Crop Profile for Strawberries in Virginia

Prepared January 2000

General Production Information

- Roughly 28 growers are currently producing 200 acres of strawberries in Virginia, with new plantings rapidly increasing (1).
- Approximately 15,000 qts./acre of strawberries were produced in Virginia accounting for 3.75 million dollars in market sales for the ’99 season (2).
- "U-pick" markets account for close to 75% of the strawberries grown in Virginia, while 25% are actually harvested through the utilization of paid labor (1).

Production Regions

Although the total acres produced have been greatly reduced in recent years, due to weed pressure and fruit rots on older matted row production farms; strawberry production areas are still widely distributed throughout the state of Virginia. As new growers discover production/marketing potentials of plastic mulched hill system berry production, the number of acres grown across the state will likely increase.

Cultural Practices

Most Virginia growers now use the plastic mulched hill system of production as opposed to conventional matted-row plantings. Although establishment costs are higher for the plastic mulched hill system, fruit production is earlier (when crop value is highest) and of higher quality. As a result, this system will be referred to for the remainder of the profile. Additional information concerning the establishment and maintenance of both matted-row plantings and plastic mulched hill system can be found in Virginia Cooperative Extension Publication No. 456-420 (3).

The Crop Profile/PMSP database, including this document, is supported by USDA NIFA.

When preparing a site for production under plastic, care should be taken to select fields with good surface and internal drainage, a southern exposure and protection from westerly winds. Strawberry plants prefer deep, fertile soil with a high organic matter content and a pH between 5.8-6.5. However, soils can often be amended with specific nutrients to establish these characteristics. Once the site has been chosen and fertilized, raised beds are prepared and fumigated. Fumigation is essential for weed control given that residual herbicides cannot provide adequate control once the plastic mulch barrier has been laid. Fumigation also offers protection against soil borne diseases on old strawberry land and nematode feeding within the raised bed strips. Possible fumigants include methyl bromide and sodium methyl dithiocarbamate (Vapam HL) (Busan 1263). After fumigation, a herbicide treatment is usually applied to unmulched row middles following the placement of drip irrigation and plastic mulch to the raised beds. Drip irrigation is used to supply both water and fertilizer to the plants and developing fruit. An approximate period of 20 days will be necessary to allow the fumigant to act and disperse. Plants are then typically placed 12 to 14 inches apart in a staggered pattern in double rows during late August-early September. Choice of plant type will vary depending on the geographical location of the grower (i.e. Appalachian vs. Tidewater/Eastern Shore). The variety known as *Late Star* is typically grown in the area northwest of Richmond, while *Chandler* is the preferred variety to the southeast of Richmond. Strawberries usually ripen within 28-30 days after the first bloom and are harvested normally every other day (hot weather) or every third day (cooler weather) over a four-week period for about 10-12 pickings. Cultivars grown on plastic always ripen earlier than those grown in matted rows.

Strawberries are one of the highest value per acre crops grown in North America with annual yields ranging from four to 20 tons/acre and gross values ranging from $6,000 to $20,000 per acre (2). As a result, management of strawberry pests is crucial since even minor yield reductions resulting from injury can have important economic effects. In the 1992 survey from which pesticide use data was obtained, treatment acres were used to account for the multiple applications of a given chemical that a grower might use to treat a crop (4). At the time of the survey, it was estimated that producers planted 1,200 acres of strawberry in Virginia (5). That number has been greatly reduced in recent years, however, in the case of that particular survey, it was used to determine the approximate average number of applications used per acre on strawberries. The calculation can be done by dividing the treatment acres by the acres of strawberry reported to be grown (i.e. if the results stated that there were 300 treatment acres when a grower reported growing 100 crop acres, then pesticides were used about three times on each acre.

In addition to drip irrigation, overhead irrigation is essential to help firm in newly set plants, cool the plants/plastic in warm weather and improve renovation following harvest. Floating Row Covers (FRC) are often applied in early December for protection against the desiccating effects of winter winds and also early spring frosts in colder areas of the Mid-Atlantic region. In addition, overhead mist irrigation is frequently used for spring frost and freeze protection.

Immediately following harvest, strawberry beds must be renovated to thin the crowns and retain vigor and berry size in subsequent years. Plant tops should either be shortened with a rotary mower or hand-thinned with an asparagus knife. Combinations of these two techniques may also be necessary for certain varieties.

Insect Pests

Insect descriptions found below were modified from information presented in the Insect Pests of Strawberries and Their Management section of the Virginia Small Fruits web site (6).

Control recommendations were taken from the Pest Management Guide for Horticultural and Forest Crops (1999) (7) *and also from the strawberry section of the Commercial Vegetable Production Guide* (3). *Efficacy data (where applicable) was obtained from a table found in the 1996 Ohio Commercial Small Fruit and Grape Spray Guide* (8).

DIRECT PESTS

Ranked in order of importance to the production of strawberries in Virginia (1=most important)

Tarnished Plant Bug (Lygus Bugs)--1

L. lineolaris (Palisot de Beauvois)
L. hesperus Knight

Tarnished plant bugs (TPB) damage strawberry fruit by puncturing individual seeds, which in turn, stops development of the berry in the area surrounding the feeding site. Often this type of feeding results in the characteristic cat-faced appearance of certain irregularly shaped berries. Adults become active in early spring and deposit their curved eggs into stems, and leaf midribs. Egg hatch takes place about 1 week later depending on temperature. There are three to six generations of this pest each year in Virginia.

