale prices range from $0.40 to $0.55/lb, and retail prices range from $0.55 to $0.90/lb. Cash value of Satsumas in Alabama is approximately $1.0M annually based on current production level.

Production Regions

In Alabama, Satsuma is grown mainly in the two coastal counties (Mobile and Baldwin counties) that surround Mobile Bay with a few small growers scattered in the southern part of the state. An informal grower questionnaire/survey conducted in November 2005 revealed that Alabama had approximately 7,000 trees in the

Baldwin/Mobile county area in 13 orchards, representing approximately 25.3 hectares (ha). Respondents also indicated that another 10.1 ha were planned for planting in 2006. Orchard size among this group of growers ranged from 100 to 2,000 trees, and 8 of the 13 orchards had less than 300 trees. Alabama also has approximately 500 trees in three orchards in Escambia county; 300 trees in three orchards in Houston county (near Dothan, AL), and 175 trees in 3 orchards north of Montgomery, AL, which are considered "high tunnel" greenhouse production.

Trees ranged in age from 1 to 22 years old in the orchards located in Baldwin and Mobile counties, where small numbers of trees survived the winter 1983-84 freeze, but most were planted after the winter 1989-1990 freeze. All of the plantings described in the survey that were in other counties were six years old or younger.

Satsumas in Alabama are generally propagated on rootstocks by nurseries or by the growers themselves. Trifoliate orange (*Poncirus trifoliata*) is the most common rootstock in Alabama. Trifoliate orange prefers acidic to slightly acidic soils in the range of 4.5 to 6.5. This pH range is readily found among the soils of southern Alabama, in both forest and cropland sites. Several cultivars of trifoliate orange are used including "Rubidoux" and the more dwarfing "Flying Dragon". Both forms are used in all of the cultural production methods discussed in this profile. Another rootstock used in Alabama is "Swingle citrumelo", which is also widely adaptable to soils, including the soil conditions found in Alabama. Satsumas are usually planted on upland sites with good air drainage in order to reduce the incidence of cold air settling or "frost pockets". Often growers will seek sites that have a wooded area on the north side of the planting to serve as a windbreak and cold air buffer during advective freeze events. Fertilizer rates for Satsumas on Alabama soils are typical of other commercial citrus production regions, such as Florida and Louisiana, and many soils used for production maintain good fertility. Dooryard citrus producers on the extreme coastal areas often have greater fertility requirements, since soils in those locations may be very sandy.

Cultural Practices

Three different methods of Satsuma mandarin culture are employed in the Gulf Coast region. The foremost method is the "irrigated grove (orchard)", with irrigation designed and installed principally for orchard freeze protection. Trees in this method are usually planted 4.6-6 m within rows and 6-7.6 m between rows, giving a tree density of 269 to 287 trees/ha. Little pruning is done with this method, other than "skirting" (removal of low limbs to facilitate herbicide application) and heading back of the uppermost portion of the canopy every third or fourth year to limit overall height and facilitate hand harvesting of all of the fruit from the ground. The water volume recommended per tree at planting is 45 l/hr, which is adequate for freeze protection for the first four years of growth and production. After the fourth growing season, either a second sprinkler is added for each tree and placed within the established canopy having a volume equal to or greater than the first. Alternatively, the original sprinkler may be placed within the canopy, and the water volume increased to 90 l/hr (Nesbitt et al., 2000).

The second method of culture is the "interplanted grove (orchard)", wherein Satsuma mandarin trees are interplanted with pine trees, either Loblolly Pine (*Pinus*

taeda) or Slash Pine (*Pinus elliottii*) to reduce frost injury during the winter season. This method of culture was employed by growers in the region prior to the advent of irrigation technology and is still used today on a limited scale on sites where water is limiting. Tree spacing in interplanted orchards is typically closer than in irrigated orchards with in-row spacing of 3-4.3 m and between-row spacing of 6 m, giving a tree density of 359 to 384 trees/ha. Every third tree in each row of trees is a pine tree and alternating rows have pines in alternating positions. When co-planted at the same time, the pine trees offer little frost protection to the Satsumas during the first 4-6 years of growth and development, and then provide increased frost protection with each year of canopy growth of the over-story species.

The third method of culture for Satsuma mandarins in Alabama is "high tunnel greenhouse" production, with trees permanently planted in greenhouses that are covered in the months of December to April with a single-layer of white-colored, 4-mil or 6-mil polyethylene plastic. The structures themselves vary in width, length, and height, and planting arrangement varies from double-row houses with a spacing of 1.8 m in-row and 3.6 m between rows to single-row houses with trees spaced 1.8-2.4 m apart. Supplemental heat is provided by typical greenhouse heaters, water stored in black-colored drums, or with microsprinklers. Trees grown at present in high tunnels are young (less than 6 years old), and pruning requirements, potential for overcrowding and yield potential are still unknown.

Varieties

The original Satsuma mandarin variety that was introduced to the U.S. from Japan in the late 1800's is 'Owari', a variety that reaches desirable eating quality in early November in south Alabama (Ebel et al., 2004). Owari is still the predominant variety of Satsumas in the region today, accounting for 80-90% of the orchard variety composition. 'Armstrong Early' is a variety of unknown origin that ripens 30-40 days earlier than Owari, and has thin peel and compact growth habit. Armstrong Early has been grown for over two decades on a limited scale due to inconsistent internal fruit quality. Three recently-introduced varieties: 'Brown's Select' (Bourgeois et al., 1995), a mid-season selection; 'Early St. Ann' (Bourgeois et al., 2002a), an early variety; and 'L.A. Early' (Bourgeois et al., 2002b), an early variety have garnered interest among growers in Alabama and are being planted with Owari in new plantings, in order to extend the harvest period. Varieties from China and Japan, such as 'Xie Shan', 'Miyagawa Wase', and 'Okitsu Wase', have only recently been introduced to this region and are under study in variety trials. It is unknown at present whether any of these early ripening varieties can consistently bear fruit with acceptable internal quality in this region.

