

# Crop Profile for Strawberries in North Carolina

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## General Production Information

- North Carolina ranked fourth in national production of fresh market strawberries.
- North Carolina produces 1.2% of the nation's fresh market strawberries in 2001.
- Production in 2001 was 1,700 acres with a cash value of 16.7 million dollars.
- Production costs on a yearly basis total \$12,000 per acre (plasticulture).
- 100% of the crop is marketed as fresh market.

## Production Regions

- Strawberries are produced throughout the state of North Carolina.

## Production Practices

- The majority of the strawberries produced in North Carolina are grown in an annual hill plasticulture system. Raised beds are formed on four to five foot centers. Black plastic mulch and drip irrigation are used. The soil is usually fumigated with methyl bromide and chloropicrin. Fields are planted in October with double rows on the raised beds (approximately 17,500 plants per acre). Strawberries are harvested the following spring. Over-head irrigation is generally needed each year to protect the flowers/fruit from frost/freeze damage. The plants are then removed after the spring harvest. Some growers will plant another crop on the raised beds to get a second use out of the black plastic and drip irrigation.
- There are several growers in the western mountain regions of North Carolina that produce strawberries in a matted row culture system. This system does not use plastic mulch or drip irrigation. The crop is generally not harvested the first year. Plantings are maintained for three to five years.

## Pest Management: General Considerations

There are many safe, practical methods of pest control used by growers, several of which are listed below. However, these methods may not always be alternatives to pesticide use. Some are preventive measures that may eliminate the necessity to spray; still others are most beneficial when used in conjunction with pesticides. Farm operations that incorporate many tactics appear to be most successful

in managing pests.

## **Resistant Varieties and Pest-Free Transplants**

This is the primary nonchemical defense against pests. Resistant varieties are those which are not colonized, repel, are unattractive to, or otherwise are unsuitable as food for certain pathogens and insects or which withstand colonization/feeding by certain pests with little reduction in yield or quality. Use of resistant varieties fits well into just about any production schedule. However, growers weigh the probable impact of a pest against the desired quality or type of produce. Currently, there are no varieties used in North Carolina that have resistance to common pest problems. ‘Sweet Charlie’ appears tolerant to anthracnose fruit ripe rot but is susceptible to the crown rot phase. Research efforts strive to achieve resistance to anthracnose, caused by *Colletotrichum* species (a priority issue), but no commercial varieties are available yet.

## **Avoidance**

Grower’s who produce their own transplants, are encouraged to raise the plants under conditions that will minimize the introduction of pests. In the greenhouse during plug growth, diseases and insects can be effectively minimized by proper management practices. Sanitation, isolation of transplants from infested areas, frequent and thorough examination of plants for initial infestations and prompt treatment will favor plant establishment and minimize pest problems. Growers who purchase plants are also encouraged to inspect them carefully for pests such as mites and aphids, and for diseases including anthracnose, *Phytophthora* crown rot, angular (bacterial) leaf spot and other less serious disorders. Many growers who use straw mulch will produce the straw on their farm or inspect grain fields prior to harvest to ensure straw will not be contaminated with high weed seed populations.

## **Good Management Practices**

Management covers a wide range of practices that are all designed to promote healthy, vigorous plant growth. Careful selection of a well-drained planting site, good soil preparation, planting transplants at proper depth when soil temperature and moisture are favorable, and properly timed harvesting are all factors considered in advance. During the growing season, attention is focused on adequate fertilization, irrigation, and pest management practices. The more vigorous the plants, the better they will be able to tolerate low-level insect damage and possibly weed and disease incidence.

## **Crop Rotation**

It is often advisable to avoid planting strawberries in the same place year after year and many North Carolina growers are able to do so. However, much of the acreage committed to strawberry production has been fitted with solid set irrigation or is proximal to easy access for Pick-you-own (PYO) customers. In such situations combined with the current efficacy of methyl bromide, rotation is not practiced.

## **Cultivation, Weed Control, and Sanitation**

These practices are interrelated. Cultivation is used in the establishment phases for matted row systems and annual strawberry systems. It is also used in the renovation phase of matted row strawberries. Cultivation is used to control weeds, to bury or destroy crop residue, or to expose soil pests to the elements. Regardless of the intended purpose, soil cultivation has the potential to disturb overwintering or oversummering sites, eliminate alternate host plants, bury residue in which pests may persist, and often outright kill soil-inhabiting pests.

Of course, weed control and sanitation can be accomplished without cultivation. Pulling weeds from plant holes in the plastic cover is not uncommon during the winter months. Sanitation also includes the removal and destruction of dead or diseased plants and tissue where practical. Some technologies have recently been developed, but not well evaluated, to remove dead host tissue and decrease disease pressure.

## **Mechanical Barriers**

The greenhouse is an obvious example of a mechanical barrier in strawberry production. Yet, even if a grower pays close attention to screening vents and other openings, some pests, especially smaller ones like mites, may gain entry. Mechanical barriers are most effective when aimed at excluding one or a few pests rather than all pests. Most plug-plants are grown in tobacco-style greenhouses that employ natural venting and dropped sidewalls that lack mechanical barriers. More recently, most growers find it more economical to root their plug-plants outside of a greenhouse structure on gravel beds covered with landscape cloth.

## **Removal/Rouging**

On a commercial scale, removal and destruction (burial) of diseased plants or alternate hosts surrounding the field is used to reduce pest problems. Growers are encouraged to explore border vegetation that may encourage beneficial insects and their relatives while minimizing pest pressure.

## **Traps**

Insect traps are used for survey, detection and management purposes, and may be useful in large scale, commercial production as indicators of potential infestations. Efficient commercially traps for diseases (e.g., spore traps) are not available for strawberries.

## **Scouting**

Scouting for pests is on the increase in commercial strawberry production. A check of fields every 2 or 3 days for insects, damaged foliage, insect eggs and frass, disease symptoms, and weed pressure keeps the grower aware of the status of pest populations. Regular scouting can give early signals of emerging

problems. For some diseases and insects such as soil pests, it is not possible to forecast outbreaks. Such pests, which are likely to recur year after year, need to be controlled routinely. In this way, damaging infestations will not have a chance to develop

## **Parasites, Predators, and Diseases**

Beneficial organisms are often natural inhabitants of production fields. Although several companies advertise the sale and shipment of insect parasites and predators, successful establishment of these organisms in new environments has been difficult. New products are also being introduced in fields or currently under evaluation and may offer biological control of mites and diseases.

## **Organic Producers**

Although the number is very low, growers who choose the "organic" method of control (no synthetic chemicals) keep in mind several factors. The primary focus in organic production systems is "plant health" management that requires a holistic approach focussing on soil quality, plant quality and timely management decisions with regard to use of crop rotation, cover crops, compost tea and other inputs.

