Tennessee's Strawberry Strategic Plan Meeting

Knoxville, TN
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2003 Workshop Participants for Tennessee's Strawberry Industry

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Executive Summary

Objectives of the meeting and the document:

Participants at the workshop helped to develop a prioritized list of critical research, regulatory, and educational needs for Tennessee's strawberry industry. This document may be used to:

- Identify the registration needs and priorities of Tennessee's strawberry industry for the Environmental Protection Agency (EPA) and registrants.

- Aid scientists when seeking USDA funds for the research priorities that have been identified; and

- Identify the research, regulatory and educational needs within Tennessee's strawberry industry

CRITICAL NEEDS AND PRIORITIES OF TENNESSEE'S STRAWBERRY INDUSTRY

RESEARCH

- Methyl bromide replacements such as methyl iodide (iodomethane, Midas, TM-425) should be investigated. In the absence of a multi-purpose material equivalent to methyl bromide, research is needed to identify the various situations (soil types, pests present, etc) in which each alternative or combinations of alternatives are economically feasible in Tennessee.
- Develop a plant breeding program for the Southeast that address anthracnose, angular leaf spot and Botrytis.
- Herbicides for improved weed control in matted row production systems.
- Disease incidence in production of "Bare Root" vs. "Tips"
- Find new effective approaches for deer control, especially if Thiram is lost.
- Testing new products with similar broad-spectrum activity as captan and thiram. These should be non-strobilurin fungicides.
- Industry should work more closely with IR-4
- Funding for more efficacy trials
- Controls for vetch, wild onion, wild garlic, henbit and yellow nutsedge
- Investigate more vertebrate pest control products for control of rabbits, terrapin, mice, vole and deer.

REGULATORY

- Registration of new methyl bromide alternatives, such as Midas.
- Development of plant certification programs at state plant production nurseries.
- Registration of other products developed as needed.
- Increase harvest numbers of whitetail deer
- Fast-track registration of thiomethoxam, fipronil, imidacloprid, methoxythiozide and

other insecticides that are pending registration.
- Registration of products Visor, Stinger and other herbicides which are pending registration.

EDUCATION

- Develop a program on the How-to's of Plant and Tip production for Tennessee.
- Increase knowledge of growers how to determine presence and properly identify anthracnose.
- Keep stressing to growers to purchase only from reputable source.
- Re-enforce idea to plant only healthy disease and insect free plants.
- As reniform nematodes become more of a problem in West Tennessee areas, growers should be aware that it is important to sample and inspect plants.
- A system developed by industry / university to apprize university specialists of new pesticide registrations, for all commodities. This would expedite the education process.
- Plasticulture should not be pushed as a method until replacements for methyl bromide are obtained.

Strawberry Production in Tennessee

Tennessee was not ranked within strawberry fresh market production. However the crop is very important to the state's economy. Currently, two types of production systems are prevalent in Tennessee. These are the matted-row system and plasticulture.

Matted-row production in Tennessee consists of 400-450 acres. Establishment cost of a matted-row system is approximately $1,500 per acre and if fumigation is used, production cost is increased by $1,200 per acre. Annual production costs range from $1500 - $3000 per year. Fields may be replanted every 3rd to 4th year, however rotation is recommended. Net returns of $5,000-6,000 per acre per year are normal for 3 years only in a matted-row production system. Varieties most commonly used in matted-row systems include, Early Glow, Allstar, Delmarvel, and Cardinal.

Plasticulture acreage during 2003 was approximately 350-400 acres. Establishment cost per acre varies around $5,000 - 6,000 and production costs vary from $10,000 - 12,000 per acre. Annual gross returns in plasticulture strawberry production vary from $20,000 - $30,000 per acre depending on growing conditions and management practices used. Yield obtained from an acre varied from 15,000 - 16,000 quarts of berries in 2003. Average price received was $2.00 per quart with prices ranging from $1.50 - 3.00 per quart throughout the season. The variety "Chandler" is most commonly grown in plasticulture production systems.

Strawberry production is scattered across the state of Tennessee. In East and Middle Tennessee, tobacco and row crop growers have been looking for new ways to supplement farm income due to the uncertainty and changes that have been occurring in tobacco production. Strawberry production has filled this void for some growers and using annual plasticulture

systems can be a very lucrative. However, frequent or heavy rainfall and/or extremely cold temperatures during bloom can drastically reduce yields of strawberries.

Various pests occur within strawberry production and may cause severe losses if not controlled. From year to year growers can expect to see losses from disease, insect and weed infestation. Fumigation provides broad spectrum control of various pest categories and is often practiced by growers. The biggest pest concerns in strawberry production include: diseases; anthracnose and Phytophthora crown rot, weeds include; yellow nutsedge, vetch and various broadleaf weeds and insects include; strawberry weevil (clipper), strawberry weevil, and the whitefringed beetle.

Worker Activities

There are two types of production methods or systems utilized in Tennessee. These systems are known as the matted-row system and annual plasticulture. Matted-row systems are the predominate production methods used by growers. However, growers are slowly adapting and utilizing the annual plasticulture system. By utilizing the plasticulture production, growers often observe less pest pressure from insects, diseases, and weeds, after plant establishment Methyl bromide fumigation is recommended in Tennessee. The majority of strawberries grown in Tennessee are produced in matted-row production system. This system is so- named because plants are allowed to runner freely within a certain row width to produce solid beds (or mats) of plants. Dormant plants are planted in mid-Spring (March-May), and are not harvested until the following year. Bearing plantings are renovated each year in July, after harvest. This consists of an herbicide application, narrowing the rows, removing foliage, and then allowing runner plants to fill in the rows again. The most commonly grown cultivars in matted-row systems in Tennessee are Early Glow, Allstar, Delmarvel, and Cardinal. Plantings are normally maintained for 3 – 4 years, and rarely are maintained to 5 years before rotation or replanting occurs.

Annual plasticulture systems use fumigation, plastic-mulched raised beds, trickle irrigation and have high plant densities. Plug plants are planted in late August to late September and harvested the following spring. Production is dependent on branch crown formation on the mother plant. Row middles may be seeded with annual ryegrass to help reduce erosion and suppress other weed species. Growers may hold their plantings over for a 2nd and sometimes 3rd year, however due to potential disease problems, this is rare in Tennessee. Runners are removed each year if growers select to continue into a 2nd or 3rd year of production. Decreased competition with weeds, less time to production, less insect, disease pressure and an earlier harvest season are the reasons most commonly given for using annual plasticulture. Higher yields and returns per acre are generally received using this production system and ‘Chandler’ is the cultivar most commonly grown. The plastic used in the plasticulture system is often reused to produce subsequent crops such as, pumpkins, squash, tomatoes and sweet corn.

Prior to Planting

In matted-row systems, methyl bromide with chloropicrin may be applied in the fall prior to

planting to aid in control of soil inhabiting insects, weed seeds and soil born disease causing organisms. Fumigants are applied two to three weeks prior to transplant.

In plasticulture systems, soil is cultivated, bedded and covered with plastic and irrigation drip tape is installed at the same time while a fumigant is injected into the soil. This normally done 2 – 3 weeks prior to planting.

Fumigation

Fumigants – are usually non-selective killing agents that are commonly used in strawberry production. Methyl bromide is favored over other fumigants since it provides adequate control of multiple pests that may be encountered in strawberry production. Listed below are fumigants which are labeled for use in strawberry production. These all provide some control of soil inhabiting insects and other pests of strawberries.

1,3-Dichloropropene (Telone II) has a 5-day REI and a 21-day PHI listed on the label. This product is a restricted use pesticide. Applied at the rate of 27 – 35 gallons per acre or 265.88 – 344.66 lbs active ingredient per acre, if applied as a broadcast application. For shallow rooted plants such as strawberries the rate is normally reduced to 15-27 gallons or 147.71 – 265.88 lbs active ingredient per acre or if applied in a broadcast application and less if applied as a band application. This product has warning as the signal word.

1,3-Dichloropropene + chloropicrin (Telone C-17, C-35, In-Line) has a 5-day REI and 21-day PHI listed on the label. This product contains 8.6 lbs of 1,3-Dichloropropene and 1.75 lbs of chloropicrin per gallon. These products have danger listed as the signal word. May be applied as high as 32.4 – 42 gallons formulation per acre, if broadcasted. This product is normally applied at the rate of 35 gallons formulation per acre. Occasionally there have been some phytotoxicity issues raised from use of these products due to the longer time the active ingredients volatilize.

Metam Sodium (Vapam HL and 4.26) has a 48 hour REI and no PHI is listed on the label. Applied at the rate of 37.5 – 75 gallons per acre or 159.75 – 319.50 lbs active ingredient per acre. This product suppresses many weeds, insects and several disease causing organisms. Danger is listed as the signal word on the label. Inconsistent disease control has been observed with use of this product. This product has a longer replant time than methyl bromide.

Methyl bromide 67%, chloropicrin 33% (Bromo-gas) Brom-o-gas contains 14.3 lbs active ingredient per gallon of product. Rates vary depending on selected application technique. An average of 300 – 400 lbs per acre is normally applied in strawberry production. Danger is the signal word listed on this product.

Alternatives:

- Dazomet (Basamid) is labeled only for non-bearing strawberries at this time.

Unregistered products:

- Midas is a methyl bromide replacement which causes no harm to the ozone.

Planting / setting – matted-row or plasticulture
The majority of strawberry transplants are bare-root dormant plants that are planted by hand in the fall (late August). Growers are slowly adapting and utilizing mechanical transplanters. Utilizing mechanical transplanters (tobacco setters), reduces handling time in which workers directly contact transplants. Workers may re-enter the field with in 1-2 weeks of transplanting to replace dead, missing or unthrifty plants. Workers generally do not re-enter the field unless they are installing row covers in November and removal in early March or until picking begins. Occasionally, workers, farm managers and/or owners may inspect the field weekly or every two weeks to observe the crops performance.

In matted-row systems after setting, carbaryl or chlorpyrifos are usually applied to aid in control of the strawberry crown borer.

Plasticulture systems utilize plug plants and are set by hand or by using a waterwheel setter.

Cleaning rows
In late February, rows may be cleaned using hydraulic brush or by hand and broom.

Pre-bloom (matted-row or plasticulture)
Pesticide applications including insecticides and/or fungicides begin in March during the first warm period (65◦C +). Pre-emergent herbicides may be applied at this time. Generally, pre-emergent herbicides are not applied between bloom and harvest.

Weeds in row middles may be plowed or chemically controlled with Roundup, paraquat, or other products.

Occasionally workers may hand-hoe areas with heavy weed infestations prior to or 3-4 days after herbicide application.

In systems using irrigation, lines may be checked for functionality.

In matted-row systems, spring pesticide applications begin in late March to early April. Insecticides are applied at 10-14 day intervals until pests are controlled.

Bloom
Usually at 5-10% bloom until most petals have fallen, in both matted-row and plasticulture systems, insecticides are generally **not** sprayed at this time to eliminate the possibility of harming honey bees. Fungicides may be sprayed at this time, if conditions or pest pressure are present.

Post-bloom through harvest
Insecticides and fungicides are applied as needed during this time and harvest restrictions are strictly followed. Most pesticides are applied with a boom sprayer on a tractor. For small acreage farms insecticides and fungicides may be applied by hand sprayer.

Post-emergent herbicides may be applied at this time for control of annual and perennial grasses and broadleaf weeds. Herbicides are often used to control weeds in row middles.

Harvest
All strawberry systems are harvested by hand in April to early June. Picking may be conducted by workers and/or the general public at U-PICK or farmer market farms. The approximately 50% of the workers wear cotton gloves to reduce hand contact with fruit.

Post-harvest for matted row only
Insecticide applications are generally made every 10-14 days as needed to control pests. Fungicides used to control leaf spots, anthracnose and powdery mildew may be applied during this time on a similar spray schedule, if conditions and/or presents of the diseases warrant their application.

Irrigation
Drip irrigation is applied to < 5% of the matted-row system acreage and approximately 95% of all plasticulture systems. Drip lines are installed two to three weeks prior to setting during plastic installation at fumigation. Workers occasionally enter the field to correct any plugged lines after setting. Drip irrigation systems contain injected fertilizers to promote plant growth and vigor.

Over-head irrigation is used to reduce damage that may be caused by early season frosts/freezes that may occur. Row covers may be substituted for overhead irrigation as well as used in conjunction with overhead irrigation with 75% of the matted-row systems using overhead irrigation.

Mowing
Occasionally producers will mow weeds between rows to reduce weed seed production and habitats for insect development. This occurs two to four times per season.

Mulching
Mulching occurs late in the fall to protect plants from frost damage and depending on warm weather mulch removal begins in March and may extend into April.

Table 1, Worker activities; a timeline for strawberry production.