Very few other citrus crops are grown Alabama. While 'Washington' navel oranges are produced for commercial trade in south Louisiana, no navels or sweet oranges are grown commercially in Alabama. A wide array of citrus may be found in home landscapes in this region, but the only varieties planted in high enough numbers for commercial potential include 'Meyer' lemon x sweet orange, 'Meiwa' sweet kumquat (*Fortunella crassifolia*), and 'Nagami' sour kumquat (*Fortunella margarita*).

Worker Activities During the Growing Season

Developmental (Non-Bearing Phase): After planting, young Satsuma trees may receive frequent pruning of long shoots and removal of rootstock suckers which arise periodically during the growing season (Mid-March to Late September). Fertilizer is typically broadcast by hand in February, May and June. Insecticides may be applied with backpack or ATV-powered equipment during June-September. Fruit is hand-removed during the first two years in May or June. Weed control may involve: installation of weed barrier fabric around trees, post-emergence herbicide application and removal of weeds by hand or with a string trimmer. Mowing of sod around trees occurs frequently.

Mature (Bearing Phase): Broken or dead limbs may be pruned annually in February, and skirting (pruning of low limbs) is done by hand, usually in early June. Mowing is performed regularly to control grass height in sod middles, and tree spacing is usually sufficient such that mowing is done with tractor-powered rotary mower. Many orchards are irrigated spring and summer, requiring frequent trips through the orchard to keep irrigation equipment operational. Growers have not adopted fruit thinning practices to date, but harvest is performed entirely by hand from late September through October for early maturing varieties, and from late October to December for standard varieties.

Insect/Mite Control

A comprehensive survey of select Satsuma orchards in Baldwin and Mobile counties was conducted from 2004 to 2006 to determine the identity and population dynamics of arthropod pests and their natural enemies. Twenty eight arthropod pest species were encountered (Fadamiro et al., 2007; Table 1). These include 24 insect species from five orders: Hemiptera (18 species), Hymenoptera (1 species), Lepidoptera (2 species), Orthoptera (2 species), and Thysanoptera (1 species). In addition, four species of pest mites (Acari) were identified. At least seven species could be considered major (key) pests of Satsuma in Alabama due to their occurrence in all surveyed orchards (widely distributed) at high population densities. The major foliage pests of Satsuma in Alabama include citrus whitefly (*Dialeurodes citri* Ashmead), purple scale (*Lepidosaphes beckii* Newman), Glover scale (*L. gloveri* Packard), citrus leafminer (*Phyllocnistis citrella* Stainton), and citrus red mite (*Panonychus citri* McGregor). The major direct pests (fruit-attacking) of Satsuma in Alabama are leaf-footed bugs (*Leptoglossus* spp.) and citrus rust mite (*Phyllocoptruta oleivora* Ashmead), although purple scale and citrus red mite damage can also occur on the fruit, in particular when infestations are heavy. The minor (secondary) pests include citrus mealybug (*Planoccocus citri* Risso), black citrus aphid *Toxoptera aurantii* Fonscolombe), flower thrips *(Frankliniella bispinosa* Morgan), green stink bug (*Acrosternum hilare* Say), and red imported fire ant (*Solenopsis invicta* Buren). Occasional pests (encountered only sporadically) include broad mite *(Polyphagotarsonemus latus* Banks), brown soft scale (*Coccus hesperidium* L.), chaff scale (*Parlatoria pergandii* Comstock), Florida red scale (*Chrysomphalus aonidium* L.), and orthopteran pests such as eastern lubber grasshopper (*Romalea microptera* Beauvois) and American grasshopper (*Schistocera Americana* Drury) (Fadamiro et al., 2007; Table 1).

Several species of natural enemies were encountered in Alabama Satsuma orchards including predators, parasitoids, and fungal pathogens (Fadamiro et al., 2007). The most common predators observed in the survey were predatory spiders, green lacewing (*Chrysoperla* spp.), minute pirate bug (*Orius insidiosus* Say), ladybeetles, mirid bugs, six-spotted thrips (*Scolothrips sexmaculatus* Pergande), and ants. All of these are generalist predators of several pests including citrus leafminer, citrus whitefy, scale insects, and mites. In addition, we recorded many species of predatory mites from several families. Many of these predatory mites may be important predators of citrus red mite and other pest mites.

A few parasitoids were recorded in association with some key pests. These included *Encarsia lahorensis* (Howard) (Hymenoptera: Aphelinidae), the dominant parasitoid of citrus whitefly. Two parasitoids were reared from citrus leafminer: *Ageniaspis citricola* Logvinovskaya (Hymenoptera: Encyrtidae), an endo-parasitoid, and *Cirrospilus ingenuus* Gahan (Hymenoptera: Eulophidae), an ecto-parasitoid. Widespread epizootic infection by the fungal pathogen, *Aschersonia aleyrodis* Webber was also recorded on citrus whitefly at most of the locations (Fadamiro et al., 2007).