## **Worker Activities**

Workers hand transplant fresh dug, bare-root plants ("fresh dugs") by hand or with the use of a small hand tool in the annual hill strawberry plasticulture system (the main production system in North Carolina). In recent years, strawberry plugs have become a popular alternative to fresh dugs and these are mechanically transplanted with a water wheel. Following transplanting in the fall, workers will go back into the field within 1 to 2 weeks to replace unthrifty or dead transplants. With the exception of the owner/operator, workers do not re-enter the strawberry plasticulture fields again until the end of the Post-Transplant period (Table 1) for applying winter row covers (spunbonded polyester covers used for winter protection). The next field exposure for workers occurs in the Dormant period for pulling row covers off the field and to hand remove dead leaves and runners. In the Pre-Harvest period, workers will return to the field for hand pulling branch crowns through the plastic film. At this time, workers will also hand remove any weeds that have emerged in the area of the transplant hole. Both preemergent and postemergent herbicide applications are applied in winter or early spring (row middles) with shielded, tractor mounted spray equipment. About 25% of the industry uses annual ryegrass in the middles for weed suppression, soil conservation, and later for a spring mulch during harvest. Other producers (not using annual ryegrass) keep the row middles weed-free with shielded postemergent sprays of paraquat in the late Post-Plant, Dormant and Pre-Harvest periods. After the Pre-Harvest herbicide application, a backpack sprayer may be used to control escape weeds in the row middles. There is no hand weeding once the harvest season is underway. Insecticides and fungicides are applied from early spring up to harvest primarily with drop-nozzle field type sprayers delivering 150 to 200 pounds per square inch in 50 to 100 gallons per acre. Virtually all of the strawberry acres are harvested by hand (April to May) for

direct marketing (U-pick, Ready-Pick, Farmers Markets) although a few of the larger operations harvest for the fresh market.

Table 1. Summary of operations for the annual hill strawberry plasticulture system in North Carolina.

<b>OPERATION</b>	<b>LABOR</b>	<b>MACHINERY</b>	<b>MATERIALS</b>	<b>TOTAL</b>
<b><i>LAND PREPARATION</i></b>				
Treat old crop with paraquat	14.85	20.52	7.38	42.75
Remove and dispose plastic	158.40	68.80	0.00	227.20
Disking	2.52	5.86	0.00	8.38
Liming	0.00	0.00	26.00	26.00
Planting soybeans for cover crop	24.75	89.13	39.33	153.21
<i>Total LAND PREPARATION</i>	<i>200.52</i>	<i>184.31</i>	<i>72.71</i>	<i>457.54</i>
<b><i>PRE-PLANT</i></b>				
Ordering plant material, fumigant, plastic mulch (10% dep)	5.74	0.00	219.80	225.54
Rotovating cover crop	56.04	118.02	0.00	174.06
Pull greenhouse shade cloth	4.95	0.00	187.74	192.69
Set-up misting system	9.48	0.00	0.00	9.48
Plug supplies (tips, trays, soil)	2.06	0.00	1,884.44	1,886.50
Stick runner tips for plugs	315.81	0.00	0.00	315.81
Handling trays	33.01	0.00	0.00	33.01
Subsoiling	14.85	8.15	0.00	23.00
Disking (break up soil clods)	2.52	5.86	0.00	8.38
Moisten soil media	8.25	0.00	0.00	8.25
Irrigate and fertilize plugs (20-20-20)	8.25	0.84	0.72	9.81
Spray mites w/ Vendex4L	8.25	0.17	28.00	36.42
Assembling irrigation system	99.00	2.04	0.00	101.04
Irrigating for fumigation (0.5")	0.83	7.61	0.00	8.44
Rotovating for fumigation	28.03	59.01	0.00	87.04
Preplant fertilizer (amm. nitr., potas. sulf., triple superphosph.)	7.43	10.42	48.46	66.31

Preplant fumigation (Methyl Bromide)	39.34	288.06	873.70	1,201.10
Seed annual ryegrass aisles	<u>0.84</u>	<u>0.63</u>	<u>11.00</u>	<u>12.47</u>
<i>Total PRE-PLANT</i>	<i>644.68</i>	<i>500.81</i>	<i>3,253.86</i>	<i>4,399.35</i>
<b><i>TRANS-PLANT and POST-PLANT</i></b>				
Transplant plugs and replant 2%	255.75	39.18	0.00	294.93
Irrigating plug establishment (3x)	101.48	169.53	0.00	271.01
Drip irrigation (3x2-hour applications)	4.95	30.96	0.00	35.91
Spray mites w/ Brigade (2 applications)	4.58	6.92	248.00	259.50
Tissue sample	2.06	0.00	4.00	6.06
Winterize drip system	16.50	0.00	0.00	16.50
<u>Apply floating row covers</u>	<u>50.48</u>	<u>2.04</u>	<u>1,079.00</u>	<u>1,131.52</u>
<i>Total TRANS-PLANT and POST-PLANT</i>	<i>435.80</i>	<i>248.63</i>	<i>1,331.00</i>	<i>2,015.43</i>
<b><i>DORMANT</i></b>				
Internet and weather service (annual fee)	0.00	0.00	83.88	83.88
Remove and reapply row covers	297.00	0.00	0.00	297.00
Deer control	24.75	0.00	96.25	121.00
Ordering containers, fertilizers, etc.	12.30	0.00	0.00	12.30
Remove row cover, dead foliage, mow leaves	478.50	6.30	0.00	484.80
Dormant spray (Captan)	2.29	3.46	14.00	19.75
<u>Scout for insects, mites</u>	<u>16.39</u>	<u>0.00</u>	<u>0.00</u>	<u>16.39</u>
<i>Total DORMANT</i>	<i>831.23</i>	<i>9.76</i>	<i>194.13</i>	<i>1,035.12</i>
<b><i>PRE-HARVEST</i></b>				
Pull plants through plastic	123.75	0.00	0.00	123.75

Herbicide aisles w/ Gramoxone & Crop oil conc.	2.29	3.46	10.15	15.90
Scout for insects, mites, str. weevil, ants, clipper	65.56	0.00	0.00	65.56
Spray mites w/ Brigade (2 applications)	4.58	6.92	248.00	259.50
Connect drip system	49.50	0.00	0.00	49.50
Check overhead irrigation system	8.20	0.00	0.00	8.20
Inject Ridomil Gold EC (2 applications)	32.78	27.36	210.00	270.14
Spray str. weevil w/ Losban 4EC	2.29	3.46	11.60	17.35
Tissue sample (3 applications)	6.18	0.00	12.00	18.18
Pull plants and weed	82.50	0.00	0.00	82.50
Inject fertilizer (Sul-Po-Mg, Boron, Liq.N)	16.39	13.68	169.30	199.37
Re-apply row covers for freeze	198.00	0.00	0.00	198.00
Freeze protection-OH Irrigation (4 applications)	52.44	399.98	0.00	452.42
Botrytis control w/ Captan	2.22	3.78	14.00	20.00
Polination with bees	0.00	0.00	70.00	70.00
Inject fertilizer (Sul-Po-Mg, Liq.N)	16.39	13.68	168.83	198.90
Botrytis control w/ Elevate	2.29	3.78	51.56	57.63
Inject fertilizer (Sul-Po-Mg, Cal. nitrate)	16.39	13.68	19.29	49.36
Spray mites w/ Agri-mek	2.29	3.46	83.04	88.79
Botrytis contr. w/ Elevate & powdery mildew w/ Nova	2.29	3.78	74.06	80.13
<u>Inject fertilizer (Potassium nitrate)</u>	<u>16.39</u>	<u>13.68</u>	<u>14.54</u>	<u>44.61</u>
<i>Total PRE-HARVEST</i>	<i>702.72</i>	<i>510.70</i>	<i>1,156.37</i>	<i>2,369.79</i>
<b><i>Total PRODUCTION COSTS</i></b>				<b><i>10,277.23</i></b>
<b><i>HARVEST</i></b>				
U-pick supervision	693.00	0.00	466.90	1,159.90

