the Southern Region small fruit consortium

Strawberry Training - November 5-6, 2008

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STRAWBERRY

SRSFC SPONSORED COUNTY AGENT TRAINING

November 5-6, 2008

Hilton University Place

Charlotte, North Carolina

in cooperation with

2008 Southeastern Strawberry Expo

“Strawberry Production Update”

SRSFC

11-06-08

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Extension Specialist
Small Fruit Crops, NC State

Purpose

- Update the 2005 Production Guide found on SRSFC website
- Discuss new economic budget
- Conclude with “10 rules” for new growers

Important changes

- Varieties
- Plant Material Options
- Row Cover Management
- New Fumigant Option: Midas (not available until 2008)
- Costs!! (new enterprise budget)

Recommended Varieties

- Chandler
- Camarosa
- Sweet Charlie
- Strawberry Festival
- Other possibilities
  - Galletta – new from NCSU
  - Albion – new from Univ. Calif.

Phytophthora cactorum!

- Sweet Charlie – very susceptible
- But, Chandler and Camarosa are susceptible!

Galletta – well adapted to plasticulture!

Data from Clayton

variety	Total Yd	Market Yd	Cull
Albion	22,351	21,749	602
Camarosa	35,826	33,848	1,978
Chandler	39,727	36,161	3,566
Festival	35,210	33,813	1,397
Galletta	26,767	25,810	957
Sweet Ch	22,356	21,327	1,029


UC Release
Albion
Chandler

Production- Systems and Varieties

- **Choices are intrinsically linked**
- **Manage for each individual variety**


1.5 oz per sq yd

Why Small Growers Like Row Covers

Experience of Agents

Variations in GA and SC

Critical Temperatures (air)– Perry and Poling (1985)

Frost Protection

Sprinkling…

Buds Internal	Buds Closed	Flowers Open	Small Green Fruit
10 F -12.2 C	22-27 F -5.5 to -2.7	30 F -1.1 C	28 F -2.2 C

Fumigant Situation!

Ag Economics or WHY Bother?

- **Latest Budget Safley and Poling**
- **Do Strawberries = Profits?**
  - ***Expensive***
  - ***Risky***
  - ***But everybody loves 'em***
  - ***LIGHTS ON – Review New Budget***

Production- Final 10 Points


LAS VEGAS, NEVADA
Sir William
Sir William
Snapple

STRAWBERRY
SRSFC AGENT TRAINING
November 5-6, 2008

Slide Script
"Strawberry Production Update"
Barclay Poling, NCSU

Introduction:

(Slide 1 - Purpose) My primary goal in this approximate one hour presentation is to provide you with a production update to the *2005 Southeast Regional Strawberry Plasticulture Production Guide* (Poling, Krewer, Smith), and I also hope to reserve a few minutes to discuss the new strawberry plasticulture enterprise budget (Oct. 2008) developed by Dr. Charles Safley and myself.

(Slide 2 – Older Guide) Since the publication of the 2005 production guide for the SRSFC website, there have been some important developments with varieties, plant material options and improved strategies for row cover management.

A. Varieties (Spring Season): Since Dr. Ballington will be concentrating on varieties for extended season production (summer and fall) and protected culture, I will be confining my comments to the performance of several spring season strawberry varieties.

(Slide 3 – Summary Table of Recommended Varieties)

(Slide 4 - Camarosa) In the last two years, we have observed a rather remarkable situation with Camarosa, variety that is showing potential for up to 8-9 weeks of fruiting, which is a significantly longer harvest period than Chandler, which typically does not exceed 5-6 weeks of fruiting. In hotter years, the Chandler season may be as short as four weeks, but Camarosa has the potential to continue production in warm periods, provided that the grower maintains excellent soil moisture conditions during hotter weeks in spring. In a later section of this presentation I will address the factors that "we think" are involved with this extended spring cropping potential with Cama

(Slide 5 – Sweet Charlie) Sadly, we seem to be losing a favorite early season strawberry cultivar, Sweet Charlie to PHYTOPHTHORA CROWN ROT, caused by *Phytophthora cactorum.* I am not sure, but perhaps the heavy rains in Canada this past summer had something to do with the greater scarcity of this variety. Traditionally, we have recommended that a typical pick-your-own and local sales type operation should include a "mix" of three varieties with 10 percent Sweet Charlie, 60 percent Chandler, and 30 percent Camarosa.

(Slide 6 – Galletta - an answer to Sweet Charlie?) A new strawberry variety developed at North Carolina State University ripens early in the growing season and produces big,

attractive, good-quality berries as you can see in this slide. In the Raleigh, NC area, Galletta ripens in late April to early May, which is a week to 10 days before Chandler, which is the most widely grown strawberry in North Carolina. Along the coast, Galletta may ripen as early as mid-April. It has particularly attractive fruit with a glossy finish. According to Dr. Ballington, the new variety produces better quality fruit than Sweet Charlie.

(Slide 7 – Variety Table) This table is a summary from the 2007-2008 season at Clayton.

Variety	Total Yd	Market Yd	Cull
Albion	22,351	21,749	602
Camarosa	35,826	33,848	1,978
Chandler	39,727	36,161	3,566
Festival	35,210	33,813	1,397
Galletta	26,767	25,810	957
Sweet Ch	22,356	21,327	1,029

(Slide 8 - Albion – a new dayneutral for the spring season?). Albion is a relatively new release from UC Davis expected to replace Seascape in commercial growing in California. The fruit is long, conical, symmetrical; firm with excellent flavor. It is believed to have some phytophthora crown rot and some resistance to anthracnose crown rot. This variety is expected to do quite well in the upper mountain regions like Laurel Springs (elevation 3,000 ft) for summer and early fall. The thing that has surprised me the most about this daynetral is that it is even showing adaptation to lower elevation areas, and the data in the previous table at Clayton Central Crops indicated a marketable yield of 21,749 lbs/A. for Albion.

B. Plant type and quality. Plug plants are generally more expensive to purchase than freshly dug strawberry plants, but they do have the advantage of being suitable for mechanical transplanting with a water-wheel or disposable pot mulch planter. In contrast,

freshly dug plants are most often transplanted by hand. The establishment procedure for highly perishable freshly dug transplants depends on intense overhead sprinkling for one to two weeks, depending on weather, and the condition of the freshly dug plants. Freshly dug plants exposed to cooler temperatures, chilling in the nursery, or both will require less time for establishment than freshly dugs produced in warmer climates. Commercial grower experiences in North Carolina with plug plants indicate that these do require overhead sprinklings for the first, second, and possibly third day following transplanting for approximately 5 hours, 3 hours, and 2 hours per day, respectively.

<Slide 9 - Plugs versus freshly dugs> Freshly dugs are not usually available until the final week of September, and this is too late for transplanting in colder regions: the upper piedmont, foothills, and mountains of North and South Carolina; the low mountains of Georgia, as in northwest Georgia and the south slope of the Blue Ridge Mountains; and the high mountains within the north slope of the Blue Ridge Mountains. However, if good quality freshly dugs can be obtained in the third week of September, growers in warmer sections of Zone 6 may wish to evaluate freshly dugs from the standpoint of their relative cost savings and the possibility of enjoying a harvest season that is not quite so concentrated in picking.

<Slide 10 - Plugs are definitely recommended over freshly dugs for part-time growers> For growers who do not have the time to oversee the continuous overhead watering of freshly dug plants during the first week following field transplanting. Also, less experienced growers are encouraged to consider planting plugs because they are more "mistake-proof" than highly perishable freshly dug plants. Transplanting dates for plugs can also be slightly later than for freshly dugs without as great a yield reduction. This is because plugs establish more quickly than freshly dugs after transplanting.

<Slide 11 - “Cutoff” and “frigo” plants> Another type of transplant, called a “cutoff” or “tops off” plant is available in late October from northern California nurseries. These have accumulated considerable chilling in the nursery and have been mowed prior to digging and harvest. Cutoffs are only recommended for the very mildest winter areas in southeastern North Carolina, but not for areas further north or west. They may have some utility in coastal South Carolina and Georgia as well. Based on past research studies, fully dormant or “frigo” plants are not recommended for strawberry plasticulture in any parts of the Mid-South and Deep South.

C. Milder Winter Seasons (Global Warming?)

(Slide 12 - Warm fall conditions in recent years). Other factors besides the planting date have an important influence on the final number of branch crowns produced. Fall weather

conditions following planting in early to mid-September can play a very important role in determining ultimate plant size. Fall temperatures may be so warm as to produce excessive plant size by harvest (more than six branch crowns). In North Carolina, growers who are especially interested in optimizing fruit size and shape will purposely set out a portion of their crop several days to one week later than recommended for their area in case of an unseasonably warm fall. Chandler plugs set at the "normal planting date" may produce two to three runners per plant in a warm fall, and removing these runners can involve a significant labor expense. In colder plasticulture regions in the Mid-South, such asthe higher elevations in western North Carolina, it may be better to delay the winter row-cover application until late November or early December if you are experiencing an unusually warm fall season.

(Slide 13 – What to do when plants are set very late?). Growers can only "go so far" with later and later plating dates, and though I am in favor of setting perhaps a week later than "normal," I do not recommend setting any later than this. However, in some years growers encounter very late deliveries of plants from their nursery suppliers, and in some cases in fall 2008, this was a very serious problem for NC growers. One of the very exciting adjustments I have seen in recent time to the problem of late plant delivery has been to apply a very light weight row cover, and I would personally even consider using a cover as light as 0.5 – 0.6 oz/sq yard, as this cover will provide nearly ideal light levels beneath the cover for late fall plant growth. I recommend against the use of heavier covers like a 1.5 oz/sq yard, as this will actually causes excessive shading. There is always the question of "when" the cover should be applied to achieve additional fall and winter season growth enhancement, and in the question and answer period I wish to address this subject in more detail.

D. Changes in Row Cover Usage – An Update

(Slide 14 - Important Reason Why Row Covers Appeal To Smaller Growers). The use of sprinkler irrigation to protect strawberry flower buds and blossoms has been the accepted practice for frost protection for many decades, and if a grower did not have an adequate water supply for overhead sprinkler irrigation system, he or she was simply advised to not go into strawberry production. The water requirement for an overhead sprinkler irrigation system is usually estimated on the basis of three consecutive frost or freeze nights. For example, 5.4 acre-inches of water (27,152 gallons equal 1 acre-inch) would be needed for sprinkling at the rate of 0.18 inch per hour (for control down to 24^{o} F), for 10 continuous hours each night over three nights. Or 1.8 inch per night (10 hours times 0.18 inch) for three nights equals 5.4 acre-inches. An irrigation pond would need to hold about 150,000 gallons of water for each acre of plasticulture production under these conditions (5.4 inches times 27,152 gallons per acre-inch equals 146,620 gallons). That's a lot of water!

(Slide 15 – Experience of Agent). The fact that small growers like Joey Knight have demonstrated that row covers can be used for late season frost and frost/freeze protection without overhead irrigation, is a fairly exciting development from the standpoint that

farmers with relatively limited water supplies can now grow strawberries in the plasticulture system, and achieve full crops in most seasons using the covers.

(Slide 16 – Georgia and SC). Normally, row covers are not applied for the entire winter season in Georgia and SC. But, tt is important to use row covers in late winter freeze and frost/freeze situations that may occur in these states.

(Slide 17 – Critical Temperature Table). Strawberry flower buds begin to emerge from the end of January and sometimes even earlier in coastal Georgia and South Carolina. During this time, flower buds may be killed at temperatures below 22 F. Row covers work very well for tight bud stage, but lighter weight covers may not be reliable for popcorn and open blossom stages which can be killed in the range of 26.5 – 30. If you are using row covers as your only source of cold protection, then you should be prepared to lose some amount of crop, especially the popcorn and open blossom stages in late winter freezes. If you can supplement with sprinkler irrigation under colder conditions, this may be beneficial. Nonetheless, even if you do not have access to overhead irrigation to supplement row cover protection in late winter cold conditions, it is still true that row covers alone will be very beneficial compared to no protection. Windborne freezes can cause devastating crop losses and delay the harvest by one or two weeks in crops that are completely unprotected. Be sure to apply the row cover at least a day or two prior to windborne freeze events.

E. Changes in Fumigant Use: . I am also pleased that Rob Welker will be joining us for a full discussion of methyl bromide alternatives. I will be making a few remarks about our research with Midas 50:50 and Midas 98:2 at Clayton Central Crops. At this juncture I also wish to acknowledge the very important contribution of NCSU Research Associate, Rocco Schivaone, to our research program in strawberry plasticulture.

(Slide 18 – Yields with Midas). In the 2005-2006 season at Central Crops in Clayton, the total, marketable and cull yield were significantly greater for fumigated soil with Midas 50:50 compared with the control (Table 1). No statistical differences were detected for Midas 50:50 fumigation rates, but it was notable that the rate of 150 lb/acre produced the highest total and marketable yield in this trial. This information was also presented in an Orlando meeting in May 2006 when the EPA was reviewing Arysta LifeScience's request for an EUP. The 150 lb/acre broadcast rate would indicate that only 75 lb/acre of this product would be required for shank treatment in-the-bed in North Carolina, where a 5' row center is standard and the plastic mulch covered beds occupy 50% of an acre. The 100 lb/acre Midas 50:50 rate was not as satisfactory as the 150 lb rate/acre for either total or marketable yield. The control produced less than 50% of the total yield of fumigated plots.

Table 1. Yield of Chandler strawberry plants grown with different Midas 50:50 fumigant rates, Clayton Central Crops, 2005-2006

Midas 50:50	Total yield	Marketable yield	Cull yield	Crown

(broadcast rate)	(lb/acre)	(lb/acre)	(lb/acre)	number/plant
300 lb/acre	27,268 a	25,157 a	2,110 a	4.4 a
250 lb/acre	27,847 a	25,921 a	1,925 a	4.0 a
200 lb/acre	29,145 a	27,021 a	2,124 a	4.6 a
150 lb/acre	29,361 a	27,113 a	2,248 a	4.3 a
100 lb/acre	28,061 a	25,761 a	2,300 a	4.7 a
0 lb/acre (control)	13,939 b	12,832 b	1,106 b	2.4 b

In this study there did not appear to be any benefit associated with the use of metalized film covers compared to conventional polyethylene mulch films used in the North Carolina strawberry industry. However, it should be mentioned that we did encounter some problems in application of the metalized films due to their "slickness" and getting adequate tension in all directions was a definite problem with our application equipment.

(Slide 19 - 2006-2007 Season). We expanded our evaluations of plastic films in 2006-2007 to include Pliant Blockade (VIF), and also added methyl bromide:chloropicrin (67:33) treatments at 350 lb/A and 175 lb/A for comparison to Midas 50:50 at 125, 150 and 175 lb/A. The barrier film Pliant Blockade did appear to improve efficacy of MeBr:pic with 31,510 lb/A marketable fruit production vs. 28,051 with standard black LDPE at the 175 lb/A rate. However, we did not observe similar results with Midas 50:50 as the 175 lb/A rate with black LDPE plastic produced yields of 32,030 per acre (highest in study). In contrast, marketable yields were 29,927 lb/A with Pliant black VIF and Midas 50:50 at 175 lb/A. Portions of the 2005-2006 and 2006-2007 studies will be repeated in 2007-2008 to try to understand why Midas 50:50 at rates of from 150 to 175 lb/A broadcast has performed so well in North Carolina conditions without the added expense for barrier film.

Additional questions from NC Agents on Telone: I wish to share a remark from Dr. Frank Louws to one of our new agents this fall about the use of Telone. The question related to a tobacco grower who wanted to use C-17 and not C-35. Here is Frank's recommendation: "The more chloropicrin content the better. In fact, 96% chloropicrin gives the best strawberry yields (if there is low to no weed pressure).
Telone C17 will help - but is not optimal. I do not have a recommended range of rates. If the grower rotates and has not had a history of soilborne diseases I would use the lower label rate. If the grower does not rotate and/or has a history of stunting and poor crop performance, I would migrate toward the higher rate on the label.

F. Economics: Dr. Charles Safley and I have just completed a new enterprise budget for plasticulture strawberries in mid-October and this budget is included in your notebook immediately following this presentation. In this final portion of this presentation I wish to share our most recent information on the costs and returns we are projecting for a "typical" 5 acre U-Pick/Ready Pick grower.

(Slide 20 – Assumptions)
Fuel Prices:

Regular Gas	$3.50	per gallon
Diesel Fuel	$4.00	per gallon

Fumigation and Plastic Mulch Bed Costs:*

Midas 50:50 (88 lb in the bed)	$9.00	per lb
VIF Plastic Film (1.25 ml, 4 rolls)	$162.00	per roll (2400')
Drip tape (1.6 rolls)	$192.00	per roll

* the budgte builds in a 10% higher use rate per acre for fumigant, plastic film and drip tape than generally recommended. This takes into account the field experiences of commercial applicators in NC who use about 10% more fumigant, plastic film and drip tape per acre when laying plastic. For example, the budget shows a usage rate of 88 lb/A in-the-bed for Midas 50:50, to reflect the fact that about 10% more product is used than the recommended rate of 80 lb/A (160 lb/A broadcast).

Row cover:

1 ounce per sq yd (Gro-Guard)	$0.245	per sq yd

Labor Costs:

Employee:		
Base Wage Rate	$7.00	per hour
Employer Costs[1]	$7.91	per hour
Owner/Supervisor		
Base Wage Rate	$15.00	per hour
Employer Costs[1]	$16.84	per hour

[1] Employer costs includes estimated SSN, Unemployment Insurance and Workman's Compensation Insurance

Irrigation Systems:

Drip Irrigation System	$6,031	per five acres
Frost Protection	$14,712	per five acres

Strawberry Plants:

Plants Planted	15,000	per acre
Cost per Plant	$0.22	each
Four Quart Baskets	$0.68	each

(Slide 21 – Summary) I wish to conclude with my "top ten" costly mistakes from the 2007-2008 season, and this information on "Avoiding Costly Mistakes" is most appropriately shared with new growers you come into contact with as horticultural extension agents:

1. *Rule Number One* is to always carefully read the label for all pesticides you plan to apply. Follow all applicator safety requirements. Pesticide certification exams are administered by the NCDA&CS Pesticide Section (and comparable divisions and sections in other states), and your County Extension Agent can assist you in getting enrolled in a Training School. Also, be sure you have positively identified a pest before applying control measures! Do you know for sure what you are trying control? Sometimes a simple phone call to your agent can keep you from making an application of a product that will not control the problem you are having!

2. *Rule Number Two* is to make sure there is adequate moisture in strawberry plasticulture beds for fumigant application. Methyl bromide applied to a soil that is relatively dry will be completely wasted.

3. *Rule Number Three* is to allow adequate time for what is called the plantback period (period from fumigation to planting) – methyl bromide 50%: chloropicrin 50% requires 14 days. Cutting corners on this waiting period can lead to a very costly crop reduction. So, be sure to allow adequate time for the plantback period. Other registered fumigants usually require as many as 3 weeks for plantback. In fall 2008, one of the biggest surprises a number of new and veteran growers had was finding how much "gas" could still be detected when they tried to start planting a few days before the required plantback with MeBr:pic 50:50. The fumigant will not dissipate as quickly in moist clay soils and in areas of the field that had higher soil moisture at fumigation time

4. *Rule Number Four* is to be fully familiar with proper planting techniques for the type of transplant (plug, fresh dug or cutoff) you are using. It is critical to set plants at the right depth, and roots must be straight down (no J-rooted) and the growing point of the crown must never be covered in soil. Plugs that are set too shallow will have tremendous issues with "wicking out". Fresh dugs require continuous irrigation for at least 7-10 days from around 9 am to 5 pm. If you notice anything that doesn't look quite right about your plugs/fresh dug plants, be sure to call your agent as soon as possible!

