Crop Profile for Strawberry in Florida

Revised: January, 2004

Production Facts

* Florida ranks second in the U.S. in the production of strawberry (1).
* Florida produces 15 percent of the total U.S. crop, and 100 percent of the domestically produced winter crop (1).
* 220,500,000 pounds of fresh berries valued in excess of $167 million were produced during the 1999-00 crop year on 6,300 acres (2).
* Production costs (1998-99) averaged $17,100 per acre (3), which makes strawberry one of the most expensive crops to produce.
* There were 6,900 acres of production in 2002 (4).

Production Regions

Approximately 95 percent of Florida’s commercial strawberry production acreage is located in Hillsborough and Manatee counties with the remainder in several other counties (2).

Production Practices

Because of the great value of the crop as well as the initial investment, it is strongly recommended that strawberries be grown only on full-bed plastic mulch, and that a multi-purpose fumigant be applied to
the bed as the plastic is laid over it. Therefore, strawberries are grown as an annual crop in Florida using the hill (raised bed) system, with two to four rows of plants per raised bed (3). Methyl bromide, in combination with chloropicrin, is currently applied approximately two weeks prior to planting transplants for the management of soilborne diseases, nematodes, insects, and weeds. A single application at an average rate of approximately 140 to 180 pounds of product per acre (approximately 300 pounds per treated acre) is injected into the soil during construction of the raised-beds (4). Row middles are not treated. The bed is then immediately covered with plastic mulch. Virtually all of Florida’s strawberry acreage is fumigated with methyl bromide (4). Total methyl bromide usage on Florida strawberries in 2002 was reported to be 918,000 pounds, which is a 25 percent reduction from the estimated 1,230,000 pounds of active ingredient used during the mid-1990s (4,5). Over three-fourths of Florida strawberry producers list the loss of methyl bromide as being their greatest future pest management concern (5).

Worker activities include mostly tractor-driven related operations, such as cultivation, fertilization, operating the fumigation rig, and laying drip tape. For fumigation, the only field task is shoveling dirt on the mulch to bury it, which generally requires three people per end. The two-row fumigation rig will cover about eight acres a day. With an average size farm of 40 acres, shovel crews would be needed about 40 hours (five days) a year. Workers set transplants and cut runners in early and midseason, and generally wear gloves for these tasks. Fruit are harvested by hand every three days throughout the harvest season, usually without gloves. As a general rule, there is one picker for every acre during non-peak parts of the production season, and one-and-a-half workers per acre during the peak parts of the season. Picking is finished in four hours each day during the non-peak parts of the season, while picking takes place eight hours a day during the peak. The shipping container is often what is filled in the field, so very little rehandling occurs.

Several principal varieties are cultivated in Florida and these varieties can change year-to-year. To avoid re-introduction of mites, nematodes and other pathogens to the treated beds, growers are encouraged to use only the best quality transplants available. Transplants are set in late September through early November. Drip and overhead irrigation is used to help establish plants, irrigate plants, and protect the plants from frost (3). Following early vegetative growth, the cool nights and short days of winter stimulate the plant to produce flowers which, after pollination, develop into fruits ready for harvest in four to six weeks. This results in three or four crops of fruit from each plant (based on a 30-day cycle). Flowers are present on plants in production areas continuously from shortly after planting until the end of harvest, but there are typically two peak flowering periods each season, one in November or December, and the other in mid to late January. The average harvest period runs from late November through early April. Due to the frequency of harvest, preharvest intervals (PHIs) and restricted entry intervals (REIs) are important factors when growers select pesticides for use on strawberries. Pesticides are applied exclusively by ground application equipment.

**Insects/Mites**
Insect/Mite Pests

The principal pests on strawberry in Florida are the twospotted spider mite and lepidopterous larvae (fall and southern armyworms). Minor and occasional pests include corn earworm and sap beetles. Insects that may occasionally be seen on strawberry but are generally managed incidentally include fruit flies, whiteflies, lygus bugs, saltmarsh caterpillar, aphids, leaf rollers, thrips, tobacco budworm, mole crickets, and ants (5,6).