In general, the arthropod fauna of Satsuma mandarin in Alabama is similar to the citrus fauna in Florida, Louisiana, and Texas, although there are some notable differences. One major difference is that most of the emerging and newly-introduced pests of citrus in Florida were not recorded in this survey including brown citrus aphid (*Toxoptera citricida* Kirkaldy), Asian citrus psyllid (*Diaphorina citri* Kuwayama), and citrus root weevil (*Diaprepes abbreviatus* L.) (Crane et al., 2001; Aerts and Mossler, 2006). In addition, the Texas citrus mite (*Eutetranychus banksi* McGregor), which is the prevalent spider mite species in Florida (Childers, 1994) and Texas (Anciso et al., 2002) was not detected during this survey. Some of the recorded pests appeared to occur at greater or lower densities in Alabama relative to neighboring citrus-producing states. For instance, the western leaffooted bug, *L. zonatus* is the major leaffooted bug species in Alabama, whereas *L. phyllopus* is the prevalent species in Florida orchards (Baranowski and Slater, 1986). In addition, aphids which are important pests in Florida citrus (Aerts and Mossler, 2006) are currently of minor importance in Alabama Satsuma.

Key (major) Pests of Alabama Satsuma Mandarin

Citrus rust mite (*Phyllocoptruta oleivora* Ashmead)

Citrus rust mite (CRUM) is prevalent in Alabama and inflicts serious economic damage, because of the fresh fruit marketing of Satsuma mandarin. Annual occurrence varies in incidence and severity from orchard to orchard, but once established tends to be an annual problem for particular orchards. Rust mite injury on small fruit will result in reduced size and russeting, while injury on full size fruit at harvest is a distinct brown, rusty staining. The internal quality of full sized fruit with peel staining is not affected, however culling of fruit in the grading process, because of discoloration has been significant and can affect as much as 40% of the crop on infested trees. Leaves of Satsumas can also be injured and appear as russeted areas on the upper leaf surface, while the lower surface may have yellow, necrotic spots.

Table 1. Arthropod pests of Alabama Satsuma orchards (data from 2005-2006 survey)

Order	Common name	Scientific name	Pest status*	Distribution in Alabama**
Hemiptera	Citrus whitefly	*Dialeurodes citri*	Major	++++++
	Glover scale	*Lepidosaphes gloveri*	Major	++++++
	Purple scale	*Lepidosaphes beckii*	Major	++++++
	Leaffooted bug (western)	*Leptoglossus zonatus*	Minor-Major	++
	Leaffooted bug	*Leptoglossus phyllopus*	Minor	++
	Brown stink bug	*Euschistus servus*	Minor	+
	Green stink bug	*Acrosternum hilare (Nezara hilaris)*	Minor	+++
	Black citrus aphid	*Toxoptera aurantii*	Minor	++
	Green citrus aphid	*Aphis spiraecola*	Minor	+
	Cotton/melon aphid	*Aphis gossypii*	Minor	++++++
	Citrus mealybug	*Planoccocus citri*	Minor	++
	Citrus snow scale	*Unaspis citri*	Minor	+
	Cottony cushion scale	*Icerya purchasi*	Minor	++++++
	Caribbean black scale	*Saissetia neglecta*	Occasional	+
	Chaff scale	*Parlatoria pergandii*	Occasional	+
	Florida red scale	*Chrysomphalus aonidium*	Occasional	+
	Brown soft scale	*Coccus hesperidium*	Occasional	++++++
	Citron bug	*Leptoglossus gonagra*	Occasional	+++
Hymenoptera	Red imported fire ant	*Solenopsis invicta*	Minor	++++++
Lepidoptera	Citrus leafminer	*Phyllocnistis citrella*	Minor-Major	++++++
	Orangedog	*Papilio cresphontes*	Minor	++++++
Orthoptera	Eastern lubber grasshopper	*Romalea microptera*	Occasional	++
	American grasshopper	*Schistocera americana*	Occasional	+
Thysanoptera	Flower thrips	*Frankliniella bispinosa*	Minor	++++++
Acari	Citrus red mite	*Panonychus citri*	Major	++++++
	Citrus rust mite	*Phyllocoptruta oleivora*	Minor-Major	+++
	Broad mite	*Polyphagotarsonemus latus*	Occasional	++
	Six-spotted mite	*Eotetranychus sexmaculatus*	Occasional	+

*Pest status is based on population abundance and potential for economic damage;
**Distribution in Alabama is computed based on presence of a pest species in the surveyed orchards (+ indicates presence in only one of the surveyed orchards while ++++++ indicates presence in all six surveyed orchards) (data from Fadamiro et al., 2007).

Seasonal occurrence of CRUM: Damage appears from late June to harvest, with severe injury occurring in July, August and September

Scouting: Examine fruit with a 10x hand lens and a one-square centimeter template. Sample two fruit from each of four quadrants on sample trees (8 fruit/tree), 10-20 trees per orchard (depending on size). Action threshold for fresh market Satsuma mandarins is 2 CRUM/cm^2 of fruit.

Recommended chemical controls for CRUM:
Chemical name: Abamectin
Trade name: ***Agri-Mek .15 EC*** (Novartis)
Rate: 10-15 oz/acre + 0.5% v/v narrow range petroleum oil (415, 435)
Efficacy: very good

Chemical name: Fenbutatin-oxide
Trade name: ***Vendex 50 WP*** (DuPont)
Rate: 2-3 lbs/acre
Efficacy: very good

Chemical name: [2-tert-butyl-5-(4-tert-butylbenzythio)-4-chloropyridazin-3(2H)-one]
Trade name: ***Nexter*** (BASF)
Rate: 5.2-10.67 oz/acre
Efficacy: very good