ACTIVITY	Month*											
	Jan	Feb	M	A	May	June	July	Aug	Sept	Oct	Nov	Dec
Fumigation	00000	00000	00000	00000	00000	00000	0000-	-----	-----	00000	00000	00000
Planting	00000	00000	000--	-----	-----	-0000	00000	-----	-----	-0000	00000	00000
Row covers	00000	00000	------	00000	00000	00000	00000	00000	00000	00000	0----	00000
Cleaning rows	00000	00---	-0000	00000	00000	00000	00000	00000	00000	00000	00000	00000
Insecticides (s)	00000	00000	0----	00000	00000	00000	00000	00000	-----	-0000	00000	00000
Insecticides (f)	00000	00000	0----	------	----00	-----	-----	------	------	-0000	00000	00000
Fungicides (s)	00000	00000	0----	---00	00000	00000	00000	0000-	-----	-0000	00000	00000
Fungicides (f)	00000	00000	0----	-----	-----	-----	-----	-----	0----	00000	00000	00000
Herbicide (pre)	00000	00000	00---	-----	00000	00000	00000	00---	-----	-0000	00000	00000
Herbicide (pos)	00000	00000	0----	-----	-----	-----	-----	-----	----0	00000	00000	00000
Herbicide (mid)	00000	00000	000--	------	-----	-----	-----	-----	---00	00000	00000	00000
Mowing	00000	00000	00000	-----	-----	-----	-----	-----	-----	00000	00000	00000
Harvest	00000	00000	00000	00---	-----	---00	00000	00000	00000	00000	00000	00000
Irrigation	00000	00000	000--	-----	-----	-----	-----	-----	-----	000--	----0	00000
Scouting	00000	00---	-----	------	------	------	------	-----	-----	-----	-----	00000
Mulching	00000	00000	-----	-0000	00000	00000	00000	00000	00000	000--	-----	--000
Renovation	00000	00000	00000	00000	0000-	-----	00000	00000	00000	00000	00000	00000
Bed preparation	00000	00000	00---	-----	---00	00000	00000	00---	-----	00000	00000	00000
Cultivation	00000	00000	00000	00---	------	-----	-----	-----	-----	-0000	00000	00000
Fertilization	00000	000--	-----	-----	-0000	00000	00000	000--	-----	---00	00000	00000

s= soil applied, f=foliar applied, pre = preemergent, pos = post emergent, mid = row middles
0 = no activity, - = activity in the field.
* = Each month is broken into 5 sections.

ARTHROPOD (INSECT AND MITE) PESTS

Insect and mite populations vary from field to field and from year to year. Depending on productions systems (matted-row or plasticulture) chosen, pest populations may be variable. Generally, the matted-row system encounters more pests, since this system is a production system that continues over several years. Spider mite infestations are normally a more frequently occurring problem in plasticulture production systems.

NOTES:

- Many new pesticide chemistries are being developed, especially for mite control. The new chemistries normally are very expensive compared to older materials. The newer chemistries are generally species specific rather than broad spectrum, resulting in less harmful effects on beneficial organisms.
- Insecticide applications are not recommended during bloom to reduce hazardous effects on honey bees.

Strawberry crown borer (*Tyloderma fragariae*)

The adult is a small snout beetle that is incapable of flight. This pest is spread normally by movement of infested plants. Treatments begin in the spring (April) when adults or numerous holes appear in the leaves. Clean non-infested plants rarely become infested with this pest unless transplants are located near areas that are infested or near wild strawberry plants that are infested.

Organophosphate insecticides currently used:

- Azinphos-methyl (Guthion) Provides good to excellent control. This product is fairly toxic to the user. Harmful effects on bees, parasitic wasps and lady beetles.
- Chlorpyrifos (Lorsban 4E) application made pre-bloom for strawberry weevil control will aid in controlling strawberry crown borers. Provides good control. Has a long residual. Harmful effects on bees, parasitic wasps and lady bugs.
- Malathion (various tradenames) provides fair to good control of this pest. It is usually applied at post-harvest when tunneling damage is observed at the crown by legless larvae. Inexpensive and fairly safe for applicator use. Harmful effects on bees.

Carbamate insecticides currently used:

- Carbaryl (Sevin) is used in matted-row systems. Applications may be made after setting or during spring sprays. Generally, two applications of carbaryl are made at weekly intervals starting when buds first appear in both matted-row or plasticulture production systems. Applications are not recommended at bloom. Carbaryl may injure Earlidawn or Sunrise varieties. Provides good control. Inexpensive and safe to the user. Harmful effects on predatory mites, honey bees, parasitic wasps and lady beetles.

Products not used but may provide some control:

- Fenamiphos (Nemacur) is labeled for nematode control, however if applied at setting, may provide fair control. This product is extremely costly. It is a RUP and has danger as the signal word. Voluntary cancellation of all domestic uses by May 2005.
- Azadirachtin (Aza-Direct) provides fair control, however is expensive but fairly safe to the user.
- Carbofuran (Furadan) may provide fair control, but is not used for this pest.
- Dazomet (Basamid): is currently labeled non-bearing strawberries and may provide adequate control.

Non-Chemical pest management methods currently used:

- Plants are inspected prior to transplant and only clean non-infested plants are used.
- If fields are intended for production in the following season, fields are scouted after harvest for damage caused by legless larvae.
- Planting in areas not previously planted in strawberries or areas that did not have wild strawberries.

Unregistered pest management tools:

- None at this time

"**TO DO**s" list for strawberry crown borer:

Research:

- Review efficacy of imidacloprid on this pest
- Develop materials with long residual for this pest

Regulatory:

- None at this time

Education:

- Proper identification of damage and pest

Strawberry leafroller (*Ancylis comptana fragariae*)

Strawberry leafrollers over-winter as larvae or pupae in folded leaves or leaf litter. Adult moths emerge in April and May and deposit translucent eggs, usually on the lower surface of strawberry leaves. A second and/or third generation may occur in late summer. Moths of the summer generations are often present from July through September. Infestations may develop in spring and early summer, but they may also build up after harvest. As larvae feed, they secrete silken threads to fold and tie strawberry leaflets together. Within these folded leaves, larvae feed on only the epidermis of each leaf, but entire leaflets usually turn brown. Heavy infestations reduce photosynthesis, therefore reducing yields. Insecticide applications are made in the spring prior to bloom and post-bloom until harvest. These materials are applied at 10-14 day intervals until the insects are controlled.

Organophosphate insecticides currently used:

- Malathion (various): also aids in control of catfacing insects and whiteflies. Provides good control.
- Azinphos-methyl (Guthion): provides good control but is extremely toxic.
- Naled (Dibrom) provide good control, however is difficult to obtain. Should not be applied when temperatures exceed 90F. Controls various other pests. This product is harsh on beneficial insects and mites.

Pyrethroid insecticides currently used:

- Bifenthrin (Brigade): provides excellent control

Non-OP / Pyrethroid insecticides currently used:

- Azadirachtin (Aza-Direct) is expensive. Low toxicity.

Non-chemical controls currently used:

- Renovation of perennial plantings.
- Utilizing annual plantings aids in control, since there should be less overwintering sites.
- Scout to see if they have high populations of two parasites, *Macrocentrus ancylivrous* and *Cremastes cookii*, may kill a high percentage of strawberry leafroller larvae, especially during summer generations.

Unregistered pest management tools:

- None at this time

"**TO DO**s" list for strawberry leafroller:

Research:

- Search for any additional predator/parasites
- Develop threshold population

Regulatory:

- None at this time

Education:

- Stress Scouting for this pest

Strawberry rootworm (*Paria fragariae*)

The adults feed on the plants chiefly at night and are not commonly seen during the day. The larvae are white and are found in the soil. The adults spend the winter in ground litter or in other protected places and begin to become active in early May. The largest numbers of beetles

occur between late May and early June. Eggs are laid during this period and developing larvae burrow into the ground, where they feed on the roots of strawberries and other related plants. They become pupae in the soil, and new adults emerge from mid-July through August and feed on foliage the rest of the season. The most severe damage is caused by the adult beetles, which eat holes in the leaves. When adults are abundant, leaves are riddled with holes giving the plants a ragged appearance. The larvae may destroy and tunnel into the root system. If heavy infestations by adults are observed, it is likely that high populations of larvae exist.

Chemical control:

- No insecticides currently include this pest on the label. Insecticides used for control of other pests observed in the soil are likely to control this pest as well.

Non-chemical pest management tools:

- This pest builds up in perennially grown strawberries, not those replanted yearly and grown on plastic mulch.

"**TO DO**s" list for strawberry rootworm:

Research:

- Investigate for evidence of predators/parasites of this pest.
- Determine efficacy of commonly used soil applied insecticides.
- Determine economic threshold of this pest.

Regulatory:

- None at this time

Education:

- Stress the importance of utilizing annual plantings vs. perennial.

Strawberry weevil (clipper) (*Anthonomus signatus*)

The strawberry clipper, *Anthonomus signatus*, is also known as the strawberry weevil. Adults over-winter primarily in fence rows and wood lots (although a small portion of a population may remain in the strawberry field), then move to plants with developing fruit buds. The seasonal timing of strawberry flowering coincides with clipper movement from overwintering sites, so strawberries are ideal host plants for this insect. Adults feed on immature pollen by puncturing nearly mature blossom buds with their snouts. The female deposits a single egg inside the bud and girdles the bud, preventing it from opening and exposing the developing larva. The adult female then clips the stem so that the bud hangs down or falls to the ground. Larvae feed within the damaged bud for a period of 3 to 4 weeks; a new generation of adults emerges in late June and July. These weevils feed on the pollen of various flowers for a short time, but seek shelter in midsummer in preparation for overwintering. Weevils are a sporadic pest and are usually found around field margins.

Organophosphate insecticides currently used:

- Chlorpyrifos (Lorsban): may only be made as a pre-bloom application. Very effective for control of this pest. Toxic to the user. Phytotoxicity may occur when applied to strawberries experiencing high temperatures and drought stress. No more than two applications may be made per season or applied within 21 days before harvest.
- Malathion (various): provides good control of this pest. Relatively inexpensive. Fairly safe for user.

Carbamate insecticides currently used:

- Carbaryl (Sevin): Provides good control and is inexpensive. Safe if used correctly.
- Endosulfan (Thiodan, Phaser): Provides excellent control of this pest. Highly toxic to user. A broadspectrum product.
- Carbofuran (Furadan): Provides good control. Highly toxicity to applicator.

Pyrethroid insecticides currently used:

- Bifenthrin (Brigade): Provides excellent control of this pest.
- Fenpropathrin (Danitol): provides excellent control however has Danger as the signal word on the label.

Non-OP, Carbamate or Pyrethroid insecticides currently used:

- Azadirachtin (Aza-Direct) is expensive. Very safe to use.

NOTES: Applications of bifenthrin, carbaryl, fenpropathrin and chlorpyrifos are made in the spring (March) to control this pest. If this pest was a problem the prior year, then insecticide applications should be made when buds emerge and a second application should be made just prior to bloom. If no damage was observed the previous year, insecticide applications should be made at the first sign of damage to flower buds.

Non-chemical pest management tools:

- Generally these pests are not as severe in annual plasticculture production systems.

Unregistered pest management tools:

- Methoxychlor (Marlate): is an organophosphate which provides good control, uses have been suspended since 2000.

"**TO DO**s" list for the strawberry weevil (clipper):

Research:

- Longer residual materials needed

Regulatory:

- None at this time

Education:

- Stress importance of scouting for this pest

Catfacing insects (plant bugs, stink bugs) Lygus bugs (*Lygus lineolaris*, *Lygus esperus*) Stink bugs (brown: *Euschistus servus*, green: *Acrosternum hilare*)

Lygus bugs cause irregularly shaped or catface shaped fruit. Lygus bug nymphs may feed on a wide variety of plants including strawberries. They cause damage by puncturing individual seeds, causing the berry to stop developing. Punctured seeds are often confused with unfertilized or frost injured seeds. Adults over-winter in trash or under leaves of plants. Damage from feeding by nymphs may be slight to unusable fruit. Controlling young nymphs is

the most effective form of control. Later-maturing varieties are more severely affected. Although several plant bugs (*Lygus* spp. and others) may be involved, the tarnished plant bug appears to be the chief culprit. Early infestations by tarnished plant bugs may result in blossom losses therefore reducing yield.

Organophosphate insecticides currently used:

- Malathion (various): Provides good control. Reasonably priced and easy to obtain.
- Naled (Dibrom): Provides good control. Naled is difficult to find in retail markets. Should not be applied when temperatures exceed 90°F.
- Chlorpyrifos (Lorsban): Provides excellent control. Long PHI. Human toxicity issue.
- Endosulfan (Thiodan / Phaser): Provides good to excellent broad spectrum control, however is very toxic to the user.

Carbamate insecticides currently used:

- Methomyl (Lannate): Provides good control.
- Carbaryl (Sevin): Provides good control.

Pyrethroid insecticides currently used:

- Bifenthrin (Brigade): Provides excellent control, however has danger as the signal word.
- Fenpropathrin (Danitol): Provides excellent control, however has danger as the signal word.

Non-OP / Carbamate / Pyrethroid insecticides currently used:

- *Beauveria bassiana* (BotaniGard ES and Mycotrol O) is a fungal pathogen of lygus bugs that is available commercially. These products are expensive. Very environmentally friendly product.

Non-chemical pest controls currently used:

- Reducing weeds in areas surrounding the field may aid in control these migrating pests.

Unregistered pest management tools:

- None at this time

"**TO DO**s" list for the catfacing insects:

Research:

- Determine economic thresholds

Regulatory:

- None at this time

Education:

- Proper identification

Whitefringed beetle (*Naupactus leucoloma*)

Whitefringed beetles are becoming more noticeable pests of strawberries as well as many other plant species in Tennessee. The larval stage of the white-fringed beetle lives in the soil and is the stage responsible for damage to the roots. Low populations of white-fringed beetle larvae in the soil can cause significant damage to strawberries. The appearance of feeding damage on roots is varied, depending on the size of the larva (also referred to as a grub). Grubs often chew a shallow gouge or channel (1/8" to ½" wide) across the surface of the root. This injury will heal but may affect the size of the fruit. Depending on the size of the feeding hole, the damage is similar in appearance to feeding caused by wireworms or cucumber beetle larvae (small

holes), or white grubs or cutworms (large holes). Aside from the deep scarring of the roots which affects quality, soilborne disease causing organisms may invade these holes and cause further damage and reduction of fruit size or death of the plant.
Adult whitefringed beetles begin emerging from the soil in mid-to late June. Peak adult emergence occurs in mid-July and adults are present all summer and into September, when numbers begin to decrease. All whitefringed beetle adults are female, and they (obviously) can lay eggs without mating. Females can lay over 1,000 eggs (depending on their food source) on the top of the soil or on crop debris. The eggs will hatch only when there is sufficient moisture. Eggs may stop hatching during dry periods and lay dormant until the next rainfall brings sufficient moisture. After hatch, first stage legless grubs dig down into the soil and begin feeding (grubs hatched in the fall may spend the winter in the soil without feeding. Eggs hatch anytime from June into late July and develop into grubs of sufficient size to damage plant roots before harvest. Grubs hatching later in the season will overwinter in the soil, and resume feeding and development the following growing season.