SPIDER MITES (Tetranychus urticae, T. turkestani, T. tumidus)

The twospotted spider mite (*T. urticae*) is oval, about 0.5 mm long, and may be brown or orange-red, but a green, greenish-yellow or an almost translucent color is most common. All mites have needle-like piercing-sucking mouthparts. Spider mites feed by penetrating the plant tissue with their mouthparts and are typically found on the underside of the leaf. Spider mites spin fine strands of webbing on the host plant - hence their name. When twospotted spider mites remove the sap, the mesophyll tissue collapses and a small chlorotic spot forms at each feeding site. Continued feeding causes a stippled-bleached effect on the upper surfaces of leaves and later, the leaves turn yellow, gray or bronze. Complete defoliation may occur if the mites are not controlled (7).

FALL ARMYWORM (Spodoptera frugiperda)

Adults can be seen along the Florida coast during all months but are most abundant from planting to December. The fall armyworm does not enter diapause and cannot survive extended periods of low temperatures, instead maintaining populations in warmer areas from which adults move northward in the spring. The forewings are a mottled gray/brown with a variable pattern, while hindwings are a opalescent white. The female moth is highly mobile, migrating each spring from frost-free areas in the southern part of the state and spreading throughout the southeast region of the country. Eggs are laid in masses of 100 to 150, and each moth may lay over two thousand eggs in total. Control at the egg stage is extremely difficult, due to the protective covering over the mass and its preferred position on the underside of leaves. After approximately two to three weeks of feeding, larvae drop to the ground and form pupae in the soil, at a depth of about 1 to 3 inches (2 to 8 cm). In Florida, the pupal stage lasts about eight to nine days during the summer and about 20 to 30 days during the winter. Although the life cycle of the fall armyworm can be completed in about 30 days during the summer, it can take 60 days in the spring and fall and up to 90 days during the winter (7).

SOUTHERN ARMYWORM (Spodoptera eridania)

The forewings of the mature armyworm moth are gray and brown, with irregular dark brown and black markings. Up to four generations per year occur in Florida. Larvae are defoliators and feed gregariously while young, often skeletonizing leaves. As they mature they become solitary and may feed on the surface of fruit (7).
CORN EARWORM (*Helicoverpa zea*)

This caterpillar, also called tomato fruitworm and cotton bollworm, attacks a wide variety of vegetable and field crops. It is capable of overwintering throughout the state. There are up to seven generations per year in Florida, but like fall armyworm, the aggressive and cannibalistic nature of the larvae limit the number of mature larvae present at any one time. Both larva and adult corn earworm are variable in color and pattern (7).

SAP BEETLES (Family Nitidulidae)

These beetles overwinter in pupal or adult stages and become active early in spring with subsequent egg deposition at that time. Eggs may be laid as deep as 15 cm in the soil. The larvae bear a fleshy protuberance ventrally, and go through three or four instar stages. The adult beetle’s wings do not cover the entire insect, exposing the terminal abdominal segments, and the antennae are club-shaped. Both larval and adult sap beetles feed on strawberry, although many other vegetable crops are preferred hosts. In Florida, conditions can support two generations of sap beetles per year (7).

Controls

Non-chemical

The principal non-chemical control measure is the purchase and release of beneficial mites to manage spider mites (5). Over forty percent of Florida strawberry production is under this practice, which saves about four miticide applications per season (8). Other non chemical measures include using resistant varieties, purchasing or planting certified pest-free plants, and sanitation. The use of certified plants (for mites) is used, but is frequently not reliable. While there are a number of non-chemical control measures, usage is limited due to their limited effectiveness (9). It is estimated that there would be a 25 percent yield loss if current insecticide/miticides were lost (9). Most Florida growers (98 percent) report scouting for insect/mite pests and two-thirds report applying a control measure when they believe a pest/damage threshold has been reached (5).

Chemical

The predominant miticides used on Florida strawberry are hexythiazox, bifenazate, abamectin and bifenthrin (4). A small number of growers use an excitatory pheromone (Stirrup M®) in an effort to increase mite and miticide contact. Insecticides commonly used for worm management include methomyl, spinosad, naled, and malathion (4). Other foliar insecticides/miticides labeled for use in strawberry as of 2003 include azadirachtin, *Bacillus thuringiensis* (*B.t.*), *Beauveria bassiana*, carbaryl, chlorpyrifos, diazinon, dicrofot, endosulfan, etoxazole, fenpropatrin, fenbutatin-oxide, *Helicoverpa zea* nuclear polyhedrosis virus, imidacloprid, propargite (non-bearing only), pyrethrins +/- rotenone, and sulfur.
Methyl bromide is used for soil insect management prior to planting (see cultural practices). Most Florida growers report alternating pesticides to reduce pest resistance (5). It is important that insecticides and miticides from more than one chemical family be available for insect/mite management on strawberry to prevent the development of pest resistance to specific insecticides/miticides.