5. *Rule Number Five* is to be ready to put into place an electric fence soon after planting for deer control. Deer can become a problem in October soon after planting, and by early November they can destroy a new strawberry patch.

6. *Rule Number Six* is to have a 5x or greater magnifying glass for sampling new transplants for two-spotted spider mites soon after planting. In some years, mites can even be a problem in the plug trays. Gather 60 leaflets from throughout the new field and examine the underside carefully for presence of mites or their eggs. In warm production areas like NC, a 5% threshold of infested leaflets can warrant control measures. If you are using Acramite, be aware that this product can be used only one time each season (once in the fall and once in the spring).

7. *Rule Number Seven* is to be very cautious about fertilizer use in the post plant period – the pre-plant dry fertilizer application is almost always more than adequate. Further fertilizer application in the fall should only be made through the drip, and before this is done be sure you take a Plant Tissue Sample.

8. *Rule Number Eight* is to not lose any time in getting suspicious looking plants that may have a disease, such as Colletotrichum crown rot (petiole rot), diagnosed by the Plant Disease and Insect Clinic. New plantings that are heavily infected may not produce an economical crop, and if the problem is caught early enough in the fall, the producer may be able to locate a new source of plants and have the option to replant. But, past the 1st of November there is very little you can do, so act quickly to get any suspicious looking plants diagnosed. Be sure to not set the new plants in the same holes where anthracnose infected transplants grew. We remain "hopeful" that we will not see the kinds of issues with Colletotrichum crown rot (petiole rot) that we saw in 2007-2008

9. *Rule Number Nine* is to carefully evaluate the water requirements for frost protection in the spring and determine whether you might have enough water to handle as many as 10-12 nights of cold protection? If you do not have enough water for overhead sprinkling, then you must order a row cover! The best overall weight cover is 1.5 oz for general cold protection.

10. *Rule Number Ten* is to not overlook the value of having 2 healthy hives of honey bees per acre, especially with the Chandler variety.

(Slide 22) Thanks for your attention!

Cost of Producing, Harvesting and Marketing Strawberries in North Carolina
Estimated Costs for a Five Acre Direct Market Strawberry Operation
Updated: October 2008

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Month	Type of Operation		Equipment Costs	Material Costs	Labor Costs	Total Costs	Your Value
		LAND PREPARATION STAGE					
June							
week 1-4	Internet service	Total Monthly Rate	0.00	3.00	0.00	3.00	
week 1	Treat old crop w/Gramoxone (2x)	Sprayer+Tractor 55hp	65.85	23.00	28.48	117.34	
week 1	Remove plastic from previous crop	Hand	0.00	0.00	142.41	142.41	
		Lifter+Tractor 80hp	82.20	0.00	0.00	82.20	
week 2	Disposal of plastic and tape	Pickup	20.01	0.00	9.49	29.50	
week 2	Disking	Tandem 8'+Tractor 80hp	29.97	0.00	9.49	39.47	
week 2	Liming	Custom	0.00	45.00	0.00	45.00	
week 2	Planting for cover crop soybeans	Grain drill 10'+Tractor 55hp	141.18	0.00	23.74	164.92	
	Soybeans seeds		0.00	32.00	0.00	32.00	
	Millet		0.00	7.33	0.00	7.33	
TOTAL JUNE			**######**	**$110.33**	**$213.62**	**$663.17**	
		PRE-PLANT STAGE					
July							
week 1-4	Internet service	Monthly fee	0.00	3.00	0.00	3.00	
week 1	Ordering plant materials		0.00	325.50	4.21	329.71	
week 1	Ordering fumigant		0.00	79.20	0.84	80.04	
week 1	Ordering plastic mulch		0.00	64.80	0.84	65.64	
TOTAL JULY			**$0.00**	**$472.50**	**$5.89**	**$478.39**	
August							
week 1-4	Internet service	Monthly fee	0.00	3.00	0.00	3.00	
week 1	Rotovating cover crop	Rotoriller 2x+Trac 80hp	174.11	0.00	53.74	227.86	
week 2	Subsoiling	Subsoiler+Tractor 55 hp	37.18	0.00	14.24	51.42	
week 2	Disking (break up soil clods)	Tandem 8'+Tractor 80hp	8.33	0.00	2.42	10.75	
TOTAL AUGUST			**######**	**$3.00**	**$70.41**	**$293.03**	
September							
week 1-4	Internet service	Monthly fee	0.00	3.00	0.00	3.00	
week 1	Assembling irrigation system	Wagon+Tractor 45hp.	2.04	0.00	94.94	96.98	
week 1	Irrigating for fumigation (0.5")	Irrigation system	7.18	0.00	0.79	7.97	
week 1	Rotovating for fumigation	Rotoriller 1x+Tractor 80hp	87.06	0.00	26.88	113.93	
week 1	Preplant fertilizing	Rot.spreader+Tractor 40hp	12.70	0.00	7.12	19.82	
	Ammonium sulfate (60 lb N/acre)		0.00	65.63	0.00	65.63	
	Pot sulfate (60 lb K20, 22 lb S/A)		0.00	70.44	0.00	70.44	
	Triple superphosphate (50 lbs P20)		0.00	47.50	0.00	47.50	
week 2	Preplant fumigation	Fumigation rig	257.30	0.00	40.41	297.71	
	MIDAS 50:50	Tractor 80 hp	74.27	712.80	0.00	787.07	
	Plastic film		0.00	583.20	0.00	583.20	
	Drip tape		0.00	307.20	0.00	307.20	
week 2	Seed Ann. Ryegrass aisles	Rotary spreader	1.90	13.80	0.81	16.51	

Month	Type of operation		Equipment Costs	Material Costs	Labor Costs	Total Costs	Your Value
		TRANS-PLANT STAGE					
Sept., cont.							
week3	Pay Balance due for Transplants	Total Cost - 10% Deposit	0.00	2,929.50	0.00	2,929.50	
week 4	Transplant plugs	Water wheel	39.18	0.00	237.35	276.53	
week 4	Irrigating 3x- plug establishment	Irrigation system	71.80	0.00	2.37	74.17	
		Tractor 45 hp	148.91	0.00	94.94	243.85	
TOTAL SEPTEMBER			**$762.33**	**$4,733.97**	**$505.61**	**$5,941.61**	
October							
week 1-4	Internet service	Monthly fee	0.00	3.00	0.00	3.00	
week 1	Replant (2%)	Hand	0.00	0.00	7.91	7.91	
week 1	Drip irrigation - 2 hrs	Drip system	9.74	0.00	1.58	11.32	
week 2	Drip irrigation - 2 hrs	Drip system	9.74	0.00	1.58	11.32	
week 2	Inject Ridomil Gold EC	Drip system	9.74	62.50	16.84	89.07	
		Injector	3.17	0.00	0.00	3.17	
week 3	Spray mites (Acramite)	Field sprayer+Tractor 55hp	14.27	85.00	6.17	105.44	
week 3	Drip irrigation - 2 hrs	Drip system	9.74	0.00	1.58	11.32	
week 3	Tissue sample	Hand	0.00	7.00	1.98	8.98	
week 4	Weed drip system	Hand	0.00	0.00	15.82	15.82	
TOTAL OCTOBER			**$56.36**	**$157.50**	**$53.47**	**$267.34**	
November							
week 1-4	Internet service	Monthly fee	0.00	3.00	0.00	3.00	
week 1	Anthracnose Spray (Pristine WB)	Field sprayer+Tractor 55hp	14.27	66.93	6.17	87.37	
	Deer control	Field sprayer+Tractor 55hp	14.27	0.00	6.17	20.44	
	Spotnete		0.00	100.00	0.00	100.00	
	Nu Film		0.00	4.37	0.00	4.37	
TOTAL NOVEMBER			**$28.54**	**$174.30**	**$12.34**	**$215.18**	
		DORMANT STAGE					
December							
week 1-4	Internet service	Monthly fee	0.00	3.00	0.00	3.00	
week 1	Clean and weed beds	Hand	0.00	0.00	189.88	189.88	
week 1	Remove Runners	Hand	0.00	0.00	158.23	158.23	
week 1	Dormant spray - Captan	Field sprayer+Tractor 55hp	14.27	33.00	6.17	53.44	
week 2	Apply floating row covers	Hand	0.00	1,185.03	31.65	1,216.68	
	Apply row cover hold downs	Wagon+Tractor 45hp.	2.04	50.00	16.76	68.80	
TOTAL DECEMBER			**$16.31**	**$1,271.03**	**$402.70**	**$1,690.03**	
January							
week 1-4	Internet service	Monthly fee	0.00	3.00	0.00	3.00	
week 2	Ordering containers (4 qt basket)		0.00	0.00	4.21	4.21	
week 2	Ordering fertilizers and sprays		0.00	0.00	8.42	8.42	
week 3	Remove row cover	Hand	0.00	0.00	47.47	47.47	
week 4	Remove dead foliage & weed bed	Hand	0.00	0.00	316.47	316.47	
TOTAL JANUARY			**$0.00**	**$3.00**	**$376.57**	**$379.57**	
February							
week 1-4	Internet service	Monthly fee	0.00	3.00	0.00	3.00	
week 1-4	Weather advisory service	Monthly fee	0.00	9.00	0.00	9.00	
week 2	Scout for insects, mites		0.00	0.00	16.84	16.84	
week 2	Re-apply row cover	Hand	0.00	0.00	47.47	47.47	
		PRE-HARVEST STAGE					
week 3	Pull plants through plastic		0.00	0.00	118.68	118.68	
week 3	Herbicide aisles (Ann. Ryegrass)	Weed sprayer+Tractor 55hp	14.27	0.00	6.17	20.44	
	Poast		0.00	15.75	0.00	15.75	
	Crop oil concentrate		0.00	3.25	0.00	3.25	
week 3	Scout for insects, mites		0.00	0.00	16.84	16.84	

Month	Type of operation		Equipment Costs	Material Costs	Labor Costs	Total Costs	Your Value
Feb. cont.							
week 3	Spray mites (Savey)	Field sprayer+Tractor 55hp	14.27	12.48	6.17	32.92	
	Remove row cover	Hand	0.00	0.00	47.47	47.47	
week 3	Deer control	Field sprayer+Tractor 55hp	14.27	0.00	6.17	20.44	
	Spotnete		0.00	100.00	0.00	100.00	
	Nu Film		0.00	4.37	0.00	4.37	
week 4	Connect drip system	Hand	0.00	0.00	47.47	47.47	
week 4	Inject Ridomil Gold EC	Drip system	9.74	62.50	16.84	89.07	
		Injector	3.17	0.00	0.00	3.17	
week 4	Check irrigation system	Hand	0.00	0.00	8.42	8.42	
week 4	Scout for strawberry weevil		0.00	0.00	16.84	16.84	
week 4	Spray weevil (Lorsban 4EC)	Field sprayer+Tract 55hp	14.27	8.50	6.17	28.94	
TOTAL FEBRUARY			**$69.97**	**$218.85**	**$361.54**	**$650.36**	
March							
week 1-4	Internet service	Monthly fee	0.00	3.00	0.00	3.00	
week 1-4	Weather advisory service	Monthly fee	0.00	9.00	0.00	9.00	
week 1	Tissue sample	Hand	0.00	7.00	1.98	8.98	
week 1	Pull plants and weed	Hand	0.00	0.00	79.12	79.12	
week 1	Inject fertilizer	Drip system	9.74	0.00	16.84	26.57	
		Injector	3.17	0.00	0.00	3.17	
	Calcium nitrate (0.75 lb N/day)		0.00	2.19	0.00	2.19	
	Sul-Po-Mg		0.00	5.60	0.00	5.60	
	Boron (20% Solubor - 1/8 lb/A)		0.00	0.76	0.00	0.76	
week 1	Re-apply row covers	Hand	0.00	0.00	47.47	47.47	
week 2	Remove row cover	Hand	0.00	0.00	47.47	47.47	
week 2	Scout for insects, mites	Hand	0.00	0.00	16.84	16.84	
week 2	Spray mites (Acramite)	Field sprayer+Tractor 55hp	14.27	85.00	6.17	105.44	
week 2	Freeze protection (OH Irrig)	Irrigation system	135.38	0.00	16.84	152.21	
week 2	Botrytis control - Captan	PTO blast sprayer+Tract55hj	14.98	33.00	6.17	54.15	
week 3	Freeze protection (OH Irrig)	Irrigation system	135.38	0.00	16.84	152.21	
week 3	Re-apply row covers	Hand	0.00	0.00	47.47	47.47	
week 3	Remove row cover	Hand	0.00	0.00	47.47	47.47	
week 3	Pollination with bees	Rental	0.00	144.00	0.00	144.00	
week 3	Tissue sample	Hand	0.00	7.00	1.98	8.98	
week 3	Inject fertilizer	Drip system	9.74	0.00	16.84	26.57	
		Injector	3.17	0.00	0.00	3.17	
	Calcium nitrate (0.75 lb N/day)		0.00	2.19	0.00	2.19	
	Sul-Po-Mg		0.00	5.60	0.00	5.60	
week 4	Scout for fire ants, clipper, mites		0.00	0.00	16.84	16.84	
week 4	Botrytis Control - Eskeam	PTO blast sprayer+Trac55hj	14.98	18.40	6.17	39.55	
week 4	Botrytis control - Elevate	PTO blast sprayer+Trac55hj	14.98	135.00	6.17	156.15	
TOTAL MARCH			**$355.75**	**$457.74**	**$398.66**	**$1,212.15**	
April							
week 1-4	Internet service	Monthly fee	0.00	3.00	0.00	3.00	
week 1-4	Weather advisory service	Monthly fee	0.00	9.00	0.00	9.00	
week 1	Frost/freeze protection	Irrigation system	56.11	0.00	10.10	66.22	
week 1	Inject fertilizer and drip	Drip system	9.74	0.00	16.84	26.57	
		Injector	3.17	0.00	0.00	3.17	
	Cal. Nitrate - 2 wks (0.75 lb/day)		0.00	27.10	0.00	27.10	
	Sul-Po-Mg		0.00	5.60	0.00	5.60	
week 2	Tissue sample	Hand	0.00	7.00	1.98	8.98	
week 2	Frost/freeze protection	Irrigation system	42.09	0.00	10.10	52.19	
week 2	Spray mites - Kanemite	Field sprayer+Tractor 55hp	14.27	62.00	6.17	82.44	

Month	Type of operation		Equipment Costs	Material Costs	Labor Costs	Total Costs	Your Value
Apr. con.							
week 2	Botrytis control - Elevate	PTO blast sprayer+Trac55hj	14.98	135.00	6.17	156.15	
	Powdery mildew - Nova		0.00	25.00	0.00	25.00	
week 3	Inject fertilizer and drip	Drip system	9.74	0.00	16.84	26.57	
		Fertilizer Injector	3.17	0.00	0.00	3.17	
	Potassium nitrate - (0.50 N/day)		0.00	48.47	0.00	48.47	
		HARVEST STAGE					
week 3	U-pick supervision (30 hrs/wk)		0.00	0.00	47.47	47.47	
week 3	Check-out area (30 hrs/wk)		0.00	85.00	47.47	132.47	
week 3	Pre-pick harvest labor		0.00	0.00	143.75	143.75	
week 4	Drip irrigation	Drip system	9.74	0.00	3.37	13.10	
week 4	Spray mites - Kanemite	Field sprayer+Tractor 55hp	14.27	62.00	6.17	82.44	
week 4	Botrytis control - Captan	PTO blast sprayer+Trac55hj	14.98	33.00	6.17	54.15	
week 4	U-pick supervision (40 hrs/wk)		0.00	0.00	63.29	63.29	
week 4	Check-out area (40 hrs/wk)		0.00	113.56	47.47	161.03	
	Pre-pick harvest labor		0.00	0.00	192.05	192.05	
TOTAL APRIL			**######**	**$615.72**	**$625.41**	**$1,433.36**	
May							
week 1-4	Internet service	Monthly fee	0.00	3.00	0.00	3.00	
week 1-4	Weather advisory service	Monthly fee	0.00	9.00	0.00	9.00	
week 1	Tissue sample	Hand	0.00	7.00	1.98	8.98	
week 1	Inject fertilizer and drip	Drip system	9.74	0.00	16.84	26.57	
		Injector	3.17	0.00	0.00	3.17	
	Potassium nitrate - (0.50 N/day)		0.00	48.47	0.00	48.47	
	Drip irrigation	Drip system	9.74	0.00	3.37	13.10	
week 1	Evaporative cooling	Irrigation system	7.01	0.00	8.42	15.43	
week 1	Botrytis control - Elevate	PTO blast sprayer+Trac55hj	14.98	135.00	6.17	156.15	
	Powdery mildew - Nova		0.00	25.00	0.00	25.00	
week 1	U-pick supervision (50 hrs/wk)		0.00	0.00	79.12	79.12	
	Check-out area (50 hrs/wk)		0.00	170.00	47.47	217.47	
	Pre-pick harvest labor		0.00	0.00	287.50	287.50	
week 2	Inject fertilizer and drip	Drip system	9.74	0.00	16.84	26.57	
		Fertilizer Injector	14.03	0.00	0.00	14.03	
	Cal. Nitrate - 2 wks (0.5 lb/day)		0.00	18.06	0.00	18.06	
week 2	Drip irrigation	Drip system	9.74	0.00	3.37	13.10	
week 2	Evaporative cooling	Irrigation system	7.01	0.00	8.42	15.43	
week 2	U-pick supervision (60 hrs/wk)		0.00	0.00	63.29	63.29	
week 2	Check-out area (60 hrs/wk)		0.00	245.48	47.47	292.95	
week 2	Pre-pick harvest labor		0.00	0.00	415.15	415.15	
week 3	Drip irrigation	Drip system	19.47	0.00	3.37	22.84	
week 3	U-pick supervision (50 hrs/wk)		0.00	0.00	63.29	63.29	
week 3	Check-out area (50 hrs/wk)		0.00	170.00	47.47	217.47	
week 3	Pre-pick harvest labor		0.00	0.00	287.50	287.50	
week 3	Botrytis control - Elevate	PTO blast sprayer+Trac55hj	14.98	135.00	6.17	156.15	
week 3	Powdery mildew - Nova		0.00	25.00	0.00	25.00	
week 3	Drip irrigation	Drip system	19.47	0.00	3.37	22.84	
week 4	U-pick supervision (30 hrs/wk)		0.00	0.00	63.29	63.29	
week 4	Check-out area (30 hrs/wk)		0.00	85.00	47.47	132.47	
week 4	Pre-pick harvest labor		0.00	0.00	143.75	143.75	
week 4	Evaporative cooling	Irrigation system	7.01	0.00	8.42	15.43	
week 4	Drip irrigation	Drip system	19.47	0.00	3.37	22.84	
week 4	Disassemble irrigation system	Wagon	2.04	0.00	47.47	49.51	
TOTAL MAY			**$167.58**	**$1,078.01**	**$1,730.33**	**$2,973.92**	

Costs and Returns of Producing, Harvesting and Marketing Strawberries in North Carolina

Key Assumptions for Estimating Production and Harvesting Costs

Fuel Prices:

Regular Gas	$3.50	per gallon
Diesel Fuel	$4.00	per gallon

Fumigation and Plastic Mulch Bed Costs[1]:

Midas 50:50 (88 lb in the bed)	$9.00	per lb
VIF Plastic Film (1.25 mil, 4 rolls)	$162.00	per roll (2400')
Drip tape (1.6 rolls)	$192.00	per roll

[1] The budget builds in a 10% higher use rate per acre for fumigant, plastic film and drip tape than generally recommended. This takes into account the field experiences of commercial applicators in NC who use about 10% more fumigant, plastic film and drip tape per acre when laying plastic.