Monitoring: Economic threshold levels have been developed for TPBs depending on the monitoring method used. Methods include: (1. the shaking of flower clusters over a sheet of white cardboard, in which case an action threshold of one nymph per cluster or 20-25 TPB per 50 clusters is recommended; (2. using a beating sheet (12-inch embroidery hoop with muslin) to sample one plant in each 20 feet of row, sprays are applied when one lygus nymph is found in 20 plants; and (3. the Allen-vac sampling device, chemical controls are used when one lygus per 10 plants is found.

Chemical Control: See *Chemical Insect Controls* section.

Biological Control: Predators that feed on the nymphal stages of the TPB include big-eyed bugs, *Geocoris* spp., damsel bugs, *Nabis* spp., minute pirate bugs, *Orius tristicolor*, and several species of spiders.

Cultural Control: Weed control is an important factor in the maintenance of TPBs. Overwintered insects lay their eggs in weeds in January for a March hatch, therefore control strategies should be carried out in March or early April. During this time, the TPBs are in the nymph stage and less likely to migrate in strawberries or other crops. Mowing or disking of cover crops, especially legumes may also reduce the likelihood of migration.

Strawberry Sap Beetle, *Stelidota geminata* (Say)--2

Sap beetles are attracted to ripe, decaying fruit and they are especially damaging in "U-pick" beds where rotting, over-ripe berries abound. Adult sap beetles enter strawberry plantings from surrounding wooded areas to feed at the time berries begin ripening. Feeding injuries can also lead to subsequent infection by fungi causing rot diseases.

Monitoring: Baited traps are available for monitoring this pest, however, these are often used to facilitate removal of the sap beetle from the strawberry patch. At the first sign of sap beetle presence, control measures should be taken to reduce economic losses due to feeding.

Chemical Control: See *Chemical Insect Controls* section.

Biological Control: None that are commercially effective.

Cultural Control: Locating strawberry fields away from woodlots or other suitable overwintering sites of sap beetles may help to reduce infestations. Removal of damaged, diseased and overripe fruits may also reduce beetle buildup within the area and hence the probability of additional insect injury.

Strawberry Bud Weevil (Clipper), *Anthonomus signatus* Say--3

The strawberry bud weevil (SBW) is an important direct pest of berries both within Virginia and nationwide. Initial bud weevil damage is caused by the ovipositing of a single egg into the unopened bud by the female. Following oviposition, the female severs the strawberry bud from the pedicel, causing it to hang by part of the stem or fall to the ground, thus preventing fruit formation. Larvae develop in the severed buds and reach maturity in 3-4 weeks. Adults emerge in June, feed on flower pollen, then enter an aestivation in mid-summer and remain inactive the rest of the season. The SBW has one generation

per year in Virginia.

Monitoring: SBW should be sampled on plants during the early blossom/bud stage to determine the necessity of treatment. It has been suggested that an economic injury level of one female beetle per 40 row feet would require treatment (9). Another program based on sampling indices advises treatment if an average of 0.6 clipped buds per row foot are found (10).

Chemical Control: See *Chemical Insect Controls* section.

Biological Control: None that are commercially effective.

Cultural Control: Overwintering adults emerge early in the season from forest ground litter and migrate to strawberry fields (around late April in the Mid-Atlantic region). Placement of fields away from overwintering sites, such as hedgerows and other wooded areas may help to reduce SBW damage. Certain varieties, especially those with pistillate flowers are less susceptible to SBW attack given their inability to provide adequate food for developing larvae (11). Also, early-fruiting varieties are more likely to suffer attack than later-fruiting varieties.

Slugs (various spp.)--4

Slugs feed on ripening berries during the night and on dark, overcast days, leaving deep ragged holes on the surface, especially under the cap. Slugs prefer cool moist habitats, such as those present during a wet spring, with some form of covering (i.e. decaying plant material, mulch, etc.).

Monitoring: Although no thresholds have been established, control measures should be taken immediately after slug presence is detected to avoid feeding injury.

Chemical Control: See *Chemical Insect Controls* section.

Biological Control: None that are commercially effective.

Cultural Control: Adequate weed control along with the removal of plant trash between raised beds helps to eliminate favorable environments for slug development.

INDIRECT PESTS

Ranked in order of importance to the production of strawberries in Virginia (1=most important)

Two-spotted Spider Mite, *Tetranychus urticae* (Say)--1

The two-spotted spider mite (TSM) is an extremely important pest of strawberry within Virginia. Adult female TSMs overwinter in the ground cover, feeding on various weed species. During the spring, TSMs move from the ground cover into the tree canopy. TSM adults and eggs are typically found on the underside of leaves. Sap feeding by the adults' results in a change in leaf color from green to coppery-bronze and hence reduced production by the plant. TSM populations increase with hotter, dryer weather.

Monitoring: Although there is some disagreement on a reliable threshold for strawberry, an economic threshold of five mites per leaf is suggested following transplanting (before July 1). This threshold may be increased to approximately 20 mites per leaf later in the season.

Chemical Control: See *Chemical Insect Controls* section.

Biological Control: Predators of the TSM available for commercial release include *Phytoseiulus persimilis, Metaseiulus occidentalis,* and *Amblyseius fali*.. Inoculative releases of these predators should be made when the first TSM are detected. Initial releases are usually small, but additional releases may be made into hot spots (clumped areas of infestations) for further control. Following releases of predator mites, it is important to monitor the TSM to determine if they are being maintained below economically injurious levels. Insecticides, miticides, and fungicides should be chosen carefully to prevent death of the predators.