Organophosphate insecticides currently used:

- Chlorpyrifos (Lorsban): Provides good control of the immature and adults. Has a long residual. Fairly toxic to user.
- Endosulfan (Thiodan, Phaser): provides fair to good control of the adults. Provides broad spectrum control.

Carbamate insecticides currently used:

- Carbaryl (Sevin): Provides fair to good control of the adult stage of this pest. Product is fairly safe to user.

Pyrethroid insecticides currently used:

- Bifenthrin (Brigade): Provide excellent control of the adults. Danger is listed as the signal word on the label.

Non-chemical pest management tools currently used:

- Plasticulture production should have less pressure from this pest, since populations may buildup the following year.
- Proper renovation of matted-row systems will help reduce this pest.

Unregistered pest management tools:

- Thiomethoxam (Platinum): is systemic and may have persistent residues.
- Fipronil (Reagent): fairly persistent in the soil. Low rates should provide control.
- **Notes**: These two products are fairly safe to applicators.

"**TO DO**s" list for the whitefringed beetle

Research

- Investigate efficacy of fipronil, imidacloprid, and thiomethoxam.
- Evaluate efficacy of Telone
- Determine economic thresholds

Regulatory

- Speed registration for thiomethoxam, and fipronil

Education:

- Train growers how to proper identify the whitefringed beetle adults and larvae.
- Scouting is essential to determine presence and damage caused by this pest

Spittlebugs (*Philaenus spumarius*, *P. leucophthalmus*)

Feeding by spittlebug nymphs inhibits plant growth and cause plants to produce small irregularly shaped berries. A frothy mass of oozing secretions may be observed from feeding nymphs around bloom and if not controlled may persist until harvest.

Organophosphate insecticides currently used:

- Malathion (various): relatively inexpensive and provides good control. Safe material.
- Azinphos-methyl (Guthion): Provide excellent control. Highly toxic.
- Endosulfan (Thiodan / Phaser): Provides excellent control.
- Naled (Dibrom): provides good control but difficult to obtain. Should not be applied when temperatures exceed 90F.

Carbamate insecticides currently used:

- Carbaryl (Sevin): provides good control. Safe for user.

Pyrethroid insecticides currently used:

- Bifenthrin (Brigade): Provides excellent control. Danger is the signal word on the label.
- Fenpropathrin (Danitol): Provides excellent control, however difficult to obtain product. No more than two applications within a 12 month interval.

Non-chemical pest management tools:

- Control weeds and mow weeds around field edges in early spring.

"**TO DO**s" list for the spittlebugs:

Research

- Determine up to-date economic thresholds for this pest.

Regulatory

- None at this time

Education

- Inform growers the importance of scouting and recognition of feeding.

Aphids (*Chaetosiphon fragaefolii* and other genera)

Two kinds of aphids attack strawberries. One type of aphid feeds on the young foliage, stems, and crown of strawberry plants. Occasionally numbers are heavy enough to cause serious damage. Aphids are important as carriers of diseases, especially viruses. Both the larval and adult stages of lady beetles feed on aphids. Another type of aphid feeds on the roots of strawberry and is known as a root aphid, which is tended by ants. Root aphids also suck plant juices. It is important that infested plants should be immediately sprayed to reduce population build up and diseased plants removed and destroyed. Overwintering eggs on branches and stems hatch in the spring to produce a wingless form known as the stem mother. The unfertilized stem mother gives birth to living young in great numbers. Several generations may occur in this fashion, but in due time some individuals will develop wings (alates) and migrate to another host. They may deposit eggs for the winter or, after a few generations, migrate back to the original host to lay eggs.

Aphids are sucking insects that feed by thrusting a long beak into the plant tissue. They withdraw great quantities of sap, some of which they excrete as "honeydew". The honeydew makes the plant sticky. A sooty mold often develops with the honeydew blackening stems and foliage. This fungus is not parasitic to the plant, but reduces the amount of photosynthetic area. Leaves of plants may be distorted by aphids feeding on the undersides. Succulent stems may wilt or growth may be arrested by colonies of aphids.

Organophosphate insecticides currently used:

- Azinphos-methyl (Guthion) is a restricted use pesticide with danger as the signal word. Provides fair control but can be highly toxic to applicator.
- Malathion (various): Provides good control and is fairly inexpensive. Fairly safe material.
- Endosulfan (Thiodan / Phaser): provides good control.
- Naled (Dibrom): provides good control, however is difficult to obtain. Should not be applied when temperatures exceed 90F.

Carbamate insecticides currently used:

- Carbaryl (Sevin): provides poor control. Material is fairly safe to applicator.
- Methomyl (Lannate): provides fair control.

Non- OP / Carbamate / Pyrethroid insecticides currently used:

- Insecticidal soap (M-Pede): provides fair control with thorough coverage. During hot conditions may be phytotoxic. Very safe to user. No residual activity.
- Neem (various): provides fair control with thorough coverage. Very safe material.
- *Beauveria bassiana* (Mycotrol O) is environmentally friendly, but is expensive.

Non-chemical pest management tools:

- Frequent soil cultivation will help manage the ants that tend the aphids and thus aid in control of the root aphid.
- Mow weedy areas surrounding the field.

Non-registered products:

- Acetamiprid (Assail) is a new neonicotinoid class of insecticide which may provide control.

"**TO DO**s" list for aphids:

Research

- Determine up to-date economic thresholds for this pest.

Regulatory

- Speed registration of acetamiprid.

Education

- Inform growers the importance of scouting due to the pest's ability to rapidly reproduce.
- Imidacloprid (Admire) was recently registered for use in strawberry production, inform growers.

Two-spotted spider mites (*Tetranychus urticae*)

The two-spotted spider mite feeds on a broad range of hosts. In early spring in strawberry production, the adults feed on the underside of newly produced leaves and mild to heavy infestations may cause yellowed appearance of the upper leaf surface. Later the leaves may become brown and have a dried appearance. Generally, spider mite damage is most evident during hot dry weather and this is when populations increase.

Heavily infested plants become stunted or die and if fruit is produced are usually reduced in size and have a bronzed appearance. Spider mites may be spread through wind movement. Renovation may help suppress populations. Controlling weeds bordering the field in early spring may help keep populations from developing in these areas and reduce movement into the field in mid to late season. Frequent rains and cool weather both help minimize damage

from spider mites. In warm seasons mites may build in the fall, overwinter, and continue to build populations in the spring. Predatory mite populations may also help keep populations low. Scouting fields can aid growers in determining when to spray for spider mites. Releasing biologicals such as *Phytoseiulus persimilis* may be effective. If predaceous mites such as *Amblyseius fallacis* are present, miticide applications usually are unnecessary.

Organophosphate insecticides currently used:

- Naled (Dibrom): Provides good control. Should not be used when temperatures exceed 90°F. Difficult to obtain this product.
- Dicofol (Kelthane): Provides excellent control, however do make multiple applications. Toxic to user, inexpensive.
- Diazinon (various): provides fair control.
- Malathion (malathion): provides fair control. Must be rotated with other products to avoid resistance within the population. Has a 3-day PHI. This product is fairly safe to applicator.

Pyrethroid insecticides currently used:

- Bifenthrin (Brigade): Provides good control. Has Danger as the signal word.
- Fenpropathrin (Danitol): Provides good control, however difficult to obtain product.

Non – OP / Carbamate / Pyrethroid insecticides currently used:

- Hexythiazox (Savey): provides excellent control, however is expensive.
- Abamectin (Agri-Mek): Extremely effective, but is expensive
- Bifenazate (Acarmite): provides excellent control, but is expensive. Only one application per year allowed.
- Neem (various): Thorough coverage is needed to obtain effective control. This product is fairly expensive. Provides fair to good control.
- Insecticidal soap (various): Thorough coverage is needed to obtain fair control.

Non-chemical pest management tools currently used:

- Overhead irrigation provides good control when applied during dry weather.

"**TO DO**s" list for the two-spotted spider mites:

Research

- Determine up to-date economic thresholds for this pest.

Regulatory

- Speed registration of Fujimite in strawberry production.

Education

- Inform growers the importance of scouting and recognition of damage

Cyclamen mites (*Steneotarsonemus pallidus*)

Cyclamen mites are a primary problem in greenhouse plantings, however they may be found in the field plantings. Cyclamen mites are very tiny and a hand lens is usually needed to view these pests. They feed on young leaves in the crown area of the plant. Maturing leaves are usually stunted, crinkled and malformed. Heavy infestations may cause leaves to appear roughened and discolored. Leaf stems generally do not elongate and the plant takes on a characteristic of a flat appearance. During bloom, heavy infestations may cause flowers to

wither and die. Infested fruits are generally smaller and may become cracked and have a bronzed color. Female mites may overwinter in crown areas of the plant. During warm weather, usually in April, females begin laying eggs on young leaves. Cool wet springs hinder reproduction and development of young.
Using transplants free of this pest is the major method of control. Scouting fields will aid in detection of this pest. Predatory mites such as *Amblyseius fallacis* may aid in control of this pest.

Organophosphate insecticides currently used:

- Dicofol (Kelthane): must be applied with high water volumes to obtain thorough coverage.
- Diazinon (various): provides fair control.

Pyrethroid insecticides currently used:

- Bifenthrin (Brigade): more than one application increases the likelihood of resistance developing. Toxic to beneficial mites and beneficial insects.

Non-OP/Carbamate/Pyrethroid insecticides currently used:

- Potassium salts/insecticidal soaps (M-Pede): provides fair control, however is expensive.
- Neem (various): provides good control if thorough coverage is achieved. Expensive.

Non-chemical pest management tools currently used:

- Overhead irrigation may aid in control.

"**TO DO**s" list for the cyclamen mites:

Research

- Determine up to-date economic thresholds for this pest and levels of predators needed to obtain field control. Review minute pirate bug and thrips levels for control of this pest.

Regulatory

- None at this time

Education

- Inform growers the importance of scouting and recognition of damage

Sap beetles (*Stelidota geminata*)

This pest infests strawberries as the fruits begin to ripen, chewing unsightly holes in the underside or soil side of the berries. Over ripe berries which may have been over looked by unskilled pickers may attract the beetle. This pest is also responsible for disseminating fruit rot organisms as it moves about feeding on berries. Removal of damaged, diseased, and overripe fruits from the field at regular intervals is known to assist in reducing populations. Problems with sap beetles often arise with the buildup of overripe berries when rain occurs during harvest. Boxes or flats of harvested berries should be removed from the field immediately or covered to keep beetles out. Provide pickers with special containers for unmarketable berries and bury the boxes as soon as possible. Pesticides are not as effective as the cultural control practices.

Organophosphates insecticides currently used:

- Chlorpyrifos (Lorsban): provides fair to good control. PHI is long. Toxicity to user.

Carbamate insecticides currently used:

- Carbaryl (Sevin) provides excellent control and is commonly used for this pest and is safe to the user.
- Methomyl (Lannate): provides good control.

Pyrethroid insecticides currently used:

- Bifenthrin (Brigade): provides excellent control. Has Danger as the signal word.
- Fenpropathrin (Danitol): provides excellent control. Has Danger as the signal word.

Non-OP/Carbamate/Pyrethroid insecticides currently used:

- Endosulfan (Thiodan, Phaser) is an organochlorine insecticide which is highly toxic, provides good control.

Non-chemical pest management tools currently used:

- Remove ripened and/or damaged fruit. Pick fruit immediately when ripened.

"**TO DO**s" list for the sap beetles:

Research

- Determine up to-date economic thresholds for this pest

Regulatory

- None at this time

Education

- Inform growers the importance removal of ripened and/or damaged berries.

Flea beetles (Pale-stripped *Systena balanda* and eggplant flea beetle *Epitrix fuscula*)
Flea beetles attack the foliage leaving small round holes. Most serious early in the growing season, this injury eventually kills infested leaves. Flea beetles overwinter as adults among debris in or near fields of host plants. They resume activity in spring and feed on weedy hosts until crop hosts are available. Eggs, deposited in soil near the bases of host plants, may require a week or more to hatch. Grubs feed on or in roots, and lower stems for 3 to 4 weeks before pupating. After a pupal period of 7 to 10 days, a new generation of beetles emerges. The palestriped flea beetle completes only one generation each year. Can be a more severe problem in matted row production system vs the plasticulture production system.

Organophosphate insecticides currently used:

- Malathion (malathion various): provides fair to good control. Product is fairly safe.

Carbamate insecticides currently used:

- Carbaryl (Sevin 50WP): provides good control. Product is fairly safe and inexpensive.

Non-chemical pest management practices currently used:

- Rotation
- Annual production systems may reduce problems from this pest.

"**TO DO**s" list for flea beetles:

Research:

- Determine economic threshold

Regulatory:

- None at this time

Education:

- Proper identification of damage caused by this pest.

Root weevils (*Otiorhynchus* spp.)

There are many species of root weevils that attack strawberry plants. They emerge from May to August depending on species. Many feed on foliage at night and within a few weeks deposit eggs near the crowns of the plants. Larvae enter the soil to feed on the roots. Damage to the foliage reduces photosynthesis and damage to roots systems reduces growth of the plant and provides entry for disease causing organisms.