For example, the budget shows a usage rate of 88 lb/A in-the-bed for Midas 50:50, to reflect the fact that about 10% more product is used than the recommended rate of 80 lb/A (160 lb/A broadcast).

Row cover:

1 ounce per sq yd (Gro-Guard)	$0.245	per sq yd

Labor Costs:

Employee:		
Base Wage Rate	$7.00	per hour
Employer Costs[2]	$7.91	per hour
Owner/Supervisor		
Base Wage Rate	$15.00	per hour
Employer Costs[2]	$16.84	per hour

[2] Employer costs includes estimated SSN, Unemployment Insurance and Workman's Compensation Insurance

Total Investment Costs for the Irrigation Systems:

Drip Irrigation System	$6,031	for a five acre system
Frost Protection	$14,712	for a five acre system

Strawberry Plants:

Number of Plants Planted	15,000	per acre
Cost per Plant	$0.22	each
Total Costs of Plants	$3,255	per acre

Four Quart Baskets $0.68 each

Estimated Cash Flow for a Five Acre Direct Market Strawberry Operation

(Dollars per Acre)

Cash Flow Summary		
Month	Monthly Total	Cumulative Total
June	$663	$663
July	$478	$1,142
August	$293	$1,435
September	$5,941	$7,375
October	$267	$7,643
November	$215	$7,858
December	$1,690	$9,548
January	$380	$9,928
February	$650	$10,578
March	$1,212	$11,790
April	$1,433	$13,224
May	$2,974	$16,198

Estimated Returns per Acre for a Five Acre Direct Market Strawberry Operation

Key Assumptions for Estimating Strawberry Returns

Marketable Yield (lbs)	18,000
Percent Sold PYO	40.0%
Percent Sold Pre-Pick	60.0%
PYO Price	$1.00
Pre-Pick Price	$1.50

Estimated Net Revenues per Acre for Varying Prices and Marketable Yields

Price per Pound		Marketable Yield per Acre (Pounds)				
PYO Berries	Pre-Pick Berries	14,580	16,200	18,000	19,800	21,780
(Dollars per Pound)		Estimated Net Revenues (Dollars per Acre)				
$0.72	$1.08	($2,503)	($982)	$705	$2,400	$4,259
$0.85	$1.28	($97)	$1,703	$3,692	$5,681	$7,869
$1.00	$1.50	$2,756	$4,962	$7,202	$9,542	$12,116
$1.15	$1.73	$5,600	$8,021	$10,712	$13,403	$16,364
$1.32	$1.98	$8,869	$11,654	$14,749	$17,844	$21,248

Breakeven Analysis for A Five Acre Direct Market Strawberry Operation in North Carolina

Estimated Marketable Yield per Acre that must be Sold to Breakeven for Varying Direct Market Prices

PYO Prices	Pre-Pick Prices	Marketable Yield per Acre
(Dollars per Pound)		(Pounds)
$0.72	$1.08	17,245
$0.85	$1.28	14,658
$1.00	$1.50	12,460
$1.15	$1.73	10,834
$1.32	$1.98	9,421

Breakeven Prices for PYO Strawberries for Varying Pre-Pick Berry Prices

Marketable Yield	Varying Pre-Pick Price	Estimated PYO Price
18000	$1.08	$0.62
18000	$1.28	$0.34
18000	$1.50	$0.00
18000	$1.73	$0.00
18000	$1.98	$0.00

Breakeven Prices for Pre-Pick Strawberries for Varying PYO Berry Prices

Marketable Yield	Varying PYO Price	Estimated Pre-Pick Price
18000	$0.72	$1.02
18000	$0.85	$0.93
18000	$1.00	$0.83
18000	$1.15	$0.73
18000	$1.32	$0.62

Estimated Number of Customers, or Customer Visits, Needed to Sell the Breakeven Yields for the Assumed Volume of Strawberries Purchased by each Customer

Estimated Average Volume of Strawberries Purchased by:

PYO Customers	10	pounds per visit
Pre-Pick Customers	6	pounds per visit

Marketable Breakeven Yield per Acre (Pounds)	Estimated Sales Volume PYO Volume (Pounds)	Pre-Pick Volume (Pounds)	Estimated Number of Customers Needed PYO Customers (Number)	Pre-Pick Customers (Number)
17,245	6,898	10,347	690	1,725
14,658	5,863	8,795	586	1,466
12,460	4,984	7,476	498	1,246
10,834	4,334	6,501	433	1,083
9,421	3,769	5,653	377	942

Strawberry Breeding

with Emphasis on

Extended Season and Protected Culture

Jim Ballington
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Introduction

- The cultivated strawberry is grown throughout the world.

- Varieties have been developed that are adapted to widely different environmental conditions.

Introduction

- Plants of a particular variety typically grow and produce well in one area, but may do poorly in another.

- A few varieties have demonstrated broad adaptation across a wide range of environments.

Introduction

- Strawberry yields and fruit quality are influenced by a wide range of factors:
  - -Interaction of photoperiod and temperature
  - -Length of rest period
  - -Tolerance to various soil conditions
  - -Winter hardiness
  - -High temperature tolerance
  - -Inherent vigor
  - -Disease and pest resistance/tolerance

Origin and Early Development of the Cultivated Strawberry

Fragaria X ananassa Duchesne

- Resulted from hybridization between two native American species:

Fragaria chiloensis (L.) Duch. – Pacific coast of North America - Chile

Fragaria virginiana Duch. – eastern ¾ of North America

Origin and Early Development of the Cultivated Strawberry

- The original hybridization took place by chance in a garden in France in the early 1700s.

Large-fruited female *F. chiloensis* (from Chile)

Interplanted by chance with

Male plants of *F. virginiana* (from eastern North America)

Origin and Early Development of the Cultivated Strawberry

- Genetic improvement for the first 200 years was largely from the efforts of amateur private breeders.

Twentieth Century Efforts

- Throughout much of the 20th Century, strawberry breeding was conducted primarily by Federal and State Experiment Stations.
- This resulted in much accelerated progress and the development of the modern strawberry industry.

Public Twentieth Century Efforts in the Southeastern US

Arkansas

Ozark Beauty(private)

Cardinal

Comet

ArKing

Florida

Florida Ninety

Floridabelle

Dover

Sweet Charlie

Public Twentieth Century Efforts in the Southeastern US

Louisiana

- Klondike
- Klonmore
- Konvey
- Marion Bell
- Headliner
- Dabreak
- Tangi

Kentucky

- Citation

Public Twentieth Century Efforts in the Southeastern US

North Carolina

Blakemore (US & NC)
Eleanor Roosevelt (US & NC)
Fairmore (US & NC)
Massey (US & NC)
Albritton (NC & US)
Dixieland (US & NC)
Earlibelle (NC & US)
Apollo (NC & US)
Atlas (NC & US)
Titan (NC & US)
Prelude (NC & US)
Rosanne (NC & US)
Sentinel (NC & US)
Sumner (NC & US)

Public Twentieth Century Efforts in the Southeastern US

Tennessee

- McClintock
- Tennessee Supreme
- Tennessee Shipper
- Tennessee Beauty

Virginia

- Pocahontas (US & VT)

More Recent Strawberry Breeding Efforts

- During the last 25 years the number of public strawberry breeding programs has decreased significantly.

- Private strawberry breeding programs have increased in number and importance.

Current Strawberry Breeding Programs in the Southeastern US

Public Programs

- University of Florida
- North Carolina State University

Private Breeding Programs

- Peggy Chang
- Driscoll Strawberry Associates

Modern Breeding Objectives

Plant characters commonly included:

- Yield
- Vigor
- Plant architecture
- Infloresence length
- Fruiting habit (short-day, day-neutral)
- Time of ripening
- Winter hardiness
- Blossom frost hardiness
- High temperature tolerance
- Length of rest period
- Concentration of ripening

Modern Breeding Objectives

Plant characters (contd.)

- Disease resistance
  - -Root diseases
  - -Foliar diseases
  - -Crown diseases
  - -Virus tolerance
- Pest resistance
  - -Aphids
  - -Weevils
  - -Mites

Modern Breeding Objectives

- **Plant characters (contd.)**

- **Yield**, **Vigor** and **Fruiting Habit** are of primary importance in all breeding programs.

- The other characters may or may not be given high priority, depending on local significance.

Modern Breeding Objectives

Fruit characters commonly included:

- Fruit size
- Shape
- Symmetry
- Skin toughness
- Flesh firmness
- Skin color
- Skin glossiness
- Flesh color
- Flavor

Modern Breeding Objectives

Fruit characters (contd.)

- Ease of capping
- Resistance to fruit rots
- Soluble solids content
- Acidity
- Vitamin content
- Post harvest shelf-life
- Neutraceutical content

Modern Breeding Objectives

Fruit characters (contd.)

- **Fruit size**, **fruit firmness** and **flavor** are always important.

- The other fruit characters are of variable priority, depending on the goals of the program.

Objectives of the North Carolina State University Strawberry Breeding Program

1- Develop superior high yielding high quality short-day and day-neutral varieties that are resistant to anthracnose and adapted to annual hill culture.

2- Incorporate new sources of resistance to diseases and pests and tolerance to high temperatures into the current program.

Plant Characters of Importance in the NCSU Program

- **Yield**
- Vigor
- **Plant architecture**
- **Infloresence length**
- **Fruiting habit**
- Time of ripening
- Winter hardiness
- Blossom frost tolerance

Plant Characters of Importance in the NCSU Program

- **High temperature tolerance**
- **Length of rest period**
- **Concentration of ripening**
- Disease resistance

  -Root diseases

  -Foliar diseases

  -Crown diseases

  -Virus tolerance

Plant Characteres of Importance in the NCSU Program

- Pest resistance
  - **-Aphids**
  - -Weevils
  - **-Mites**

Fruit Characters of Importance in the NCSU Program

- **Size**
- Shape
- **Symmetry**
- **Skin toughness**
- **Flesh firmness**
- **Skin color**
- Skin glossiness
- **Flesh color**
- **Flavor**

Fruit Characters of Importance in the NCSU Program

- Ease of capping
- **Resistance to fruit rots**
- Soluble-solids content
- Acidity
- Vitamin content
- Post-harvest shelf-life
- Neutraceutical content

Nuts and Bolts

- Parents are typically chosen in varietal type crosses so that they (hopefully) complement each other in the traits they transmit.

Ex: Parent 1 is high yielding and has very firm fruit

Parent 2 has large fruit and very high quality

Goal – to combine the desirable traits from both parents in the progeny they produce

Nuts and Bolts

- When incorporating traits like disease resistance, crossing susceptible cultivated varieties to wild disease resistant clones is often required.
- Once resistant hybrids are identified, these are then backcrossed to cultivated types for several generations to get disese resistant types with the characteristics desired in cultivated types.

Nuts and Bolts

- On average, around 15,000 seedlings must be grown and evaluated over years and locations, for every new variety that is named and released.
- Breeding is a “numbers game”.
- It usually takes around 10 years from the time a cross is made until a variety is named from that cross.

Why Include Day-neutrals in the Breeding Objectives

- Day-neutrals have the potential to produce flowers and fruit throughout the growing season so long as maximum temperatures do not go above 90^0 F for extended periods.

- Appropriate temperatures for season-long production of day-neutrals occur in a number of areas of the southern Appalachians at around 3000 ft. elevation and above.

Why Include Day-neutrals in the Breeding Objectives

- Prices for strawberries have traditionally been higher in late summer and fall when much of the day-neutral strawberry crop would be produced.

- Day-neutral strawberries could prove to be a viable alternative to partly replace burley tobacco in the Appalachian region.

Why Include Day-neutrals in the Breeding Objectives

- Day-neutral strawberries also show promise for two season production (fall & spring);

OR

- Continuous production throughout late fall, winter and early spring;
- From plants established in late summer in high tunnels, or row covers (Deep South).

High Tunnels

Advantages

- Extended season and off-season production (higher yields)
- Significant reduction in diseases
- Reduced risk of frost at flowering
- Eliminates problems with cool wet weather causing poor pollination, reduced yields, and season delays.

High Tunnels

Advantages

- Improved fruit quality
- Significant increase in % marketable fruit
- Improved continuity of supply
- Makes organic production more feasible
- Short-day varieties developed for winter production as well as day-neutral varieties are adapted to this system.

High Tunnels

Disadvantages

- Cost of the tunnel
- Powdery mildew can be more problematic
- Mites are often more of a problem

Consider the Possibilities !!

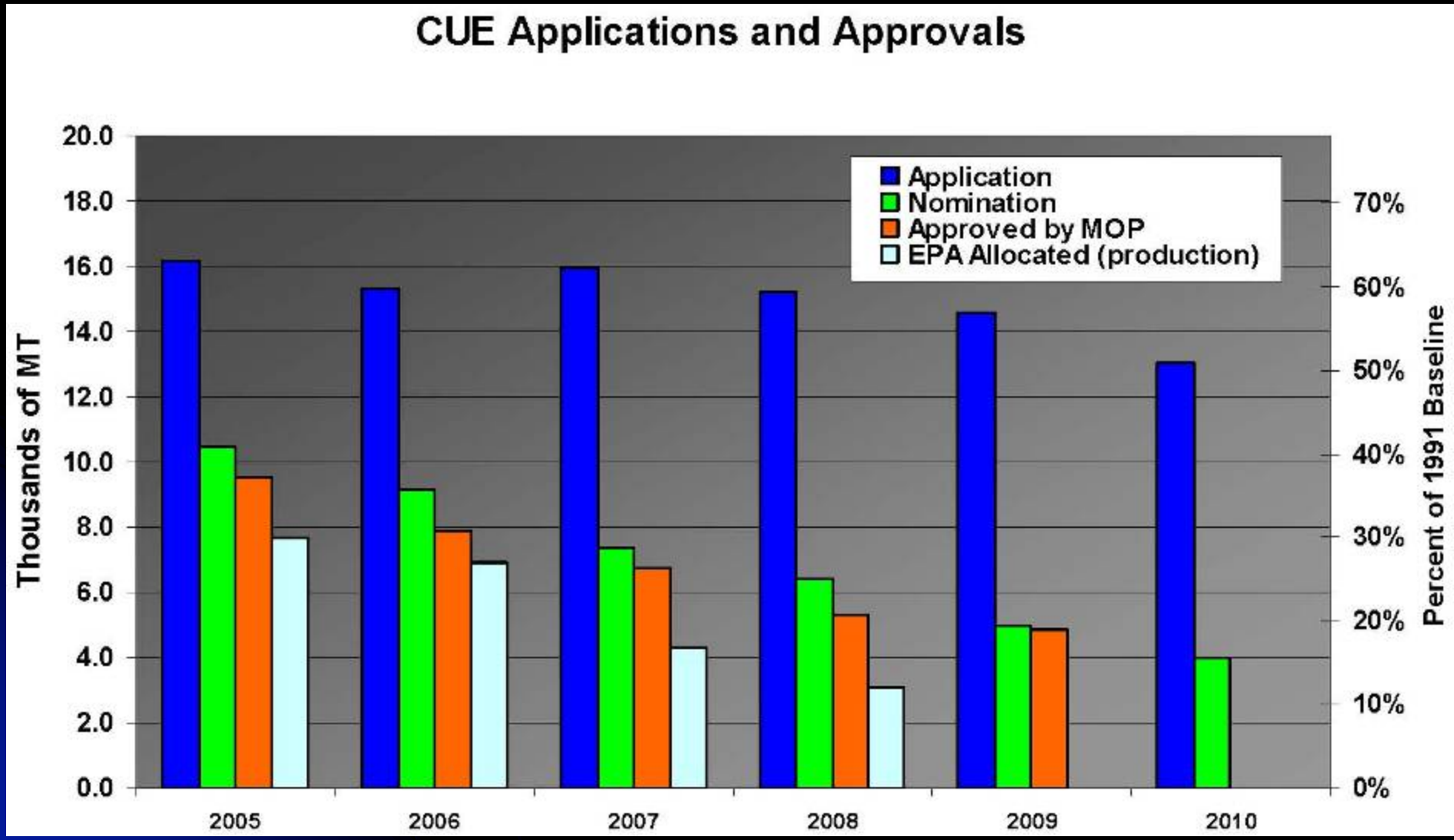
- Utilizing current outdoor spring cropping, day-neutrals in the Appalachians for summer and fall production, along with production from high tunnels from late fall until spring, we have a potential 12 month strawberry production season in North Carolina.
- What are the possibilities for the other states in the region???

NC STATE UNIVERSITY

Methyl Bromide Update

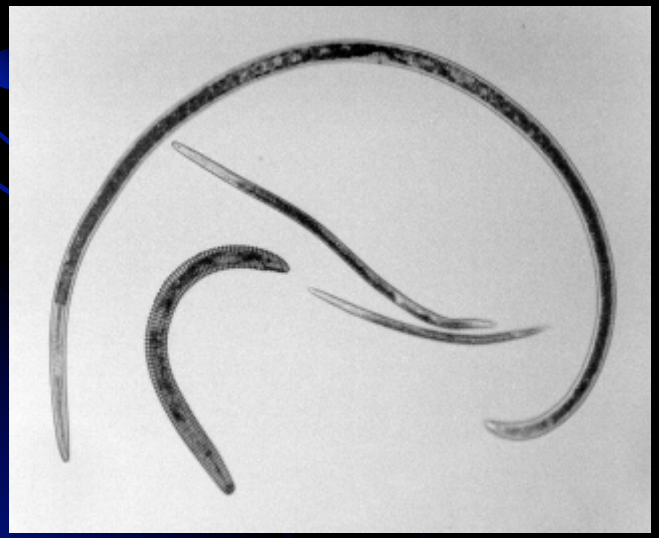
Rob Welker
Department of Plant Pathology - NCSU

Is Methyl Bromide Ever Going Away??



Potential Alternatives

The Enemies



Chloropicrin

- Little to no weed control at our use rates. Can be used to germinate some weeds (nutsedge)
- Some control of Nematodes
- Excellent disease control (fungal, bacterial)

Telone

- Moderate weed control
- Excellent nematode control
- Some disease control
- When combined with Chloropicrin (ie Telone C-35) provides excellent disease control

MIDAS

- Formulated with chloropicrin as a mixture of 50:50 or 98:2 (MIDAS:Chloropicrin)
- Similar fumigant properties as methyl bromide
- Excellent control of weeds, nematodes and diseases
- LOW application rates

Paladin (EUP in some states)

- DMDS formulated as a mixture with Chloropicrin (71:29 DMDS:Chloropicrin)
- Moderate weed control (weak on grasses) but good on nutsedge
- Good control of disease and nematodes
- Odor a potential problem

Metam Sodium/Potassium

- Lazy fumigant
- MITC generator and will only move about 2 inches from where it is placed in the soil
- Physical movement needed (rotovate, drip application)

What To Use??

Chloropicrin
Telone-C35
InLine (=EC formulation of Telone-C35)
PicClor 60
MIDAS
Metam Sodium (Vapam, Sectagon, Meta-CLR)
Paladin (DMDS)

Or – Mix and Match!!!

Telone-C35 + Metam Sodium (heavy weed pressure)
Chloropicrin + Metam Sodium or Herbicides (Goal / Chateau?)

VIF Plastic

- Used with current plastic layers with some modifications needed (tension)
- Sometimes looks loose on the beds

VIF Plastic

- Lower chemical application rates
- Better efficacy
- Same disposal issues
- More expensive

- Plant Back??
- Worker Exposure??