Cultural Control: Strawberry cultivars vary in susceptibility to TSM. Short-day cultivars are generally more tolerant of mite feeding than day-neutral cultivars, particularly later in the fruit-production season. Elimination of groundcover that fosters the TSM during the winter, may reduce population size for the following spring. This is usually taken care of under the plastic mulched hill production system.

Strawberry Aphid, *Chaetosiphon fragaefolii*--2

Strawberry aphids feed on plant juices from the leaves and stem, resulting in an overall reduction of plant productivity due to leaf stunting and curling. However, the most damaging result of aphid presence is their role in transmitting the strawberry mottled virus. Aphid feeding may also result in large amounts of secreted honeydew (feeding by-product) as population size increases. If honeydew is abundant, secondary disease infections may occur that could present the grower with additional management difficulties.

Monitoring: Thresholds will depend on management practice intensity, especially in relation to the

prevention of the strawberry mottled virus. Given that one infected aphid may transmit the virus a threshold of one would be necessary. However, non-infected aphids will cause a significantly lower amount of yield loss, resulting in higher economic thresholds.

Chemical Control: See *Chemical Insect Controls* section.

Biological Control: Several natural predators of the strawberry aphid include ladybird beetle larva and adults, aphid midges, green lacewings and syrphid fly larvae. Control by natural predators themselves, may be insufficient to prevent plant injury.

Cultural Control: None that are commercially effective.

Strawberry Root Weevil Complex--3
Cribrate Weevil, *Otiorhynchus cribricollis*
Woods Weevil, *Nemocestes incomptus*
Black Vine Weevil, *Otiorhynchus sulcatus*
Fuller Rose Weevil, *Pantomorus cervinus*

Various root weevils function synonymously to form the strawberry root weevil complex. Root weevil larvae resume root feeding in the spring following soil overwintering, which results in extensive damage. Injured plants often wilt because the roots can no longer provide moisture for leaves. Weevil larvae can also be found burrowed into the lower portion of the plant's crown. Adults emerge in late spring or summer and feed on the strawberry foliage, removing large scallops from the leaves. Such leaf damage is a good indication that weevils are present, but is not economically damaging to the plants. Root weevils have a single generation each year. The flightless adult females reproduce parthenogenetically and lay their eggs around the crowns about one month after emergence. After hatching, weevil larvae burrow into the soil and feed on strawberry roots and crowns.

Monitoring: The soil around the base of the plant (root zone) can be examined in order to detect the presence of larvae.

Chemical Control: See *Chemical Insect Controls* section.

Biological Control: None that are commercially effective.

Cultural Control: Crop rotation is a somewhat effective method of reducing root weevil infestations, although strawberries should never be planted after sod. Delayed fall plowing may help limit root weevil populations by allowing the old planting to act as a trap crop for oviposition. Sticky barriers can be used to prevent movement of adult weevils from infested second year berries and host areas to newly fumigated plantings.

White Grub--4

White grubs are the larval forms of the Japanese or scarab beetles. These larvae damage strawberry plants by direct feeding on the roots and at the base of stems.

Monitoring: The soil around the base of the plant (root zone) can be examined in order to detect the presence of larvae.

Chemical Control: See *Chemical Insect Controls* section.

Biological Control: White grubs are subject to attack by a bacterium, *Bacillus popillae* (milky disease), resulting in death. This biological control agent can protect areas from large larval populations, but it is ineffective against adults.

Cultural Control: None that are commercially effective.

Meadow Spittlebug, *Philaenus spumarius*--5

Meadow spittlebugs overwinter in eggs attached to leaf stems and leaves. Nymphs hatch from these eggs in April and begin producing a white froth over their feeding site on new growth. Nymphal feeding on the sap of leaves and fruit spurs causes the leaves to become distorted and stunted, resulting in reduced yield and inferior fruit. Only one generation of spittlebugs is produced each year.

Monitoring: Chemical treatments are most effective if applied before nymphs are half-grown. Therefore determination of this stage by scouting will be necessary where spittlebugs are active.

Chemical Control: See *Chemical Insect Controls* section.

Biological Control: None that are commercially effective.

Cultural Control: None that are commercially effective.

Strawberry Leafroller, *Ancylis comptana* (Froelich)--6

Strawberry leafrollers emerge in April and May from overwintering shelters (rolled leaves or leaf litter) to deposit eggs and feed until their death. Eggs hatch within a couple of weeks resulting in larvae that continue to feed and produce new shelters to protect themselves. Leafroller infestations are common throughout the growing season (2-3 generations/year), and may also build up following harvest. Leaf feeding results in reduced runner formation, interference with ripening fruit, and plant kill, however, strawberries are quite tolerant of the leaf feeding species and can support high population levels without economic loss.

Monitoring: Currently, no thresholds have been established for determining the necessity of chemical treatment. Alternative control methods (biological and cultural) usually provide adequate protection against extreme leafroller damage.

Chemical Control: See *Chemical Insect Controls* section.

Biological Control: Strawberry leafroller has a large complex of parasites that play a major role in lowering pest populations.

Cultural Control: Removal of accumulated plant trash in the spring may limit the potential for a large population buildup in areas with severe leafroller problems.