Harvest expense	1,534.10	0.00	0.00	1,534.10
Drip irrigation (6 applications = 18 hours)	19.68	92.88	0.00	112.56
Spray mites w/ Agri-mek	2.29	3.46	83.04	88.79
Botrytis control w/ Captan	2.29	3.78	14.00	20.07
Tissue sample	2.06	0.00	4.00	6.06
Inject fert. & drip-Pot.nitrate; Cal. nitrate (2 applications)	32.78	27.36	26.73	86.87
Evaporative cooling - OH (3 applications)	24.60	22.83	0.00	47.43
Botrytis control w/ Elevate & powd. mildew w/ Nova (x2)	4.58	3.78	148.12	156.48
<u>Disassemble irrigation system</u>	<u>49.50</u>	<u>1.03</u>	<u>0.00</u>	<u>50.53</u>
<i>Total HARVEST</i>	<i>2,364.88</i>	<i>155.12</i>	<i>742.79</i>	<i>3,262.79</i>
<b>TOTAL HARVEST AND PRODUCTION COSTS</b>				<b>13,540.02</b>

## Insects, Mites, and Mollusks

The most damaging insect/mite pest is the two-spotted spider mite. The two-spotted spider mite can be introduced on transplants or infestation can result from weeds in or around the field. This mite reproduces very quickly during warm weather. Spider mite infestation can reduce plant vigor, decrease fruit flavor, and result in reduced yields. Other insects/mites that can cause economic loss include: aphids, armyworms, crickets, cyclamen mite, cut worms, root weevils, slugs, strawberry weevil (clipper), and thrips and are not all reviewed here.

### Mites

The two-spotted mite (*Tetranychus urticae* Koch) represents one of the most important pest issues in strawberry production (Sorensen et al. 1997). The cyclamen mite (*Phytonemus pallidus*) is not a problem in North Carolina. Mites pierce the epidermis and extract sap from the undersides of leaves. Infested foliage soon assumes a whitish or bronze appearance. Lightly infested leaves have pale blotches or spots showing through the leaf; heavily infested leaves turn completely pale and dry up. The undersurfaces of leaves usually are covered with silken webs over which mites crawl. Heavily infested

plants may have webs all over them. Close examination reveals adult mites on the leaves, but the larvae initiate damage.

Twospotted spider mites overwinter in the field as females, or are brought in on plants. Females may then migrate from a heavily infested area to a lightly infested one, or may be transported by wind, mammals, or people from an infested area to a non-infested one. In warm weather, egg-laying activities increase. Each female produces up to 19 eggs per day and up to 100 eggs in all. The number of eggs laid depends largely on temperature and the eggs have an incubation period of 3 to 19 days. The mites may mature into adults in as few as 5 days or as many as 20, depending on temperature. Development is most rapid during hot, dry weather. Many generations are produced each year.

## **Control**

Early detection of mites on the undersides of leaves and full season monitoring and records, together with well-timed thorough applications of a miticide and/or the use of predacious mites constitute some effective control tactics.

## **Cultural control**

Isolation or rotation of strawberry beds 100 yards or more away from a mite-infested fields helps to prevent mites from becoming established. Destruction of broadleaf weeds around the field in fall or early spring reduces the overwintering population. During the growing season, however, this strategy will force mites to migrate into the field.

Use of mite-free plant is essential but difficult to achieve. Plugs grown in the greenhouse or nursery should be free of mites. Plugs tend to have higher populations than bare root plants. Growers are encouraged to obtain spray records from nursery and plant producers, to avoid mites developing resistance to classes of miticides.

Some cultivars, like Sweet Charlie, show some tolerance, while other cultivars, such as Selva, show a high level of susceptibility to twospotted spider mites. Chandler is somewhere in the middle.

Scouting protocols are available as follows: Inspect plants with a 10x hand lens by nursery source and lot number for mite damage and stages (eggs, nymphs, adults). Plant by source and lot number and keep detailed records of pests, diseases and crop development. In early fall, release mite predators or use a miticide as a spot treatment as needed. Continue to monitor for mites, especially on older lower leaves every 2 weeks. When hot, dry conditions prevail, leaves should be checked weekly. Sample leaves by walking a V-shaped pattern in the field and stopping at 5 to 10 locations, where the undersides of five leaves should be examined for the presence or absence of two spotted spider mites. Information should be recorded on a field map so that hot spots can be watched closely. When 25% infestation of a 60-leaf

sample occurs, chemical control may be warranted.

In January, remove older, lower leaves, and use miticides if needed. In the spring when the plants bloom and the fruiting period occurs, order and release predatory mites when 5% of the plants are infested. Once harvest is in progress, miticide application is necessary to control mite problems.

### **Biological control**

The introduction of predatory mites is encouraged in non-pesticide production fields and in other fields following a miticide program that has kept mites low or has cleaned up hot spots. Success has been achieved and protocols, including application methods, are being developed for enhanced success.

### **Chemical control**

Approximately 70 to 80% of growers will use a miticide to limit mite pressure. Growers select a suitable miticide (several provide effective control) and spot treat hot spots when and where mites are abundant or treat entire fields.

In the fall and winter, spray coverage is focussed to the undersides of leaves and to rapid growing areas during the warm periods. A second application is often used 5 to 7 days after the first.

Hexythiazox (Savey) is applied to 45% of the acreage at a rate of 3 ounces of active ingredient per acre and applied one time per season. Bifenazate (Acramite) is applied to an estimated 45% of the acreage at a rate of 0.5 pound of active ingredient per acre and an average of 2 times per season. Abamectin (Agrimek) is applied to an estimated 20% of the acreage at a rate of 0.01 pound of active ingredient per acre and an average of 2 times per season. Bifenthrin (Brigade) is used on 50% of the acreage up to 2 times per season and applied at 0.15 pound of active ingredient per acre. Fenpropathrine (Danitol) is used on 20% of strawberry acreage at a rate of 0.3 to 0.4 pound of active ingredient per acre and applied 1 time per year. Fenbutatin-oxide (Vendex) is used on 10% of the acreage 2 times per year using 0.5 pound of active ingredient per acre. Dicofol (Kelthane) is used on 30% of the acreage 3 times per year with a treatment rate of 0.7 pound of active ingredient per acre. Potassium salts are occasionally used for mite suppression on 2% of the acreage using a treatment rate of 4.18 pounds of active ingredient per acre and one application per year.

### **Products used to manage mites in North Carolina:**

<b>Product</b>	<b>TLH</b>	<b>Effect on predators and natural enemies</b>	<b>Comments</b>
Acramite	1 day	safe	good residual

Agrimek	3 days	safe	most effective, but expensive
Brigade (pyrethroid)	0 days	harmful	good activity
Danitol (pyrethroid)	2 days	harmful	broad activity
Kelthane	2 days		mites may develop resistance
Savey	3 days	safe	one application per season, excellent on eggs.
Vendex (organo-tin)	1 day	safe	mode of action is slow
Soap and pyrellin may be used in organic situations with fair results.			

**Strawberry Weevil, Strawberry Clipper, Strawberry Bud Weevil**  
(*Anthonomus signatus* Say, order Coleoptera, family Curculionidae)

The strawberry weevil adults are about 1/10 to 1/8 inch long, including the elongated head and slender snout. Antennae are mounted on either side of the snout with mouthparts at the end. In North Carolina, the weevils are found primarily on the pollen of flowers, including strawberry, blackberry, raspberry, dewberry, blueberry, grape, rose and cinquefoil.