TIF Plastic

- Totally Impenetrable Film

- I don’t know

Equipment Modifications

Flow Meter

- Meters chemical flow through the system
- NOT necessary for alternative chemical application
- Makes changing speeds or switching chemicals very easy

Orifices

- Smaller sizes needed to control fumigant flow
  - Calibrate with speed, pressure and orifice size
- Needed even with a flow meter to divide chemical flow evenly between knives
  - At least 10 PSI pressure at the manifold


1500-0

Knife Spacing

- For beds with a 30 inch or larger bed top, 3 or more knives are needed for good dispersion
  - 9 inches between knives is maximum

DEEP shanking good for fumigant dispersion up through the soil profile

Deep Shanking Good AND Bad

PPE

Label Requirements for Telone C-35

- For Handlers with liquid contact potential (equipment adjustment, any activity within 6 feet of an unshielded, pressurized hose containing the product):
  - Coveralls, chemical resistant gloves, chemical resistant footwear, chemical resistant apron, half-face respirator with a pesticide removing filter

Label Requirements for Telone C-35

- For Handlers with no liquid contact potential (tractor driving, soil sealing)
  - Face shield or safety glasses, half-face respirator with pesticide removing filter, long-sleeved shirt and long pants

Half-Face Respirator

- Probably needed for all people in the field during applications
  - Doctor certification for all wearers
  - Fit test requirements
- Difficult if not impossible for migrant workers

Drip Applications

- Flexibility in application timing
- Fewer people requiring PPE

- Possibly need 2 drip lines

Minimal Equipment

Potential for Disaster

- Proper Backflow
- All ends secured

- CONSTANT MONITORING

COST?

Fumigant	Rate	Plastic Cost (2 Rolls)	Chemical Cost	Total Cost
Methyl Bromide 50/50	200 lb in-row – Standard Plastic	380	910	$1,290
Methyl Bromide 50/50	120 lb in-row – VIF Plastic	480	546	$1,026
Telone C-35	17.5 gal in-row – Standard Plastic	380	350	$730
Telone C-35	10.5 gal in-row – VIF Plastic	480	210	$690
PicClor 60	125 lb in-row – Standard Plastic	380	344	$724
PicClor 60	75 lb in-row – VIF Plastic	480	207	$687
Inline	13 gal in-row – Standard Plastic	380	285	$665
Inline	7.8 gal in-row – VIF Plastic	480	172	$652
Chloropicrin	75 lb in-row – Standard Plastic	380	216	$596
Chloropicrin	45 lb in-row – VIF Plastic	480	130	$610
VAPAM	37.5 gal in-row – Standard Plastic	380	206	$586
VAPAM	22.5 gal in-row – VIF Plastic	480	124	$604
MIDAS	75 lb in-row – VIF Plastic	480	675	$1,155

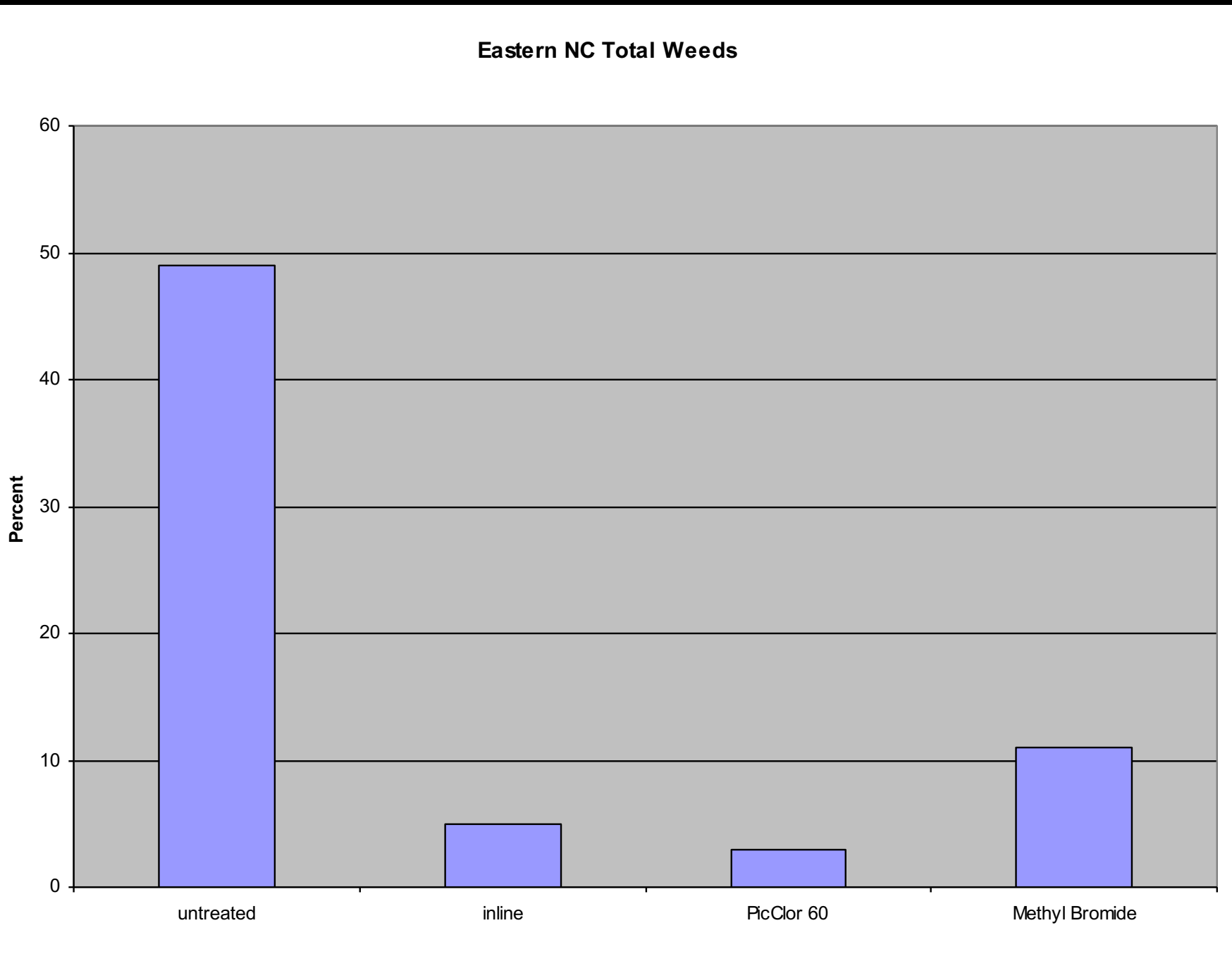
Example On-Farm Trial

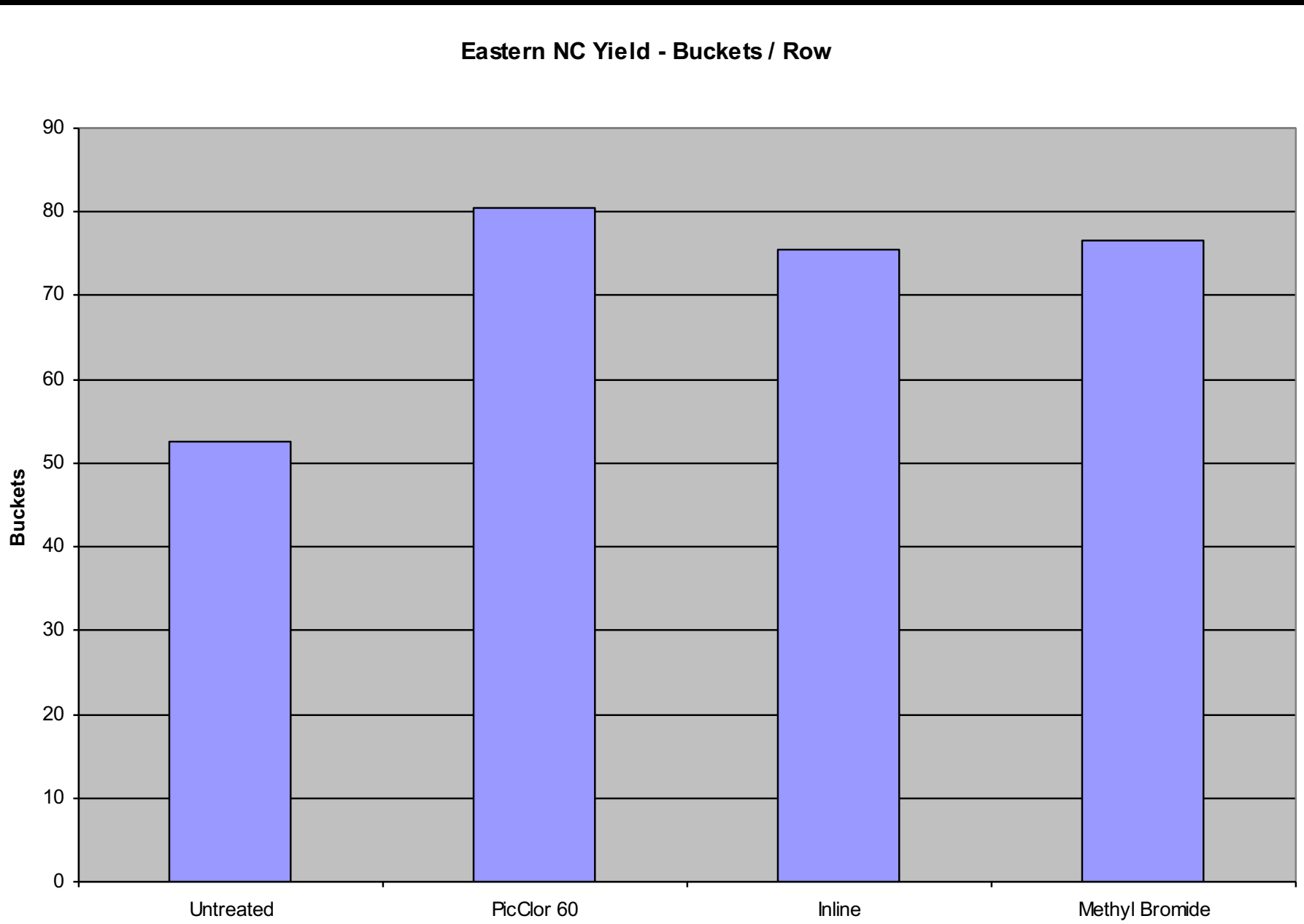
- Eastern NC (Rick Morris): 1 Acre Trial
  - Methyl Bromide 250 lb/A VIF
  - Inline 26 gal/A VIF
  - Pic-Clor 60 187.5 lb/A VIF
  - Untreated VIF

  - 1.51 % Moisture at application


Pic-Chat 60


Methyl Bromide
50/50


Eastern NC Total Weeds
Percent
60
50
40
30
20
10
0
untreated
inline
PicClor 60
Methyl Bromide


Eastern NC Yield - Buckets / Row
Buckets
90
80
70
60
50
40
30
20
10
0
Untreated
PicClor 60
Inline
Methyl Bromide

EPA Registration Eligibility Decisions (REDs) for Methyl Bromide, Chloropicrin, Metam Sodium and Dazomet

- New potential EPA regulations specify LARGE buffer areas
- No occupied structures in buffer areas – including growers own home
- Road right-of-ways have some restrictions if they are in buffer zones
- Longer re-entry waiting periods (5 days)
- No buffer zone overlap (even on same farm)
- Air monitoring around fields where occupied structures exist within 300 feet of the buffer zones

MAJOR STRAWBERRY DISEASES

Gray Mold or Botrytis Rot

Gray mold is a serious disease in all strawberry production areas and is the primary disease 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. Crown rot is discussed elsewhere. Disease is most severe during bloom and harvest in seasons with lengthy periods of cloud and rain.

Gray Mold; Botrytis Rot (*Botrytis cinerea* (de Bary) Whetzel)

Symptoms and Signs

Gray mold may be prevalent during all stages of strawberry fruit development. Infected leaves and flowers turn brown and may die. Light brown lesions usually develop on the stem end of the fruit due to flower infections but may also occur on the sides of fruit where soil, standing water, or infected berries or flower petals are in contact (Figure 1). Infected berries may remain firm, yet become covered with gray spores and mycelium, giving the fruit a velvety gray appearance. High humidity favors mycelial formation that is visible as a white cottony mass. On undeveloped fruit, lesions may develop slowly and fruit may become mis-shapened and die before maturity. Fruit that are completely rotted become dry, tough and mummified.

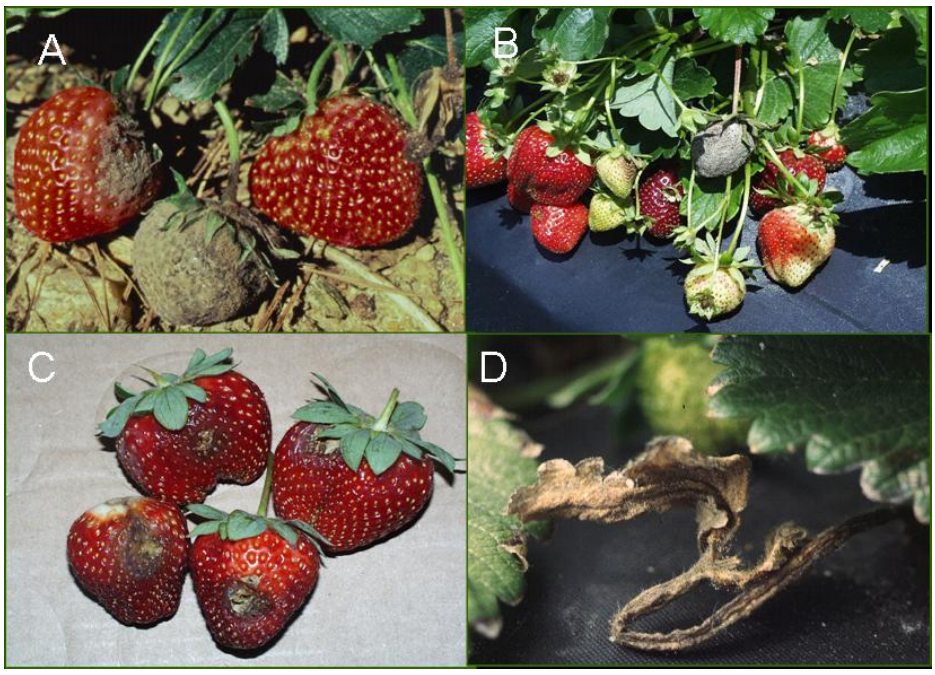


Figure 1: Gray mold symptoms: a) on fruit in a matted row production system; b) on fruit in a plasticulture production system; c) on fruit where senescent flower petals fell allowing the pathogen to directly penetrate fruit; d) on senescent tissue.

Disease cycle

Botrytis primarily enters the field on transplant foliage. The fungus can live in the green tissue but be latent, or dormant, and not cause symptoms. Botrytis can affect many different crops and therefore weeds surrounding a field could be an important source of the pathogen. The

pathogen can also produce dark hardened structures called sclerotia and these can persist in soils for years. However, in our recent experiments conducted in eastern North Carolina, we found no signs of *Botrytis* on surrounding vegetation, and found no indication of sclerotia (the overwintering form of *Botrytis*) in the soil, suggesting that those sources may be of limited importance in the spread of disease. 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 (Figure 2). Spores then form and, once environmental conditions are appropriate (between 65-75 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.

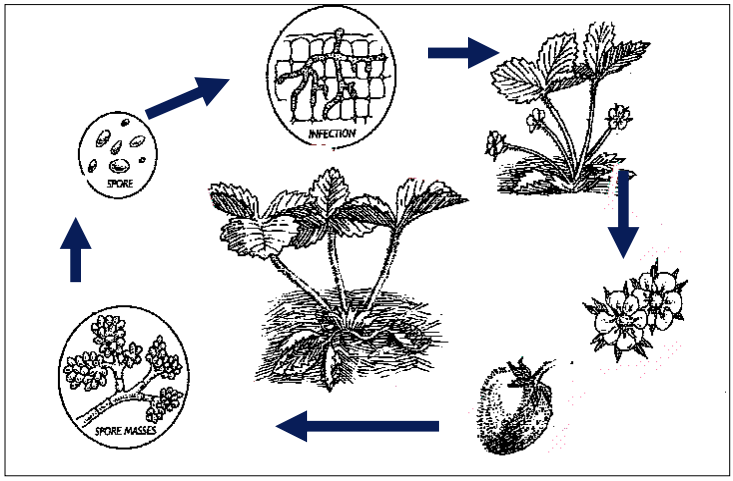


Figure 2: Infection cycle of B. cinerea in strawberry plantings from Cooley et al. 1996.

Factors of plant growth that are most important for disease development in annual planting systems:

1. Leaf senescence - Death of transplant foliage results in the production of spores from the initial inoculum introduced at planting. *Botrytis* will produce its spores on the dead leaf tissue and infect the leaves emerging during this time. Those newly infected leaves may then senesce two to three months later, during primary flower development (Figure 3).
2. Leaf emergence - Newly emerging leaves are extremely susceptible to infection. Upon infection in the fall, leaves will appear healthy until senescence occurs in the spring and the secondary inoculum is released.
3. Floral development - Release of secondary inoculum results in the infection of flowers and subsequent infection of the fruit. Rarely are the fruit themselves infected by an airborne spore, rather, *Botrytis* will stay dormant in the developing flower/fruit until factors such as increased ethylene production (ripening) and high humidity/rainfall allow for growth of the fungus.

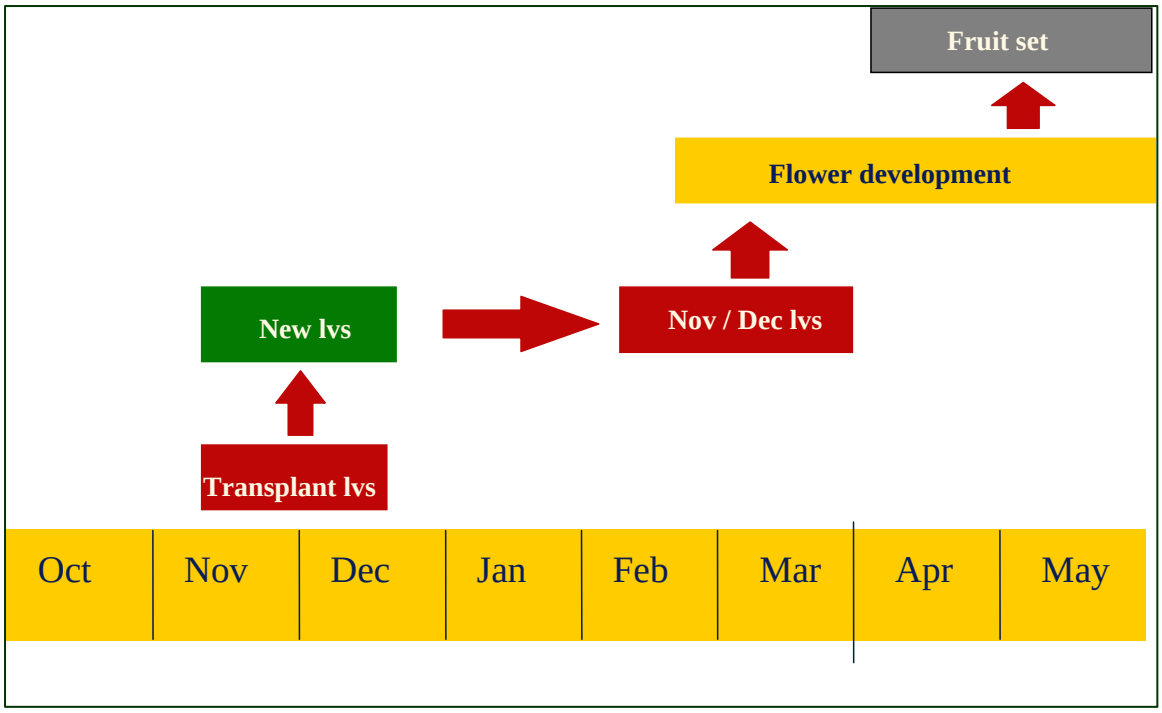


Figure 3: Proposed mechanism by which Botrytis is introduced on transplant leaves in October that subsequently die around November 15 to December 15. These dead leaves sporulate producing spores that infect newly emerging leaves. These November-December leaves die around late February to early March releasing spores as flowers are developing. The pathogen colonizes he flowers and subsequently enters the fruit to cause typical field symptoms of fruit rot.