Potato Leafhopper, ***Empoasca fabae*** **Harris--7**

The potato leafhopper (PLH) affects strawberry plants within Virginia by causing what is referred to as "hopperburn" as a result of feeding on the underside of leaves. Hopperburn results from the injection of toxic saliva that reduces the availability of water and nutrients to young leaves by collapsing the xylem and phloem tubes. This, in turn, causes the edges of infested leaves to curl downward; first turning lighter green, then yellow, and finally brown and necrotic. Young plants and leaves are especially at risk. The PLH overwinters in the Gulf Coast states, reentering the Mid-Atlantic region each spring to complete several (usually 2-4) overlapping generations.

Monitoring: Strawberry fields should be frequently inspected for the presence of PLH beginning in mid-May. Although no exact thresholds are currently available, treatment should be applied following appearance of the first adults.

Chemical Control: See *Chemical Insect Controls* section.

Biological Control: Natural enemies of PLH are present within Virginia, however, they do not generally react fast enough to prevent hopperburn on strawberry plant leaves.

Cultural Control: Growers may decrease the likelihood of PLH damage by avoiding planting alfalfa in

close proximity to strawberry fields.

Chemical Insect Control

The most recent pesticide usage survey, completed in 1992, indicated that insecticides were used on 588.6 treatment acres by 48.6% of growers (see cultural practices for explanation of treatment acres) (4). The results of the specific chemicals that were used at the time of the survey are included in the insecticide descriptions found below. Brigade WSB and Danitol 2.4 EC are relatively new insecticides and were not available for use when the survey was concluded (see results under the descriptions below).

- **abamectin (**Agri-mek**)**-PHI-28 days. Formulated as an emulsifiable concentrate for highly effective twospotted spider mite control at a rate of 0.19 lb. a.i./acre. For best results, apply to two-spotted spider mites early in the spring before eggs are laid. Agri-mek should not be applied more than twice per season. REI-12 hours.
- **azinphos-methyl (**Guthion 50W**)**-PHI-5 days. Applied 10 days after new growth begins at a rate of 0.25 lb. a.i./acre for control of the strawberry aphid and spittlebug. Applied at a rate of 0.50 lb. a.i./acre after new growth starts and before fruit buds are visible for control of the strawberry leafroller, rootworm and bud weevil; repeat 10 days later. Provides highly effective control of leafrollers, and moderately effective control against bud weevils, sap beetles, spittlebugs, and the tarnished plant bug. Azinphos-methyl was used by 14.3% of the growers surveyed on 132 treatment acres. REI-48 hours.
- **bifenthrin (**Brigade WSB**)**-PHI-0 days. Target pests include the strawberry aphid, leafroller, and root weevil, the tarnished plant bug, and the two-spotted spider mite. Applications should be made 10 days after new growth begins for the strawberry aphid and leafroller and the tarnished plant bug (0.04-0.20 lb.. a.i./acre) and at the first sign of leaf injury; repeating at 7-10 day intervals for the strawberry root weevil (0.05-0.20 lb. a.i./acre). For best result against two-spotted spider mites an application should be made early in the spring before eggs are laid at a rate of 0.10-0.20 lb. a.i./acre. Total applications should not exceed 0.50 lb. a.i./acre/season. REI-12 hours.
- **carbaryl (**Sevin**)**-PHI-1 day. Applied at a rate of 1.00 lb. a.i./acre 10 days after full bloom for slightly effective control of the strawberry leafroller and rootworm. Sevin Bait (5% or 20%) will provide some relief against sap beetles and slugs when broadcast over strawberry beds prior to harvesting, however, cultural practices are often more effective. Carbaryl was used by 25.7% of the growers surveyed on 124.6 treatment acres. REI-12 hours.
- **carbofuran (**Furadan 4F**)**-Used for postharvest control of the strawberry root weevil when applied in a direct band to the plants at a rate of 1.00-2.00 lb. a.i./acre between harvest and October 1. Should not be applied more than once per season, or if berries are present. Not needed every year given that root weevil beetles are slow to colonize an area. Carbofuran was used by 14.3% of growers on 26.5 treatment acres in 1992. **Currently this chemical is not labeled for use on strawberries**. REI-48 hours.
- **chlorpyrifos (**Lorsban**)**-Targeted for highly effective control of the strawberry weevil.

Applications can only be made during the prebloom period, when buds first appear and then 10-14 days later as needed. Should not be used once fruit sets or berries are present. Chlorpyrifos was used by 5.7% of growers on 22 treatment acres (survey data). REI-24 hours.