Alternative controls: Narrow range (NR) petroleum oils may be used instead of or in combination with recommended chemicals, if applied at low population levels followed by maintenance applications at 3-4 week intervals. Phytotoxicity is a potential problem with NR oils if applied under high temperature, low humidity and drought conditions.
Product specifications: 415 or 435 distillation temperature
Trade name: Various
Rate: ***435 Oil*** = 2% v/v (2 oz/gal water)
Rate: ***415 Oil*** = 3-4% v/v (3-4 oz/gal water)

Miticide evaluation trials carried out in the past three years (2004-2006) in Alabama have identified some potential "reduced-risk" miticides and biopesticides that may provide effective control of CRUM in Alabama (Fadamiro et al., 2005; unpublished data). These include:
Comite (Common name: Propargite; Chemical name: Sulfurous acid, 2-4 (1,1-dimethyl-ethyl) phenoxy cyclohexyl-2-propynyl ester; Rate: 3 pts/acre; Crompton Uniroyal Chemical).
FujiMite 5SC (Chemical name: Fenpyroximate; Rate: 3 pts/acre; Nichino America, Inc.).
Micromite 80 WGS (Chemical name: Diflubenzuron; Rate: 6.25 oz/acre; Crompton Uniroyal Chemical).
Note: Some of the above reduced-risk miticides may still be in the process of being registered for use in Alabama.

Cultural control practices: CRUM can be injurious on trees of any age, but adequate control is difficult in mature orchards that are crowded, even with high volume spray equipment. Planting spacings that are sufficient to allow bi-directional spraying at mature tree age may improve spray coverage and control efficacy.

Citrus red mite (*Panonychus citri* McGregor)

Citrus red mites (CREM) are also known as "red spider" and "purple mite". CREM is a major pest of Satsuma mandarin in Alabama occurring on both leaf surfaces in moderate to high densities at the majority of the orchards sampled during 2005 and 2006 (Fadamiro et al., 2007). These mites feed on foliage (primarily on mature leaves) when present in low numbers. As the population grows, fruit feeding can occur. Damage to either fruit or foliage is a loss of green color, or faded gray/bronze color. Magnification of leaves with such color loss reveals bronze-pale yellow feeding sites on the leaf surface or fruit peel. CREM is often considered a "pesticide-induced" pest, being that applications of broadspectrum pesticides may disrupt the activity of predatory mites and Satsuma orchards, significantly greater densities of CREM were recorded in conventionally-managed orchards than in unsprayed orchards, where CREM densities were generally below the economic threshold of 5-10 motile CREM per leaf (Childers et al., 2007).

Seasonal occurrence of CREM: CREM can overwinter as eggs or motiles in southern Alabama (Fadamiro et al., 2007). It prefers low relative humidity and moderate temperatures. The eggs can occur in high densities as early as January. In Alabama, CREM motiles are typically most abundant in the spring (February-April) with the population declining at the beginning of the summer and eventually crashing in July (English and Turnipseed, 1940; Fadamiro et al., 2007). In some years, a second generation can occur from September to November. While these pests do not cause acute damage to either the fruit or foliage, allowing them to buildup on the trees can cause cosmetic damage to the fruit, increased sunscald of fruit, and leaves can be sufficiently stressed to affect cold hardiness and cropping.

Scouting: Frequent scouting in the spring and fall is needed in Satsuma orchards. Sample 16 leaves per tree (4 leaves/quadrant, 2 each from the exterior and interior canopy), 5-10 trees per acre at weekly or biweekly intervals during period of high CREM activity (January-May). Place leaves from individual trees into labeled paper bags for examination under a stereomicroscope or examine individual leaves in the field with a 10X hand lens. When population densities average 5 or more motile CREM per leaf, treatment is necessary as soon as possible. Note that CREM tend to be more abundant on leaf samples collected from the exterior canopy than from leaves collected from the interior canopy (Fadamiro et al., 2007) .

Recommended chemical controls for CREM:

Narrow range (NR) petroleum oils:

Phytotoxicity is a potential problem with NR oils if applied under high temperature, low humidity and drought conditions; however, those conditions are unlikely in Alabama at the times of year when CREM is usually problematic.

Product specifications: 415 or 435 distillation temperature
Trade name: Various
Rate: ***435 Oil*** = 2% v/v (2 oz/gal water)
Rate: ***415 Oil*** = 3-4% v/v (3-4 oz/gal water)

Chemical name: Fenbutatin-oxide
Trade name: ***Vendex 50 WP*** (DuPont)
Rate: 2-3 lbs/acre
Efficacy: very good

Chemical name: [2-tert-butyl-5-(4-tert-butylbenzythio)-4-chloropyridazin-3(2H)-one]
Trade name: ***Nexter*** (BASF)
Rate: 5.2-10.67 oz/acre
Efficacy: very good

Alternative controls: Biological control with predatory mites may offer an alternative control for CREM in Alabama, however this potential is currently being investigated. Several species of predatory mites occur in Alabama orchards. These include predatory mites in the families Anystidae, Ascidae, Bdellidae, Cheyletidae, Cunaxidae, Erythraeidae, Eupalopsellidae, Phytoseiidae, and Stigmaeidae. The dominant predatory mite species in Alabama citrus orchards is *Typhlodromalus peregrinus* (Phytoseiidae) (Fadamiro et al., 2007). Many of these predatory mites may be important predators of citrus red mite and other pest mites. Other CREM predators include six-spotted thrips, *Scolothrips sexmaculatus* (Pergande). The present densities of predatory mites in Alabama Satsuma orchards are too low to provide effective suppression, and sole reliance on predatory mites for control of CREM is not recommended at this time. However, it is possible that an IPM program integrating predatory mites and petroleum oils will provide an effective control of CREM in Alabama. Further studies are needed to further characterize the predatory mite fauna in Alabama Satsuma orchards and to evaluate the efficacy of integrating predatory mites and petroleum oils for citrus mite control.