Control

1. USE DISEASE-FREE PLANTS.

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

2. MONITOR AND MANAGE

Excess nitrogen has been shown to increase fruit rot when weather conditions are favorable. To avoid over-fertilization, base fertilizer programs on leaf tissue nutrient analysis reports (see leaf sampling). Research has demonstrated increasing nitrogen levels beyond an optimum level does not increase yield but does increase fruit rot incidence.

Allow adequate spacing between plants to improve airflow in the canopy. However, manage plant spacing for optimum yields rather than to manage disease. 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 from fruit and leaves. Removal of senescing tissue from the field

may be helpful in the fall, but is likely of most benefit in the early spring, just prior to bloom, to help lower inoculum levels. An economic analysis has not been performed on the benefit of sanitation. In studies where sanitation was conducted, yields tended to be highest and benefits most pronounced if fungicides are not used (e.g. organic production systems). Harvested fruit should be monitored for disease, and infected berries removed. Rapid removal of field heat and keeping fruit at around 34 F and increasing carbon dioxide levels during shipping (12-15 % concentration in gastight storage bags) when harvested will help keep *B. cinerea* down.

3. CHEMICAL CONTROL

Fungicides play a major role 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 should 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.

A detailed fungicide schedule is included elsewhere (see www.smallfruits.org).

Botrytis cinerea has developed resistance to MBC-generating compounds (e.g. thiophanate-methyl = Topsin-M) and dicarboximides (iprodione = Rovral). Therefore, alternating between chemistries or using tank mixes is highly recommended. Topsin-M is best used in combination with a protectant fungicide such as captan. Topsin-M will be of most benefit in bare root plantings and during the bloom phase.

Elevate is a protective fungicide with good efficacy against *Botrytis*, and should prove to be a useful tool where resistance to other fungicides has become a problem. It can be used alone or in combination with other fungicides as a tank mix and can be used up to and including the day of harvest. Elevate limits penetration of the *Botrytis* pathogen into the plant by limiting spore germination, germ tube elongation and mycelial growth. Elevate should not be used for more than two consecutive sprays to avoid selection of resistant fungal populations, according to standard practices for resistance management.

Switch has 2 types of fungicides (cyprodinil = systemic + fludioxanil = protectant) and is also a superior botryticide but has a wide range of activity. It is best rotated in with other fungicides. Based on some of our data, Switch appears to reduce post-harvest fruit rot incidence also.

Pristine is also a combination product (QoI chemistry + boscalid). The boscalid component has excellent Botrytis activity. The QoI component is the same component as Cabrio (pyraclostrobin) and thus care must be taken when developing a fungicide schedule (see notes on anthracnose and the fungicide schedule elsewhere).

Other new chemistries are currently being evaluated, and should provide efficient alternatives to traditional fungicide programs.

For organic growers, vigilantly manage plant growth as described above and incorporate plant sanitation by removing dead and dying leaves just prior to bloom. Some experience is available on the use of compost teas, biological control products, and other products (biological control

products) and can be discussed further with a strawberry specialist. Harvest fruit in a timely manner and remove field heat ASAP to ensure fruit is cooled down prior to shipping or selling.

4. BIOLOGICAL CONTROL

Antagonistic fungi such as *Trichoderma harzianium* Rifai and *Gliocladium roseum* Bainier have been used in Europe and Brazil as alternatives to fungicides. Efficacy trials in the USA provide limited information on effective biological controls for plasticulture production systems. In the northeastern matted row production region, bees have been used efficiently to deliver beneficial fungi to flowers resulting in reduced gray mold incience.

Remember, *Botrytis* is in the field all season long. Don't wait until peak bloom or fruit set to begin control practices. Plan ahead and design your management program to inhibit disease progression at critical points in the season.

Causal Organism [on separate page using hot links with detailed images for the diagnostician]
Botrytis cinerea (anamorphic state *Botryotinia fuckeliana* (deBary) Whetzel) hyphae are branched, septate, hyaline. Conidiophores are long (2-5 mm), dark brown, branched primarily near the apex, determinate with swollen terminal cells that form ampullae. Conidia (8-14 x 6-9 μm) are one-celled, multinucleate, obovoid, colorless or pale brown, and are born on denticles protruding from each ampulla giving it a grapelike cluster appearance. In mass, conidia appear gray to grayish-brown. Sclerotia are black, irregular in shape, and can be up to 5 mm long.

ANTHRACNOSE OF STRAWBERRIES

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 if the pathogen is present, 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 and problems in plug production systems. *Colletotrichum gloeosporioides* tends to be associated with the crown rot phase of anthracnose. *Colletotrichum fragariae* is the primary organism causing crown rot and is not commonly a problem on fruit. It has not been isolated as a common pathogen in North Carolina since 1986. *Colletotrichum dematium* occasionally causes strawberry fruit rot, but is not considered to be a major cause of anthracnose diseases on strawberries.

Symptoms and Signs

Anthracnose **Fruit Rot or Black Spot** (*C. acutatum* and *C. gloeosporioides)*

Figure 1: Anthracnose fruit rot. The ripe rot is typical of most fields in the Southeastern region with sunken circular lesions containing masses of spores.

Anthracnose fruit rot 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 (Figure 1). Under dry conditions, the entire fruit may dry up and become mummified. Buds, pedicels, peduncles, and flowers of most cultivars are susceptible to anthracnose. Flowers may also die and dry out. If infection occurs shortly after pollination, the developing fruit remains small, hard, and is mis-shapened. Infected tissue placed in an incubation chamber will sporulate within 24 hours. Symptoms can be confused with Alternaria fruit rot, Phomopsis frit rot, Rhizoctonia dry rot, or hail damage but the combination of signs (spores, sterile setae etc) and symptoms is diagnostic for this disease.

Anthracnose Crown Rot (Colletotrichum gloeosporioides, C. acutatum, and C. fragariae)

Figure 2: a) Typical “marbled” appearance of infected crown caused by *C. gloeosporioides, or C. fragaria*. b) Brown discoloration in the top of the crown caused by *C. acutatum* infection initiated during the plug production phase.

Initial symptoms of **Anthracnose Crown Rot** are red streaks on petioles and runners. These mature into sunken, dark, and firm lesions. Advanced lesions may girdle the petioles and runners, causing the leaf or daughter plant to wither and die. Pink conidial masses develop under humid conditions and are mostly seen in the center of the lesion. Setae may be present

depending on the species involved. The lesions may also grow down into the crown and cause crown rot. Initially plants wilt in the heat of the day, which is often over-looked as drought or heat stress. In advanced infection, the entire plant will die. Cutting the crown lengthwise reveals white and reddish brown streaks, creating a marbled effect, or a firm rot (Figure 2). The fungus can be isolated from this discolored region by placing pieces of infected tissue onto potato dextrose agar. *C. acutatum* can also cause a bud rot, where infected buds turn dark brown to black and develop a firm rot. Within a crown a single bud may die and the plant will continue to thrive, or the entire crown may become infected, wilt, and collapse. Pink conidial masses usually form on the rotted bud. We have isolated *C. acutatum* from strawberry roots and such infections have been documented to cause a generalized stunting.

Disease Cycle

The primary source of anthracnose inoculum enters the fields on strawberry transplants (figure 3). *C. acutatum* has been reported to survive in soil and plant debris for 9 months, and *C. acutatum* and *C. gloeosporioides* may infect weeds growing alongside of the field. However, in North Carolina, field experience suggests overwintered (and oversummered) inoculum is not important and infected strawberry transplants are the primary source of inoculum. 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, thus cultural practices that encourage aeration and rapid drying of fruit should be used. Straw mulches may help to reduce the dispersal of spores in splashing water, but plastic mulches provide a springboard for droplets, thus encouraging the spread of disease. Overhead irrigation can also contribute to disease spread.

Crown rotting species may survive cooler temperatures by remaining latent within the crown of the plant until temperatures warm up. In annual plasticulture systems, early establishment of disease in the fall may result in wilting or death of transplants. In spring plantings, wilted plants are a source of secondary inoculum that may spread to epidemic proportions through splash dispersal.

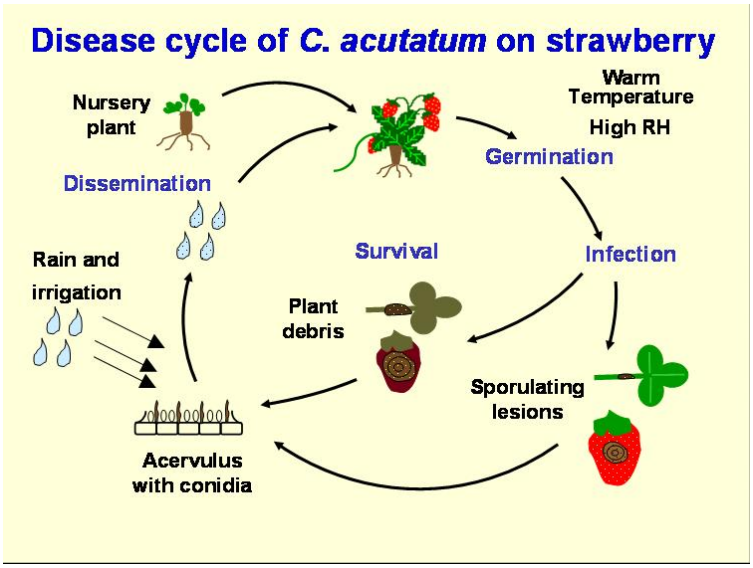


Figure 3: Life cycle of *Colletotrichum acutatum*. Composed by Leonor Leandro.

Control

1. USE DISEASE-FREE PLANTS

Rarely does anthracnose recur year after year on the same farm. The disease has been associated with asymptomatic plants imported from transplant supply nurseries. Thus, 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. Plants have reduced risk of disease if they have been micropropagated and then entered into a strict plant certification program. North Carolina State University and the North Carolina Crop improvement have implemented such a program including strict guidelines for certification. Similar standards by other nurseries or suppliers will help reduce the risk of anthracnose.

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.

2. MONITOR AND MANAGE

Periodic scouting of a field, especially during warm and wet weather, will enable early detection of anthracnose. If the problem seems to be associated with hot spots in the field, remove and destroy (bury or burn) infected plants and surrounding plants (5 to 10 foot radius). Killing the plants with herbicide will initiate spore production by the pathogen, and if these plants are not removed the problem will be aggravated.

Nitrogen levels should be kept at the required level, since high nitrogen levels in the soil favor fungal development. Keep foliage dry and reduce water splash by use of drip irrigation to help lower conidial dispersal and spread of the pathogen.

- Avoid excess overhead irrigation (e.g. for evaporative cooling) and do not over water or over fertilize.
- Always pick the infested area last and do not let personnel or equipment move from an infested area to clean areas in order to limit spread of the pathogen.
- Do not work plants when wet.
- Although the economics are not available, it may be practical to pick and remove infected berries out of the field in order to reduce the amount of inoculum. However, be aware that this pathogen colonizes leaves and other green tissue without showing symptoms. Therefore, if the pathogen is on the fruit, it will also be on the plant tissue and it will be impossible to remove entirely. Removing infected fruit should help to reduce disease pressure.

3. CHEMICAL CONTROL

See the recommended fungicide schedules elsewhere (www.smallfruits.org).

It is currently suggested that you save the strobilurin (now called QoI) fungicides (Abound, Cabrio, and Pristine) for use in controlling anthracnose ripe fruit rot during optimum disease conditions. Captan or Thiram should help to suppress anthracnose when utilized in botrytis or other disease control applications, but the QoI materials (Cabrio, Pristine, Abound) are currently

the most efficacious materials for control of anthracnose. Some of these QoI materials may have activity against multiple pathogens other than anthracnose, but unless anthracnose occurs in conjunction with these other diseases of concern, it is suggested that the QoIs not be used. With only 5 total applications of these materials per crop, it is an imperative that they be utilized effectively. Also, resistance management is extremely important with the QoIs; make sure to follow all resistance management guidelines.

For C. gloeosporioides, if there is no other option than using plants with known minor infestation, fungicide dip the fresh-dug plants with Switch @ 5-8 oz/100 gal water or dip plants in Abound @ 5-8 fl. oz/100 gal water. Dip plants for 2-5 minutes and plant as soon as possible after dipping. Follow all label directions carefully. If possible, minimize irrigation from overhead sprinklers. Our research results indicated that significant reduction of plant mortality and increase in yield can be obtained by dipping infested plants in Switch before planting.

4. ROTATION

Rotation out of strawberries for 2 or 3 years will help to rid the field of inoculum from infected plant tissues or infested debris in the soil. However, in North Carolina, the experience has been that anthracnose does not commonly reappear a second year in a field unless the disease is re-introduced on contaminated plants or if plants from the previous year persist on the farm over summer.

ADVANCED information on Anthracnose: [These could be linked to another page with detailed images.]

Colletotrichum acutatum J. H. Simonds is more commonly associated with fruit rot, but has also been associated with crown rot. Conidia form rose, salmon pink, or orange masses and are produced in an acervulus. Setae are rarely observed. Conidial (8.5-16.5 x 2.5-4 um) ends are tapered. When setae do form (generally on strawberry leaf agar), they are much smaller (5.2 x 3.2 um) than setae produced by *C. fragariae*. Colonies are pink, orange, lavender, or white and turn gray with age. This species grows slower on PDA than either *C. fragariae* or *C. gloeosporioides*.

Colletotrichum gloeosporioides (Penz.) Penz. and Sacc. tends to be associated with the crown rot phase of anthracnose but can also cause fruit rot. It has frequently been isolated in nurseries. This species commonly forms the teleomorph. Conidial masses are pale pink, whitish, or translucent. Conidia are more rounded at the base that *C. fragariae*.

Colletotrichum fragariae A. N. Brooks is the primary organism causing crown rot and is not commonly a problem on fruit. It has not been isolated as a common pathogen in North Carolina since 1986. Lesions form on petioles, runners, and leaves. Conidia (12.5-16.5 x 4.5-5 μm) are cylindrical, straight, and rounded at the apex and taper to a point at the base. They are produced in acervuli or on aerial hyphae. Setae (50-200 x 3.5-4.5 μm) are usually present and are 3-5 septate and fasciculated. On potato dextrose agar (PDA), colonies are olive, gray or black with dark gray or olive reverse. Isolates have not been reported to form a teleomorph.

Colletotrichum dematium has sickle-shaped conidia (18-26 x 2-3 μm) and are produced in acervuli with abundant setae. Colonies on PDA are gray with a white margin. This species occasionally causes strawberry fruit rot, but is not considered to be a major cause of anthracnose diseases on strawberries.

Phytophthora Crown Rot

Strawberry infection by *Phythophthora cactorum* is aggravated 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.

Phytophthora Crown Rot (*Phytophthora cactorum* (Lebert and Cohn) J. Schrot.)

Symptoms

Stunting of plants or wilting of young leaves are the first symptoms and may appear at any time during the season. Current plant collapse problems are associated with fruit production and the warm weather. The pathogen infects the crown and causes a uniform brown discoloration (Figure 1) and plants will die. The dark brown discoloration may appear at the base or middle of the crown. In many cases, the brown discoloration in the crown is associated with roots that are infected and by which the pathogen enters the crown. This crown infection results in symptoms similar to severe drought stress. Leaf margins begin to turn brown and entire leaves will die (Figure 2). Plants may break freely at the upper part of the crown when pulled. Roots often are discolored brown also. In contrast, tissue infected by the anthracnose pathogen takes on a darker cinnamon color, is more firm, and often has a “marbled” appearance. In diagnostic clinics, root surface scrapings will (often) reveal *P. cactorum* oospores in the tissue (Figure 3) using a compound microscope.

Disease Cycle

Infection is favored by wet conditions. The primary inoculum sources include oospores in the soil and infected transplants. Most epidemics in the southeastern region to date have been associated with plant problems and the importance of soil-borne inoculum is not well documented. Disease expression is influenced by time of planting and environmental conditions. Plantings established in fall may have wilted plants soon after planting but it is possible the disease will not be expressed until the following spring after the pathogen has resumed activity.

Figure 1: Left) Internal crown discoloration due to Phytophthora infection. Right) Mature planting near bloom showing empty spaces where infected plants died. Neighboring plants did not appear to be infected.

Figure 2: Left) Part of the plant has wilt symptoms due to Phytophthora infection. Right) Leaves show symptoms of drought stress beginning at the leaf margins.

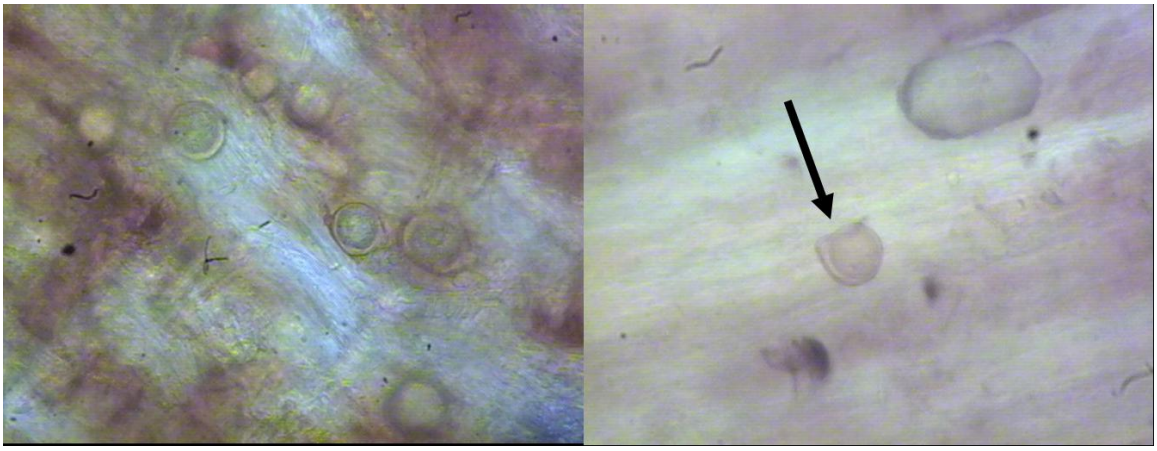


Figure 3: Clinics or labs with microscopes can take root tissue and directly observe oospores in infected tissue to achieve a rapid diagnosis. We also culture on Phytophthora selective media to confirm the problem. These oospores can escape into the soil and potentially persist for years.

Control

1. SITE SELECTION AND PREPARATION

   Choose a site with adequate soil drainage and avoid fields with a history of disease. Plant in raised beds, not low wet spots, and rip fields during preparation. Soil fumigation may help to reduce inoculum.
2. USE DISEASE FREE PLANTS.

   Use healthy plants, although symptoms may not be apparent at the time of field setting.

3. MONITOR AND MANAGE
   Use proper irrigation practices; do not overwater as inoculum is spread by runoff.
4. CHEMICAL CONTROL

Phytophthora cactorum, has become a recurrent, though not common problem in our industry. Under conditions of heavy rains experienced by plant suppliers and/or wet soil conditions in fall, growers should consider the use of Ridomil Gold in their planting beds. The label allows for the "first application after transplanting". It should not be used on plug plants prior to planting, as a dip, or in the transplant solution as these are not labeled uses and can cause plant stunting – in our experience. Use 1 pt per treated acre (NOTE: Only half of an acre of strawberries is actually under plastic meaning 1 acre of land has 0.5 acres of treated area). It is best to apply Ridomil Gold after the time of excess watering and when the plants have taken a root-hold – approximately 2 weeks after transplanting. Ridomil Gold is best applied through the drip irrigation system. Ridomil Gold is much more effective than the phosphorous acid generators (e.g. Aliette, Prophyt, Phostrol etc) for managing Phytophthora. The phosphorous acid generators are helpful in specific circumstances where Ridomil cannot be applied or when strawberry roots are severely damaged and a foliar spray of a product is the best option.