- **diazinon (**Diazinon 4EC**)**-PHI-5 days. Apply at a rate of 0.38 lb. a.i./acre in accordance with the label recommendations for various pests. Provides highly effective control against aphids, moderately effective control against leafhoppers, leafrollers, sap beetles, spittlebugs, and white grubs, and slightly effective control against root weevils and the tarnished plant bug. Should not be applied more than 3 times per season as a foliar application. REI-24 hours.
- **dicofol (**Kelthane50WP**)**-PHI-2 days. Applied when mites appear at a rate of 0.40-1.00 lb. a.i./ acre for highly effective control; repeated as needed. Dicofol was used by 8.6% of the growers surveyed on 42 treatment acres. REI-12 hours.
- **endosulfan (**Thiodan 50W**)**-PHI-4 days. Applied 10 days after new growth appears at a rate of 1.0 lb. a.i./acre for highly effective control of the strawberry aphid, spittlebug and rootworm and tarnished plant bug.. Alternate with other miticides to prevent resistance. Should not be reapplied within 15 days or more than twice within a 35-day period when berries are present. Endosulfan was used by 5.7% of the growers surveyed on 26 treatment acres. REI-48 hours.
- **fenpropathrin (**Danitol 2.4EC**)**-PHI-2 days. Applied at a rate of 0.2 lb. a.i./acre 10 days after new growth begins for highly effective control against the strawberry aphid and spittlebug and the tarnished plant bug. For best results against two-spotted spider mites an application should be made at the same rate early in the spring before eggs are laid. Provides moderately effective control of two-spotted spider mites. Alternate with other miticides to prevent resistance. Total applications should not exceed 2.67 pt./acre/season. REI-24 hours.
- **fenbutatin-oxide (**Vendex 50WP**)**-PHI-1 day. Applied at a rate of 0.75-1.0 lb. a.i./acre for highly effective control of two-spotted spider mites (150-200 gal./acre). Alternate with other miticides to prevent resistance. Should not exceed 4 applications per season. REI-48 hours.
- **malathion**-PHI-3 days. Malathion 8EC is recommended at a rate of 2.0 lb. a.i./acre for slightly effective control of root weevils and the strawberry sap beetle. Cythion, an alternative formulation of malathion is recommended at a rate of 0.94-1.56 lb. a.i./acre for potato leafhopper control. Malathion was used by an average of 2.9% of growers on 180 treatment acres/year (1992). REI-12 hours.
- **methomyl (**Lannate**)**-PHI-3 days. Applied 10 days after new plant growth begins at a rate of 0.67-0.9 lb. a.i./acre for control of strawberry aphids. Should not exceed 4.5 lbs. a.i./acre per season. REI-48 hours.
- **methyoxychlor (**Methyoxychlor 2EC**)**-PHI-14 days. Applied at a rate of 1.0-1.5 lb. a.i./acre at the first sign of leaf injury to provide moderately effective control of bud and root weevils. REI-12 hours.

Alternative Insect Control

- entomopathic nematodes (*Heterohabdtitis bacteriophora*)-Apply 1-2 billion organisms per acre during evening or early morning when soil temperatures are 60ºF or greater and then irrigate

them into the soil for control of the strawberry root weevils and grubs.

Diseases

Disease descriptions found below were modified from information presented in the Strawberry diseases and their control section of the Small Fruits Information for North Carolina web site(12).

Control recommendations were taken from the Pest Management Guide for Horticultural and Forest Crops (1999) (7).

DISEASES

The two most important diseases continually affecting strawberry production are listed below and are designated "1" and "2". The other diseases described within this section are subsequently ranked although variations in their prominence from year to year often result in quite diverse rankings.

Black Root Rot--1

The black root rot disease is caused by complex factors including a variety of fungi along with nematode feeding. The most prevalent fungi causing black root rot are *Rhizoctonia* and *Pythium*. Plants affected by this disease become stunted and produce few berries and runners. The disease complex tends to build up within the soil over a period of years and may cause severe damage to replant sites.

Monitoring: See *Disease Monitoring* section.

Chemical Control: Nematicide application or preplant fumigation may prove beneficial when used in conjunction with crop rotations (see *Cultural Control* below).

Biological Control: None that are commercially effective.

Cultural Control: Given the complex nature of the black root rot disease, multiple methods are necessary for effective control. Crop rotations (4-5 years) and well-drained sites are an extremely important part of the management strategy for this disease. However, nematicides may provide

additional control (see *Chemical Nematode Control* section).

Gray Mold, *Botrytis cinerea*--2

Gray mold, caused by the fungus *Botrytis cinerea*, is one of the most severely damaging fruit rot diseases of strawberries in Virginia. This disease occurs often and affects petals, flower stalks, fruit caps and strawberry fruit. Susceptibility increases as weather conditions become moist, with young blossoms and maturing fruit at the highest risk of infection. Fruit infections first appear as soft, light brown areas, eventually resulting in mummification of the fruit. Mummified fruit becomes covered with a gray dusty powder, through which the infection continues to be spread.

Monitoring: See *Disease Monitoring* section.

Chemical Control: Each of the chemicals listed for control of gray mold on developing and maturing strawberries may be used interchangeably. Applications typically begin at 5%-10% bloom and may continue up to 10 days until harvest. During periods of excessive moisture, the spray interval may need to be shortened to 5-7 days. See *Chemical Disease Control* section.

Biological Control: None that are commercially effective.

Cultural Control: See *Cultural Disease Control* section.

Red Stele, *Phytophthora* spp.

The red stele fungus, *Phytophthora fragariae* causes a very serious disease of strawberries in Virginia. This fungus attacks plants during the cool part of the year, although symptoms are not apparent until March-July. The causal fungus spreads from one area to another in the roots of infected plants, contaminated surface water and/or soil carried on farm implements. Red stele affected plants become stunted and wilt in dry weather. Older leaves turn yellow or red particularly along the margin. The symptom that helps to identify red stele is the brick red discoloration in the center (stele) of live white roots. The red color may extend the length of the root, or it may show up for only a short distance above the dead root tip. This symptom is obvious only during winter and spring.

Monitoring: See *Disease Monitoring* section.

Chemical Control: Fumigation with either methyl bromide + chloropicrin (67% + 33%) at a rate of 250 lb./acre or sodium methyl dithiocarbamate (Vapam HL) (37%) at a rate of 50-100 gal. concentrate/acre should be done prior to fall planting. See *Chemical Disease Control* section.