The weevils puncture the flower buds, giving the petals a shothole appearance upon opening. Flower stalks are clipped below the buds, causing them to dangle from the plants. Infestations tend to be most prevalent in strawberry beds adjacent to woods, fencerows or similar weedy areas, which may harbor hibernating strawberry weevils. Occurrence tends to be sporadic and uncommon, varying greatly with year and location, and is believed to be due to control by natural enemies.

Overwinterized adults may emerge to feed on various flowers and leaves as early as late March when the temperatures reach the low 60's (degrees F). After moving to strawberry (or some other major host plant), the female chews small holes in the flower buds, inserts one or more eggs (spherical and glassy white) into the holes, and then girdles the bud stalk below the bud to prevent it from opening and exposing the larva. The damaged bud fails to develop, may turn brown or black, and often falls from the plant. This is the primary economic concern in infested fields. The egg laying period may vary with winter weather conditions, but lasts for about a month. Inside the injured bud, the eggs typically hatch in one week.

**Cultural control**

Site selection can be important to locate strawberry beds away from woods and brambles to avoid overwintering weevils. Profusely flowering and pistillate strawberry varieties, which may be less susceptible to attack can reduce damage impact but are not a viable option in North Carolina. Maintenance of clean, weed-free beds and avoidance of development of full-canopy beds or excessive

use of mulch discourages the establishment of new weevil populations. Annual production systems have fewer weevil problems, because strawberry plants are not available year round as overwintering sites.

There is considerable variability in number of strawberry weevils from year to year. Scouting recommendations are as follows: Scouting should begin in late March to April, when temperatures reach the 60's (degrees F) and flower trusses are visible in the crown. Scout along field edges, especially those located nearest potential wintering sites Weevil infestations emerge rapidly, so sampling should occur at least 3 times a week to avoid underestimating populations. Developing buds should be inspected carefully for either damage or the presence of adult weevils. Adult weevils can be counted, but it is usually easier to sample for clipped buds. Sample once a week in a V-shaped sampling pattern at about 5 to 10 sampling locations. Use a 2-foot-square frame to scout a 2-foot section of the row at each sampling location.

### **Chemical control**

Current research does not provide clear thresholds at which chemical treatment is justified. Some researchers question if treatment is justified at all. Research has demonstrated that even when strawberry buds are damaged, the plant often compensates with larger surviving fruits such that there is little or no reduction in total crop yield. This research has not been conducted under North Carolina growing conditions, and results have not been consistent for all varieties. Until better information is available, growers are cautioned to monitor damage carefully prior to making treatment decisions. Early damage is often less significant than damage later in the season when the plant is less capable of compensating.

If chemical control is necessary, early morning pesticide applications have been found to be most successful as the weevils feed during the day. Spraying the borders of the field may be sufficient for control. A second application may be necessary 7 to 10 days later if the field has a history of weevil problems.

Carbaryl (Sevin) is applied to 51% of the acreage for an average number of 2.1 applications per season using a treatment rate of 1.28 pounds of active ingredient per acre. Carbaryl is used as a general insecticide not exclusively for weevils. Chlorpyrifos (Lorsban) is used on 30% of the acreage 2 times per year with an application rate of 1 pound of active ingredient per acre.

### **Tarnished Plant Bug**

*Lygus lineolaris* (Palisot de Beauvois)

Like most lygus bugs, the tarnished plant bug is oval in shape, slightly flattened, and has a characteristic white triangle between the "shoulders." Its legs and antennae are relatively long. The adult may be one of several shades of brown with reddish brown markings on the wings and is approximately 6.4 mm long. Damage is limited in North Carolina, but in states farther south and in the southwest, economic injury occurs annually. Nymphs of the tarnished plant bug feed on flowers and cause varying degrees of

fruit distortion. The insects puncture seeds on the developing fruit, causing that portion of the berry not to develop. Sometimes there is a concentration of seeds near the tip, a deformation referred to as button berries, nubbins, or cat-faced berries. When larger seeds are damaged they often turn brown in color and look hollow. This distinguishes the damage caused by the tarnish plant bug from poor pollination and frost injury. Shiny circular spots of excrement on various plant parts also indicate the presence of these pests, which may pierce buds and terminal growth with their needle-like mouthparts and extract plant juices. New growth may be yellowed and distorted, causing plants to appear unthrifty.

In North Carolina, adults hibernate in plant debris and resume activity in spring. At this time females insert eggs into succulent host plant tissue with their sword-like ovipositor. Tiny, elongate, slightly curved eggs hatch 1-1/2 to 3 weeks later into the wingless nymphs that range from 1.5 mm to slightly less than adult size, and are yellow-green to green with several black spots on their backs. Immatures are similar in appearance to aphids in that they are small and pale green, yet the body is more tapered and they move more quickly. The nymphs develop through five instars over a three-week period as they feed on plant sap. The fourth instar nymphs have wing pads, and when mature, molt and emerge as adults. The first few generations develop on preferred hosts such as small grains, alfalfa, wild grasses, vetch, dock, and fleabane. As hay is cut or as other plants dry out, tarnished plant bugs migrate in large numbers to succulent hosts such as cotton or vegetable crops. During summer, the life cycle (from egg hatch to adult emergence) is completed in 4 weeks, with as many as five generations possible each year.

### **Cultural control**

Control of weeds, destruction crop residue, and planting strawberry crops as far away as possible from forage and cotton crops preferred by this pest can minimize population sizes. Mowing or disking weeds during the strawberry bloom period should be avoided since this may force the tarnished plant bug to migrate into the strawberry field.

Several Northern cultivars have some level of resistance, and breeding programs that include these plants may result in other commercial cultivars. Early maturing varieties tend to suffer less damage than late maturing varieties.

Scouting protocols are as follows: Begin monitoring for tarnished plant bugs when flower trusses are first visible. Traps may be set around the edges of the field to monitor adult tarnished plant bugs, but the nymphs do not fly and therefore will not be trapped. To detect nymphs, conduct a weekly sample of at least thirty flower clusters evenly distributed throughout the field (follow a V-shaped pattern) by shaking them over a white surface such as cardboard or plastic. If more than 5 bugs are found per trap, or the nymph count is greater than 0.25 nymphs per flower cluster before 10% bloom, or there are more than four out of thirty clusters infested with nymphs, then chemical treatment may be justified. If no nymphs are found until mid to late bloom, the threshold should be raised to 0.5 nymphs per flower cluster.

### **Chemical control**

Use of insecticides can affect natural predator populations and can also disrupt spider mite control. Insecticides are more effective against nymphs than adults. If treatment is necessary, insecticide applications are recommended after blossom buds first become visible. A second application can be made again if reinfestation occurs just before bloom.

Growers apply endosulfan on 5% of the acreage for tarnished plant bug control using 1 pound of active ingredient per acre per application and an average of 1.3 applications.

### **Gray garden slug; spotted garden slug**

*Agriolimax reticulatus* (Muller); *Limax maximus* Linnaeus

Slugs overwinter in protected areas in the field and favor moist environments, such as those provided by heavy mulching and dense plantings. Slugs feed on any above ground plant part, but the most significant damage is to the fruit. Slugs are mollusks, not insects. They are slimy, legless creatures requiring high moisture to survive. Unlike snails, slugs have no shell. Spotted garden slugs range from about 1 to 7 inches. When small, they tend to be dark, but larger slugs are yellowish gray or brown with conspicuous spots. The gray garden slug is basically whitish, cream or flesh colored, has gray spots and measures 2 to 5 cm.

During the day slugs are likely to be found in moist or damp places under boards, debris and stones. Foliar injury usually appears between veins, on leaf margins or on petals. Small slugs merely rasp away the leaf or petal surface. Larger ones leave sizeable holes in leaves, petals and fruit and along plant margins. A silvery slime trail is usually left behind as evidence.