**Methomyl** (Lannate®). Growers depend the most on methomyl as the insecticide for broad spectrum insect pest management. More than 40 percent of growers believe that acceptable management of insect pests would NOT be possible without methomyl (5). Growers using predatory mites only use methomyl at the end of the season to manage sap beetles and fruit flies because using it earlier would eliminate beneficial mites and lead to a plant-feeding mite outbreak (8). Methomyl is a carbamate insecticide applied to between 65 and 89 percent of the strawberry acreage, usually about five times during the season (2,4). The median price of methomyl is $25.12 per pound of active ingredient (lb ai), and the approximate cost of a labeled application (0.9 lb ai/A) is $22.61 (10,11). However, the usual range of application extends from 0.5 to 0.7 lb ai/A (2,4). During times of severe insect pest pressure (1994), producers have had to make more than 11 full-rate applications of methomyl to manage insect pests effectively. However, the label (2003) now states that no more than 10 applications (or 4.5 lb ai/A) can be applied to any one crop. The REI is 48 hours and the PHI is three days (ten days for processing berries).

In 2002, strawberry growers in Florida applied methomyl (at 0.55 lb ai/A) to 75 percent of their acreage 4.0 times for a total crop use of 2.23 lb ai/A/year. The total amount used on Florida strawberries was estimated to be 11,600 pounds (4).

**Abamectin** (Agri-Mek®). Abamectin is a soil bacterium derivative compound that is applied to between 48 and 77 percent of the strawberry acreage, usually from two to four times during the season (2,4). The median price of abamectin is $4570.00 per pound of active ingredient, and the approximate cost of a labeled application (0.019 lb ai/A) is $85.69 (12,19). The label states that no more 0.075 lb ai/A can be applied to any one crop. The REI is 12 hours and the PHI is three days.

In 2002, strawberry growers in Florida applied abamectin (at 0.02 lb ai/A) to 77 percent of their acreage 2.9 times for a total crop use of 0.05 lb ai/A/year. The total amount used on Florida strawberries was estimated to be 300 pounds (4).

**Bifenthrin** (Brigade®). Bifenthrin serves as a miticide and insecticide. It is applied to between 32 and 42 percent of the strawberry acreage, usually one or two times during the season (2,4). The median price of bifenthrin is $180.73 per pound of active ingredient, and the approximate cost of a labeled application (0.2 lb ai/A) is $36.15 (11,13). However, the usual range of application extends from 0.12 to 0.14 lb ai/A (2,4). The label states that no more than 0.5 lb ai/A can be applied to any one crop. The REI is 24 hours and there is no PHI.

In 2002, strawberry growers in Florida applied bifenthrin (at 0.12 lb ai/A) to 36 percent of their acreage 2.5 times for a total crop use of 0.31 lb ai/A/year. The total amount used on Florida strawberries was
Naled (Dibrom®). Naled is an organophosphate insecticide applied to a third of the strawberry acreage in Florida. While naled is efficacious on pests, it is harsh on beneficials, which tends to limit its use (8). Naled is applied to between 7 and 33 percent of the strawberry acreage, two to four times during the season (2,4). The median price of naled is $10.91 per pound of active ingredient, and the approximate cost of a labeled application (0.94 lb ai/A) is $10.26 (11,14). The usual range of application extends from 0.8 to 1.0 lb ai/A (2,4). The label states that no more than 4.7 lb ai/A may be applied to any one crop. The REI is 48 hours and the PHI is one day.

In 2002, strawberry growers in Florida applied naled (at 1.14 lb ai/A) to 33 percent of their acreage 1.9 times for a total crop use of 2.2 lb ai/A/year. The total amount used on Florida strawberries was estimated to be 5,000 pounds (4).

Spinosad (Spintor®). Spinosad is a microbial fermentation product that is toxic to select insects, and as such, has negligible effects on populations of beneficial mites. Strawberry growers use it to manage mainly lepidopteran larvae. The price of spinosad is $262.50 per pound of active ingredient, and the approximate cost of a labeled application (0.094 lb ai/A) is $24.68 (19,22). The REI is 4 hours and the PHI is one day. The label states that other chemistries should be used after two consecutive spinosad applications and there is a five application limit (0.45 lb ai/A) per crop.