Biological Control: None that are commercially effective.

Cultural Control: *Allstar, Darrow*, *Earliglow*, *Guardian, Lateglow*, *Lester*, *Redchief, Scott*, and the *Sunrise* strawberry varieties all have resistance to several races of the red stele fungus. Crop rotation is of little value given the persistence of this fungus within the soil. Planting in well-drained soils or high, raised beds may provide a measure of relief. When possible, care should be taken to prevent fungus transfer with cultivation equipment and surface runoff water.

Anthracnose

Anthracnose is a constant threat to strawberry growers within Virginia, typically resulting in the death of entire plants and possibly fields of strawberries. Two subspecies of the Anthracnose fungus attack strawberries, causing either a black rot on the fruit or plant death. Given the establishment and severity of the various forms of this disease within North Carolina, particular attention was paid, in Virginia, to the development of disease resistant plants, (i.e. *Sweet Charlie*) which would withstand the present growing conditions. As a result, the disease has not been a problem. If this disease were to become a more serious pest, management tools are limited.

Monitoring: See *Disease Monitoring* section.

Chemical Control: Resistance has developed to many of the commonly used fungicides. Newly developed chemistries may provide control, although these have not been fully tested given the absence of this disease in Virginia. See *Chemical Disease Control* section.

Biological Control: None that are commercially effective.

Cultural Control: At the earliest onset of the disease, infected plants should be removed from the field and destroyed. Once the infection has spread, entire fields could be lost. Limiting the amount of water applied to fruiting plants may help to prevent Anthracnose.

Leaf Spot, *Mycosphaerella fragariae*

Symptoms of the leaf spot disease caused by the fungus *Mycosphaerella fragariae* begin as round purple spots 1/8-1/4 inch in diameter on upper leaf surfaces. As the spots age, the centers become tan or gray, then almost white with a purple border. The disease can also occur on immature petioles, fruit stalks, runners and caps of susceptible cultivars.

Monitoring: See *Disease Monitoring* section.

Chemical Control: Applications typically begin 10-14 days before full bloom; susceptible varieties may require fall sprays on a 3-week schedule. See *Chemical Disease Control* section.

Biological Control: None that are commercially effective.

Cultural Control: See *Cultural Disease Controls* section.

Leaf Scorch, *Marssonia fragariae*

Leaf scorch is a foliar disease caused by the fungus, *Marssonia fragariae*. Typically this disease occurs around leaf margins resulting in a "scorched" appearance.

Monitoring: See *Disease Monitoring* section.

Chemical Control: Applications typically begin 10-14 days before full bloom; susceptible varieties may require fall sprays on a 3-week schedule. See *Chemical Disease Control* section.

Biological Control: None that are commercially effective.

Cultural Control: See *Cultural Disease Controls* section.

Leather Rot, *Phytophthora cactorum*

Leather rot occurs occasionally on either green or ripe strawberries, resulting in light brown areas on the fruit. In the late stages of decay, the fruit becomes tough and leathery, hence the distinctive name of the disease.

Monitoring: See *Disease Monitoring* section.

Chemical Control: See *Chemical Disease Controls* section.

Biological Control: None that are commercially effective.

Cultural Control: See *Cultural Disease Controls* section.

Verticillium Wilt, *Verticillium albo-atrum*

The verticillium wilt disease is a serious problem with most varieties of strawberry grown in Virginia. Fortunately, the disease occurs infrequently with symptoms similar to those described for red stele, except for the red discoloration in the roots.

Monitoring: See *Disease Monitoring* section.

Chemical Control: Fumigation with either methyl bromide+chloropicrin (67%+33%) at a rate of 250 lb./acre or sodium methyl dithiocarbamate (Vapam HL) (37%) at a rate of 50-100 gal. concentrate/acre should be done prior to fall planting. See *Chemical Disease Control* section.

Biological Control: None that are commercially effective.

Cultural Control: The strawberry varieties, *Catskill, Surecrop, Guardian, Delite,* and *Lateglow* have good wilt resistance; *Allstar*, *Sunrise*, *Earliglow*, *Midway*, and *Redchief* have moderate resistance; while *Honeoye*, *Raritan*, *Jerseybelle*, and *Sparkle* are quite susceptible. The resistant and moderately resistant varieties should be incorporated where possible to provide some control against wilt disease, however even resistant varieties will become infected if the soil is heavily infested with *Verticillium*. Crop rotations involving strict weed control are important to rid the soil of the *Verticillium* fungus.

Leaf Blight, *Dendrophoma obscurans*

Leaf blight typically occurs on older strawberry leaves, and is more severe on red stele resistant cultivars. Blight spots appear as large circles or ovals that are approximately 0.5-1.0 inch in diameter. Young spots are reddish-purple, but develop a brown center bordered by a purple zone as they enlarge with age. Small black fungal fruiting structures may be observed in the center of the spot. Lesions may also develop on runners of susceptible cultivars, but not often on the leaves.

Monitoring: See *Disease Monitoring* section.

Chemical Control: Applications typically begin 10-14 days before full bloom; susceptible varieties may require fall sprays on a 3-week schedule. See *Chemical Disease Control* section.

Biological Control: None that are commercially effective.

Cultural Control: See *Cultural Disease Control* section.

Disease Monitoring

Weekly monitoring for strawberry diseases typically occurs in the early spring as fruit is developing and ripening. This process is especially important in growing seasons with increased humidity, cool temperatures and high rainfall. Once diseased plant material is found, it should be removed from the field and destroyed. Following harvest, plants should be checked periodically to evaluate the likelihood of infection the following season.