Organophosphate insecticides currently used:

- Malathion (various): provides fair to good control. Product is fairly safe.
- Fenamiphos (Nemacur) is labeled for nematode control, however may provide fair control if applied prior to translplanting. Not a primary material for root weevil control. Not economically feasible for control for this purpose. Voluntary cancellation of all domestic uses by May 2005.

Carbamate insecticide currently used:

- Carbofuran (Furadan) provides excellent control. Can be hazardous to applicator.

Pyrethroid insecticides currently used:

- Bifenthrin (Brigade): provides excellent control. Product has Danger as the signal word.

Other pesticides currently used:

- Methyl bromide (Bromo-gas): provides excellent control. Controls other pests.

Non-chemical pest management practices currently used:

- Annual production systems may result in less damage from this pest.
- Rotation in annual systems will also be of benefit.

Non-registered Pesticides:

- Methoxychlor (Marlate): provides good control, uses have been suspended since 2000.

"**TO DO**s" for root weevil control:

Research

- Look for products that will provide residual control
- Investigate predators and parasites
- Evaluate efficacy of imidacloprid, fipronil and thiomethoxam.

Regulatory

- None at this time

Extension

- Stress proper identification

Potato leafhopper (*Emposasca fabae*)

Generally, potato leafhoppers do not overwinter in Tennessee. This is usually a mid to late season pest. Plants infested with potato leafhopper have an appearance of leaf burn. This is due to the toxic effects from injected salivary fluids into the leaf tissue. Young plants are most susceptible.

Organophosphates insecticides currently used:

- Malathion (malathion, various): provides good control of this pest, inexpensive. Product is fairly safe for user.
- Azinophos-methyl (Guthion): provides excellent control. Product is highly toxic.

Pyrethroid insecticides currently used:

- Bifenthrin (Brigade): provides excellent control of this pest. The product has Danger as the signal word.

Cultural control:

- Avoid planting near alfalfa.

"**TO DO**s" for potato leafhopper:

Education:

- Identification of damage caused by this pest

Other occasional insect invaders include:

Black Vine Weevil (*Otiorhynchus sulcatus*)

The adult black vine weevil notches the edges of the leaves in June and July. The larvae feed on the fibrous roots and cause stunting and death of the plants.

Chemical controls currently used:

- Carbaryl (Sevin): is a carbamate insecticide which is fairly safe and provides good control.
- Chlorpyrifos (Lorsban): provides good control but can be toxic to user.

Non-chemical controls:

- Rotation may provide some control

White grubs (*Phyllophaga* spp.)

White grubs can be a serious pest, especially, when turning over sod areas (lawn, pasture, fallow) for purposes of new strawberry plantings. White grubs may take out most of the new plantings if some control measures are not taken. The May and June beetle larvae have 1-2 year life cycles. Large grubs may consume all the roots on strawberry plants. Adults are normally observed in late May to late August. Larvae are normally observed damaging roots from late September until spring.

Chemical control: Carbaryl (Sevin) will control adult black vine weevil adults and Japanese beetle adults. Larvae may be controlled by fumigation priorto setting.

Alternatives: Use of diazinon, or chlorpyrifos (Lorsban) prior to setting may aid in control of larvae. Diazinon is very inexpensive.

Cultural control: avoiding areas which have been previously planted in sod. Utilizing annual production systems will also aid in control.

"**TO DO**s" for white grub control:

Research:

- Development of a material with long residual
- Evaluate efficacy of imidacloprid, thiomethoxam and fipronil

Whiteflies (*Trialeurodes vaporariorum*)

Whiteflies pierce and suck sap from the underneath side of leaves. These pests rapidly reproduce and if not controlled early, may become a serious problem and persist throughout the growing season.

Chemical control: malathion or azinphos-methyl (Guthion) are organophosphate insecticides which are commonly used for control of whiteflies. Whiteflies reproduce rapidly and controls should be in place as soon as infestations are observed.

Alternatives: Endosulfan (Thiodan / Phaser) and Fenpropathrin (Danitol).

Cultural control:

- Inspect plants in greenhouse prior to movement into the field.

Biological control:

- *Beauveria bassiana* (Botanigard ES, Mycotrol O) is expensive and has a short shelf life.

Non-registered pesticides:

- Acetamiprid (Assail): a new neonicotanoid class insecticide provides excellent whitefly control.
- Buprofezin (Applaud): is an insect growth regulator that may provide some control for this pest. The product is safe to the honeybee.
- Pyrofoxefin (Esteem, Knak, Distance): an insect growth regulator

"**TO DO**s" for whitefly control:

Regulatory:

- Speed registration on acetamiprid, buprofezin and pyriproxyfen.

Education:

- Scout regularly and the need to control this pest when it is first observed.
- Imidacloprid (Admire) was recently labeled, inform growers of its potential

Slugs (Mollusks) Agriolimax spp.

Slugs can be especially troublesome in wet weather or where heavy mulches are used. Slugs damage fruit by eating deep holes into the surface of berries. Slugs that damage strawberries in the spring and early summer hatched from eggs deposited in strawberry plantings the previous fall. Conditions that favor egg-laying in the fall include the continuous presence of straw mulches. Slug survival and fruit damage in the spring are greatest in dense, wide rows and when overcast and rainy weather creates continuously moist conditions in strawberry beds.

Cultural Control: Removal of straw mulch after harvest, summer renovation, and delaying fall mulching as long as is practical are effective steps in reducing slug populations.

Chemical Control:

- Metaldehyde 5% (Deadline) may be used in strawberries only if the baits are applied to the soil surface (and to mulch) and do not contact fruit. Can be toxic to children and pets.
- Iron phosphate (Sluggo, Escargo and Worry Free) is another material commonly used. This product is not toxic to non-targeted pests. Using chemical baiting early in the season helps reduce late season slug populations.
- Other bait products containing mixtures of 5% carbaryl with metaldehyde are also used.

Non-chemical controls:

- Use of wooden boards in smaller infested areas may be helpful.

Non-registered products:

- Measurol would result in similar control, however is not labeled for use in food crop production. Also, may aid in thrip control.

INSECTICIDES / MITICIDES

Organophosphate insecticides

Azinphos-methyl (Guthion) has a 48 hour and 4 day REI and a 5-day PHI. REI is 48 hours for mowing, irrigating or scouting only; 4-day REI for all other purposes. Applied at the rate of 1 lb formulation per acre or 0.5 lbs active ingredient per acre per application. Cost of $10.90 per acre per application. Limited to four applications per crop per season. Five days should be allowed between applications. Application by backpack or hand wand sprayer is prohibited. Used to control aphids, leafrollers, whiteflies and spittlebugs. This product is a restricted use pesticide and has danger as the signal word. Possible harmful effects to bees during flowering. Harmful effects to parasitic wasps and lady beetles.

Chlorpyrifos (Lorsban 4E) 24 hour REI and a 21-day PHI. Applied at the rate of 1 lb active ingredient per acre per application. Cost is approximately $10 per acre per application. May only be applied pre-bloom and is limited to two applications per season. Primarily used to control strawberry weevils, however may aid in control of white grubs, rootworms, wireworms, and ants. Possible harmful effects to parasitic wasps and lady beetles.

Malathion (Malathion 5E) has a 12 hour REI and a 3-day PHI. Malathion is applied at the rate ranges of 24 – 48 fl. oz. or 0.9375 – 1.875 lbs active ingredient per acre per application. Cost ranges from $4.88 – 9.72 per application per acre. It may cause phytotoxicity, if sprayed with other materials. Compatibility should be checked prior to mixing with other pesticides. It is used to control spittlebugs, aphids, whiteflies, leafrollers, root weevils, strawberry crown borers and catfacing insects. Broad spectrum, good in a rotation plan, and is very affordable. Possible harmful effects to bees if sprayed during bloom.

Naled (Dibrom 8EC) has a 24 hour REI and a 1-day PHI. It is applied at the rate of 1 lb active ingredient per acre per application. No more than 5 lbs active ingredient per acre may be applied per season. It is used to control aphids, Omnivorous leaftiers, spider mites, leafrollers, spittlebugs, thrips and lygus bugs. Quick knockdown has good efficacy if applied early when populations are low. This product is harsh on beneficials. Should not be applied when temperatures exceed 90˚F.

Diazinon (AG500, various): has a 5-day PHI. Applied at the rate of 1 pint formulation or 0.5 lbs ai per acre. No more than 1 lb ai per acre per season may be applied. Not recommended any more because it is not residually effective. This product is inexpensive. Used to control aphids, spidermites, cyclamen mites, strawberry leaf rollers and mole crickets. Can be harmful to bees if applied near bloom. Harmful to parasitic wasps and lady beetles.

Carbamate insecticides

Carbaryl (Sevin 50WP, 80S, 4XLR) has a 12 hour REI and a 7-day PHI. Carbaryl may injure Earlidawn and Sunrise varieties. Carbaryl may be applied up to a total of five times but not more often than once every seven days. Applied at the rate of 2-4 lbs formulation of 50WP or 2.5 lbs 80S or 1-2 quarts of 4F or 1 – 2 lbs active ingredient per acre per application. Cost ranges from $15.63- 31.80 depending on formulation and rate used. Used to control flea beetles, leafrollers, strawberry crown borer, sap beetles, and strawberry clipper. Harmful to predatory mites, bees, parasitic wasps and lady beetles.

Methomyl (Lannate 90SP) is a restricted use pesticide which has a 48 hour REI and a 3-day PHI for fresh picked berries and a 10-day PHI for processing berries. Applied at the rate of 0.45 – 0.90 lbs active ingredient per acre per application. Cost ranges from $11.18 – 22.35 per acre per application. No more than 4.5 lb a.i. per acre per crop. No more than 10 applications per crop. Used to control armyworms, thrips, aphids, omnivorous leaftiers and lygus bugs. May be harmful to bees and predatory mites.

Pyrethroid insecticides

Bifenthrin (Brigade 10WSB) has a 12 hour REI and 0-day PHI. Applied at rate ranges from 6.4 – 32 oz formulation or 0.04 – 0.2 lbs active ingredient per acre per application at a cost ranging from $13.76 – 68.80. No more than 80 oz. formulation per acre per season. Used to control leafrollers, catfacing insects, spittlebugs, spider mites, sap beetles, and root weevils. Cost and effectiveness is rate dependent. Must be careful around aquatic areas. Highly toxic to aquatic organisms. Very effective. May be used in a resistant management rotation program.

Fenpropathrin (Danitol 2.4EC) has a 24 hour REI and a 2-day PHI. This is a restricted use pesticide. It is applied at the rates of 10.66 – 21.33 fl.oz. or 0.20 – 0.40 lbs active ingredient per acre per application. Danitol should be applied before mite populations exceed 20 per leaflet (eggs & motiles). A second application can be made with a retreatment interval of no less than 30 days. No more than two applications totaling 2.67 pints of formulation or 0.8 lbs active ingredient per acre to the same planting in 12 consecutive months. Cost per application ranges from $11.61 to 23.23 per acre depending on rate used. This product is used to control lygus bug, spittlebug, tarnished plant bug, fall armyworm, sap beetle, strawberry clipper, two spotted spider mites, yellow striped armyworms and whiteflies. This product is fairly inexpensive, is broad spectrum used in resistance management programs, however sequential treatments may cause resistance to build within the population.

Non-OP, Carbamate, or Pyrethroid Insecticides

Dicofol (Kelthane 50WSP) has a 48 hour REI and a 3-day PHI. Applied at rates ranging from 1 – 4 lbs formulation or 0.5 – 2lbs active ingredient per application per acre. Higher rates are used for cyclamen mite control. No more than 2 applications may be made per season. Cost ranging from $13.40 – 53.60 depending on rate used. This product has danger as a signal word

on the label. It is primarily used to control cyclamen mites. Must rotate often, possible resistance without rotation. Product is fairly inexpensive.

Endosulfan (Thiodan 3EC, Phaser) has a 24 hour REI and a 4-day PHI. Applied at the rate of 1 lb active ingredient per acre per application. If lower rates are used, endosulfan should not be repeated within 15 days or more than twice during a 35 day period when fruit is present. At higher rates, endosulfan should not be applied at intervals less than 35 days when fruit is present. No more than three applications per year may be made. Cost ranges from $19.95 – 40.00 per application per acre. Used to control spittlebugs, aphids, and catfacing insects. May be harmful to bees, parasitic wasps and lady beetles.

Bifenazate (Acarmite 50 WS) has a 12 hour REI and 1-day PHI. Is applied at the rate range of 0.75 – 1 lb or 0.0.375 – 0.5 lbs active ingredient per acre. No more than one application per harvested crop per year. Cost ranges from $45 – 60 per application. This product provides excellent control of spider mites only. Very expensive.

Abamectin (Agri-Mek 1.5EC) has a 12 hour REI and 3-day PHI. Applied at the rate of 16 fl.oz formulation or 0.18 lbs active ingredient per acre per application. No more than 64floz. formulation per acre per season may be applied. Cost of an application is $85.60 per acre. Can not repeat treatment within 21 days of second application. Used to control spider mites and provides excellent control. May be harmful to predatory mites, parasitic wasps and lady beetles.

Hexythiazox (Savey 50DF) has a 12 hour REI and a 3-day PHI. Applied at the rate of 6 oz. per acre for spider mite control. No more than one application per year. Rotational crops not listed on the label may not be planted for 120 days after application of hexythiazox. Cost per application is $106.50 per acre. Used to control spider mites only and is relatively expensive.

Fenbutalin-oxide (Vendex 50WP) is a restricted use pesticide and has a 48 hour REI and a 1-day PHI. Applied at the rate range of 1.5 – 2 lbs formulation or 0.75 – 1 lb active ingredient per acre per application. No more than two applications per season may be made. No more than 4 lbs formulation or 2 lbs active ingredient per acre per season may be made. Cost ranges from $32.25 – 43 per acre. This product should be applied as soon as mites appear since mites are difficult to control. Not frequently used.