Miticide evaluation trials carried out in the past three years (2004-2006) in Alabama have identified some potential "reduced-risk" miticides and biopesticides that may provide effective control of CREM in Alabama (Fadamiro et al., 2005; unpublished data). These include:
Biomite (Chemical description: A liquid mixture of terpenes; Rate: 1 gallon/acre; Natural Plant Protection / Arvesta Corporation).
FujiMite 5SC (Chemical name: Fenpyroximate; Rate: 3 pts/acre; Nichino America, Inc.).
Kanemite 15SC (Chemical name: Acequinocyl; Rate: 21-31 oz/acre; Arysta LifeScience).
Note: Some of the above reduced-risk miticides may still be in the process of being registered for use in Alabama.

Leaf-footed Bugs/Stink bugs

The dominant leaf-footed bug/plant bug species in Alabama is the western leaf-footed bug *(Leptoglossus zonatus* Dallas) (Fadamiro et al., 2007). During the harvest period, leaf-footed bugs (LFB) and stinkbugs (SB) may move into Satsuma orchards

from other crops such as soybeans and cotton. These insects will puncture the peel of a Satsuma, transfer yeast to the juice vesicles, and cause single or multiple dry, damaged segments per fruit. Stinkbug injury causes the fruit to fall off the tree; but the fruit injured by leaf-footed bugs does not fall off and cannot be detected by visual inspection of the outer peel.

Scouting: Begin monitoring orchards when fruit start to change color. Leaf-footed bugs often aggregate in clumps when young, and can be spot treated with an insecticide from a hand sprayer. However if these insects are scattered throughout the orchard, a general spray with a tree sprayer may be needed. Scout orchards regularly throughout harvest period! Repeat sprays may be needed to reduce pressure. No systematic threshold data has been generated in Alabama, but orchards with as few as 5-10 adults per orchard of any size are at risk for significant economic loss.

Recommended chemical controls for plant bugs:
Chemical name: Fenproprathin
Trade name: ***Danitol 2.4 EC*** (Valent)
Rate: 16-21.33 oz/acre
Efficacy: good

Chemical name: Malathion
Trade name: ***Malathion 5EC***; Various
Rate: 2-2.5 pts/acre
Efficacy: very good

Chemical name: Chlorpyrifos
Trade name: Various
Rate: 1.5 pts/acre
Efficacy: poor

Alternative controls: Planting of trap crops around orchards may offer some protection against plant bugs. Plant species that are attractive to stinkbugs and leaf-footed bugs may be planted on the orchard perimeter using a planting date that will create seeds or fruit during the time immediately prior to ripening of Satsumas. These trap crop plots may then be monitored and treated to decrease insect pressure. Known attractive plants include soybeans, southern peas, sunflowers, and cotton. Further research is necessary to develop an efficient trap crop system for managing plant bugs in Alabama citrus orchards.

Citrus whitefly (*Dialeurodes citri* Ashmead)

Citrus whitefly (CWF) is a major pest of Satsuma in Alabama, occurring in high densities in all orchards surveyed during 2005 and 2006 (Fadamiro et al., 2007). Infestation of CWF is confined almost entirely to the lower (underside) surface of leaves. CWF is usually more abundant in the interior tree canopy, which is likely the preferred site for oviposition and development (Fadamiro et al., 2007). If CWF populations get high, young leaves may wilt from the phloem sap sucking caused by the nymphs

(immatures). High infestation can also result in large amounts of honeydew and the associated infection by the sooty mould fungus on leaves and fruit.

Seasonal occurrence: Adults usually appear in early spring after the first growth flush, and lay eggs on the underside of new leaves. The eggs hatch in 6 to 20 days, depending on temperature. At least two-three generations of CWF occur per year in Alabama (English and Turnipseed, 1940; Fadamiro et al., 2007). Immatures (nymphs and pupae) could be found in south Alabama orchards as early as January, with the first population peak occurring around April to May and another peak in September to October (Fadamiro et al., 2007). Population densities are usually very low in the summer and winter months. Several natural enemies could be found in association with CWF in Alabama including generalist predators such as ladybeetle, mirid bugs, and green lacewings. The key parasitoid of CWF in Alabama is *Encarsia lahorensis* (Hymenoptera: Aphelinidae) (Fadamiro et al., 2007). Another important direct source of CWF mortality in Alabama citrus is infections by the pathogenic fungus, *Aschersonia aleyrodis* (Fadamiro et al., 2007).

Recommended chemical controls for CWF:
Narrow range (NR) petroleum oils:

Phytotoxicity is a potential problem with NR oils if applied under high temperature, low humidity and drought conditions; however, those conditions are unlikely in Alabama at the times of year when Citrus Red Mite is usually problematic.
Product specifications: 415 or 435 distillation temperature
Trade name: Various
Rate: ***435 Oil*** = 2% v/v (2 oz/gal water)
Rate: ***415 Oil*** = 3-4% v/v (3-4 oz/gal water)

Chemical name: Dimethoate 2.67 EC
Trade name: Various
Rate: 1 pt/100 gal water
Efficacy: very good

Chemical name: Malathion
Trade name: Malathion; Various
Rate: 2-3 lbs/acre
Efficacy: very good

Chemical name: Chlorpyrifos
Trade name: Various
Rate: 1.5 pts/acre
Efficacy: good

Chemical name: Imidacloprid
Trade name: ***Provado 1.6F*** (Bayer CropScience)
Rate: 10 oz/acre
Efficacy: good

Alternative controls: There are pathogenic fungi (i.e. *Aschersonia aleyrodis*) that help suppress whitefly in citrus, however, fungicide sprays in the spring may counteract their effect and cause CWF to be a problem in the spring. Oil sprays applied prior to the hatch of the overwintering immatures may be effective. If high numbers of CWF do occur in the spring and control is desired, delay insecticide applications for at least 10 days after most adults have stopped flying. Such timing will give better control of hatching nymphs. Control fire ants around trees. Fire ants protect CWF larvae and eggs from beneficial insects.