Chemical Disease Control

In general, fungicides were used on an average of 735.3 treatment acres by 51.4% of the growers surveyed during the 1992 growing season (4). Results of the 1992 survey were the most recent available at the time of publication. The majority of chemicals listed below were used by growers surveyed (see results under individual descriptions).

- **benomyl (**Benlate 50W**)**-PHI-1 day. Targeted for control of gray mold, leaf spot, leaf scorch, and leaf blight when applied at a rate of 0.50 lb. a.i./acre in combination with Captan 50W (1.50 lb. a. i./acre) or Thiram 65W (2.47 lb. a.i./acre). Applied individually at a rate of 0.50 lb. a.i./acre for control of leather rot. Benomyl was used by 40% of growers on 149.6 treatment acres. The current Benlate label specifically states that the chemical is **"not for use in home plantings or once any commercial crop is turned into U-pick, Pick Your Own or similar operations."** REI-24 hours.
- **captan (**Captan 50W**)**-PHI-1 day. Used to control leaf spot, leaf scorch, and leaf blight when applied at a rate of 2.25 lb. a.i./acre and gray mold when applied at a rate of 3.00 lb. a.i./acre. Captan was used by 42..9% of growers on 304.8 treatment acres REI-24 hours.
- **dodine (**Syllit**)**-PHI-14 days. Applied at a rate of 0.98 lb. a.i./acre for control of leaf spot, leaf scorch, and leaf blight. REI-48 hours.
- **fosetyl-Al (**Aliette 80 WSP or WDG**)**-PHI-7 days. Used as a preplant dip at a rate of 2.50 lb./100 gal. for red stele and leather rot control. Strawberry roots and crowns may be dipped for 15-30 minutes and should be planted within 24 hours following dipping. Aliette may also be applied as a foliar spray for red stele control at a rate of 2.00-4.00 lb. a.i./acre 14-21 days after planting and continued on a 30-60 day interval as long as conditions favor disease development. For leather rot control, applications of Aliette can be applied at 10% bloom and early fruit set and continue on a 7-14 day interval if disease conditions are present. Should not exceed 24.0 lb. a.i./acre per season. REI-12 hours.
- **iprodione (**Rovral 50WP**)**-PHI-0 days. Targeted for control of gray mold and leather rot when applied at a rate of 0.50 lb. a.i./acre in combination with Captan 50W (3.00 lb. a.i./acre) or Thiram 65W (2.47 lb. a.i./acre). Also used at a rate of 2.00 lb./100 gal. as a preplant dip for the

control of gray mold on strawberry transplants. Iprodione was used by 5.7% of growers on 5 treatment acres. REI-12 hours.

- **mefenoxam (**Ridomil Gold 4EC**)**-PHI-30 days. For established plantings, apply to foliage at a rate of 0.13 lb. a.i./acre in the spring before first bloom for control of red stele and leather rot. Additional treatments may be applied during harvest for supplemental leather rot control or after harvest in the fall. For new plantings, one application should be made after transplanting and then a second one 30 days before the beginning of harvests. A third applications may be made during harvest season if needed. REI-12 hours.
- **thiophanate-methyl (**Topsin-M 70W**)**-PHI-1 days. Targeted for control of leaf spot, leaf scorch, and leaf blight, gray mold and leather rot when applied at a rate of 0.70 lb. a.i./acre. May be combined with Captan 50W to improve effectiveness (1.50 lb. a.i./acre). Thiophanate-methyl was used by 14.3% of growers on 99.5 treatment acres. REI-12 hours.
- **vinclozolin (**Ronilan 50WP**)**-PHI-0 days. Applied at a rate of 0.50 lb. a.i./acre when used to treat gray mold or leather rot. Vinclozolin was used by 25.7% of growers on 156.5 treatment acres. **Label withdrawn effective January 1, 2000.** REI-12 hours.
- **thiram (**Thiram 65W**)**- PHI-3 days. Applied at a rate of 3.25 lb. a.i./acre to control blossom blight and also to aid in deer feeding control. Often used in combination with other fungicides to increase effectiveness. Thiram was used by 5.7% of growers on 20 treatment acres. REI-24 hours.

Cultural Disease Control

In addition to the controls listed previously, both chemical and cultural, it is also necessary to note the importance of obtaining certified strawberry plants prior to planting. Certification offers some assurance to Virginia fruit producers that the plants purchased from certified growers are true to variety and apparently free from injurious insects and serious diseases. No other single measure has contributed more to the control of strawberry diseases in Virginia.

Nematodes

Control recommendations were taken from the strawberry section of the 1999 Commercial Vegetable Production Guide (3).

NEMATODES

Those nematodes affecting strawberries in Virginia are as follows: the Northern root knot (*Meloidogyne hapla*), lesion (*Pratylenchus* spp.) and sting (*Belonolaimus* spp.). Affected plants are stunted, older leaves die and few runners are produced. Symptoms often appear during the summer and usually occur in isolated spots or areas within a field. On affected plants, roots may be short and stubby, with root tips swollen. Roots die completely in later stages. Damage is often more severe on sandy soil rather than on clay soil.

Monitoring: Soil sampling can help to determine nematode presence as well as population size and species type.

Chemical Control: See *Chemical Nematode Control* section.

Biological Control: None that are commercially effective.