Spinosad (SpinTor 2SC) has a 4 hour REI and a 3-day PHI. It may be applied at the formulation rate range of 4-6 fl. oz. per acre per application or 0.0625 – 0.09375 lbs active ingredient. May not be applied more than three times in succession. Cost ranges from $17.50 – 26.25 per acre per application depending on rate used. Spinosad is used to control leafrollers and thrips. Expensive however very safe to use.

Metaladehyde (Deadline) used to control mollusks. Provides fair to good control. Toxic to pets and children.

Iron Phosphate (Sluggo): provides good control of mollusks.

Alternatives:

Imidacloprid (Admire 2, Provado, Gaucho, Marathon II) is a chloronicotinyl insecticide which primarily effective against sucking insects (aphids, whitefly, scales) as well as beetles and grubs which recently became labeled. This product has a 12 hour REI and a 14-day PHI. It may be applied at the rate range of 24-32 fl.oz. per acre or 0.375 - 0.50 lbs active ingredient per acre. It is applied just prior to transplanting or at transplanting. No more than 0.5 lbs per season may be applied. Costs ranges from $109.69 – 146.25 per acre per application. This product is used to control whiteflies and aphids. Timing is critical for whitegrub control. Applications made in early June will provide excellent control for whitegrub control. Wire worm control is poor. Can be applied at post harvest renovation. Cost may be expensive for this product vs other products available. May be harmful to predatory mites.

Etoxazole (Zeal, Secure, Zoom) is an oxazoline insecticide and acaricide for control of Panonychus spp and Tetranychus spp., including hexythiazox resistant mite strains. Inhibition of molting, effective on eggs, larvae and nymphs which became labeled in late 2003. This product has a 12 hour REI and a 1-day PHI. It may be applied at the rate of 0.66 – 3.0 oz formulation per acre or 0.02 – 0.135 lbs active ingredient per acre. No more than 3 oz formulation per season or more than 1 application per season may be applied. Labeled for control of twospotted spider mite, lygus bug, spittle bug and tarnished plant bug. Higher rates are used to control spidermites and lower rates are used in combination with Danitol for control of true bugs. Cost will be approximately $45.00 per acre per application.

Bacillus thuringiensis (Dipel, Thuricide, Xentari, Biobit etc.) This product has a 4 hour REI and a 0-day PHI. It is used to control lepidopterous pests. Rates and formulations vary. Cost varies between manufacturers.

Methoxychlor (methoxychlor) is an organochlorine insecticide, uses have been suspended since 2000.

Azadirachtin (Neemix, Niblecidine) Extract from neem oil and acts as a hormonal analog which disrupts molting action. It provides control of whitfly, leafminer, and lepidopterous pests. Product is fairly expensive.

Canola oil (Neu): natural oil for control of aphids, mites, whiteflies, leaf hoppers, and plant bugs.

Products which have a Potential use:

- *Chrysoperia carnea* (Kagetaro®) is a biopesticide which controls aphids.
- Oils (Valoram® II) has contact killing and some repelling ability.
- Fenpyroximate (Fujimite®) Phenoxypyrazole insecticide controls mites including two-spotted spidermites European, read and citrus rust mite and psylla.
- *Metarhizium anisopliae* (Taerain®) a biocontrol which controls whiteflys, thrips and mites.

- Rosemary oil (Hexacide®) a natural product kills scale insects on contact may provide control on aphids and spidermites.
- Streptomyces (Virtuoso) a biocontrol product which has a broadspectrum of activity against Lepidoptera, fleas, flies, and spider mites.
- Carbofuran (Furadan) is a carbamate insecticide which was labeled for use in several states. This product can be phytotoxic to some varieties.
- Cinnamaldehyde (Cinnacure): biopesticide currently registered in other areas controls mites, downy and powdery mildews, thrips, Botrytis, leafhoppers and aphids.
- Tetradecan (Isomate BAW) is a pheromone used for beet armyworm control. It is a mating disrupter.
- Beauvaria bassiana (Mycotrol): is a pipeline record already registered which may provide control of thrips, whiteflies, beetles, leafrollers, white grubs.
- Clofentezine (Apollo SC): is a tetrazine acaricide and has potential use to control eggs of mites.

Insecticides Pending registration

- Acetamiprid (Assail): a new neonicotanoid class insecticide provides excellent whitefly control. Labeled on various vegetables and fruit.
- Acequinocly / TM 413 (KANEMITE®, PITON®) is a quininoline provides broad spectrum mite control but does not have rust mite activity. Has a long residual and is easy on beneficials.
- Chlorfenapyr (Pylonga®) is a pyrrole growth regulator controls selective leptopteran larva, mites, some aphids, thrips, scale and leafminors.
- Indoxacarb (Avant): for control of leaf rollers.
- Methoxythiozide (Intrepid) is in the MAC chemistry, provides control of several lepidopterous pests.
- Milbemectin (Koromite, Mesa) a macrocylic lactone insecticide which provides control against aphids, leafminers, thrips, leafhoppers and provides excellent control against mites.
- Pyridaben (Pyramite) is a pyridazinone insecticide which provides control against whiteflies, mites, aphids, mealybugs, leafhoppers, and thrips. Offers long term residual control.
- Pyriproxyfen (Knack, Distance, Esteem) a Pyridine insecticide or growth regulator selective for juvenile hormone analog. Controls scales, whiteflies, thrips, pear psylla, codling moth and ants. Non toxic to humans or wildlife.
- Methyl iodide / iodomethane with 2% chloropicrin (MIDAS®), a new fumigant alternative for methyl bromide in strawberries with a chemistry family of alkyl halide. Has a 7 day plant back with a 36 hour REI. It is a soil fumigant for the control of soil borne diseases, weed seeds, nematodes and insects. Testing since 1999 has demonstrated control of soil pests and disease equivalent to methyl bromide with the following value added benefits: MIDAS offers efficacious control at reduced rates per acre (100 - 235 lbs/ treated acre) and may be applied using conventional equipment (shank - flat/raised bed or drip fumigated). When injected into the soil, it distributes itself through the soil profile bringing control of target pests in a variety of soil types and conditions. Its slower transition from a liquid to a gas compared to methyl bromide creates a longer concentration over time and less pounds per acre for equivalent control.

MIDAS offers enhanced worker safety and environmental safety. US EPA has accepted the MIDAS ozone depletion potential of less than (0.002). MIDAS presents no threat to ground water. MIDAS is expected to receive US EPA registration in advance of the 2005 phase out of methyl bromide. Midas is manufactured by Arvesta Corporation (formerly Tomen Agro, Inc.), San Francisco, CA 94105.

- Buprofezin (Applaud 70WP) is an insect growth regulator currently labeled on several vegetables. It controls leaf hoppers, plant hoppers, whiteflies and is safe to bees.
- Spirodiclofen (BAJ 2740, Envidor, Daniemon) is a Spirocyclic phenyl substituted tetronic acid effective against all important whitefly and mite species as a contact product. Juvenile mite stages are more susceptible than adults. Use is pending EPA's review.
- Thiomethoxam (Platinum, Actara, Adage, Centric): is a second generation neonicotinoid chemistry systemic root uptake and transport in the xylem which has broad spectrum activity against soil dwelling pests, sucking pests, and some chewing pests. Effective against aphids, whiteflies, thrips, leafhoppers, and certain beetles. This is an OP alternative.

Table 2, Alternative pest control techniques used in strawberry production.

	ROTATION	RENOVATION	Annual production system	SCOUTING	SANITATION	Weed control	CULTIVATION	Overhead irrigation	Predators and parasites	Avoid planting near alfalfa
Strawberry crown borer	x			x	x					
Strawberry leaf roller		x	x	x					x	
Strawberry root worm			x							
Strawberry clipper	x		x		x		x		x	
Catfacing insects						x				
Whitefringed beetle		x	x			x				
Spittle bugs						x				
Aphids						x	x			
Spidermites				x				x		
Cyclamen mites				x				x		
Sap beetles					x					
Flea beetles	x		x							
Root weevils	x		x							
Potato leaf hopper										x
Black vine weevil	x									
White grubs	x		x							
White flies				x						
Slugs					x					

Sanitation = using plants free of infestation, cleaning trash from field, remove fallen fruit
Weed control = weed control within the row, in row middles, and/or areas bordering the field

WEEDS

Weeds are normally categorized as broadleaves, grasses or sedges. These categories may be further broken down into sub-categories for the length of their life cycle, such as annual (one year), biennial (two years) and perennial (three or more years). There are several weeds that constantly cause problems in strawberry production. Yellow nutsedge is one weed that can be a severe problem if adequate moisture is available to the weed. This pesky weed may penetrate plastic mulches which allows loss of moisture and may allow entry of various diseases. Other weeds commonly observed in strawberry production include, common chickweed, henbit, dead nettle, sheperdspurse, and vetch. Summer annuals that are often observed include marestail, mayweed and various pigweeds.

In plasticulture, fumigation used in raised beds aids in reducing populations of various weed species as well as the application of preemergent herbicides used in both production systems. Post emergent herbicides are generally applied to target weeds after they have emerged. Post directed herbicide are normally applied to row middles to reduce weed populations between rows. The herbicides most commonly used in strawberry production include methyl bromide, clethodim, paraquat, devrinol, roundup, sinbar and sethoxydim. Effective replacements are needed for the loss of methyl bromide.

Cultural control

Rotation will aid in controlling many types of weed species. Removing weeds by hand and hoeing are common in strawberry production. These methods can be a great time expense and if hired out, may increase labor costs, if weed populations are great. Cultivation between rows provides good control of weeds in row middles; however it can promote erosion. Many growers do maintain row middles by planting annual ryegrass in these areas. Mowing field edges in the fall and spring helps prevent movement of weeds into the field.

Yellow nutsedge (*Cyperus esculentus*)

Yellow nutsedge is a sedge which reproduces by seed, rhizomes and tubers. The rhizomes radiate from the plant with a single bulb or tuber, the end of which may produce new plants. This plant tolerates high soil moisture and is intolerant of shade. However, this is a major pest and may penetrate plastic coverings allowing escape of moisture and provides entry for other pests.

Chemical control:

- Glyphosate (Roundup): provides fair control, if applied several weeks prior to transplant.

Non-chemical controls:

- Site selection is one way to reduce problems from yellow nutsedge.
- Yellow nutsedge prefers wet low areas in the field. Avoid these areas to reduce the need for use of products for their control.
- Rotation

"**TO DO**s" for yellow nutsedge

Research:

- More effective controls

Regulatory:

- Speed registration on S-metolachlor and terbacil.

Education:

- None at this time

Common Chickweed (Stellaria media)

Common chickweed is a prostrate, winter annual that is found throughout Tennessee. It has a shallow, fibrous root system and produces numerous seeds. Common chickweed is often observed in turfgrass, lawns and winter small grains.

Shepherdspurse (*Capsella bursa pastoris*)

Shepherdspurse is a winter annual up to 18 inches in height. It reproduces by seed and one plant is capable of producing thousands of small seeds. Preventing seed production is an obvious control. One of the first plants to appear in the spring, shepherdspurse can grow slowly in the rosette stage during the cooler months. Seed stalks appear when the temperatures warm. Because shepherdspurse is in the mustard family, it resists trifluralin and most of the herbicides registered for broccoli, cabbage, and cauliflower.

Chemical control:

- Oxyflourfen (Goal, Galigan) is a diphenyl ether herbicide, has a 24 hour REI. Provides good control.
- Glyphosate (Roundup): applied prior to transplant may provide some control in following season. Product is safe to use.

Cultural Control methods:

- Stale seedbed treatments can help prepare the beds, water to encourage the weed seeds to germinate, and then kill by shallow tillage, or herbicide application. Then plant the crop.
- Rotating to a cool season crop other than strawberries or one of the cole crops should be included as part of an integrated approach to managing shepherdspurse.

Non-labeled products:

- Simazine (Princep) is a triazine herbicide has a 12 hour REI.

Marestail, horseweed, horsetail (*Equisetum arvensae* Fam *equisetaceae*)

Horseweed (marestail) is an annual weed that often becomes a problem in continuous no-till fields, although it has also been a problem in some tilled fields in recent years. Horseweed can follow a winter annual or summer annual life cycle. While the majority of the horseweed emerges in the fall, it can also emerge in spring and early summer. Horseweed does not mature until late summer, so unlike many other winter annuals that mature in late spring, horseweed competes directly with other crops' growth during the growing season and interferes with harvest also. It is usually not a problem in plasticulture production systems.

Horseweed is more easily controlled when it is small in the late fall or early spring. As the horseweed becomes larger in the spring and early summer, it becomes more difficult to control. Horseweed should be prevented from producing seed in the summer/fall after harvest with herbicide applications in fields to be replanted or cultivation in late July or early August.

Chemical control:

- Many populations of horseweed in West Tennessee appear to be resistant to glyphosate and herbicides with this site of action will be ineffective for horseweed control. Producers should assume most horseweed populations are resistant, so use of an effective postemergence option and rotation should be considered.
- The most effective and economical treatments are 2,4D ester (0.5 to 1.0 lb ai/A), or a combination of 2,4-D ester plus glyphosate (0.56 to 1.125 lb ae/A). Application of 2,4-D alone in the in the fall will greatly reduce horseweed populations the following spring. When applied in early spring to small (less than 2 inches) horseweed, 2,4-D ester (1.0 lb ai/A) is usually effective.
- Combinations of glyphosate plus 2,4-D ester should be used on larger horseweed.

Hairy vetch or winter vetch and **common vetch** (*Vicia villosa, V. sativa*)

Many fields are rotated with leguminous plants to replenish the soil with nutrients, such as increasing nitrogen levels. Vetchs have hard sees that germinate over long periods in the spring or fall. In plasticulture, seeds may germinate under plastic and the plant eventually finds its way to tears or openings within the plastic liner. In production meetings growers are advised not to plant in vetch infested fields due to the persistence of this weed in strawberry production.