Scale insects

Of the six or more species of scale insects found in Alabama (Table 1), the two most important scale pests of citrus in Alabama are purple scale (*Lepidosaphes beckii* Newman) and Glover scale (*L. gloveri* Packard). Both species are important pests of attacking Satsuma leaves, trunk, twigs, and sometimes fruit. Heavy infestations could result in tree death, while moderate infestations could weaken trees and make them more susceptible to freeze damage (English and Turnipseed, 1940). Infested fruit will have visible scale present and/or discolored spots and may ripen slowly.

Seasonal occurrence: Both species of scale insects reproduce several generations each year and all stages (including crawlers) could be found in the orchard throughout the year. However, the highest population densities are typically recorded during spring in Alabama with a smaller population peak in the fall (English and Turnipseed, 1940; Fadamiro et al., 2007). Like CWF, both species of scale insects are more abundant in interior tree canopy than in exterior tree canopy (Fadamiro et al., 2007). The main parasitoid of scale insects in Alabama citrus is *Aphytis lepidosaphes* Compere (Hymenoptera: Aphelinidae) (Fadamiro et al., 2007)

Recommended chemical controls for scale insects:

Narrow range (NR) petroleum oils:

Phytotoxicity is a potential problem with NR oils if applied under high temperature, low humidity and drought conditions.

Trade name: Various
Rate: ***435 Oil*** = 2% v/v (2 oz/gal water)
Rate: ***415 Oil*** = 3-4% v/v (3-4 oz/gal water)

Chemical name: Chlorpyrifos
Trade name: Various
Rate: 1.5 pts/acre
Efficacy: good

Chemical name: Imidacloprid
Trade name: ***Provado 1.6F*** (Bayer CropScience)
Rate: 10 oz/acre
Efficacy: good

Citrus leafminer (*Phyllocnistis citrella* Stainton)

Citrus leaf miner (CLM) is prevalent in most Alabama citrus orchards. CLM attacks tender, flush growth of Satsuma trees and other citrus varieties. This pest may have several generations per year and attack each growth flush, but the first spring growth flush, which makes up the biggest percentage of the leaves for the year, is usually not attacked. Therefore this pest is not an economic threat to mature trees. Young trees however can be seriously damaged, with growth and early production stunted.

The larval stage of this tiny moth makes serpentine mines just underneath the outer surface of the leaf, causing it to twist and curl. Leaf mines are usually on the bottom leaf surface, except in heavy infestations when both leaf surfaces are used. Larvae have four instars, and development takes from 5-20 days. Entire generations may be completed in less than 14 days during July and August. Pesticide application should be considered only when the new flush of growth is anticipated to constitute 20% of the canopy area or more. Under these conditions, pesticide application should begin when about 30% of the flush leaves show active mines to maximize susceptibility of the larvae and have the greatest impact on control. Only new, developing leaves need to be treated.

Recommended chemical controls for CLM:

Chemical name: Abamectin
Trade name: ***Agri-Mek .15 EC*** (Novartis)
Rate: 10-15 oz/acre + 0.5% v/v narrow range petroleum oil (415, 435)
Efficacy: very good

Chemical name: Imidicloprid
Trade name: ***Provado 1.6F*** (Bayer CropScience)
Rate: 10 oz/acre
Efficacy: good

Chemical name: Azadirachtin
Trade name: ***Neemix 4.5*** (Certis USA)
Rate: 4.0-7.0 oz/acre
Efficacy: unknown

Thrips

Flower thrips are a minor pest of citrus in Alabama. However, high infestations can cause cosmetic damage (“silver scar”) to Satsumas. Winged adult thrips are attracted to Satsuma flowers on which they feed. This feeding does little damage, however, they lay eggs in the receptacle portion of the flower, and the tiny larvae that hatch feed on the developing ovaries, resulting in a light silver scarring of the small fruit. Insecticide application during bloom period reduces the thrips population. Usually one application is sufficient if timed properly.

Note: If thrips are determined to be an economic problem, insecticide use for control should be weighed against potential impact of bees present in the orchard. Although bees are not needed for Satsuma flower pollination, pollination of other crops and honey production could be negatively affected by insecticide sprays made when bees are visiting Satsuma trees. Managed bee colonies should be temporarily relocated if insecticide sprays are made while any flowers are present.

Recommended chemical controls for thrips:
Chemical name: Dimethoate 2.67EC
Trade name: Various
Rate: 1 pt/100 gal water
Efficacy: very good

Chemical name: Malathion
Trade name: Various
Rate: 2-3 lbs/acre
Efficacy: good

Chemical name: Chlorpyrifos
Trade name: Various
Rate: 1.5 pts/acre
Efficacy: good

Orangedog (*Papilio cresphontes* Cramer)

Orangedog caterpillars are larvae of giant swallowtail butterfly (*Papilio cresphontes)*. Orangedog is a minor pest of citrus in Alabama. The caterpillars are insignificant pests of mature trees, causing very small amounts of damage, however they can cause substantial leaf loss on young trees and in nurseries. The slow-moving caterpillar has a gray-white coloration often resembling bird droppings. They can reach 2 inches long at maturity. Multiple generations may occur each growing season.