Mature slugs may lay eggs anytime during the warmer months. The immature slug resembles the adult but is smaller, and is usually dull white. Newly hatched slugs may require a year to develop to maturity; however, under optimum conditions development may proceed faster.

### **Cultural control**

Elimination of breeding and hiding places can be helpful. Trimming course grass and weeds along fences and ditches in the vicinity of susceptible crops is also advisable. Strategies used for weed management may conflict with slug control tactics. For example, excessive amounts of mulch and closely spaced plantings encourage slug infestation.

### **Chemical control**

For best control, chemicals are applied on a warm, clear night. However, since all slugs do not emerge every warm night, two or more treatments at 5 to 7 day intervals may be necessary to obtain adequate control.

Metaldehyde is used on approximately 1% of the acreage using 0.8 pound of active ingredient per acre

applied once per year.

## Weeds

In the plasticulture system methyl bromide is used injected under black plastic mulch to provide weed control in the crop row. Row middles are generally seeded with annual ryegrass to prevent water erosion and suppress weeds. The ryegrass is suppressed and then killed with sethoxydim prior to strawberry harvest. In the matted row production system weed control can be very difficult, especially in the first year. DCPA or Napropamide or Tercil is used for pre-emergence weed control after plants are established.

Control of weeds represents one of the major costs in strawberry production. Weeds reduce berry size and number by competing with the crop for nutrients, space and light, and can interfere with harvest. They also make pick-your-own operations unsightly to customers. Nationally, 64 genera of weeds have been identified as economically damaging in strawberries, and growers may spend in excess of five hundred dollars per acre to control weeds in many fields. Within each region and production system (plasticulture or matted row) growers must contend with different weed problems.

### Cultural control

Site Selection And Preparation: Site selection is one of the ways growers manage weeds to avoid planting or rotating strawberries into fields where existing weeds are difficult to control, especially those with high populations of perennial weeds. This is particularly true in matted row production systems. Some growers would begin weed management by cultivating the soil one or two years before planting. Plowing, disking or rotovating can significantly reduce annual and perennial weed problems. Ideally, cover crops should be established in the field for one year prior to planting strawberries to suppress weeds in perennial systems and during the summer months in annual systems, but growers do not always implement this. In general, rotating strawberries with unrelated crops, such as grasses and grains, can provide significant weed suppression.

The nonchemical management practices described below are commonly used for controlling weeds in strawberries. However, in both culture systems, strawberry production would be reduced (up to 30% nationally in matted row culture) without the use of herbicides. Thus, herbicides are useful tools for assisting in the control of weeds, but are not generally substituted for effective management practices.

Hand weeding and hoeing - Removing weeds by hand is the most common nonchemical control strategy for removing weeds that have escaped fumigation, herbicides and cultivation. Many growers will have crews to hoe newly planted beds in perennial systems and hand-pull emerging weeds out of the plant hole in the plastic mulch in the annual systems. In annual strawberries, growers currently hand pull weeds two to three times during the growing season.

Cultivation between rows - Cultivating (with a cultivator or rototiller) provides effective control of weeds during the establishment phase and renovation phase of matted row systems. It is not used in annual systems because cultivation tools are destructive to plastic mulch.

Mulches: Mulches are helpful in controlling most annual weeds, but are less effective for suppressing perennial weeds.

1. **Plastic Mulches**: The most cost effective nonchemical strategy for weed control is use of plastic mulch. Black plastic is good for suppressing weed growth and is routinely combined with methyl bromide fumigation.
2. **Organic Mulches** are especially helpful in suppressing weeds in between rows during the growing seasons beginning the second year in matted row systems. Growers take care to ensure straw mulch is free of excess or new weed seeds to prevent volunteers from sprouting up. Organic mulches are used in annual systems also, between the plastic beds.
3. **Living mulches** in established plantings: Cover crops such as annual ryegrass are commonly seeded in between plastic mulched beds in the fall and herbicide-killed in the spring to reduce weed problems and to limit erosion.

### **Chemical weed management practices in the plasticulture system**

Growing strawberries as an annual crop on black plastic requires a different weed management strategy than matted-row strawberries. When black plastic is combined with fumigation by methyl bromide, excellent control of most weed seed can be expected. However, weeds such as vetch emerge for long periods of time and have hard seed coats and can establish in the row. They emerge in late fall or spring, grow under the plastic for a period of time, and emerge from any holes in the plastic near the strawberry plant. When strawberries are planted year after year, an increase in weeds that are not controlled by current weed management programs occurs. Rotation into different fields can prevent increases in persistent weeds. Avoid fields that have been previously treated with herbicides that have potential to persist and cause damage to strawberries.

Three areas where weeds can easily establish in strawberries grown on plastic are:

1. The middles between the rows have excellent fertility and moisture and thus can support weed growth easily. Once these weeds become established, their roots can penetrate the row under the plastic, or they can shade the crop and compete with strawberries for nutrients, soil moisture and sunlight.

One option is to apply a preemergence herbicide in the middles between the rows prior to weed emergence. Another option is to apply a postemergence herbicide to young actively growing weeds. At this stage of weed growth, postemergence herbicide application is safest and most effective. **NOTE: All herbicide applications between rows should be banded and not applied over the plastic. Herbicides can remain active on the plastic and injury can occur if herbicides are applied over the plastic.**

2. Weeds can emerge from the hole around the strawberry plant. Weeds growing in this area compete with strawberries, often reducing strawberry growth, yield, and quality. Additional stress can result in plant death. Thus, frequent scouting and hand removal are necessary to prevent this from happening. Growers typically have labor go through the field 2 to 3 times per year to hand remove emerged weeds in planting holes.

3. Weeds such as horseweed, sow thistle, and prickly lettuce often establish at the ends of fields. If these weeds are not controlled, they will produce seeds that are capable of blowing into the production field. Thus, growers are advised to always scout at the ends of fields and implement cultural and/or chemical control measures when needed. Control is implemented prior to flowering of weeds to prevent weed seed production.

The following herbicides are labeled for use in strawberries.

<b>Herbicide</b>	<b>Rate/Acre*</b>	<b>Remarks</b>
Methyl bromide	See label. Various	Inject into the soil 4 to 6 inches deep and cover with black plastic immediately. Soil moisture should be near field capacity and soil temperature should be at least 50°F at the treatment depth. Allow 2 weeks after application before transplanting.
Paraquat (Gramoxone) 2.5 S	0.5 lb. a.i. 1.5 pints	Apply using a shielded sprayer to the middles between plastic to kill emerged weeds. Do not allow spray to contact strawberry plants or serious crop injury will result. <b>RESTRICTED USE PESTICIDE.</b>
DCPA (Dacthal)	6 to 9 lb. a.i. 8 to 12 lb.	Apply as a banded preemergence treatment to the middles between plastic prior to weed emergence. Tank mixtures with paraquat will provide pre and postemergence weed control. Note: DCPA will prevent ryegrass from germinating if applied prior to ryegrass establishment.
Napropamide (Devrinol) 50 DF	4 lb. a.i. 8 lb	Apply as a banded preemergence treatment to the middles between plastic prior to weed emergence. Tank mixtures with paraquat will provide pre and postemergence weed control. Rainfall or irrigation within 24 hours after application is needed for optimum control. Note: Napropamide will prevent ryegrass from germinating if applied prior to ryegrass establishment.