Cultural Control: Avoidance of sites with histories of nematode problems will reduce the amount of damage resulting from their presence. Areas with little or no nematode presence should be selected prior the planting of new fields.

Chemical Nematode Control

Nematicides were used by 20% of the surveyed growers in 1992 on an average of 59.5 treatment acres. Survey data from 1992 is the most current assessment of nematicide usage available. As stated previously, treatment acres were used to account for multiple applications (4). Recommendations for both types of production systems are found below given that the primary fumigant used in the plastic mulched hill plantings is slated for removal from commercial production in 2004. Currently, no alternatives are available to replace the broad-spectrum activity of this chemical.

Plastic mulched hill plantings:

- **methyl bromide**-Applied in strips injected into raised beds just prior and in conjunction with plastic mulch covering. One treatment usually maintains effectiveness for up to 3 years following application and is necessary, especially on previously planted in strawberries. Methyl bromide was the most commonly used nematicide by 17.1% of growers on 51.5 treatment acres.

Matted-row plantings:

- **carbofuran (**Furadan 4F**)**-Used for postharvest control of nematodes when applied in a direct band to the plants at a rate of 1.00-2.00 lb. a.i./acre between harvest and October 1. Should not be applied more than once per season, or if berries are present. Carbofuran was used by an average

of 2.9% of growers on 8 treatment acres in 1992. Currently this chemical is not labeled for use on strawberries. REI-48 hours.

- **fenamiphos (**Nemacur 3SC**) (**Nemacur 15G**)**-PHI-6 months. Apply Nemacur 3SC at a rate of 1.80-2.70 lb. a.i./acre or Nemacur 15G at a rate of 2.00 lb. a.i./acre in 12-18 inch bands over row and incorporate. No more than 1 application should be made per season. Best if applied to non-bearing strawberries or nursery stock. REI-48 hours.

Weeds

Control recommendations were taken from the strawberry section of the 1999 Commercial Vegetable Production Guide, VCE Pub. 456-420, revised annually (3).

WEEDS

The most common weeds encountered by Virginia growers include field pansy, woodsorrel (*Oxalis*) species, bindweed species, red sorrel, hemp dogbane, horsenettle, yellow nutsedge, common chickweed, bermudagrass, and quackgrass (13).

Monitoring: Weekly scouting, especially during the start of the season, will allow for early detection of weed pests. This, in turn, will be beneficial to the selection of an appropriate herbicide.. This is particularly important in matted-row plantings.

Chemical Control: See *Chemical Weed Control* section.

Biological Control: None that are commercially effective.

Cultural Control: Plastic mulch provides full-season control of most weed pests.

Chemical Weed Control

Given the shallow root systems of strawberry plants, they do not compete effectively with weeds for sunlight, nutrients and moisture, thereby reducing yields (up to 40%). In severe cases, an over abundance of weeds may limit airflow through the canopy, which may create favorable conditions for

fungal infestations. By design, the plastic mulched hill system provides effective relief against weed pressure and also helps to alleviate the problem of the declining number of herbicides labeled for use on strawberries. Under this system, fumigation is essential to the control of weeds, however several additional weed control options are available to manage troublesome winter annuals and other weeds that grow around plant holes. After fumigation other management strategies may be carried out (see below) to provide additional weed control. Following fumigant and herbicide treatment, drip irrigation and plastic mulch can be laid. Approximately 20 days of waiting should be observed to allow the fumigant to act and to disperse. Weeds between the mulched beds can be controlled with band treatments of standard, strawberry weed control herbicides (i.e. terbacil (Sinbar), DCPA (Dacthal), and oxyfluofen (Goal), etc.) Grasses between the rows and around plant holes can be controlled by postemergence applications of sethoxydim (Poast 1.5EC).

- **napropamide** (Devrinol 50DF)-PHI-2-3 months. Apply 2.00-3.00 lb. a.i./acre to the surface of the bed and the area between beds. The status of Devrinol is questionable at this point. In early, 1999, Zeneca sold the product to United Phosphorus, but did keep some uses. Searches for product labels from both companies produced no result and registrations, although still in force, may not reflect the current status of the products.

In the most recent (1992) survey completed by Virginia Tech in conjunction with Virginia Cooperative Extension, herbicides were used by 80% of growers on 746.7 treatment acres (4). Herbicides used included sethoxydim by 22.9% of growers on 200 treatment acres, terbacil by 51.4% on 197.4 treatment acres, napropamide by 54.3% on 135.5 treatment acres, methyl bromide by 2.9% on 115 treatment acres, 2,4-D by 14.3% on 61.9 treatment acres, DCPA by 34.2% on 29.3 treatment acres, chloroxuron by 2.9% on 6 treatment acres, and paraquat by 2.9% on 1.6 treatment acres (4).

On-Line Resources

C&P Press Online Crop Protection Reference
http://www.greenbook.net/free.asp

North Carolina Information for Small Fruits
http://ipmwww.ncsu.edu/small_fruit/index.html

Office of Pest Management Programs/Pesticide Impact Assessment Program Site
http://ipmwww.ncsu.edu/opmppiap

Virginia Pesticide Impact Assessment Program

http://www.vtpp.ext.vt.edu/htmldocs/vanapiap.html

Virginia Small Fruits Page
http://www.ento.vt.edu/Fruitfiles/VirginiaSmallFruitSite.html

Virginia Tech Pesticide Programs
http://www.vtpp.ext.vt.edu

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