Recommended chemical controls for orangedog:
Chemical name: *Bacillus thuringiensi*s subsp. kurstaki
Trade name: ***Dipel DF*** (Valent)
Rate: 0.25-1.0 lb/acre
Efficacy: very good

Chemical name: Spinosad
Trade name: ***Spintor 2SC Naturalyte*** (Dow AgroSciences)
Rate: 4-10 oz/acre
Efficacy: very good

Weed Control/Orchard Floor Management

The overall approach to orchard floor management is a “sod and strip” system where a sod covering is maintained throughout the life of the planting for accessibility of equipment in wet weather, and a weed-free strip is maintained to reduce weed competition for water and nutrients. A continuous weed free strip is not necessary in young orchards, but may be easier to maintain with a boom-herbicide applicator. Individual weed free plots or “squares” around each tree in the first 4-5 years of the planting are adequate and reduce chemical cost, but increase the amount of mowing that must be done in the orchard. Centipede grass [*Eremochloa ophiuroides* (Munro) Hack.] is

an excellent sod species for orchards in Alabama, because its low growing nature reduces mowing frequency.

Newly transplanted trees

A) Mulch with undecomposed organic matter, such as pine straw or pine bark; or B) install weed barrier fabric around each tree; or C) hand weed or apply post-emergence herbicides in conjunction with protection of the tree with a protective sleeve. Mulched or weed mat area should be 4-6' wide in two directions, and organic mulches should be 4 inches deep minimum.

Trees planted for one or more years

Trees established one year or more should continue to have a 4-6' wide area (2 directions or square pattern) for adequate reduction of weed competition. Bare soil around the tree as opposed to weedy areas around tree is also better for freeze protection in that bare soil stays warmer, because it has lower radiational cooling than soil covered by vegetation.

***Preemergence herbicides for grasses**:*
Chemical name: Oryzalin
Trade name: ***Surflan AS***
Rate (light to medium soils): 2 qts/acre

Chemical name: Norflurazon
Trade name: ***Solicam DF***
Rate (light to medium soils): 2.5 lbs/acre

Preemergence herbicides for broadleaf weeds:
Chemical name: Diuron
Trade name: ***Karmex DF***
Rate (light to medium soils): 2 lbs/acre

Chemical name: Simazine
Trade name: ***Princep DF***
Rate (light to medium soils): 2 lbs/acre

Postemergence herbicides:
Chemical name: Glyphosate
Trade name: ***Roundup, Rattler, Touchdown, Glyphomax***
Rate: Varies with trade name
Efficacy: Annual weeds and perennial weeds

Chemical name: Paraquat
Trade name: ***Gramoxone***
Rate: 1.7-2.7 pts/acre
Efficacy: Annual grasses and broadleaf weeds

Chemical name: Sethoxydin
Trade name: ***Poast 1.5 EC***
Rate: 1.5-2.5 pts/acre
Efficacy: Annual grasses and perennial grasses

Trees planted for three years or more

Trees established for at least three years can use products at the rates listed for one year-old trees, but may also use higher rates and additional products.

Preemergence herbicides for broadleaf weeds:
Chemical name: Diuron
Trade name: ***Karmex DF***
Rate (light to medium soils): 2-3.2 lbs/acre

Chemical name: Simazine
Trade name: ***Princep DF***
Rate (light to medium soils): 2.2-3.96 lbs/acre

Preemergence herbicide for broadleaf and grass weeds:
Chemical name: Diuron & Bromacil
Trade name: ***Krovar 1 DF***
Rate (light to medium soils): 2-6 lbs/acre
Note on soil type interaction with preemergence herbicide rates: Rates should be increased 1.5 to 2.0 times for medium to heavy-textured soils.

Disease Control

Spring & Summer Diseases

Citrus scab (*Elsinoe fawcettii* Bitancourt & Jenk.)

Citrus scab is a fungal disease that causes warts or raised bump-like lesions on the peel and leaves of Satsumas. Fruit quality is not affected by scab, but outward appearance of scab causes decreased marketability. Scab overwinters in the tree on twigs, leaves, and fruit not removed from the orchard. New growth and fruit are infected in early spring with temperatures of 24-27ºC and frequent rains.

Control strategy: Orchards with appearance of scab in spring should treat at 2/3 petal fall in the following spring with a fungicide. For orchards with a severe problem, a late winter application of fungicide prior to the petal-fall spray should also be made at first sign of spring growth flush commencement.

Recommended chemical controls for citrus scab:
Chemical name: neutral or fixed copper
Trade name: Various
Rate: Varies with product

Efficacy: good

Chemical name: Pyraclostrobin
Trade name: ***Headline*** (BASF)
Rate: 12 oz/acre
Efficacy: good

Chemical name: Azoxystrobin
Trade name: ***Abound*** (Syngenta)
Rate: 14 oz/acre
Efficacy: good

Chemical name: Trifloxystrobin
Trade name: ***Gem*** (Bayer CropScience)
Rate: 4-8 oz/acre
Efficacy: good

Melanose (*Diaporthe citri* Wolf)

Melanose is a fungal disease that attacks small, developing Satsuma fruit and leaves in the spring and early summer. Melanose typically is more of a problem on older trees (10 years and older), and overwinters in dead twigs and branches. Early-season melanose causes sunken brown spots on the fruit peel. These spots can coalesce into "mudcaked"-appearing stains on the fruit. The distribution of spots or mudcaking often follows water flow over the fruit and can appear in streaks. Severe melanose is similar in appearance to rust mite injury; however, rust mite feeding injury is smooth whereas melanose-infected areas will be slightly raised and rough textured. Fruit become immuned to infection about three months after petal fall (late July).