Oxyflourfen (Goal) 2XL	0.25 to 0.5 lb. 1 to 2 pt.	Apply to pre-formed beds just prior to applying plastic mulch for preemergence control of weeds including Florida pusley, Carolina geranium, cutleaf eveningprimrose, red sorrel (from seed), filaree, henbit, woodsorrel, pepperweed, thistles and species of clover, mustard and thistles. Apply at least 30 days prior to planting strawberries.
Clethodim (Select) 2 EC	0.094 to 0.125 lb. a.i. 6 to 8 oz.	Apply as postemergence application to kill emerged grasses. Most effective on actively growing grasses. See label for size of grasses to treat. Add 1 quart per acre of crop oil concentrate to spray solution. Very effective control of ryegrass and annual bluegrass, but will not control sedges.
Clopyralid (Stinger) 3 EC	0.125 to 0.25 lb. a.i. 1/3 to 2/3 pt.	Apply postemergence to weeds growing in the crop row. Controls clovers, docks, dandelion, groundsel, prickly lettuce, red sorrel, and vetch. Suppresses many thistles. Can not be applied within 30 days of harvest.
Sethoxydim (Poast) 1.53 EC	0.2 to 0.5 lb. a. i. 1 to 2.5 pint	Apply as postemergence application to kill emerged grasses. Most effective on actively growing grasses. See label for size of grasses to treat. Add 1 quart per acre of crop oil concentrate to spray solution. Very effective control of ryegrass but will not control sedges.

\* Rate represents a broadcast rate per acre. Reduce rate proportionately with banded applications.

### **Weed control in matted strawberries**

Prior To Planting: The matted row cultivation system is very dependent on the use of herbicides for weed control. Methyl bromide and methyl bromide plus chloropicrin combinations, when properly applied to the soil prior to planting, will kill most weeds, along with nematodes, and some soil borne diseases and insects. With the impending phase out of methyl bromide, other soil fumigants are being considered for pest management. However, these fumigants do not give effective control of most weeds. Thus, they will most likely be used with herbicides to improve weed control. Once the plants are set, the area between them needs to remain weed free in order for the runners to become established. Hand weeding, hoeing, and herbicide use are the only methods available for clearing weeds from this area. Weed control practices must continue in this manner throughout the entire growing season.

An alternative method of weed control is to plant strawberries into killed cover crop. The cover crop will suppress weeds during transplant establishment and the soil is left undisturbed, reducing weed seed germination. The seed for cover crop (such as grain rye) should be planted in autumn the year before

planting, and mowed in the spring when it starts to flower. A narrow strip can then be cultivated in the residue where strawberries may be planted. Straw mulch (free of seeds) can be laid between the rows. This system helps to control weeds for the first 2 months after planting. After this time, cultivation may be necessary.

After Planting: Cover crops may also be established over a strawberry planting in open areas to displace undesirable weeds that might otherwise move in. Frost sensitive species, such as oats and sudan grass, may become established, prevent invasion of weeds, and die before producing seed.

Preemergence Herbicides: These materials only kill weeds if applied prior to their emergence. Therefore, cultivation and hoeing should precede their application to destroy established weeds.

1. DCPA (Dacthal) at rates of 6 to 9 pounds of active ingredient (8 to 12 pounds of Dacthal) provides 10 to 12 weeks of control of annual grasses and several small seeded broadleaf weeds including chickweed, crabgrass species, foxtail species and common lambsquarters. Apply preemergence over strawberries. Do not apply between bloom and harvest.
2. Napropamide (Devrinol) at rates of 2 to 4 pound of active ingredient per acre (4 to 8 pounds per acre of Devrinol 50 DF) provides 10 to 12 weeks control of annual grasses and several small seeded broadleaf weeds. Apply preemergence over well-established strawberries and irrigate to wet the soil 2 to 4 inches deep. On established plantings do not apply between bloom and harvest. Precaution: On new plantings do not apply during runner plant production because rooting will be reduced. Napropamide is effective for controlling many grasses from seed such as crabgrass, goosegrass, foxtail, volunteer grain and many small seeded broadleaf weeds such as chickweed, common sowthistle, lambsquarter and pigweed.
3. Terbacil (Sinbar) can be applied at a rate depending on soil type (less than 1% organic matter – up to 3 ounces of Sinbar per acre; more than 1% but less than 2% organic matter – up to 4 ounces of Sinbar per acre). Use 2 to 3 ounces of Sinbar per acre after transplanting but before new runner plants start to root. In late summer or early fall, 2 to 4 ounces of Sinbar per acre can be applied for the control of winter annual weeds. Make a band or broadcast application immediately after post harvest renovation (complete removal of old leaves is essential) but before new growth begins or in the dormant season from late fall to winter. Can also be used in late fall to extend weed control through the following year. Do not exceed use rates for annual treatment. Controls many broadleaf weeds. The cultivar "Guardian" is listed as sensitive on the label. See label for more information.

Postemergence Herbicides: These materials will control certain emerged weeds if applied at the correct stage of weed growth. They have little or no preemergence activity.

Broadleaf weeds:

1. Clopyralid at the rate of 0.125 to 0.5 (1/3 to 2/3 pt per acre) pound per acre. Stinger will give excellent postemergence of weeds growing in the crop row. It will control clovers, docks,

dandelion, groundsel, prickly lettuce, red sorrel, and vetch. Suppresses many thistles. Can not be applied within 30 days of harvest.

2. Paraquat (Gramoxone Extra) at a rate of 0.5 pound of active ingredient per acre will control emerged annual broadleaf weeds and grasses and provide top kill and suppression of perennial weeds between the rows. Direct the spray between the row and use shields to eliminate spray contact with crop plants. Add a nonionic surfactant at a rate of 8 ounces per 100 gallons of spray mix. Apply when weeds and grasses are succulent. Do not allow the spray to contact strawberry plants as crop injury or excessive residues will result. Do not apply more than three times per year or within 21 days of harvest.

3. 2,4-D amine (Formula 40 or Weedar 64A) at rates of 0.5 to 1.0 pound of active ingredient per acre (1 to 2 pint of a 4 pound per gallon formulation) controls susceptible broadleaf weeds. This herbicide can be applied immediately, after harvest or during the dormant season (winter). For best results, weeds should be relatively small and immature. 2,4-D amine will control dandelions, wild lettuce, evening primrose, morningglory, cocklebur, and ragweed.

#### Grass weeds:

1. Clethodim (Select) at rates of 0.094 to 0.128 pound of active ingredient per acre (6 to 8 ounces of Select per acre) will provide excellent control of all emerged annual and perennial grasses. This herbicide has no soil activity and no activity on broadleaf weeds or sedges. Add one quart of crop oil concentrate to spray solution. It may be applied over the top of strawberry foliage; however, avoid application on days when it is unusually hot and humid as this may result in foliar burn to the strawberries. Do not apply Select within 4 days of harvest.
2. Sethoxydim (Poast) at rates of 0.2 to 0.5 pound of active ingredient per acre (1 to 2.5 pints of Poast) will provide excellent control of all emerged annual and perennial grasses. This herbicide has no soil activity and no activity on broadleaf weeds or sedges. One quart of crop oil concentrate must be added per acre. It may be applied over the top of strawberry foliage; however, avoid application on days when it is unusually hot and humid as this may result in foliar burn to the strawberries. Do not apply Poast within 7 days of harvest.