Chemical control:

- Glyphosate (Roundup): fair control, if applied in fall prior to transplant. May not be sprayed over the top.
- 2,4-D (2,4-D): use has been 6 plus weeks prior to planting.

Non-chemical pest management tools:

- Rotation
- Frequent cultivation over a number of weeks, prior to transplant

"**TO DO**s" for vetch control:

Research

- Find additional products with long residual to control this pest

Extension

- Stress the importance of avoiding infested areas

Mayweed (*Anthemis cotula*)

Mayweed chamomile, often called dog fennel, is an annual bushy plant that germinates in early spring. It is adaptable to many growing conditions. The mature plant is 6 inches to 3 feet (15 - 90 cm) tall. Mayweed's flower have odor that may not be pleasant. The majority of seeds are produced through spring and summer, although as the plant may grow at any time of the year, seed production occurs throughout the year. It germinates mainly in Autumn and Spring but it can germinate any time in the year if there is plenty of moisture.

Pigweed (*Amaranthus* species)

There are various pigweeds that are observed in strawberry production, these include: redroot pigweed (*A. retroflexus*), prostrate pigweed (*A. blitoides*), smooth pigweed (*A. hybridus*), green pigweed (*A. palmerii*), spiny pigweed (*A. spinosus*), tumble pigweed (*A. albus*). Pigweeds are summer annual weeds that reproduce by seed. Each plant may be capable of producing

thousands of seed normally produced late in the summer through the fall. Germination usually occurs in spring to early summer. Some species contain thorns on the stems.

Chemical control:

- Simazine (Princep): Provides good control
- Glyphosate (Roundup): Provides fair control and relatively inexpensive. Must not drift on crop.

Non-chemical pest management tools:

- Rotation
- Cultivation prior to transplant in fall

Henbit (*Lamium amplexicaule*)

This member of the Mint family often appears as a garden weed. The 1/2- 2/3 inch (1.3-1.6 cm) long flowers circle the square stem in the axils of the upper leaves. Henbit is common in fields and along roadsides. Its flowers bloom in March to April. This weed is often confused with red or purple deadnettle.

Chemical control:

- Terbacil (Sinbar): is moderately expensive and difficult to find. Has a long residual and may persist. Should not be applied within 2 years of a prior treatment.
- Napropamide (Devrinol): provides poor control of henbit. Fairly expensive.

Non-chemical control:

- Rotation

"**TO DO**s" for henbit control:

Research:

- More alternatives are needed for henbit control.
- Investigate any biocontrol agent

Education:

- Proper identification of this pest

Herbicides

Weed control is essential in both types of strawberry production systems. Weeds compete for sunlight, moisture and nutrients which are essential to developing strawberry plants. Weeds also may provide an environment suitable for many insects and disease causing organisms. Environments conducive for pest development, generally means greater populations of pests and in return more damage to the crop. Both annual and perennial weeds are observed in strawberry production. Weeds may be spread by the movement of seeds, rhizomes, underground nutlets and stolons. Table 4, lists various weeds and the months they are most often observed.

Herbicide rates are provided as rates used for broadcast applications. Reduced rates are commonly used since growers often treat as a banded application. In many instances row middles may be spot sprayed to reduce chemical costs.

Clethodim (Select 2E) is a postemergent herbicide and is used for established grass weeds. This product has a 24 hour REI and a 4-day PHI. It is applied at rates ranging from 6-8 fl.oz. formulation or 0.09375 – 0.125 lbs active ingredient per acre per application. Cost ranges from $8.55 – 11.40 per acre per application. Select is used for the control of annual and perennial grasses, including bermudagrass and rhizome johnsongrass. A crop-oil concentrate is used at 1% v/v in the finished spray volume. Do not apply more than 8 fl. oz. product/A per application.

Napropamide (Devrinol 2E, 10G, 50WP) is applied at post-transplant or when plants become established at the rate of 2-4 lbs active ingredient per acre. Cost ranges from $43.75 – 87.50 per acre. Used to control annual grasses and annual broadleaf weeds. Controls bromes, wild barley, cupgrass, annual bluegrass, crabgrass, barnyardgrass, prickley lettuce, filaree, groundsel, chickweed, fiddleneck, knotweed, lambsquarters, malva, pigweed, purslane, sowthistle and many others. This product should not be applied during active runnering and daughter plant establishment. No more than one application per year. Applications are normally made in early to mid-October. No applications made from bloom to harvest. This product does not control established weeds. This product is only active in the soil and is activated by incorporation by rainfall or irrigation.

Terbacil (Sinbar) provides preemergence control of several grass and broadleaf weeds and provides extended residual control. Can be applied broadcast over the crop and the row middles. Make an initial application no earlier than 6 months after planting, or after postharvest renovation before new growth begins. Application can also be made in late fall for additional control of winter annual weeds. For best control of emerged weeds, weeds should be 1 inch in height or diameter when treated. Do not apply more than 8 oz. per acre per growing season. Planting must be established for at least 6 months. Has the potential to cause some level of injury. Do not apply to soils with less than 2% organic matter. Applied at the rate range of 0.1 - 0.3 lbs active ingredient per acre at a cost ranging from $3.13 – 9.40 per acre. This product is difficult to obtain from retailers. It is available in 5 lb bags at the cost of $ 25 per pound. Terbacil (Sinbar) is very effective, however some varieties are sensitive to this product. PHI is 110 days. Only one application allowed each year. Provides good to excellent control of yellow nutsedge, quackgrass, plantains, sheep sorrel, barnyard grass, foxtails, fall panicum, brome grass and crabgrass.

2,4-D Amine (Amine 4EC) Applied at the rate of 1.0 – 1.5 lbs active ingredient per acre. Cost ranges from $3.57 – 5.36 per application per acre. Provides postemergence control of certain established broadleaf weeds. Apply to well established plantings after harvest or at renovation before mowing or this product can be applied when the crop is dormant. Timing is critical to avoid damage (do not apply during bud, flower or fruiting stages). Amine formulations of 2,4-D are used. Formulations other than amine can damage the crop. P align=center>Fluasifop (Fusilade DX-2EC) has a 12 hour REI and applied to non-bearing plants only. Applied at the rate of 0.25 – 0.375 lbs active ingredient per acre. Cost ranges from $16.88 – 25.31 per application per acre. Repeat applications may be necessary for re-growth of perennial grasses. For post emergence control of annual and perennial grasses. A low rate may be used for annual grasses before they exceed 4 inches tall. May cause crop injury if mixed with other products especially with Sinbar. Crop oils (1pint / 25 gallons) are normally mixed with Fusilade for added control. Should not be applied within 1 year of the first harvest.

Sethoxydim (Poast 1.5) has a 12 hour REI and a 7-day PHI. It is applied at the rate of 2.5 pints or active ingredient 0.46875 lbs per acre. Cost for this product per acre is $21.53. No more than one application per season is allowed.

Paraquat (Gramoxone 2.5, 3) applied as a post-directed spray. It has a 24 hour REI and a 21-day PHI. This product is a restricted use pesticide. It is applied at the rate of 1.5 or 1.3 pints depending on formulation or 0.46875 lbs active ingredient per application per acre. Cost of $7.50 per application per acre. No more than 3 applications per season are allowed.

Oxyfluorfen (Goal, Galigan) applied on a fallow bed prior to transplanting at the rate of 0.25 - 0.5 lbs active ingredient per acre. Cost ranges from $12 – 24 per acre. Must have a 30-day treatment to planting interval. Mulch may be put down any time during this period. Apply as a preemergence broadcast or banded treatment to pre-formed beds as a fallow bed application. This product is used to control Carolina geranium, cutleaf evening primrose, red sorrel, thistles, various species of clover, mustard, henbit, and woodsorrel.

DCPA (Dacthal W-75) has a 12 hour REI and must be applied before bloom. Applied at the rate of 12 lbs formulation or 9 lbs active ingredient per acre per application. Usually applied at transplanting and as long as 6 weeks after. Cost ranges from $120 – 144 per acre. This product is fairly expensive.

Glyphosate (Roundup 4L) has a 12 hour REI and a 30-day PHI. Several formulations are available and may have shorter REIs. It is applied at the rate of 1 quart formulation or 1 lb active ingredient per acre per application. It is normally applied to row middles using a shielded sprayer. No more than 5.3 quarts per acre per year may be applied. Generally this product is not applied in the fall. Applications cost is usually $13.00 per acre per application.

Fluazifop-P-butyl (Fusilade II) may be used on non-bearing strawberries only for grass control. Has a 365-day PHI.

Alternative Herbicides:

- Pelargonic Acid (Scythe) is a fatty acid contact, non-selective herbicide with broad spectrum activity. Material is foliar applied. It is applied at preplant directed-shielded application at the rate of 3-10% v/v active ingredient. This product is a contact, nonselective, foliar herbicide. It has no residual control and may be tank mixed with soil residual herbicides.

Non-Registered products:

- Simazine (Princep) is not labeled in Tennessee, only in western states.

- Carfentrazone-ethyl (Aim) may be labeled in the near future for row middles in plasticulture. Is a non-selective herbicide.

- Aciflorafen (Blazer) was previously assigned as a B2 carcinogen however this is no longer in affect.

- Pendimethalin (Prowl): inhibits germination of several weed species. Manufacturer may not support use of this product in strawberry production.

- S-metolachlor (Dual Magnum): Provides effective control against yellow nutsedge.

Herbicides Pending registration

- Clopyralid (Stinger®, Lontrel) Pyridone herbicide pending use in strawberry. Broad spectrum broadleaf weed herbicide. Tennessee may obtain a 24C at a later date.
- Flumioxazin (Valor® 50WD) N-phenylphthalimide derivative (PPO inhibitor). A new low rate use pre-emergence broadleaf herbicide with contact and residual soil activity. It may be labeled in the near future for use in row middles of plasticulture or as a broadcast in matted-row systems.
- Sulfentrazone (Authority®, Spartan®) is an aryl triazinone a PPO inhibitor controls both broadleaf and grass species. Provides control of buttercup, groundcherry, Amaranth, nightshade, spurge, lambsquarter, carpetweed and many others.
- Thiazopyr (Visor®) pyridine herbicide for control of annual and perennial broadleaf weeds, including crabgrass and nutsedge.
- Triflusulfuron-methyl (Upbeet®) a sulfonylurea herbicide (ALS inhibitor) for control of broadleaf weeds.
- Prohexadione calcium (Apogee®) calcium carboxylate is a plant growth regulator that reduces vegetative growth.

"**TO DO**s" in Weed Control:

Research

- Post emergent control of clover and broadleaf weeds in a matted row production system.
- Effective controls are needed for vetch, wild onions, sedges and butter cup.

Regulatory

- Fast track registration for clopyralid, flumioxazin, sulfentrazone, thiazopyr triflusulfuron-methyl, S-metolachlor and prohexadione calcium.

Extension

- Proper identification of weeds.
- Stress importance of rotation

Table 3, Efficacy of herbicides used in strawberry production.

	DACTHAL	DEVRINOL	GOAL	PRINCEP	PROWL	SINBAR	FUSILADE	POAST	SELECT	2,4-D
Barnyardgrass	F	G	E	E	E	G	G	G	G	N
Crabgrass	G	E	E	G	E	G	E	E	E	N
Fall panicum	P	G	F	G	E	E	E	E	E	N
Foxtails	F	G	E	G	E	G	G	E	E	N
Goosegrass	G	E	E	G	E	G	G	E	E	N
Johnsongrass (seedling)	N	P	F	P	E	G	E	E	E	N
Broadleaf signalgrass	N	G	F	P	E	G	G	G	G	N
Bermudagrass		P	P	P	P	F	G	F	G	N
Dalligrass		F	P	P	P	-	G	G	G	N
Fescue (Tall)	N	F	P	F	P	-	E	G	E	N
Johnsongrass (Rhizome)	N	P	P	P	P	P	F	G	E	N
Yellow nutsedge	N	P	P	P	N	F	N	N	N	F
Sheperdspurse	P									
Nightshades	G	P	E	G	P	G	N	N	N	E
Chickweed, common	E	E	E	E	G	G	N	N	N	G
Henbit	P									E
Wild garlic / onions	N	N	P	P	N	G	N	N	N	G
Wild mustard	N	F	G	G	N	P	N	N	N	F

N = no activity, P=poor, F= fair, G=good, E=excellent

Princep® is currently registered for strawberry production in OR and WA only.

Table 4, Weeds and month(s) most often observed

Weed	Month											
	Jan	Feb	March	April	May	June	July	Aug	Sept	Oct	Nov	Dec
Barnyard grass					-	-	-	-	-	-		
Crabgrass					-	-	-	-	-	-		
Fall panicum						-	-	-	-	-		
Foxtails					-	-	-	-	-	-		
Goosegrass					-	-	-	-	-	-		
Johnsongrass (seedling)					-	-	-	-	-	-		
Johnsongrass (rhizome)				-	-	-	-	-	-	-		
Signalgrass					-	-	-	-	-	-		
Bermudagrass					-	-	-	-	-	-		
Dallisgrass							-	-	-	-		
Fescue, Tall			-	-	-	-	-	-	-	-	-	
Nutsedge, yellow					-	-	-	-	-	-		
Nightshades					-	-	-	-	-	-		
Chickweed, common	-	-	-	-	-						-	-
Cocklebur					-	-	-	-	-	-		
Galinsoga				-	-	-	-	-	-	-		
Horseweed			-	-	-	-	-	-	-	-	-	
Jimsonweed					-	-	-	-	-	-		
Lambsquarter				-	-	-	-	-	-	-		
Morning glories					-	-	-	-	-	-		
Pigweeds					-	-	-	-	-	-		
Pickly sida					-	-	-	-	-	-		
Primrose, evening	-	-	-	-					-	-	-	-
Smartweed				-	-	-	-	-	-	-		
Ragweed, common				-	-	-	-	-	-	-		
Wild mustards	-	-	-	-	-			-	-	-	-	-
Dogfennel					-	-	-	-	-	-		
Wild garlic, onion	-	-	-	-	-	-	-	-	-	-	-	-
Horsenettle					-	-	-	-	-	-		
Musk thistle					-	-	-	-	-	-		
Plantains					-	-	-	-	-	-		

- = observed

STRAWBERRY DISEASES

A number of diseases affect the fruit, leaves, roots and crowns of strawberries. Reference is made to two systems of strawberry production in Tennessee. The matted-row system is a perennial system in which the plants are allowed to spread, and the planting is maintained for several years. Plasticulture is a term often used to refer to an annual system of production in which planting takes place in plastic-mulched rows in the fall, and the plants are destroyed the following summer, after harvest is completed. Table 6, lists reactions of some of the commonly selected strawberry varieties to disease.