In 2002, strawberry growers in Florida applied spinosad (at 0.11 lb ai/A) to 23 percent of their acreage 1.8 times for a total crop use of 0.20 lb ai/A/year. The total amount used on Florida strawberries was estimated to be 300 pounds (4).

Malathion. Malathion has only a moderate adverse impact on populations of beneficial mites. The eggs and some motile forms of the beneficial mites can survive one or two applications of malathion (8). The median price of malathion is $5.44 per pound of active ingredient, and the approximate cost of a labeled application (2.0 lb ai/A) is $10.88 (11,15). However, the usual range of application is approximately 1.0 lb ai/A (4). The REI is 12 hours and the PHI is three days.

In 2002, strawberry growers in Florida applied malathion (at 0.64 lb ai/A) to 3 percent of their acreage 2.4 times for a total crop use of 1.57 lb ai/A/year. The total amount used on Florida strawberries was estimated to be 400 pounds (4).

**Nematodes**

Nematodes are a serious problem affecting Florida strawberry production areas. No nematode resistant strawberry varieties exist, and there are no post-plant remediation strategies available. Strawberries are susceptible to multiple nematode species. Sting nematodes, root-knot nematodes and foliar nematodes
are the main problems, with sting nematode being the most severe. Methyl bromide is applied approximately two weeks prior to planting transplants for the control of nematodes (see Production Practices).

Preliminary field surveys suggest that plant parasitic nematodes are a potentially major problem in at least 40 percent of Florida’s strawberry producing acreage. Sting nematodes can be very damaging to nursery seedlings and transplants. As a general rule, most other crop plants (non-strawberry) are not killed by sting nematodes unless they are subjected to other adverse conditions. However, affected strawberry plants undergo progressive decline and may eventually die. Older plants that have already developed an extensive root system can still be severely affected. Nematode infested plants are much more susceptible to drought conditions and injury from fertilizer salt accumulation (16).

Controls

Nematode management is viewed first and foremost as a year-round, programmatic activity requiring consideration of all cultural, chemical, and agronomic practices within the areas where strawberry plants are grown. Because strawberries must be vegetatively propagated and transplanted into the field, growers must first pay special attention to the source of strawberry transplants to ensure that they are not infested with nematodes (as well as mites, diseases, etc.). After final harvest, the crop is destroyed as quickly as possible to remove nematode food sources. In most cases, delays in crop destruction contributes to greater nematode population increases and greater difficulty in achieving nematode management (16).

Non-chemical

The fact that all populations of sting nematode have such a wide host range, including numerous weeds and grasses, must be considered in developing programs such as crop rotation systems for nematode management. Cover crop rotations with American jointvetch, hairy indigo, or sunn hemp have been shown to reduce sting nematode populations. In addition to sting nematode suppression, hairy indigo as also been reported to be resistant to several root-knot nematode species. Field fallowing, particularly when coupled with early crop destruction, generally provides a reduction in total nematode densities in soil (16).

Chemical

Over the decade of the 1990s, methyl bromide use remained fairly constant. The material was used by over ninety-eight percent of Florida growers, and approximately 200 pounds of the material was used per field acre. Total state usage of methyl bromide for strawberry production ranged from 845,000 to 1,230,000 pounds between 1992 and 2002 (2,4). However, the United States’ participation in the Montreal Protocol requires a gradual phase-out of methyl bromide by 2005. Methyl bromide manufacturers have begun this phase-out by adding higher percentages of chloropicrin into the methyl bromide formulations. Evidence of this transition is apparent in the 2002 chemical use values, which
report a state use of 918,000 pounds of methyl bromide and 449,000 pounds of chloropicrin, which is roughly equivalent to one-third of the total fumigant use.