In fields with severe and widespread stunting, the use of Aliette or ProPhyt (phosphorous acid generators) may prove beneficial as a foliar spray. Such plants may have poor root systems and will not take up Ridomil efficiently. Aliette and ProPhyt will be absorbed into the leaves and move down the plant to the crown and roots. Excess use of Ridomil will lead to pathogen populations resistant to the chemical.

In the spring, additional applications may be beneficial. We generally recommend an application during the period of active new root growth (early March).

Our experience with Phytophthora crown rot of pepper has shown that there is benefit when Ridomil Gold is applied as a broadcast treatment prior to forming the beds. Alternatively, Ridomil Gold could be drip applied prior to field setting transplants. This apparently ensures Ridomil is available to the plants when they are field set. It can be difficult to get adequate concentrations of Ridomil Gold to the plants relying on drip irrigation only in the fall. These thoughts are consistent with the label but have not been adequately researched in strawberry production systems.

About The Use Of Ridomil Gold During The Harvest Season. Growers ask about the use of Ridomil Gold during harvest and the waiting period required after treatment. The label offers no clear guidelines and I pursued this with the company. There is no waiting period for Ridomil when applied through the soil as recommended. This may seem concerning since Ridomil Gold is a systemic fungicide and may pose a health concern. However, the answer probably relates to the anatomy of the strawberry leaves and fruit. Ridomil moves through the apoplastic tissue (dead tissue and cells like the xylem or water conducting tissue). Therefore, soil applied Ridomil Gold typically follows the transpiration stream of the water and will accumulate in the leaves and other tissue that have stomates and therefore transpire a lot of water. However, the strawberry fruit does not have stomates and the fruit does not transpire large volumes of water.

Rather, the fruit is a sink accumulating sugars etc from the symplastic pathway (living cells such as the Phloem). Therefore, Ridomil Gold does not accumulate in the fruit reducing residue concerns. I was involved in a number of studies with Ridomil 15 years ago documenting this type of effect. Therefore, in fields where harvest has not reached a peck and plant vigour is good, benefit may be achieved with a Ridomil Gold application if *Phytophthora cactorum* has been diagnosed. Strawberry plants will continue to put out adventitious roots and (in previous work I've done with red steele at least) there is a curative effect. Dr. Fernandez and I have had students who monitored root growth and plant anatomy and after this peek growth period the plant seems to go "downhill" and there is likely little benefit to the use of Ridomil Gold to limit disease problems. That is why in our previous recommendations we emphasized the use of Ridomil Gold as the spring growth season really initiates.

PLEASE NOTE:
Recommendations of specific chemicals are based upon information on the manufacturer's label and performance in a limited number of trials. Because environmental conditions and methods of application by growers may vary widely, performance of the chemical will not always conform to the safety and pest control standards indicated by experimental data.

Recommendations for the use of chemicals are included in this publication as a convenience to the reader. The use of brand names and any mention or listing of commercial products or services in this publication does not imply endorsement by the North Carolina Cooperative Extension Service nor discrimination against similar products or services not mentioned. Individuals who use chemicals are responsible for ensuring that the intended use complies with current regulations and conforms to the product label. Be sure to obtain current information about usage and examine current product label before applying any chemical. For assistance, contact your county North Carolina Cooperative Extension Service agent.

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Alternatively, if roots are badly damaged, plants have responded well to an Aliette application. These products are not needed if Phytophthora is not present.

Bacterial Angular Leaf Spot

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.

Bacterial Angular Leaf Spot (*Xanthomonas fragariae*)

Symptoms and Signs
Water-soaked lesions first appear on the lower surface of the leaf, becoming angular as they enlarge and usually delineated by veins (Figure A). 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. These symptoms are difficult to distinguish from common leaf spot and leaf scorch. One identifying characteristic is the translucent nature of lesions when leaves are held up to a bright light; looking from the backside, light will pass through the angular lesions. Entire leaves and major veins may become infected, giving the leaves a ragged appearance (Figure G). Berry caps may become infected, darkened, have angular lesions and are unappealing (Figure C). Vascular infection and wilting by *X. fragariae* may lead to plant death, but this is not as common as leaf spot. This systemic infection may be confused with wilt of anthracnose or Phytophthora crown rot; however, crown tissue infected by *X. fragariae* does not become discolored. Infected material will typically ooze bacterial cells when dissected and viewed under a compound microscope (Figure F).

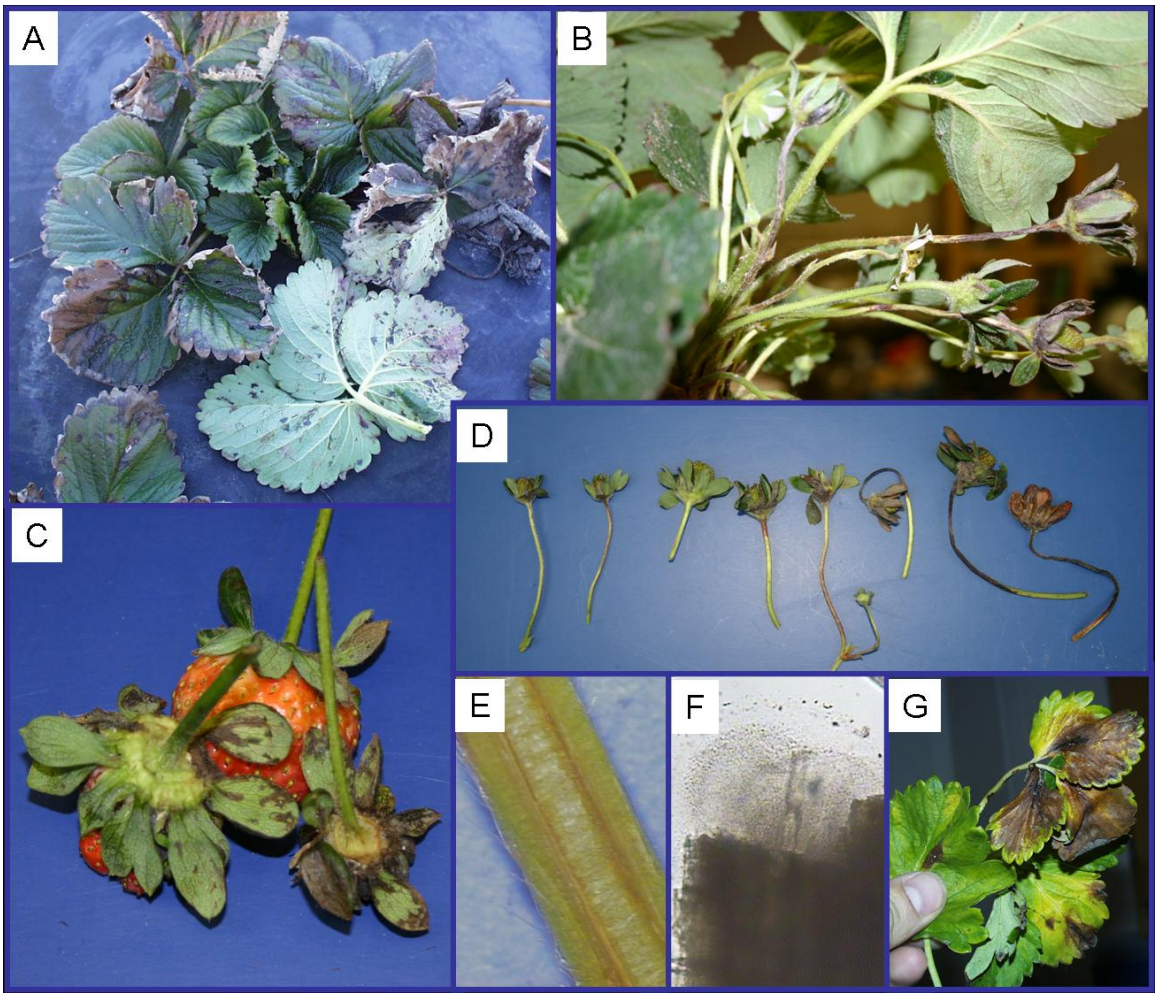


Figure: A) Plant severely infected by *Xanthomonas fragariae* and overturned leaf showing angular leaf spots between veins where bacteria have colonized the tissue; B) A flower truss with symptoms of black discoloration on the calyx and peduncle; C) Angular lesions on the calyx of developing fruit; D) range of symptoms on the calyx and peduncles; E) brown discoloration in the xylem tissue due to systemic infection by the bacteria; F) Bacterial ooze from infected strawberry tissue that serves as a positive diagnosis for angular leaf spot (100x); G) Leaf showing a blight symptom associated with systemic infection by *X. fragariae*.

Disease Cycle

X. fragariae primarily enters the field via infected planting stock, and may persist in the field by overwintering or oversummering 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. The pathogen cannot survive freely in the soil, but can survive on transplants in cold storage for one year and on plant debris through long dry periods. Bacteria become active and are splash-dispersed to healthy leaves in wet weather or with irrigation water. *X. fragariae* favors low day (60F) and night temperatures (near freezing) and high relative humidity. Favorable conditions for disease development occur during transplant establishment and when frost protecting. Cool wet weather during flowering and fruit formation can cause loss of fruit (figure B & D) or lead to a discolored calyx – rendering the fruit unmarketable. Healthy plant tissues are more likely to become diseased than stressed tissues. In most cases, yield losses due to angular leaf spot are not

common but may occur when severe systemic infection occurs. Losses can be substantial if a large portion of the fruit calyxes are infected and unsightly.

Control

1. SITE SELECTON

Choose a site with good air circulation and sun exposure to promote drying of foliage.

2. USE DISEASE-FREE PLANTS

Use certified plant material. Be aware that 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, especially for annual production systems.

3. MONITOR AND MANAGE

Control weeds to allow air to circulate freely around plants. Remove infected leaf debris by hand, raking or vacuuming. DO NOT remove infected debris if anthracnose is suspected to be present. Avoid using overhead irrigation if possible. Under serious disease conditions, ensure all strawberry debris is soil incorporated to optimize tissue break down. Rotation is not essential. A change in weather patterns from cool and wet to warm and drier results in disease decline.

4. CHEMICAL CONTROL

No bactericides are labeled for use nationally against angular leaf spot. 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 within the plant tissue. Caution should be taken when using copper fungicides because accumulations can be phytotoxic. Angular (bacterial) leaf spot can be a serious problem during cool, wet conditions. Registered copper compounds provide some control of the peduncle and calyx infections. In fields with a known problem, apply copper fungicides when flowers and fruit are present and when cool wet weather is predicted. Repeat applications at 7 to 10 day intervals. Discontinue when phytotoxicity appears, usually after 4-5 applications.

Integrated Disease Management of Strawberry

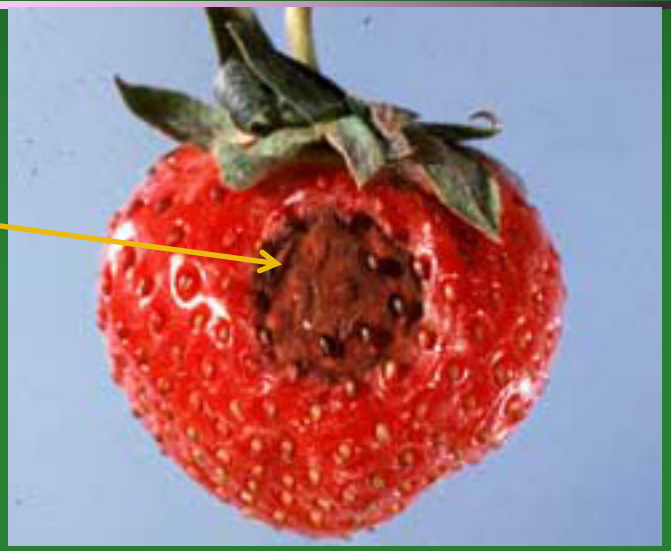
Mahfuzur Rahman and Frank Louws
Dept. of Plant Pathology
NC State University

Overview

- Anthracnose/Glo crown rot
- Abiotic problem mistakenly taken as disease
- Anthracnose/*acutatum* fruit rot
- Gray mold/Botrytis rot
- Summary

Major disease: Anthracnose

Ripe fruit rot: Colletotrichum acutatum



Crown rot: C. gloeosporioides

Anthracnose/*P.cactorum* crown rot

- Proper diagnosis is important - different management options
- Last year most samples were anthrac crown rot
- *C. glo* has a wide host range
- Wild/noncultivated host -initial source
- Infected nursery - the most important Inoculum source for fruiting field

Nursery establishment and disease introduction

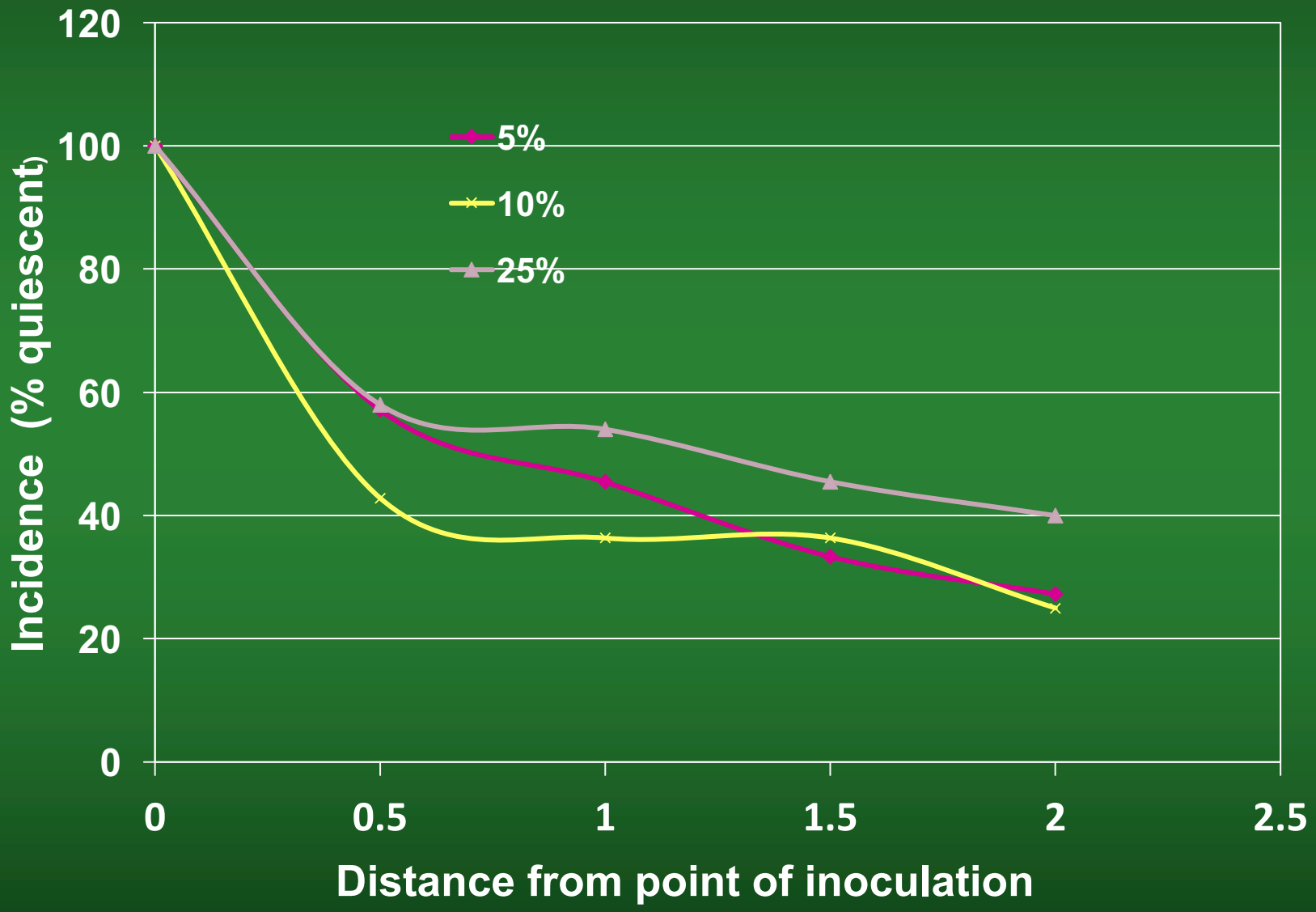
Inoculation is done at the early stage of runner production

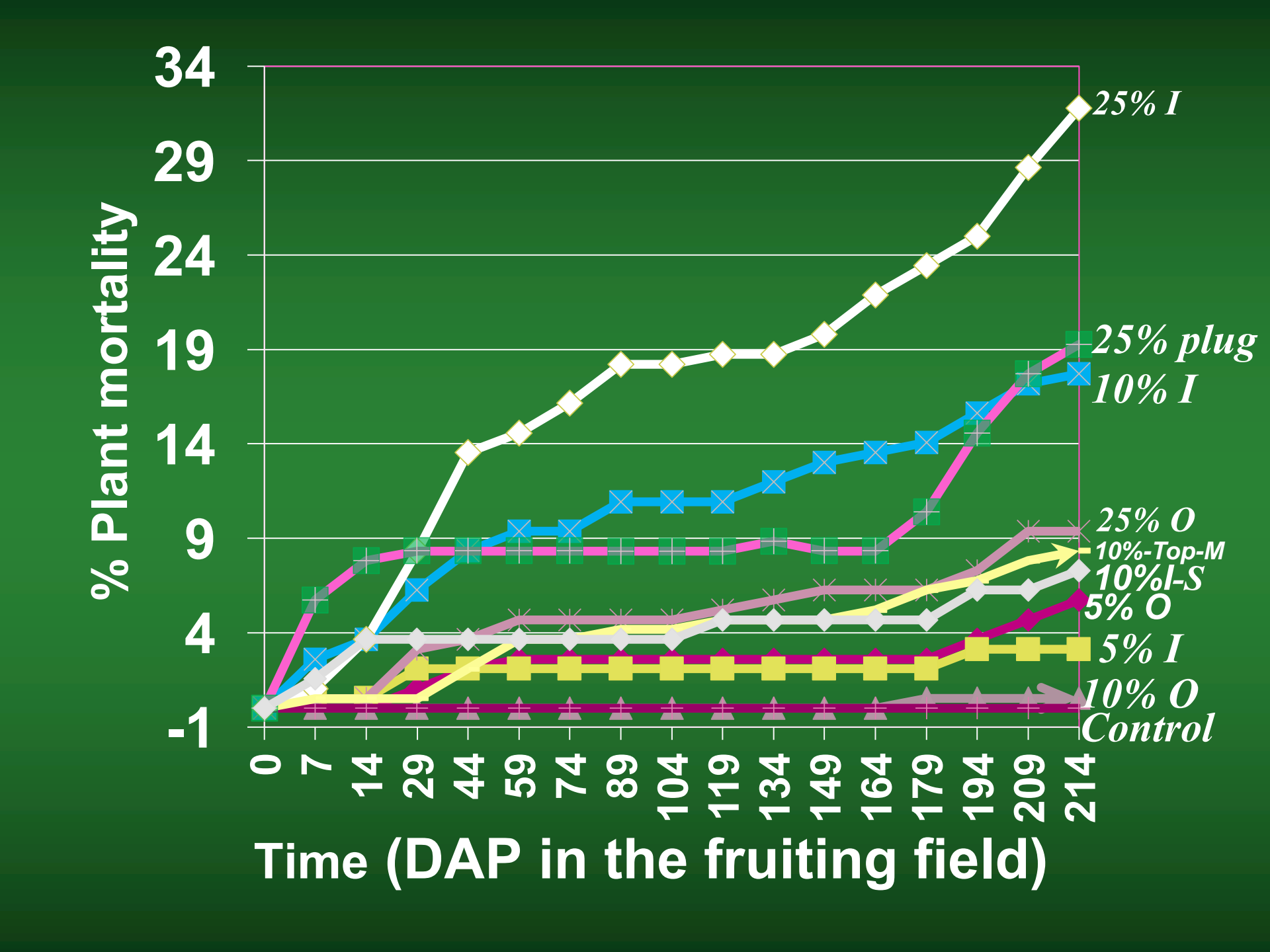
Inoculation of mother plants

Symptom on leaf

Black irregular lesion, not visible from underneath

Inoculum dispersal




% Plant mortality
34
29
24
19
14
9
4
-1
0
7
14
29
44
59
74
89
104
119
134
149
164
179
194
209
214
Time (DAP in the fruiting field)
25% I
25% plug
10% I
25% O
10%-Top-M
10%I-S
5% O
5% I
10% O
Control

Fruit yield and plant biomass production in different treatments originating from the nursery inoculation at different levels

Treatment	Marketable Yield (lb/A)	Plant dry wt (g/5 plants)	#crown /plant	Root dry wt (g/5 roots)	Root length (inch)
5% Outer	22848 abc	242.96 a	4.9	21.59 ab	8.80 a
5% Inner	20008 abcd	179.96 b	4.1	19.32 ab	8.16 b
10% Outer	21510 abc	174.87 b	4.2	23.26 ab	8.32 b
10% Inner	*14405 d*	159.48 b	3.9	17.53 b	8.42 b
25% Outer	*18415 cd*	179.71 b	3.6	18.47 b	8.04 b
25% Inner	*17765 cd*	173.74 b	4.6	19.48 ab	8.24 b
Control	25559 a	265.41 a	5.0	28.76 a	8.89 b
10% I-Tops M	20379 abc	163.65 b	3.9	17.53 b	7.95 b
25% plug	23813 ab	280.37 a	5.9	27.05 ab	9.94 a
10% I-Switch	19943 abcd	273.42 a	4.4	21.29 ab	8.72 b
LSD (α = 0.05)	*5744*	*48.28*	*…*	*9.72*	*0.97*

Means within a column followed by the same letter are not significantly different according to Fisher's protected LSD test ($P \leq 0.05$)

How devastating can it be?