## **Diseases**

### **Fruit Diseases**

#### **Gray Mold or Botrytis Rot**

*(Botrytis cinerea)*

Gray mold is a serious disease in all strawberry production areas and is one of the primary diseases of

concern in most years. The disease is a problem not only in the field, but also during storage, transit, and market of strawberries, due to onset of severe rot as the fruits begin to ripen. Other parts infected by the fungus include leaves, crown, petals, flower stalks, and fruit caps. Disease is most severe during bloom and harvest in seasons with lengthy periods of cloud and rain.

Recent research in North Carolina has demonstrated *Botrytis* enters the field primarily on transplant foliage. The fungus can live in the green tissue but be latent, or dormant, and not cause symptoms. As the infected strawberry leaf begins to die, the pathogen goes into an active stage, colonizing the leaf and obtaining its nutrients from the dead tissue. Spores then form and, once environmental conditions are appropriate (between 65 to 75 degrees F and damp or rainy weather), they are dispersed by water splash and/or wind onto newly emerging leaves or blossoms. Immature fruits become infected primarily through blossom infections. Once the berries begin to ripen, the fungus is able to colonize them and sporulate, producing the mold often seen in the field.

### **Cultural control**

*B. cinerea* is commonly associated with transplant leaves and two years of research has demonstrated that there are no differences due to plant source. Currently, it is not possible to obtain disease free plants. However, plug production practices may favor crown rot problems and excess use of certain fungicides during the propagating phase results in resistant populations and poor control with these fungicides in fruit production fields.

Optimum fertility management is important since excess nitrogen has been shown to increase fruit rot when weather conditions are favorable. Increasing nitrogen levels beyond an optimum level does not increase yield but does increase fruit rot incidence. Optimum (for yield/disease pressure balance) plant spacing improves airflow in the canopy. Planting in raised beds improves drainage and also increases airflow, resulting in lower disease levels. Plastic mulch helps keep down rain splash, plant and soil-surface contact, weeds that may harbor *Botrytis* inoculum, and reduces moisture within the canopy. Drip irrigation provides a direct source of water and eliminates excess moisture on fruit and leaves. Removal of senescing tissue from the field may be helpful in the fall, but is of most benefit in the early spring, just prior to bloom, to help lower inoculum levels. Many growers do find it practical to remove senescent leaves as workers hand pull weeds and pull plants that grew under the plastic mulch. Harvested fruit is typically monitored for disease, and infected berries removed. Postharvest conditions e.g. keeping fruit at around 34 degrees F, are manipulated to keep gray mold incidence down.

### **Biological control**

*Trichoderma harzianum* and *Gliocladium roseum* have been used in other production areas as alternatives to fungicides but are not used in North Carolina. Research has been conducted to evaluate biological agents such as bacteria and other microorganisms for control. However, such agents are not currently used commercially.

## Chemical control

Fungicides play an important role for most growers in the management of this disease. Fungicide applications are critical in problem fields during early and full bloom. These fungicides are targeted to limit flower infection that leads to fruit infection, and thus limit the need for late season applications to the fruit. A few well-timed sprays are less costly and more effective in controlling gray mold than frequent fungicide applications through harvest. *Botrytis cinerea* has developed resistance to MBC-generating compounds (benomyl, carbendazim, and thiophanate-methyl) and dicarboximides (iprodione). Therefore, alternating between chemistries or using tank mixes is recommended.

Use patterns are based on a recent survey (Sorensen et al. 1997). The benzimidazoles (Topsin-M) continue to play an important role in North Carolina. Approximately 20% of the acreage is treated with one of these products. Typically, 2 applications are made per season usually in combination with the protectant fungicide Captan and at a rate of 0.5 pounds of active ingredient. Captan applied at 2 pounds of active ingredient per acre is a commonly used product and used up to 5 times per season on an estimated 75% of the acreage (Louws, unpublished).

Iprodione (Rovral) has historically been used up to 2 times per season at a rate of 0.87 pounds of active ingredient per acre and on 20% of the acreage. However, new label restrictions will limit growers to one application per season. Fenheximid (Elevate) and cyprodinil + fludioxinil (Switch) have recently been registered. Elevate is used 3 to 4 times per season on 75% of the acreage and Switch two times per season on 25% of the acreage (limited by crop rotation restrictions).

### Anthracnose of Strawberries

(*Colletotrichum acutatum*, *C. gloeosporioides* and *C. fragariae*).

Anthracnose is an important disease of strawberry fruit, crowns, leaves, petioles and runners. Three related species of the fungus *Colletotrichum*, including *C. acutatum*, *C. gloeosporioides*, and *C. fragariae* can be associated with strawberry plants. Disease control is difficult when environmental conditions are favorable, and the disease can be especially destructive to California strawberry cultivars when grown on black plastic. *Colletotrichum acutatum* is more commonly associated with fruit rot, but has also been associated with crown rot. *Colletotrichum gloeosporioides* tends to be associated with the crown rot phase of anthracnose but can also cause fruit rot. *Colletotrichum fragariae* causes crown rot and is not commonly a problem on fruit. It has not been isolated as a common pathogen in North Carolina since 1986.

Anthracnose fruit rot is the disease of most concern and appears as brown to black, water-soaked spots on green and ripe fruit. Firm, sunken lesions can develop over time. Pink, salmon, or orange-colored masses of spores may form in the lesion under humid conditions.

The primary source of anthracnose inoculum enters the fields on strawberry transplants. Conidia are

produced in abundance on petioles, runners, and fruit and are dispersed through rain-splash, especially wind-driven rain. Movement of machinery and workers through the field also may contribute to inoculum spread. Warm, humid conditions are optimal for this disease and overhead irrigation can also contribute to disease spread.

### **Cultural control**

The use of disease-free plants is the most important management strategy for controlling this disease. Currently there is no rapid detection method for diagnosing anthracnose-infected transplants prior to planting. Resistant cultivars are available and breeding efforts have shown promise. For example, Sweet Charlie is less susceptible to the fruit rot phase than other cultivars commonly grown on plastic.

Periodic scouting of a field, especially during warm and wet weather, enables early detection of anthracnose. As soon as disease is discovered, immediate removal and destruction of infected and surrounding plants has worked to reduce inoculum levels. Avoidance of overhead irrigation as done in the plasticulture system limits conidial dispersal and spread of the pathogen.

### **Chemical control**

The effectiveness of protective fungicides is generally low. *C. acutatum*, the most common ripe rot pathogen, is naturally insensitive to the benzimidazoles. Captan has some efficacy and is routinely used for gray mold management as outlined above. In cases where ripe rot is noted, growers may implement weekly applications of Captan for the duration of the season (5 to 9 applications). The strobilurins (Quadris and Cabrio) are highly effective against *Colletotrichum* species, especially when combined or rotated with Captan.

Quadris and Cabrio have a similar mode of action and improper use will make the fungicide ineffective for the control of anthracnose if the problem pathogens acquire resistance. Resistance management is an essential component of using the strobilurins.

Recurrent problems with anthracnose has forced growers to use Captan and the strobilurins more frequently. Captan is used up to 5 times per year as outlined above and the strobilurins 4 to 6 times per year on 75% of the acreage, depending on disease pressure.

## **Foliar Diseases**

### **Bacterial Angular Leaf Spot** (*Xanthomonas fragariae*)

Angular Leaf Spot disease of strawberry, caused by the bacterium *Xanthomonas fragariae*, is often confused with common leaf spot and leaf scorch diseases. Once infection is established, little can be

done until the wet cool conditions subside. Fortunately, this disease generally does not affect yields severely. The pathogen is a gram-negative bacterium.