During the methyl bromide phase-out period, research and registration efforts have been ongoing to find suitable replacements for methyl bromide in strawberry production. To that end, the state and the EPA have registered as of September 2001 two formulations of 1,3-dichloropropene (Telone® EC and InLine®) under Special Local Needs [24(c)] registrations. Telone® consists of 91.7 percent 1,3-dichloropropene, while InLine® contains 60.8 percent 1,3-dichloropropene and 33.3 percent chloropicrin. Other nematicides registered in Florida in 2003 include fenamiphos (Nemacur®), metam sodium, azadirachtin, and fermentation products of *Myrothecium verrucaria* (Ditera®). Each of these has one or more limitations with regard to replacing methyl bromide. Telone alone generally controls only nematodes, while the addition of chloropicrin helps eliminate soil pathogens, but does not affect weed germination. Fenamiphos controls nematodes, but the registrant (Bayer CropScience) requested the voluntary cancellation of all uses of fenamiphos effective May 31, 2005. Ditera® and azadirachtin are both expensive and relatively untested in terms of efficacy. Metam sodium has shown limited activity against all major pest groups. However, performance has been erratic in extensive research trials in Florida. Despite attempts to improve application technology, performance has not been significantly improved. Currently, the most promising replacement for methyl bromide are the 1,3-dichloropropene products, used with a second application of chloropicrin plus a herbicide just prior to laying the plastic mulch. Extreme care must be given in the application (either mechanically or through irrigation lines). Mechanically, only the Yetter Avenger coulter applicator has given good results with this material. If done with irrigation, the bed generally must have at least two drip lines over it and it must be compact enough to allow capillary action. Consequently, no one product currently addresses all the pests that methyl bromide has controlled historically. The biggest need if any one of these products is used is for a herbicide which controls nutsedge. This will be discussed in the weeds section. One advantage of irrigation line application is that the plant material can be quickly destroyed after final harvest.

### Diseases

Plant pathogens attack virtually all strawberry plant parts resulting in direct yield loss as well as loss due to quality factors (9). Infection of fruit by one pathogen may lead to infection or colonization by other pathogens, confounding the situation. According to survey responses from growers, the major disease problems on Florida strawberry fruit are botrytis (gray mold) and *colletotrichum* diseases, while powdery mildew, angular leaf spot, common leaf spot, leaf blight, and leaf scorch are primarily strawberry leaf diseases (5). Surprisingly, virus’ (often associated with vegetatively propagated crops) are not currently an issue in Florida strawberry production.

**BOTRYTIS FRUIT ROT (GRAY MOLD) (*Botrytis cinerea)*

Gray mold is the most important strawberry disease in Florida, and nationally. It attacks fruit in all
stages of development in the field and in transportation. The disease flourishes under cool, wet weather conditions, at which time the fuzzy gray mold appears. Under less severe conditions, light brown spots, which later turn dark brown, develop on the fruit. The fruit becomes soft at first, then hard and dry, with no clear line of demarcation between infected and healthy fruit tissue (17).

In severe epidemics the fungus can also cause blight of flower buds and stalks, foliage buds, and unexpanded young leaves. Attack on these parts of the plant usually occurs during prolonged periods of cool, damp weather. These structures turn dark in color and die (17).

**COLLETOTRICHUM DISEASES** (*C. fragariae*, *C. acutatum*, *C. gloeosporioides*)

Colletotrichum can cause a range of different diseases on strawberry in Florida. Currently, the most important diseases are anthracnose fruit rot and root rot caused by *C. acutatum*. Anthracnose root rot causes problems during the plant establishment period in October and causes a blackening of the roots that can reduce the vigor of plants and when severe, cause the plant to wilt and die. Anthracnose fruit rot epidemics can force growers to abandon production fields. The disease develops on young fruit and produces sunken dark lesions on the fruit making them unmarketable. In severe epidemics the pathogen also causes a flower blight and can produce sunken lesions on leaf petioles. Colletotrichum crown rot can also be an important disease and is primarily caused by *C. gloeosporioides*. The crowns of infected plants become necrotic and cause the sudden wilt and death of apparently healthy plants when temperatures are warm in the fall or spring (17).

**POWDERY MILDEW** (*Sphaerotheca macularis*)

Once infected, strawberry leaf edges begin to roll upward, and a sparse white growth of conidia and conidiophores may be seen on the under surface of the leaves. If infection is severe, leaves may show purple blotches or they may be killed (17).

**ANGULAR LEAF SPOT** (*Xanthomonas fragariae*)

This disease is favored by cool wet weather and can become severe when overhead irrigation is used for freeze protection. The first signs of angular leaf spot are dark green water lesions on the under surfaces of the leaves. These later become visible on the upper surfaces as reddish or brownish angular spots of variable size. The most notable sign is the occurrence of whitish, slimy droplets of bacterial exudate on the under surface of the leaflets during cool weather. When the droplets dry, a thin clear scaly film or clear raised bumps. The leaf under surfaces may also appear as if coated with clear lacquer at this point. The disease diminishes upon the onset of warmer weather (17).