- Extent of plant mortality & yield loss from the disease-
- Depends on isolate aggressiveness & level of infestation
- Overall 5-7%, can go up to 50-80%
- Yield loss-insignificant at lower level of infestation

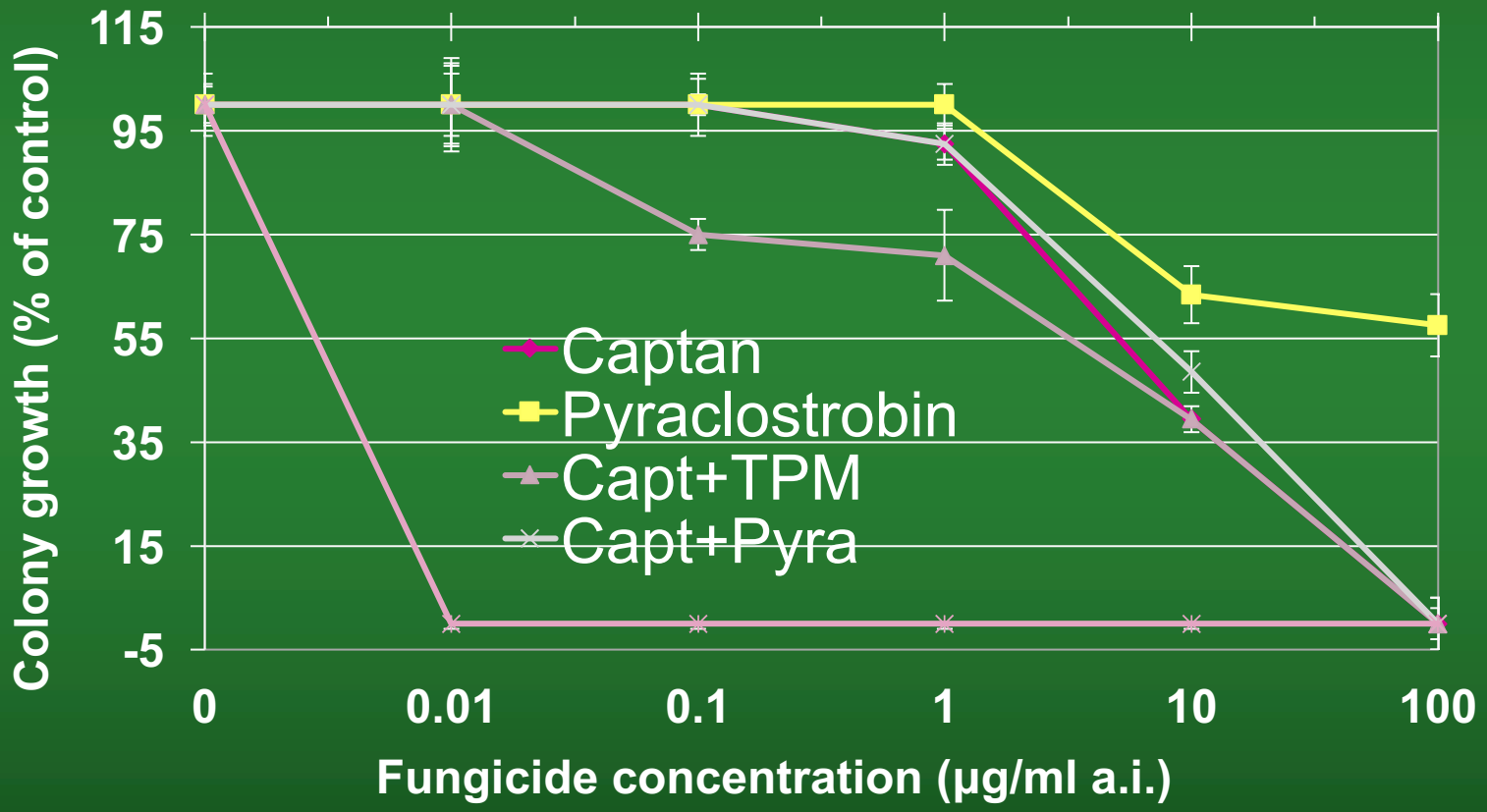
Abiotic causes involved with plant mortality

ECe: 40 ds/m; standard >2 ds/m ……sensitive to chloride ions

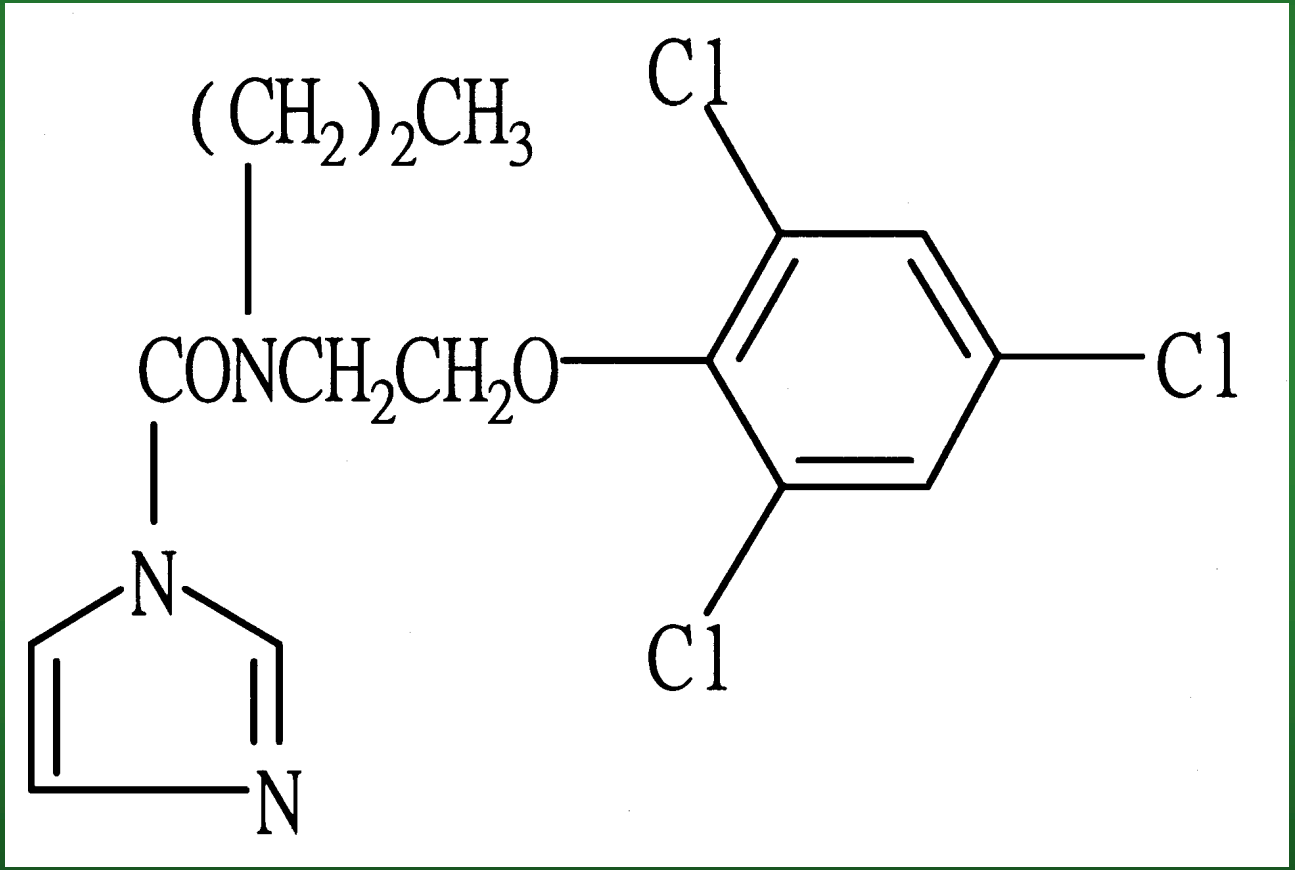
Check list

- Ask plant supplier of any incidence of glo symptom in the nursery or plug production facility
- If yes, fungicide (recommended rate) dip the plants, minimize overhead sprinkler
- Make sure soil salt conc. is in the acceptable range
- Do not over fertilize, especially Nitrogen

Control (invitro efficacy result)



Prochloraz



Phytophthora crown rot

Disease diagnosis

Cut the crown longitudinally

No discolorati-on inside crown

Abiotic causes are most likely

* *High salt*
* *Boron toxicity*
* *Improper planting depth*

Marbled reddish brown- most likely glo crown rot

Dull brown color- most likely Phytophthora

Incubate the crown in a plasic container on 3 layers of moist paper towels

Salmon color spore mass

If nothing works, DNA based detection is the last resort

Management options: IDM

- Clean plant source – latent infection – technology evolving
- With known infestation – drip/drench before planting: Switch, Topsin-M, Quadris
- Overhead spray: Captan + strobilurin
- Removal of collapsed plants
- Minimizing row cover and sprinkler use

Replanting the same land that had glo infestation

- *C. glo* is not a soilborne pathogen
- Survival in the plant debris buried in soil suggest that *C. glo* does not over summer in strawberry tissues in Florida
- The time between the end of last season strawberry crop and the planting of the next season (four to six months) should be sufficient
- Soil moisture should be ~22% or field capacity

Anthracnose fruit rot

- Clean plant is the key
- Weather condition at the time of fruit development
- Field with no fruit rot had *C. acutatum* latent infection in leaves
- # of sprays can be brought down in unfavorable weather/absence of inoculum

Anthracnose fruit rot: Chemical control

Trt #	Fungicide (rate/acre)	Schedule	%anthrac	Marketable yield (lb/A)
1.	Non-treated	xxx	46.72 a	12,685 cd
2.	Captan 50 WP 4.0 lb + Topsin M 70 W 1.1 lb; Pristine WG 1.45 lb CaptEvate Abound 12 fl oz	spray #1 spray #2,4 spray # 3,5,7,9 spray # 6,8	***21.60 c***	***20,151 a***
3.	Captan 50 WP 4.0 lb + Topsin M 70 W 1.1 lb Pristine WG 1.45 lb CaptEvate	spray #1 spray #2,4 spray # 3	***29.87 bc***	***18,130 ab***
4.	K-Phite@3pts/A + Captan 50WP @4.0 lb/a	spray #1 - 9	30.60 bc	16,945 abcd
5.	Actinovate WYEC 108 (organic-bacteria)	spray #1 – 9	39.78 ab	11,456 d
6.	Captan 50WP, 4.0 lb + Topsin-M 70W, 1.1 lb Distinguish (Trifloxistrobin) 16 fl.OZ, Bayer	spray #1,3,5,7,9 Spray#2,4,6,8	33.89 b	16,832 abcd
7.	Captan 50 WP 4.0 lb + Topsin M 70 W 1.1 lb Evito 480 SC (Arysta) Fluaxostrobin 4.0 fl oz CaptEvate Evito 4.0 fl oz	spray #1 spray #2,4 spray # 3,5,7,9 spray # 6,8	38.20 ab	17,000 abc
8.	Captan 50 WP 4.0 lb + Topsin M Evito 4.0 fl oz	spray #1,3,5,7,9 Spray#2,4,6,8	38.61 ab	13,538 bcd
9.	Milsana 1% v/v +NuFilm-P at 0.02% Captan 50WP, 4.0 lb + Topsin-M 70W, 1.1 lb Milsana 0.5% v/v +NuFilm-P 0.01% + Captan 50WP, 2.0 lb + Topsin-M 70W, 0.52 lb	Spray #1-2 Spray#3-4 Spray#5-9	***21.14 c***	***20,046 a***

Gray Mold (*Botrytis cinerea*- necrotroph)

1) **Are the inocula coming with the plants and multiply over time or**
2) **coming from the surrounding environment?**
3) **Resistant population is common at the later stage**

Early stages of gray mold on strawberry fruit.

Later stages of gray mold on strawberry fruit.

Gray mold: Chemical control

Trt #	Fungicide (rate/acre)[w]	Schedule[x]	Gray mold (%Inc)[y,z]	Marketable yield (lb/A)[z]
1.	Non-treated	xxx	17.83 a	34960 bc
2.	Switch 62.5 WG, 12.0 oz	spray #1-9	9.1 bc	36657 ab
3.	Captan 50WP, 4.0 lb + Topsin-M 70W, 1.1 lb Pristine WG, 23.0 oz Switch 62.5 WG, 11.0 oz Pristine WG, 23.0 oz	(spray #1) (spray #2) (spray #3) (spray #4)	*7.25 c*	*36103 abc*
4.	Captan 50WP, 4.0 lb + Topsin-M 70W, 1.1 lb Pristine WG, 23.0 oz Switch 62.5 WG, 11.0 oz	spray #1 spray #2,4,6,8, spray #3,5,7,9	*6.08 c*	*37025 ab*
5.	Captan 50WP, 4.0 lb + Topsin-M 70W, 1.1 lb Pristine WG, 23.0 oz Captan 50WP, 4.0 lb	spray #1 spray #2,4,6,8 spray #3,5,7,9	6.18 c	34430 bc
6.	Penthiopyrad/LEM 17 9.6 fl. Oz	spray #1-9	15.78 a	33756 c
7.	Alexin plus, + Citrox 14W plus,	Fall spray #1-5 Spring #1-9	17.98 a	34955 bc
8.	LEM 17(Pyrazole carboxamide, RC-II) 16.8	spray #1-9	17.27 a	33305 c
9.	LEM 17 24 fl. Oz	spray #1-9	14.68 a	36829 ab
10.	Milsana 1% v/v +NuFilm-P 0.02% Captan 50WP, 4.0 lb + Topsin-M 70W, 1.1 lb Milsana 0.5% v/v +NuFilm-P 0.01% + Captan 50WP, 2.0 lb + Topsin-M 70W0.52 lb	Spray #1-2 Spray#3-4 Spray#5-9	15.8 a	34769 bc
11.	HMO 736 (A.K.A. Vacciplant) (14.4 fl. OZ) Captan 50WP, 4.0 lb + Topsin-M 70W, 1.1 lb HMO 736+ Captan 50WP, 4.0 lb + Topsin-M 70W, 1.1 lb	Spray #1-2 Spray#3-4 Spray#5-9	13.75 ab	36671 ab
12.	Captan 50WP, 4.0 lb + Topsin-M 70W, 1.1 lb	Fall spray #1-5 Spring #1-9	*6.17 c*	*38379 a*

Summary

- Integrated approach is the best fit for managing strawberry diseases
- Diagnosis on time is crucial
- Most of the glo isolates are less aggressive and manageable
- Fungicide use can be brought down significantly without compromising disease control

Acknowledgement

- Dr. Frank Louws
- Dr. Barclay Poling
- Jim Driver, Mike Carnes
- Hort. Crop Res. Station, Clinton

Registered Miticides for spider mites[1] on strawberries in North Carolina

Modes of Action

Miticide	Active Ingredient	REI	PHI	Life Stages Targeted	IRAC Mode of Group[2]
Abacus	Abamectin	12 hours	3 days	Adults and larvae	6
Abba	Abamectin	12 hours	3 days	Adults and larvae	6
Acramite	Bifenazate	12 hours	1 day	All stages	25
Agri-Mek	Abamectin	12 hours	3 days	Adults and larvae	6
Brigade	Bifenthrin	12 hours	NA	Adults and larvae	3
Danitol	Fenpropathrin	1 day	2 days	Adults and larvae	3
Ecotrol	Rosemary & Peppermint Oils	NA	NA	Adults and larvae	Botanical
Ecotec	Rosemary & Peppermint Oils	NA	NA	Adults and larvae	Botanical
Epi-Mek	Abamectin	12 hours	3 days	Adults and larvae	6
Kanemite	Acequinocyl	12 hours	1 day	All stages	20B
Kelthane	Dicofol	2 days	3 days	Adults and larvae	UNC
Oberon	Spiromesifen	12 hours	3 days	All stages, most effective on eggs and larvae	23
Omite[3]	Propargite	3 days	NA	Adults and larvae	12C
JMS Stylet Oil/Organic JMS Stylet Oil	Paraffinic Oil	4 hours	NA	Adults and larvae	Mineral oil
Reaper	Abamectin	12 hours	3 days	Adults and larvae	6
Savey[4]	Hexythiazox	12 hours	3 days	Toxic to eggs and larvae, sterilizes adult females	10A
Temprano	Abamectin	12 hours	3 days	Adults and larvae	6
Zeal	Etoxazole			Toxic to eggs, inhibits molting in juveniles, sterilizes adult females	10B
Zoro	Abamectin	12 hours	3 days	Adults and larvae	6

[1]Spider mites include *Tetranychus* spp., including *T. urticae* (two-spotted spider mite) and *T. atlanticus* (strawberry spider mite).

[2]Same number indicates same mode of action. Different MOAs should be chosen for rotation.

[3]Non-bearing crop use only.

[4]Do not use in strawberry nurseries.

To manage potential resistance in mite populations, rotate between IRAC Groups for successive treatments.

The trade names and label information presented here is subject to change. As with any pesticide, read and following the label instructions.