Fruit Diseases

Diseases of the fruit are very important because they cause a direct loss of the harvested product. One of the fruit diseases, anthracnose, also affects many other parts of the strawberry plant.

Anthracnose (*Colletotrichum acutatum*)

Anthracnose is a very destructive disease that can affect almost any part of the strawberry plant. Several species of the fungus Colletotrichum can cause strawberry anthracnose, but the predominant species is *C. acutatum*. In matted-row plantings, anthracnose can cause bed-fill problems during runner production in the summer, while fruit rot can affect either type of strawberry planting.

Anthracnose fruit rot is characterized by circular, slightly sunken, tan to brown spots that usually turn black but may remain tan. Under humid conditions, the center of the spot can become covered with orange or salmon-colored spore masses. The spots enlarge until the entire berry rots and shrivels. Green berries also can be infected, producing small, hard, deformed fruit with a dark brown lesion. If warm, humid weather occurs during the bloom period, flowers and their stems may become infected, and entire flower clusters may die. Calyx (cap) infections result in dark, dry caps. On stolons (runner stems) and petioles (leaf stems), anthracnose lesions are dark, firm, sunken and dry. The lesions can quickly girdle and kill stolons and young runner plants. Small anthracnose lesions on stems can be confused with lesions of other diseases.

In infected matted-row plantings, established plants become debilitated, showing lack of growth, dead older leaves and little runner production. The root system is usually dark and decayed. The fungus can enter the crown, causing the plants to quickly wilt and die. A lengthwise cut through the crown reveals a reddish-brown, firm rot.

Anthracnose is favored by hot, rainy weather. In most years, symptoms are difficult to find prior to the harvest period. However, severe fruit rot can occur despite a lack of stem symptoms, if the weather is favorable. The fungal spores are dispersed by splashing rain. Infected transplants often serve as the source of the disease in a planting. The fungus can survive one winter in plant debris, and can also survive in alternate hosts.

Chemical controls:

- Azoxystrobin (Quadris): provides fair to good control of anthracnose, leaf blight, and powdery mildew and provides good to excellent control of common leaf spot. Provides poor control of gray mold and leather rot. Fairly expensive. Must be rotated with non-strobulin materials to reduce resistance buildup.
- Pyraclostrobin 12.8% and boscalid 25.2% (Pristine): provides good to excellent control of gray mold, common leaf spot, and powdery mildew. Provides fair to good control of anthracnose.

- Cyprodinil / Fludioxonil (Switch): This product has two active ingredients which provide fair to good control of this disease.
- Captan (Captan): provide fair to good control. Captan is an excellent general-purpose fungicide that protects against a wide range of fungi. Classified as a B2 probable human carcinogen.
- Fenhexamid 14.3% with captan 53.6% (Captevate): provides good to fair control. This product has two modes of action.
- Thiram (Thiram): provides fair control. Inhibits feeding by deer and several other vertebrate pests.
- Thiophanate-methyl (Topsin-M): provides poor control of *C. gleosporioides* and no control for *C. acutatum*

Non-chemical controls:

- Anthracnose problems can be avoided by using certified disease-free transplants and by using resistant varieties (Table 1). If a planting is known to have anthracnose, follow a weekly fungicide spray program. In most years, adequate control is obtained by beginning the spray program at or just before the beginning of harvest. To protect against the occasional early outbreak, a spray program that includes fungicides effective against both anthracnose and gray mold should be initiated at early bloom. In matted-row plantings, control of anthracnose on susceptible varieties during the summer is difficult, because of the number of sprays required.
- Do not sprinkler-irrigate infected plants, if possible.
- Non-infested fields located near infested fields can remain clean if care is taken to prevent spread.
- Pickers should never move from an infested field to a non-infested field.
- There have been reports of success in checking spread by removing plants showing anthracnose fruit rot from the field. In this method, which is practical if the disease begins in a small area, all infected plants and surrounding plants are removed and destroyed.

"**TO DO**s" for anthracnose control:

Research:

- Methods of production of transplants free of the disease

Regulatory:

Extension:

- Training of producers how to recognize disease symptoms

Gray Mold (*Botrytis cinerea*)

Gray mold, caused by the fungus *Botrytis cinerea*, is the most common strawberry fruit rot. Losses can be high if persistent wet weather occurs during bloom or the fruiting season. The fuzzy brown to gray spore masses can develop on any injured or senescent tissue, but most economic losses result from fruit rots and, sometimes, blossom blight. The fungus can also cause a crown rot. Fruit infections appear as light brown, rapidly expanding spots. They are irregular in shape, as opposed to the circular shape of anthracnose lesions. The gray mold fungus is readily airborne and commonly encountered. Winter carryover is greatest in fields in which there is a large amount of dead plant material, on which the fungus develops. Mild, wet, humid weather is most favorable for infection. Most infections of the fruit result from blossom

infections that remain latent in the developing berry, becoming active and causing a rot when the fruit ripens.

Chemical controls:

- Pyraclostrobin (Cabrio): provides poor to fair control. Should be rotated with other non-strobilurin products to reduce possible resistance. Is a product which is primarily used for gray mold control.
- Captan (Captan): Provides fair to good control. Classified as a B2 probable human carcinogen.
- Azoxystrobin (Quadris): Provides poor to fair control. This product usually is not selected as the primary product for control of this disease. Should be rotated with other non-strobilurin products and should not be applied more than two times consecutively.
- Fenhexamid 14.3% with captan 53.6% (Captivate): Provides good to excellent control.
- Pyraclostrobin 12.8% and boscalid 25.2% (Pristine): Provides good to excellent control.
- Cyprodinil / Fludioxonil (Switch): Provides good to excellent control.
- Thiram (Thiram): Provides fair to good control. Also suppresses feeding by deer and rabbits.
- Thiophanate-methyl (Topsin-M): Provides good to excellent control. Should be rotated with other materials to avoid buildup of resistance within the pest population.

NOTES: Key times for applying protective fungicide sprays are during bloom. The period between early bloom (5 to 10 percent open blooms) and late bloom (90 percent of blooms having opened) is most critical. Sprays can be continued through harvest, observing the label restrictions of the fungicides.

Non-chemical controls:

- Planting in a sunny location that provides good air movement and has good soil drainage. Mulching helps prevent contracting the fungus from the soil. Do not sprinkler irrigate, except for frost protection. Avoid applying nitrogen fertilizer in the spring, as this practice leads to soft berries and excessive leaf cover. A common practice in plasticulture systems is to remove winter-killed foliage from the field before bloom, to eliminate an important food base for the fungus. Pick fruit frequently and remove diseased fruit. Matted-row plantings should be properly renovated after harvest, narrowing the rows and removing diseased and dead plant parts. Certain varieties, such as Earliglow and Delmarvel, have resistance to gray mold.

"**TO DO**s" for gray mold control:

Research:

- Development of a breeding program for tolerant or resistant varieties.

Regulatory:

- Fast track registration on Sonata AS, Frupica, and Endura fungicides.

Extension:

- Recommending producers practice preventative control measures in fields with poor air movement and practice sanitation of winter killed foliage in plasticulture systems.

Leather rot (*Phytophtora cactorum*)

Leather rot is a fruit rot caused by *Phytophthora cactorum*. In Tennessee, losses to leather rot are slight, except where drainage is poor or plant growth is excessive. Leather rot can present a marketing problem in that some infected berries appear normal, but have a sour odor and unpleasant taste. Processing such berries can produce bitter tasting jams and jellies. Infected green berries become brown, while mature berries can be brown, lilac or dark purple. A sparse, white mold may cover the surface of the berry. Initially soft, the rotted berry later becomes tough and leathery.

Chemical control:

- **Mefenoxam** (Ridomil Gold): provides good to excellent control and provides fair to good control of crown rot. Possible resistance build up within pest population with continued use.
- **Aluminum-tris** (Aliette): provides good to excellent control.

Non-chemical control:

- Avoid overhead irrigation, since the spores are spread by splashing or wind-blown water. Avoid over-fertilization, especially in the spring, and keep matted-row plantings properly thinned.
- Mulching aids control by preventing fruit contact with the soil, and preventing splashing of the spores onto the fruit. Certain fungicides are also helpful.

"**TO DO**s" for leather rot control:

Research:

- Evaluate new chemistries to provide an arsenal of products if resistance occurs with currently used products.

Extension:

- Programs to inform how to reduce resistance within the pest population.

Leaf Diseases

Leaf diseases commonly appear on strawberry plants. The three fungal diseases and one bacterial disease discussed below can cause significant damage on susceptible varieties if environmental conditions are conducive for their development. In such cases, enough leaf tissue can be destroyed that the plant is weakened, thus causing it to be more subject to winter injury. Additionally, the organisms that cause these diseases can infect berries, calyxes or berry stems, causing quality problems or even loss of fruit.

Fungal leaf diseases are controlled by planting certified, disease-free plants in a location exposed to all-day sun; the use of resistant varieties; avoidance of overhead irrigation, except for frost protection; and proper renovation (in matted-row plantings) that includes narrowing the rows and clipping excess foliage. Fungicide spray programs may be needed. Many of the fungicides used in the spring for prevention of gray mold are also effective against the fungal leaf diseases. There may be a need for fungicidal control in matted-row plantings in the summer and fall, and in plasticulture fields in the fall. These needs may be met on an as-needed basis. Unless a highly susceptible variety is planted, adequate control can be maintained by delaying the application until disease activity is observed.

Leaf blight (*Phomopsis obscurans*)

Leaf blight is an important summertime disease because so few varieties have adequate resistance to it. Once considered to be a disease only of older or weakened leaves, leaf blight has become an important disease, aggressively attacking leaves of any age. Lesions begin as circular to elliptical, purple spots that can appear identical to those of common leaf. Young (left) and older spot or leaf scorch. The purple spots develop dark brown centers as they lesions of leaf blight. Some infected leaves display large V-shaped lesions, with the widest part at the leaf edge. If the spots become numerous, large areas of the leaf become purple or red, and the leaf may die. The fungus can also cause dark lesions on stems and berry caps. On berries, infection can cause a soft, light pink lesion that develops a tough, tan-colored center. Leaf blight prospers in hot, wet weather, usually not producing symptoms until late spring. Spores are produced in brown, speck-sized fruiting structures in lesions and are spread by splashing water to other fruit.

Chemical products used to control:

- Myclobutanil (Nova): provides good to excellent control.
- Thiophanate-methyl (Topsin-M): provides fair to good control.
- Thiram (Thiram): provides good control and repels deer and other vertebrates. Has broad spectrum of activity against other pests.
- Captan (Captan): provides good control, however is classified as a B2 probable human carcinogen. Has a broad spectrum of activity against other pests.

Non-chemical control:

- Removal of dead leaves and stems may reduce disease pressure the following year because the disease may overwinter on remaining plant parts.
- Reduce splashing during watering or rainfall.

"**TO DO**s" for leaf blight control:

Research:

- Testing of new products to determine efficacy

Regulatory:

Education:

- Stressing importance of sanitation

Common leaf spot (*Mycosphaerella fragariae*)

This disease is frequently encountered, but most of our commonly planted varieties have adequate tolerance to it. On highly susceptible varieties such as Idea, control practices are essential. Common leaf spot is characterized by small, 1/8-inch, circular leaf spots. These spots begin as purple to reddish purple lesions, developing distinctive tan to grayish white centers (Figure 12). Infections that occur on stem structures are similar to those on the leaves. The fungus can cause a black seed condition on the berries, and the tissue immediately surrounding a seed may become black. Common leaf spot is more prevalent in cool, wet weather. Some spread can even be expected during mild periods of winter, especially under straw bed covers. Outbreaks are most severe in spring and fall. The fungus overwinters on infected leaves that survive the winter.

Leaf scorch, caused by the fungus Diplocarpon earliana, is not as common in Tennessee as leaf blight or common leaf spot. Many of our varieties have adequate tolerance to leaf scorch under Tennessee conditions. Leaf scorch symptoms are very similar to the early stages of leaf blight or common leaf spot. Leaf spots are up to 1/4-inch in diameter and purple to red (Figure 13).

The centers may become brown, but not white or gray as with common leaf spot. As with Phomopsis leaf blight, considerable scorching can occur, i.e., blighting and death of leaves. Reddish lesions may form on stem structures or calyxes. Leaf scorch can be active during spring, summer or fall. Spores produced in lesions are spread mainly by splashing water. The fungus overwinters on infected leaves that survive the winter.