**COMMON LEAF SPOT** (*Cercospora vexans/Mycosphaerella fragariae*)

Spots are small, purplish-red lesions less than 3 mm in diameter. The final lesions size depends on the variety. On certain varieties, the lesions remain very small and numerous and leaflets appear "rusty." On
others, the lesions increase in size to 6 mm or larger and develop white or gray centers with reddish-purple to dark purple borders. Severe infection can results in death of leaflets and defoliation of plants (17).

**LEAF BLIGHT/FRUIT ROT** (*Phomopsis obscurans*)

*Phomopsis* leaf blight and fruit rot can be a serious problem on plants produced in the southeastern U.S. The initial infection spots of this fungus are larger than leaf spot. From one to five lesions may occur on a leaf. The lesions are circular and reddish-purple at first. Mature lesions are zonate and dark brown in color, with a light brown to tan periphery ringed by a purple zone. The spots are frequently V-shaped with the widest part of the lesions at the leaf margin and the narrow base centered on a vein. Black specks (pycnidia) dot the central area of the older lesions.

This fungus also affects fruit. Initial lesions appear as round, light pink, watersoaked areas on the surface. Lesions may coalesce. Infected areas turn brown and the entire fruit ultimately becomes infected (17).

**LEAF SCORCH** (*Marssonina fragariae/Diplocarpon earliana*)

This fungus produces numerous purplish blotches of irregular shape and small size. Clusters of the blotches turn brown, but never white or gray as in the case of leaf spot. Dark glistening acervuli appear in the lesions on the upper surfaces of the leaves. In severe cases, the leaf margins curl upward and the leaves progressively dry to a tan color from the margins to the midrib (17).

### Controls

**Non-chemical**

Non-chemical control strategies include planting certified plants, using resistant varieties, crop rotation, irrigation management, sanitation/ destruction, and use of plastic mulch. However, their use alone or in the absence of fungicides would result in severe losses (9). Non-chemical methods must be considered as tools that, in the presence of all other factors at a given time, add effectiveness to the overall disease management program (9). Growers must plant multiple varieties of strawberries to reduce the risks posed by various diseases and pests, and also take advantage of market conditions. There is effort placed in producing disease resistant varieties; however, there are currently no major marketable varieties available with high levels of resistance to multiple pathogens (9). Certain varieties show select disease resistance, but no single variety has all the necessary characteristics for season-long productivity. It is estimated that the loss of all fungicides would result in a 90 percent yield loss for Florida strawberry growers.

**Chemical**
Fungicides used for strawberry disease control in Florida include captan, benomyl, thiophanate-methyl, fenhexamid, myclobutanil, potassium bicarbonate, and thiram (4). Prior to planting, methyl bromide/chloropicrin is used for soilborne disease control. Benomyl production ceased in the spring of 2001. Other fungicides actively registered in Florida in 2003 include copper (in hydroxide, sulfate, oxychloride, and octanoate forms), azoxystrobin, pyraclostrobin, fludioxonil, cyprodinil, boscalid, iprodione, triflumizole, mefenoxam, *Trichoderma harzianum*, kaolin, harpin protein, fosetyl-Al, dodine, sulfur, phosphoric acid, and carbonic acid. The mixture of fludioxonil and cyprodinil (Switch®) is efficacious for the control of gray mold, but growers are hesitant to use it because a 12-month plant-back restriction does not allow a second crop (such as cantaloupe) to be grown after the strawberry harvest is finished. Other new pesticides also have restrictive plant-back labeling.

**Captan**. Captan is the primary fungicide growers utilize and depend upon for disease management programs. This fungicide is used primarily for gray mold and anthracnose, but it is efficacious in managing other foliar and fruit rot diseases common to strawberry. Captan is applied to nearly all of Florida’s strawberry acreage an average of 10 to 21 times during the growing season, at a rate between 1.75 and 2.2 pounds of active ingredient per acre (2,4). During severe disease pressure years (1992), growers have applied 20 full-rate applications of captan (2). Total captan usage on Florida strawberries is estimated to be from 124,600 to 222,100 pounds of active ingredient annually (2,4). A primary concern of Florida growers is the retention of existing fungicide registrations (particularly captan) on strawberry to insure their ability or capability to manage strawberry diseases in the future (5). The median price of captan is $6.16 per pound of active ingredient, and the approximate cost of a labeled application (3.0 lb ai/A) is $18.48 (3,11). The REI is 24 hours and there is no PHI.