The pathogen causes water-soaked lesions that first appear on the lower surface of the leaf, becoming angular as they enlarge and usually delineated by veins. When conditions are very moist, lesions may exude a viscous yellow substance that is actually a mass of bacteria. Upon drying, a characteristic white film is left on the leaf surface. In time, lesions will also be visible on the upper leaf surface as irregular, reddish brown spots that may be surrounded by a yellow halo. Berry caps may become infected, darkened, and unappealing. Vascular infection and wilting by *X. fragariae* may lead to plant death, but this is not as common as leaf spot.

*X. fragariae* primarily enters the field via infected planting stock, and may persist in the field by overwintering in infected plants and dead leaves. In the Southeast, problems have not persisted from one year to the next in annual plantings due to soil inoculum. Bacteria are splash-dispersed to healthy leaves in wet weather or with irrigation water. *X. fragariae* favors low day (60 degrees F ) and night temperatures (near freezing) and high relative humidity. Favorable conditions for disease development occur during transplant establishment and when frost protecting.

### **Cultural control**

Use of disease-free plants is the most effective way to manage angular leaf spot. However, infected transplants may not exhibit signs of infection until exposed to a more favorable climate, such as exists in the southern states. Resistance to angular leaf spot exists in some genotypes, yet no commercially desirable cultivars contain high levels of resistance.

### **Chemical control**

Early application of registered copper materials prior to rapid growth may reduce disease, but fungicides are not very effective in managing angular leaf spot because the bacteria can reside out of reach within the plant tissue. Some growers (3% of entire acreage) will implement a copper-based spray program when disease occurs, applying up to 3 applications of copper using 1.2 to 1.8 pounds of active ingredient per acre.

### **Common Leaf Spot** (*Mycosphaerella fragariae*)

Leaf Spot or *Mycosphaerella* Leaf Spot is one of the most common diseases of strawberry, but rarely reaches economic levels in North Carolina. Several California cultivars are very susceptible, especially when grown on black plastic. Symptoms begin as small round purple spots 1/8 to 1/4 inches in diameter on upper leaf surfaces. Lesions may also develop on fruit (black seed), caps, fruit trusses, petioles, and runners, and can grow to 3 to 6 mm in diameter. On older leaves the center of the lesion changes from

tan or gray to white, with reddish purple to rusty brown margins, while on younger leaves the lesions stay light brown. Leaves may die if numerous lesions coalesce. Usually the lower leaves die out. The pathogen is most commonly imported on plants in North Carolina.

### **Cultural control**

Use of disease-free plants is the most important strategy to limit common leaf spot problems. Some northeastern varieties have resistance to *M. fragariae*, but there are no resistant southeastern varieties. Growers sometimes use sanitation and heavily infected bottom leaves are removed to reduce inoculum pressure.

### **Chemical control**

Growers generally do not treat for this disease specifically, but broad-spectrum fungicides used to control other diseases also control this one. Use of protective fungicides is only necessary on highly susceptible varieties and if common leaf spot symptoms are prevalent in the transplants. Some resistance to fungicides has been observed but not documented in the southern region.

## **Root and Crown Diseases**

### **Phytophthora Crown Rot** (*Phytophthora cactorum*)

Strawberry infection by *Phytophthora cactorum* occurs on poorly drained, over irrigated soils, or during long periods of rain in warm climates. Symptoms of disease are enhanced during periods of high water need, such as after transplants are set, during hot dry weather, or as the fruit load increases. This disease historically has been rare but more recently has been recorded in North Carolina fields. In many cases, problems are associated with infected transplants. Stunting of plants or wilting of young leaves are the first symptoms and may appear at any time during the season. Infected plants may remain stunted, or foliage may turn bluish and the entire plant may wilt rapidly until total collapse.

### **Cultural control**

Use of disease-free plants is the most important management strategy in North Carolina but protocols are not available to detect the pathogen prior to planting. Growers will also avoid poorly drained land or fields with a history of the disease. Soil fumigation may help to reduce inoculum but the importune of soil-borne inoculum has not been documented.

### **Chemical control**

In cases where problems are identified growers will apply mefenoxam (Ridomil Gold) up to 2 to 3 times

per season at a rate of 0.5 pound of active ingredient per acre. An estimated 25% of the acreage may be treated.

## **Black Root Rot**

Black Root Rot is a disease complex on strawberry, meaning that one or more organisms can be involved in the infection, including the fungi *Pythium* spp., *Fusarium*, spp., *Rhizoctonia* spp., and several species of nematodes. It is a common disease in North Carolina and is generally more severe in older (matted row) plantings, especially during dry weather and close to harvest. Infection usually sets in the first fruiting year and worsens the following year. Black root rot is enhanced by stresses like poor soil drainage, cold, drought, flooding, soil compaction and repeated freezing of roots. The pathogens can be isolated from plants raised in the plasticulture system but the impact on plant productivity is not well known. Above ground symptoms including lack of vigor leading to plant collapse may resemble red stele (caused by *Phytophthora fragariae*), but the root vascular tissue does not become discolored as in red stele. Plants may be stunted with small fruit, few runners, and numerous dead older leaves. Infected plants do not respond to fertilization or improved growing conditions, and yields may be reduced.

### **Cultural control**

Site selection is a key management strategy. Most growers attempt to choose a site with adequate aeration and drainage. Rotation out of strawberries at least every 3 years into crops that are **not** hosts of *Rhizoctonia* spp. can be helpful. Recent research in North Carolina has documented that all strawberry transplants, despite the source, have these pathogens associated with their roots.

### **Chemical control**

Most growers will pre-plant fumigate their soils to manage this complex. Methyl bromide is applied at 200 pounds of product per treated acre. Approximately 80% of the acreage is treated with methyl bromide.

## **Red Stele**

(*Phytophthora fragariae*)

Red Stele is one of the most serious diseases of strawberry in matted row systems. There are numerous races of *P. fragariae*, and certain strawberry cultivars show varying degrees of resistance to some of them. However, no cultivar is resistant to all races, and the disease is recurrent in North Carolina. This disease is rare in plasticulture systems.

Diseased plants are generally aggregated in low, wet areas of a field and aboveground symptoms appear when temperatures warm, from March to July. Young foliage may appear bluish, but with age leaf tips

become tinged with red, orange, or yellow discoloration. In hot, dry summer weather, severely diseased plants become stunted and wilted. Plants may remain wilted even in the presence of adequate moisture, followed by collapse and death. Fruit size and runner production may be reduced. Diseased plants will have few new roots, and feeder roots may decay and fall off leaving a "rat-tail" appearance. The fungus is spread primarily by symptomless, infected planting stock, but may also be carried in surface water or contaminated farm equipment. Once established, the fungus may persist for many years in the absence of the strawberry host.

### **Cultural control**

Growers will avoid areas of the field where red stele has been reported and avoid fields with poor drainage. Use of disease-free plants is important to limit the introduction of the pathogen on any given farm. However, no diagnostic protocols are routinely available for detection of the pathogen on transplants. Resistant cultivars are available, but they are not resistant to all races of the pathogen.

### **Chemical control**

Ridomil Gold is registered for red stele control and helps to reduce losses if disease develops in an established planting, although Ridomil-resistant strains of *P. fragariae* have been isolated from strawberry fields. Application rates are 0.5 pound of active ingredient of Ridomil Gold with 2 to 3 applications per year. The product may be used on approximately 2% of the acreage for red stele control. Alliete WDG is also registered for control of red stele but rarely used.

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