Chemical control:

- Pyraclostrobin (Cabrio): is a strobilurin fungicide which provides good to excellent control.
- Myclobutanil (Nova): is a conazole fungicide which provides good to excellent control.
- Azoxystrobin (Quadris): is a strobilurin fungicide which provides good to excellent control.
- Pyraclostrobin 12.8% and boscalid 25.2% (Pristine): has multiple active ingredients which should provide better control. It is classified as a strobilurin and anilide fungicide
- Thiram (Thiram): has a broad spectrum of activity against several fungi. Is a dithiocarbamate fungicide.
- Thiophanate-methyl (Topsin-M): is a benzimidazole precursor or carbamate fungicide which provides fair to good control.

Non-chemical control:

- Sanitation by removal of old fallen foliage

Angular leaf spot (*Xanthomonas fragariae*)

Is caused by a bacterium, which became a problem in Tennessee strawberry production in the 1990s. It is seen more often in plasticulture than in matted-row production. Leaf lesions are reddish brown and often angular in shape, delimited by leaf veins. Under certain conditions, however, the spots are less angular and may resemble leaf blight or leaf scorch. The diagnostic symptom is the presence of dark green, water-soaked lesions on the underside of the leaf. These are recent infections and are translucent when the leaves are held up to a light. Calyxes and fruit stems can be infected, reducing marketability due to dry, brown calyxes. This aspect of angular leaf spot is, perhaps, its most damaging one.

The bacterium overwinters on infected dead leaves and also enters plantings on infected transplants. Plant-to-plant movement is through splashing water and on the hands of workers. Development of angular leaf spot is favored by moderate to cool daytime temperatures, cool nighttime temperatures and high humidity. Overhead irrigation for frost control enhances the disease, since water and near-freezing temperatures favor infection.

Chemical control:

- Angular leaf spot is difficult to control with chemical sprays, so avoidance is the best means of control.
- **Fixed Copper** (various): Foliar sprays provide some control of the leaf spot phase of angular leaf spot, but have not proved satisfactory for control of calyx infections. Repeated use of copper can cause phytotoxicity.

Non-chemical control:

- Disease-free planting stock is key, but this disease can be present in symptomless plants.
- Avoid overhead irrigation, except for frost protection. Infested fields should not be worked when plants are wet, and work healthy fields first to avoid spread.

Non-registered products:

- Benzothiadiazole (Actigard): turns on the immune system of plants. Less opportunity for pathogen to overcome resistance. Research is needed to determine if this product will work in strawberry production.

"**TO DO**s" for angular leaf spot control:

Research:

- Review efficacy and phytotoxicity of Actigard.
- Evaluate phytotoxicity of varieties to foliar copper applications.

Regulatory:

- Speed registration of any new product that has efficacy towards this pest.

Education:

- Stress the importance of repeated use of copper products to avoid phytotoxicity.

FUNGICIDES

Table 5, lists the effectiveness of fungicides commonly used for control of strawberry diseases.

Registered

- Azoxystrobin (Heritage, Abound, Quadris) has a 0-day PHI and a 4 hour REI. It is a strobilurin fungicide which has broad spectrum of activity against Cladosporium, Venturia, Alternaria, Rhizoctonia, Pythium, Erysiphe, Sphaerotheca and many others. Provides excellent control, should be used in a rotation with non strobilurin fungicides. Possible resistance buildup within pest population with continual use.
- Cinnamaldehyde (Cinnacure, Cinnamite): has a 0-day PHI and a 4 hour REI. This is a natural product used to control downy and powdery mildews, botrytis, aphids and mites. Efficacy unknown.
- Copper octanoate (Neu 1140F): hasa 0-day PHI and a 48 hour REI. Copper octanoate used to control powdery and downy mildews and anthracnose. Provides fair to good control when used in a rotation scheme.
- Cyprodinil / Fludioxonil (Switch): has a 0-day PHI and a 12 hour REI. This product is a mixture of an anlinopyrimidine and phenylpyrrole class fungicides which controls Botrytis, Alternaria and other fungi. Provides excellent control. No more than 56 oz per acre per year should be applied. No other crop should be planted for 12 months after application unless listed on the product label. Contains 375g/kg cyprodinil and 250g/kg of fludioxonil.
- Fostyl aluminum / aluminum tris (Aliette): Red steele (*Phythophthora fragariae*) and leather rot (*P. cactorum*) control. Should not exceed 30 lbs per acre per season. Not to be applied with fixed wing or rotary aircraft. Has a 12 hour PHI and a 12 hour REI. Should not be mixed with copper compounds due to phytotoxicity. I copper is used pH of spray solution should be raised to pH of 6.0.
- Benomyl (Benlate): is a benzimidazole fungicide which has a 1-day PHI and a 24 hour REI. Benlate can not be used in a U-Pick operation. No more than 5 lbs per acre per year may be applied. Should be alternated with non-benzimidazole fungicides. Product has been cancelled as of 2002, use was limited to stocks on-hand.

- Pyraclostrobin (Cabrio): 0-day PHI and a 12 hour REI. Used to control anthracnose, leaf spot and powdery mildew. No more than two sequential applications should be made to reduce chances of resistance within the population. Up to five applications per season. May provide some suppression of gray mold (*Botrytis cinerea*).
- Captan (Captan 50WP): has a 0-day PHI and a 24 hour REI. No more than 24 lbs active ingredient per acre per year may be applied. Provides fair control of gray mold and common leaf spot. Classified as a B2 probable human carcinogen.
- Fenhexamid 14.3% with captan 53.6% (Captivate 68 WDG): for control of gray mold and anthracnose. Has Danger as the signal word. Has a 24 hour REI and a 0-day PHI. No more than 21 lbs formulation per acre per season should be applied.
- Fenhexamid (Elevate 50): 1-day PHI. No more than 4 applications per season may be made and has caution as the signal word on the label. More than 2 sequential sprays should be avoided. Use for control of gray mold.
- Copper (various fixed coppers): has a 0-day PHI and a 48 hour REI. May cause leaf burn as well as burn of berries if applied during hot weather when fruit is developing.
- Myclobutanil (Nova): has a 0-day PHI and a 24 hour REI. No more than 30 oz per acre per year may be applied. Provides good control of powdery mildew, common leaf spot and leaf blight.
- Triflumizole (Procure): has a 1-day PHI and a 12 hour REI. Used for control of powdery mildew and provides good to excellent control.
- Pyraclostrobin 12.8% and boscalid 25.2% (Pristine®): contains 1.024 lbs pyraclostrobin and 2.0224 lbs active ingredient of boscalid per gallon of formulation. This product has caution on the label has a 0-day PHI and maximum number of applications of 5 per season with no more than 115 oz. per acre per season. Used to control botrytis, common leaf spot and powdery mildew. Possible resistance buildup within pest population with continued use.
- Mefenoxam (Ridomil Gold): has a 0-day PHI and a 12 hour REI. No more than 1.5 quarts formulation per acre may be applied. Used to control leather rot and red steel. This product is an acylalanine fungicide.
- Iprodione (Rovral): has a 24 hour REI. This product should not be applied after first flower and no more than one application per year may be applied.
- Thiram (Thiram): has a 3-day PHI and a 24 hour REI. It is used as a fungicide and as a repellent for rabbits and deer. Provides fair to good control of common leaf spot and gray mold. Provides poor to fair control of anthracnose, leaf blight and leather rot.
- Thiophanate methyl (Topsin M): is a benimidazole fungicide which has a 1-day PHI and a 12 hour REI. No more than 5 lbs per acre per year may be applied. Should not be applied with benomyl or benimidazole fungicides.
- Sulfur (Sulfur): has a 0-day PHI and a 24 hour REI. Some varieties are sensitive to the product. Provides poor control of powdery mildew and common leaf spot.
- Chitosan (Elexa 4): for control of downy and powdery mildew, and Botrytis. This product is a reduced risk pesticide.
- *Gliocladium catenulatum* J1446 (Primastop): is a biopesticide which is used to control damping-off, stem and seed root rot.
- *Trichoderma harzianum* T-30 / T-22 (Trichodex / Rootshield): is a biopesticide which controls botrytis.

Products Pending registration

- *Ampelomyces quisqualis* isolate 10 (AQ 10): a biocontrol for powdery mildew.
- *Bacillus pumilus* strain 2808 (Sonata AS): a biocontrol for Botrytis, downy and powdery mildews, rusts, Sclerotinia blight and rots.
- *Bacillus subtilus* strain GB03: a biocontrol for control of various diseases.
- *Candida saitoana* (Biocure) a biocontrol used as a post-harvest preventative product.
- Quinoxyfen (Quintec, Legend): is a quinoline fungicide which disrupts early cell signaling activities. Should provide good to excellent control of powdery mildew (*Sphaerotheca macularis*).
- Famoxadone (Famozate, Equation, Contact): it is a oxazolidinedione fungicide which has broad spectrum activity for downy mildew and other fungi.
- Mepanipyrim (Frupica) is an anilinopyrimidine fungicide which control botrytis.
- Extract of Knot weed (Milsana) induces phytoalexins which infer resistance to powdery mildew and other diseases such as botrytis.
- Nicobifen (BAS 510, Honor, Endura): is a nicotanamide fungicide which manages powdery mildew, botrytis, and several other diseases.
- Phosphonic acid (Foli-R-Fos, Agri-Fos) controls downy mildew and root rot.
- Phosphorous acid (Phostrol, Fosphite) controls Phytophthora, Pythium and downy mildew.
- Pyrimethanil (Scala): is an anilinopyrimidine fungicide which controls botrytis, alternaria and other fungi. It is safe to birds and bees.

Potential Control Products:

- *Bacillus subtilis* strain QST 713 (Serenade, Rhapsody) a biocontrol which has some SAR activity and controls Botrytis, powdery and downy mildews and other fungi.
- *Canadida oleophila* a biocontrol used to control post harvest diseases
- Fluazinam (Omega) would provide some disease control however is a skin sensitizer.
- Simeconazole (Sanlit, Mongarit): has a triazole chemistry and is effective against basidiomycetes.

Table 5. Effectiveness of Fungicides for Control of Strawberry Diseases.

		Anthracnose[a]							
Product	Angular leaf spot	C. acutatum	C. gloeo sp.	Gray mold	Phomopsis	Common Leaf spot	Leather rot	Crown rot	Powdery mildew
Aliette	0	0	0	0	0	0	+++	?	0
Cabrio	0	++	++	+	?	+++	+	0	++
Captan	0	+	+	++	+	++	+	0	0
Captevate	0	+	+	+++	+	++	+	0	0
Copper	+	0	0	0	0	+	+	0	0
Elevate	0	0	0	+++[b]	0	0	0	0	0
Nova	0	0	0	0	+++	+++	0	0	+++
Quadris	0	++	++	+	++	+++	+	0	++
Pristine	0	++	++	+++	?	+++	?	0	+++
Procure	0	0	0	0	?	?	0	0	+++
Ridomil	0	0	0	0	0	0	+++	++	0
Switch	0	++	?	+++	?	0	0	0	0
Sulfur	+	0	0	0	+	+	0	0	+
Thiram	0	+	+	++	+	++	+	0	0
Topsin-M	0	0	+	+++[b]	++	++	0	0	+

+++ = highly effective, ++ = moderately effective, + = somewhat effective., 0 = not effective.

Ratings reflect on use of these materials on a regular preventative schedule prior to the onset of disease.

[a] = Colletotrichum acutatum and C. gloeosporioides. C. acutatum normally infects any part of the plant and C. gloeosporioides infects the crown.

[b] = Botrytis can develop resistance if fungicide applications are not made correctly.

Table 6. Disease Reactions of Selected Strawberry Varieties.

Variety	Leaf Spot	Leaf Scorch	Leaf Blight	Anthracnose	Red Stele	Verticillium Wilt
Allstar	R	M	S	S	R	R
Cardinal	R	M	--	S	S	S
Chandler	M	--	S	S	S	--
Delmarvel	R	R	M	R	R	R
Earliglow	M	R	S	S	R	R
Idea	S	--	M	R	--	--
Latestar	M	R	--	--	R	R
Primetime	R	R	--	--	R	R
Redchief	M	M	S	S	R	R
Sweet Charlie	M	--	S	R	--	--

R = moderately resistant to highly resistant; M = moderately resistant to moderately susceptible; S = moderately susceptible to highly susceptible; -- = unknown.

Table 7, Efficacy of non-chemical pest management tools for disease control

Disease	ROTATION	RENOVATION	Certified disease free plants	Avoid overhead irrigation	Sanitation	Location	Resistant Varieties	MULCHING
Anthracnose	G	G	E	E	G			
Gray mold				F	F	G	G-E	
Leather rot	G			G				F
Leaf blight				F	G			
Common leaf spot				F	G			
Angular leaf spot			E	G				
Crown rot	G		G		P	P		
Powdery mildew		G				F		
Red steele	G			G				

P = Poor, F= Fair, G = Good, E = Excellent control

Vertebrate Pest Management

Deer are attracted to nearly all species of fruit and in remote areas where greater populations of wildlife occur, greater damage occurs which has the potential to reduce yields. Deer, rabbits, terrapins and birds all may cause severe yield losses when populations are high. Severity of damage the previous year may be an indicator of potential problems the following season. Damage may prevent transplants from ever reaching their potential, so minimizing damage can be a key to success. Several methods have been recommended to reduce damage primarily by deer and are used by many producers in Tennessee.

Non-chemical controls:

- Habitat modification (removal of brushy areas near field edges)
- Allow hunting on property
- Out of season wildlife control permits
- Repellents
  NOTES: Repellents generally do not work satisfactorily in high-pressure situations.

Chemical controls:

- Ammonium soap (Hinder):
- Egg solids (Rockland Deer Guard):
- Capsaicin (Hot Sauce Animal Repellent): may cause eye irritation to user
- Thiram (Thiram, Chew-not): Also provides control of some diseases
- Thiram with acrylic polymers (Bonide Rabbit-Deer Repellent): Provides some control of diseases.

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