In 2002, strawberry growers in Florida applied captan (at 2.15 lb ai/A) to 88 percent of their acreage 9.5 times for a total crop use of 20.6 lb ai/A/year. The total amount used on Florida strawberries was estimated to be 124,600 pounds (4).

**Thiram**. Thiram is also used to manage gray mold as well as anthracnose. Thiram is applied to 32 to 88 percent of Florida’s strawberry acreage an average of 4 to 8 times during the growing season, at a rate between 0.71 and 1.39 pounds of active ingredient per acre (2,4). Total thiram usage on Florida strawberries is estimated to be from 6,500 to 44,000 pounds of active ingredient annually (2,4). The price of thiram is $6.46 per pound of active ingredient, and the approximate cost of a labeled application (3.25 lb ai/A) is $21.00 (18,19). The REI is 24 hours and the PHI is three days.

In 2002, strawberry growers in Florida applied thiram (at 1.33 lb ai/A) to 78 percent of their acreage 4.1 times for a total crop use of 5.59 lb ai/A/year. The total amount used on Florida strawberries was estimated to be 30,000 pounds (4).

**Fenhexamid** (Elevate®). This fungicide is used to manage gray mold. In 2002, strawberry growers in Florida applied fenhexamid (at 0.70 lb ai/A) to 71 percent of their acreage 1.8 times for a total crop use of 1.32 lb ai/A/year. The total amount used on Florida strawberries was estimated to be 6,500 pounds (4). The price of fenhexamid is $59.00 per pound of active ingredient, and the approximate cost of a
labeled application (0.75 lb ai/A) is $44.25 (3,19). There is a 3.0 lb ai/A/season limit of use and it is recommended that the material not be used more than twice consecutively. Specifically, the label states that after the second application, use an alternative fungicide for two consecutive applications before reapplying fenhexamid. The REI is 12 hours and there is no PHI.

**Thiophanate-methyl** (Topsin-M®). This fungicide is used to manage powdery mildew, gray mold, leaf spot, and leaf scorch. It is also the replacement for benomyl. Thiophanate-methyl is applied to 17 to 47 percent of Florida’s strawberry acreage an average of 2 to 6 times during the growing season, at a rate between 0.64 and 0.78 pounds of active ingredient per acre (2,4). Total thiophanate-methyl usage on Florida strawberries is estimated to be from 3,700 to 8,800 pounds of active ingredient annually (2,4). The median price of thiophanate-methyl is $22.14 per pound of active ingredient, and the approximate cost of a labeled application (0.7 lb ai/A) is $15.50 (3,11). There is a 2.8 lb ai/A/year limit of use and it is recommended that the material be used in conjunction with a non-benzimidazole fungicide. The REI is 12 hours and the PHI is one day.

In 2002, strawberry growers in Florida applied thiophanate-methyl (at 0.70 lb ai/A) to 35 percent of their acreage 3.5 times for a total crop use of 2.49 lb ai/A/year. The total amount used on Florida strawberries was estimated to be 6,000 pounds (4).

**Myclobutanil** (Nova®). This fungicide is also used to manage powdery mildew. In 2002, strawberry growers in Florida applied myclobutanil (at 0.07 lb ai/A) to 22 percent of their acreage 1.2 times for a total crop use of 0.10 lb ai/A/year. The total amount used on Florida strawberries was estimated to be 100 pounds (4). The price of myclobutanil is $150.00 per pound of active ingredient, and the approximate cost of a labeled application (0.07 lb ai/A) is $10.50 (19,22). There is a 0.25 lb ai/A/season limit of use. The REI is 24 hours and there is no PHI.

**Potassium bicarbonate** (Armicarb®). Potassium bicarbonate is used to manage powdery mildew. The price of potassium bicarbonate is $10.00 per pound of active ingredient, and the approximate cost of a labeled application (4.25 lb ai/A) may range from $8.50 at 20 GPA to $42.50 at 100 GPA (19). The REI is 4 hours and there is no PHI.

In 2002, strawberry growers in Florida applied potassium bicarbonate (at 2.4 lb ai/A) to 15 percent of their acreage 1.1 times for a total crop use of 2.8 lb ai/A/year. The total amount used on Florida strawberries was estimated to be 2,800 pounds (4).