Control strategy: Remove dead limbs in late winter before spring growth commences. Applications of neutral copper should be made before bloom to reduce overwintering inoculum and protect small fruit. If symptoms were serious in the previous year, a second application of copper or a fungicide should be made two weeks after fruit set, and again 4 weeks later.

Recommended chemical controls for melanose:
Chemical name: neutral or fixed copper
Trade name: Various
Rate: Varies with product
Efficacy: good

Chemical name: Pyraclostrobin
Trade name: ***Headline*** (BASF)
Rate: 12 oz/acre
Efficacy: good

Chemical name: Azoxystrobin

Trade name: ***Abound*** (Syngenta)
Rate: 14 oz/acre
Efficacy: good

Chemical name: Trifloxystrobin
Trade name: ***Gem*** (Bayer CropScience)
Rate: 4-8 oz/acre
Efficacy: good

Greasy spot (*Mycosphaerella citri*)

Greasy spot is a fungal disease that causes raised, dark brown colored, greasy-appearing blisters or blotches on undersides of leaves. Infection occurs when long periods of leaf wetness and warm temperatures occur (summer). Symptoms may take 3-6 months to show up. Defoliation in January to April the following season may be severe and counterproductive to fruit set. Greasy spot can be found on young and mature orchards, but defoliation caused by the disease is aggravated by tree to tree crowding in older orchards.

Control strategy: Fallen leaves that are decomposing on the orchard floor in the spring are the primary source for inoculum and new infections. Removal, covering or irrigating fallen leaves to limit spore release may aid in disease suppression, however, orchards with significant disease must treat spring and summer flush leaves with fungicides to prevent infection.

Recommended chemical controls for greasy spot:
Chemical name: neutral or fixed copper
Trade name: Various
Rate: Varies with product
Efficacy: good

Chemical name: Pyraclostrobin
Trade name: ***Headline*** (BASF)
Rate: 12 oz/acre
Efficacy: good

Chemical name: Azoxystrobin
Trade name: ***Abound*** (Syngenta)
Rate: 14 oz/acre
Efficacy: good

Chemical name: Trifloxystrobin
Trade name: ***Gem*** (Bayer CropScience)
Rate: 4-8 oz/acre
Efficacy: good

Narrow range petroleum oils

Trade name: Various
Rate: ***435 Oil*** = 2% v/v (2 oz/gal water)
Rate: ***415 Oil*** = 3-4% v/v (3-4 oz/gal water)
Efficacy alone: fair (may improve control when tank-mixed with recommended fungicides).

Harvest Period Diseases

Brown Rot

Brown rot is a fungal disease caused by two species of *Phytophthora*: soil-borne (*Phytophthora nicotinae*) and air-borne (*Phytophthora palmivora*) causing large, soft and brown-colored spots on ripe fruit prior to or after harvest. Splashing rainwater carries the fungus from the soil to low-hanging fruit, and rotting will occur during warm weather. Control is aided by pruning low limbs or removal of fruit that is either on branches that are contacting the soil or has been dislodged from the tree.

Control strategy: A fungicide specifically for *Phytophthora* spp. should be used during harvest if rainy, warm weather occurs. Store fruit at temperatures less than 40^{o}F (4^{o}C).

Recommended chemical controls for brown rot:
Chemical name: Aluminum tris
Trade name: ***Aliette WDG*** (Bayer CropScience)
Rate: 5 lbs/acre
Efficacy: good

Chemical name: Potassium Phosphite
Trade name: ***Prophyt*** (Helena)
Rate: 4 pts/acre
Efficacy: good

Green mold (*Penicillium digitatum*)

Green mold is a postharvest fungal disease most likely infecting fruits that touch the ground or have peel damage and get soil/rain-splashed on the surface. Mold appearance is rapid at room temperature, but delayed at temperatures below 40^{o}F.

Control strategy: field application of fungicide to ripe fruit 14 days or less prior to harvest. Cultural control practices include proper sanitization of handling and grading equipment, cold storage of fruit immediately after harvest, and use of clean, uncontaminated boxes for packing fruit.

Recommended chemical controls for green mold:
Chemical name: Pyraclostrobin
Trade name: ***Headline*** (BASF)
Rate: 12 oz/acre
Efficacy: good
Chemical name: Azoxystrobin

Trade name: ***Abound*** (Syngenta)
Rate: 14 oz/acre
Efficacy: good

Chemical name: Trifloxystrobin
Trade name: ***Gem*** (Bayer CropScience)
Rate: 4-8 oz/acre
Efficacy: good

Nematode Control

Nematode problems have not been suspected or investigated in existing Satsuma mandarin orchards in Alabama. The two most devastating nematodes in the southeastern U.S. are citrus nematode (*Tylenchulus semipenetrans* Cobb) and burrowing nematode (*Radopholus citrophilus*). There is currently no evidence that burrowing nematode is present in Alabama, however, old notations in literature indicate that citrus nematode may have become established in Alabama prior to 1940. The primary means of preventing nematode problems in citrus is by selecting resistant rootstocks. The most widely used rootstock in Alabama is trifoliate orange [*Poncirus trifoliata* (L.) Raf.]. This rootstock is considered resistant to citrus nematode but susceptible to burrowing nematode. A second rootstock that has been implemented recently is 'Swingle' citrumelo (*Citrus paradise* Macf. 'Duncan' *x P. trifoliata*). Swingle is also susceptible to burrowing nematode, and tolerant of citrus nematode.

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