**Weeds**

Several grass and broadleaf weeds impact Florida strawberry production; however, the single most troublesome weed is nutsedge (9). Nutsedge is capable of penetrating plastic mulch as it emerges. Historically, the weeds growing on the production beds have been managed by methyl bromide. Weeds
are also a season-long problem in the row middles. With a production season spread over six to seven months, weed species composition and density change. No herbicide could be expected to suppress weeds for the total production season (20). Consequently, a combination of weed control measures is needed.

Controls

Non-chemical

Florida strawberries are grown in methyl bromide fumigated raised beds covered with plastic mulch. The plastic generally suppresses certain annual weed populations; however, external borders of the mulch and transplant holes allow weeds to germinate. Hand weeding may be used for these areas, but it is time consuming and costly. An additional expense of $800 to $2,000 per acre would be incurred if no herbicides were available (9). Nutsedge is unable to penetrate paper mulch, but this material often rots off at the base before the entire season is complete.

Chemical

In the Florida strawberry production system, herbicides are only applied to the row middles between the raised production beds to manage grass, broadleaf, and sedge weed pests. The currently labeled herbicides were generally registered during a time when plastic mulch was not the standard in the industry or they were registered based on research without mulch film. Mulch may also affect the residual concentrations of herbicide, leading to occasional crop damage situations. Commonly used herbicides for row middle weed management include paraquat and glyphosate. Care is taken to prevent herbicide drift from contacting any portion of the strawberry plant or its fruit. Other herbicides actively registered in Florida in 2003 for use in strawberry include napropamide, pelargonic acid, daetral, oxyfluorfen, clethodim, and terbacil.

As of fall 2002, methyl bromide was still the choice of strawberry growers, even at its elevated price. Consequently, very few growers have experience with herbicides that could be used on the raised beds. The lack of a selective herbicide or one that controls small-seeded annuals in the winter months will severely impact strawberry production as the methyl bromide phaseout concludes.

Paraquat (Gramoxone®). Paraquat is applied only to the row middles. This herbicide is non-selective and applied post-emergent, so care must be taken (i.e., shielded sprayer) not to expose the strawberry plants to the material. Paraquat is applied to 52 to 89 percent of Florida’s strawberry acreage an average of 1 to 2 times during the growing season, at a rate between 0.23 and 0.93 pounds of active ingredient per acre (2,4). Total paraquat usage in Florida strawberry production is estimated to be from 2,200 to 7,000 pounds of active ingredient annually (2,4). The median price of paraquat is $12.07 per pound of active ingredient, and the approximate cost of a labeled application (0.67 lb ai/A) is $8.09 (11,12). No more than three applications of paraquat can be made per season. The REI is 12 hours and the PHI is 21 days.
In 2002, strawberry growers in Florida applied paraquat (at 0.34 lb ai/A) to 52 percent of their acreage 1.4 times for a total crop use of 0.49 lb ai/A/year. The total amount used on Florida strawberries was estimated to be 1,800 pounds (4).

**Glyphosate** (Roundup®). Glyphosate is also applied only to the row middles. This herbicide is another non-selective, post-emergent herbicide that is applied with a shielded sprayer. Glyphosate is applied to 3 to 39 percent of Florida’s strawberry acreage an average of 1 to 2 times during the growing season, at a rate between 0.3 and 1.3 pounds of active ingredient per acre (2,4). Total glyphosate usage in Florida strawberry production is estimated to be from 100 to 4,600 pounds of active ingredient annually (2,4). The median price of glyphosate is $10.95 per pound of active ingredient, and the approximate cost of a labeled application (1.5 lb ai/A) is $16.43 (11,21). The REI is 4 hours and the PHI is 14 days.

In 2002, strawberry growers in Florida applied glyphosate (at 0.56 lb ai/A) to 38 percent of their acreage 1.5 times for a total crop use of 0.89 lb ai/A/year. The total amount used on Florida strawberries was estimated to be 2,400 pounds (4).

**Other Pests**

Other pests in Florida strawberry include sporadic pests such as birds and slugs/snails. Although no chemical use was reported for either of these pests in any statistical reports, growers report bird problems that affect yields once every four or five years. The only two active ingredients registered in Florida that claim repellency and that can be used on strawberry are azadirachtin and thiram. For slugs/snails, there is metaldehyde +/- carbaryl, or a phosphoric acid/iron bait.

**Key Contacts**

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