Strawberry Insect Pest Management
Minimize, Monitor, and Manage

Hannah J. Burrack
Department of Entomology
North Carolina State University

Topics

- Insect Pests
  - Twospotted spider mites
  - Cutworms/Armyworms
  - Thrips
  - Sap beetles
  - Aphids
- Occasional Pests
  - Thrips
  - Lygus bugs
  - Corn earworms

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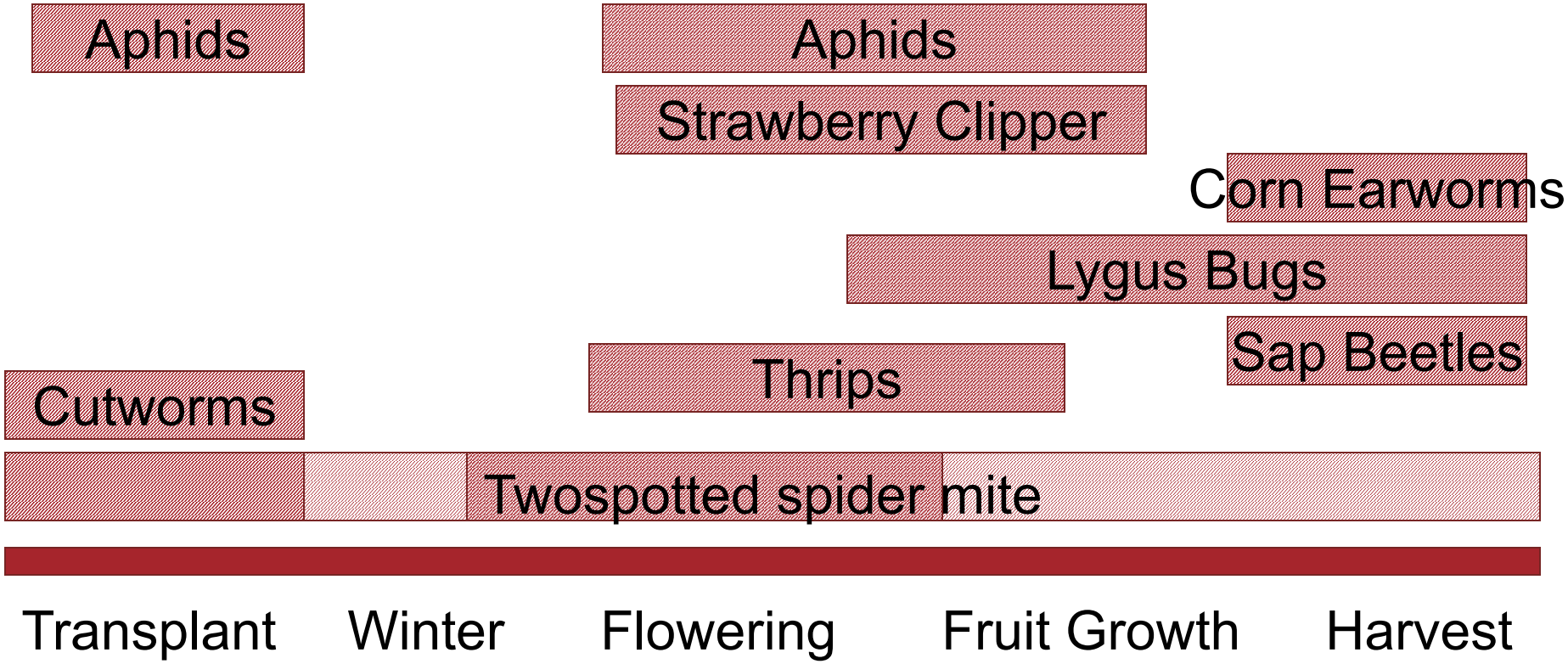
  - Thrips
  - Lygus bugs
  - Corn earworms
  - Strawberry clippers
  - Whiteflies

Thresholds

Sampling Methods

Management Tools

Strawberry Insect Pest Timeline



An Environment Unfavorable to Pests

- Annual production has limited (and eliminated) the severity of some insects pests of strawberries:
  - Thrips, whiteflies, cutworms, strawberry clippers are all less intense in annual plantings
  - Strawberry weevils are not a pest in annual production

Twospotted Spider Mites

- *Tetranychus urticae*
- TSSM are the most common economically important pest of strawberries in the southeast

Adult Male and Eggs

Adult Female

Diapausing Adult Female

Photos: UC IPM Program

Other Mites

- Cyclamen mites(*Phytonemus pallidus*) and Carmine mites (*Tetranychus cinnabarinus*) may also occur in NC
  - Distribution in SE not clear

Photos: UC IPM Program

TSSM Biology

- Where do mites come from?
  - Mites may be present on plants at transplant or may move in from surrounding vegetation
  - Spider mites are polyphagous (poly = many, phagous = feeding) and are common pests on many crops, including tomatoes, cotton, melons, and caneberries

TSSM Biology

- How many generations can spider mites have, and how fast do they develop?
  - Need at least 54°F to develop
  - Ideal temperature is 86°F
  - Under ideal conditions, can turn a generation in as little as 1 week
  - Female can lay 50-100 eggs/day
  - **This is why weekly monitoring is SO important

TSSM Biology

- What do spider mites do during winter?
  - We're not entirely sure for NC conditions
  - Diapause is governed by photoperiod, and to a lesser extent, temperature

TSSM Biology

- How do spider mites damage plants?
  - Spider mites feed by sucking the contents out of individual plant cells
  - Spider mites reduce plant vigor and impact yield
  - In annual production, early season damage (following transplant, before fruit set) results in the greatest loss

- How do we manage TSSM in strawberries?

TSSM Thresholds and Monitoring

- Monitoring
  - Sample 10 mid tier leaflets/acre for fields < 10 acres, 5 leaflets/acre for fields > 10 acres
  - Observe with 10x hand lens or use mite brush/microscope
- Thresholds
  - Yield loss detectable at 1 mite/leaflet
  - CA research
    - 5 mites/leaflet, early season
    - 10 mites/leaflet, fruiting
  - FL research
    - 2 mites/leaflet

Creating an environment unfavorable to TSSM

- Varietal Preference
- Minimizing plant stress
- Preplant chilling
- Dust and sand
- Plan for bad seasons (hot, dry weather)

Creating an environment unfavorable to TSSM

- Varietal Preference
  - Varieties differ in susceptibility to TSSM
  - Chandler has intermediate resistance
- Minimizing plant stress
- Preplant chilling
- Dust and sand
- Plan for bad seasons (hot, dry weather)

Creating an environment unfavorable to TSSM

- Varietal Preference
- Minimizing plant stress
  - Post transplant watering, proper fertilization
- Preplant chilling
- Dust and sand
- Plan for bad seasons (hot, dry weather)

Creating an environment unfavorable to TSSM

- Varietal Preference
- Minimizing plant stress
- Preplant chilling
  - Max chilling allowable = more resistant plants
  - Fall transplants do better than summer transplants
- Dust and sand
- Plan for bad seasons (hot, dry weather)

Creating an environment unfavorable to TSSM

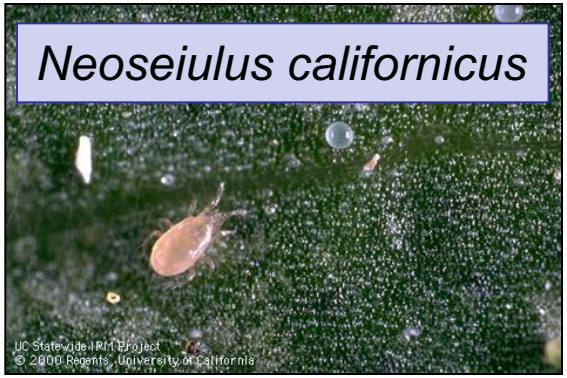
- Varietal Preference
- Minimizing plant stress
- Preplant chilling
- Dust and sand
  - Road dust = mite refugia
- Plan for bad seasons (hot, dry weather)

Biological Control

TSSM Biological Control

- Biological Control
  - At least 3 mite predators of SMs are commercially available
- Mite releases
  - SM populations should be monitored closely following any release

Galendromus occidentalis



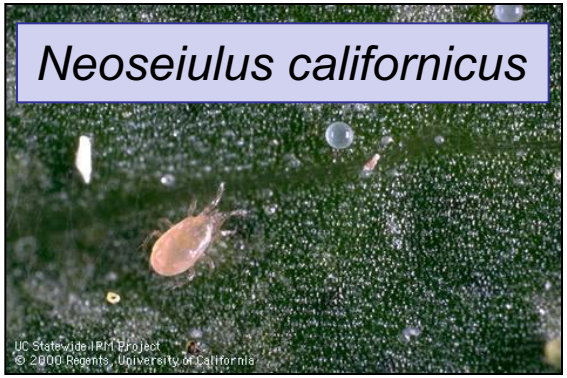
Neoseiulus californicus

Phytoseiulus persimilis

TSSM Biological Control

- *P. persimilis* = high temp/high humidity
- *G. occidentalis* = high temp/high humidity
- *N. californicus* = tolerates lower humidity and temps


Galendromus occidentalis

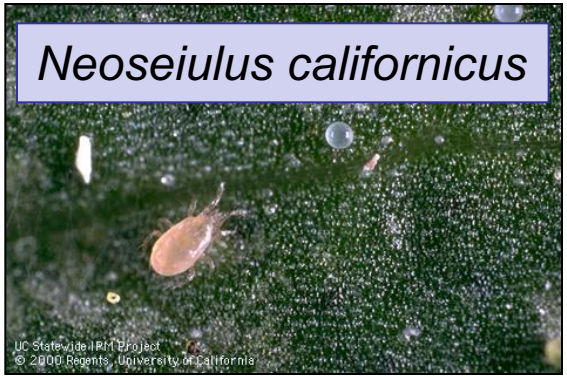



Phytoseiulus persimilis

TSSM Biological Control

- Release rates?
  - *P. persimilis*
  - Releases rates are lower prethreshold (2-3/predators per plant) than when spider mites reach threshold (5 predators/plant)
  - Thresholds of 10:1, SM:Pred also used


Galendromus occidentalis



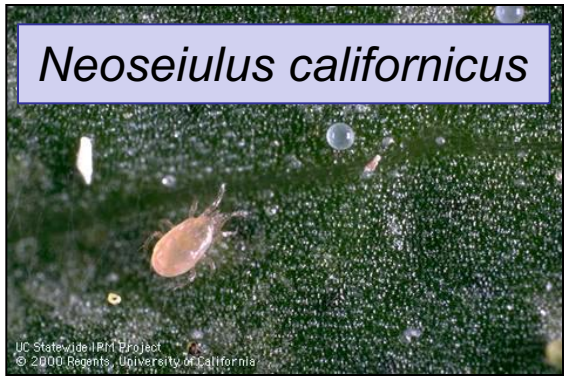
Neoseiulus californicus


Phytoseiulus persimilis

TSSM Biological Control

- Release rates?
  - Assuming 10,000 plants/A, prethreshold = 30,000 predators/A
- Cost?
  - *P. persimils* $6-30/1000 mites
  - *N. californicus* $10-33/1000 mites
  - *G. occidentalis* $10-34/1000


Galendromus occidentalis




Phytoseiulus persimilis

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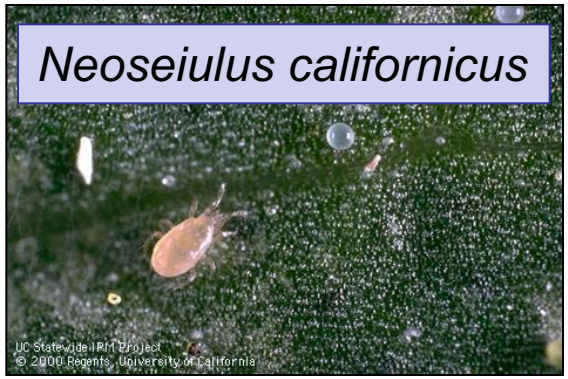



Phytoseiulus persimilis

TSSM Chemical Control

- Adulticides, larvicides, and materials with both activities are available
  - Choice depends on populations and time of year

TSSM Ovicides/Larvicides

Trade Name	Chemical Name	MOA	REI/PHI
Acramite	Bifenazate	25	12 hr/1 d
Kanemite	Acequinocyl	20B	12 hr/1 d
Savey	Hexythiazox	10A	12 hr/3 d
Zeal	Etoxazole	10B	12 hr/1 d
Oberon	Spiromesifen	23	12 hr/3 d

TSSM Adulticides

Trade Name	Chemical Name	MOA	REI/PHI
Agri-Mek (and generics)	Abamectin	6	12 hr/3 d
Danitol	Fenpropathrin	3	24 hr/2 d
Brigade	Bifenthrin	3	12 hr/NA
Omite*	Propargite	12C	72 hr/NA
Ecotec/Ecotrol	Rosemary & Peppermint oils	NA	NA/NA
JMS Stylet Oil	Paraffinic oil	NA	4 hr/NA

Cutworm Biology

- Feed in the soil at the base of plants
  - Curl into c-shape when disturbed
- Several species of cutworms occur in the SE
  - Black cutworm (*Agrotis ipsilon*) most common
- Polyphagous moths will migrate in from weed hosts in fall
- Young larval feeding leaves small web-less holes
- Adults “cut” leaves and plants

Photos: UC IPM Program

Cutworm Threshold and Monitoring

- No threshold developed in strawberries
- Observe recently transplanted plants for signs of feeding
- In fields with a history of cutworm damage, moths can be monitored with pheromone traps
- Check for larvae under plastic, at night
  - If larvae are present, consider treating

Photos: UC IPM Program

Cutworm Management

- Cultural
  - Weed management
    - Weed removal should be initiated at least 2 weeks before transplant
- Chemical
  - Registered materials include:
    - Spinosad
    - Bt
    - Malathion
    - Carbaryl
  - For larvae under plastic mulch, a formulation applied through drip irrigation or a bait may be most effective

Photos: UC IPM Program

Aphid Biology

- Multiple species of aphids may feed on strawberries in the Southeast

Macrosiphum euphorbiae

Chaetosiphon fragaefolii

Myzus persicae

Photos: UC IPM Program

Aphid Biology

- Multiple species of aphids may feed on strawberries in the Southeast
- Aphids reproduce rapidly (females do not need to mate or lay eggs, male aphids are rare)
- All strawberry feeding species are polyphagous
  - Aphids prefer new growth, and will move on when plants get old

Aphid Threshold and Monitoring

- Fairly high levels of aphids can be tolerated, and in typical SE conditions, aphids should not reach damaging numbers
- Treatment threshold: 10 aphids/leaflet
- Sampling method:
  - At each plant sampled for TSSM, collect one newly expanded leaf
  - Count aphids with a hand lens
  - If aphids are present, monitor weekly

Aphid Threshold and Monitoring

- Exceptions:
  - Nursery production
    - Aphids transmit viruses in strawberries and not tolerable in nurseries
      - Strawberry crinkle virus
      - Strawberry mottle virus
      - Strawberry mild yellow edge virus
      - Strawberry vein banding virus
    - Treatment should be initiated at the first sign of aphids
  - Perennial production
    - Virus transmission can also occur in perennial production

Aphid Management Methods

- Aphids are attracted to high nitrogen levels in plants - avoid over fertilization
- Row covers and tunnels reduce aphid populations
- Numerous, naturally occurring, wasp parasitiods attack aphids in the Southeast
  - Do not include parasitized aphids in survey count
  - If a large proportion of the aphid population is parasitized, consider delaying treatment

Biological Control

Aphid Management Methods

- Numerous, naturally occurring, wasp parasitiods attack aphids in the Southeast
  - Do not include parasitized aphids in survey count
  - If a large proportion of the aphid population is parasitized, consider delaying treatment

Aphid Management Methods

- Materials available for aphid management
  - Imidacloprid
  - Thiamethoxam
  - Pyrethrins*
  - Insecticidal soap*
  - Horticultural oils*

Sap Beetle Biology

U. FL, J. Price

- Sap beetles feed on over ripe fruit and are attracted to the alcohols produced by the microbes feeding on this fruit
- Can be problematic in peach, plum, and apple production as well
- At least 3 species of ripe fruit feeding beetles are pests of SE strawberries
  - Strawberry sap beetle (*Stelidota geminata* (Say)), Picnic beetles (*Clishchrochilus quadrisignatus* or *C. fasciatus*)

Sap Beetle Biology

- SBs are late season pests but may become problematic if summer berry production (using day neutral varieties) is adopted

U. FL, J. Price

Sap Beetle Thresholds and Monitoring

U. FL, J. Price

- There are no thresholds developed for sap beetles in strawberries
- Observe ripe fruit when picking for surface damage and tunneling
- If harvest is anticipated to run long, or if beetle damage is suspected, bait buckets placed at the edge of fields will attract the small adult beetles
  - Buckets can be baited with over ripe fruit or bread dough
  - Dispose of baits off site

Sap Beetle Management Methods

- Cultural control is the only recommended form of SB management
  - There are registered chemicals, but because SBs occur during harvest, pesticide applications should be kept to a minimum
- Bait buckets can trap out adult beetles
  - Check at least weekly and dispose of off site
- Frequent, thorough harvest eliminate attractive over ripe fruit
  - Dispose of culls offsite
  - Watch U-Pickers

Thrips Biology

- No such thing as a “thrip”
- Minute insects rasp open plant cells to feed
- Floral feeding thrips, particularly Western flower thrips (*Frankliniella occidentalis*) are thought to cause bronzing near the stem

Thrips do not catface or reduce pollination

WFT populations are spotty in the Southeast

Thrips Threshold and Monitoring

- The treatment threshold for thrips is 10/flower
- Thrips populations will be higher as temperatures increase
- Sample thrips by beating collected flowers against a white piece of paper and counting the dislodged thrips as they scatter

Thrips Management Methods

- Because thrips are present in blooms, care must be taken to avoid materials toxic to bees

Lygus Bug Biology

- Are Lygus bugs important pests of strawberries in the Southeast?

- Catfacing due to Lygus feeding but can also be caused by poor pollination

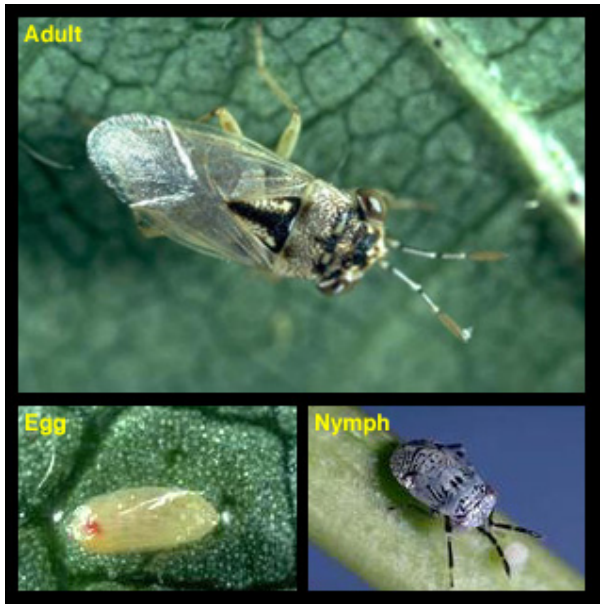
Lygus Bug Biology

- Lygus are not typically a pest in NC strawberries, but are in FL and CA and could potentially cause problems in other warm SE areas
- Growers have been concerned about lygus but damaging populations have not been recently observed

Lygus Bug Biology

- What Lygus are not:

Tarnished Plant Bug
(*Lygus lineolaris*)



Big Eyed Bug
(*Geocoris* spp.)

False Chinch Bug
(*Nysius raphanus*)

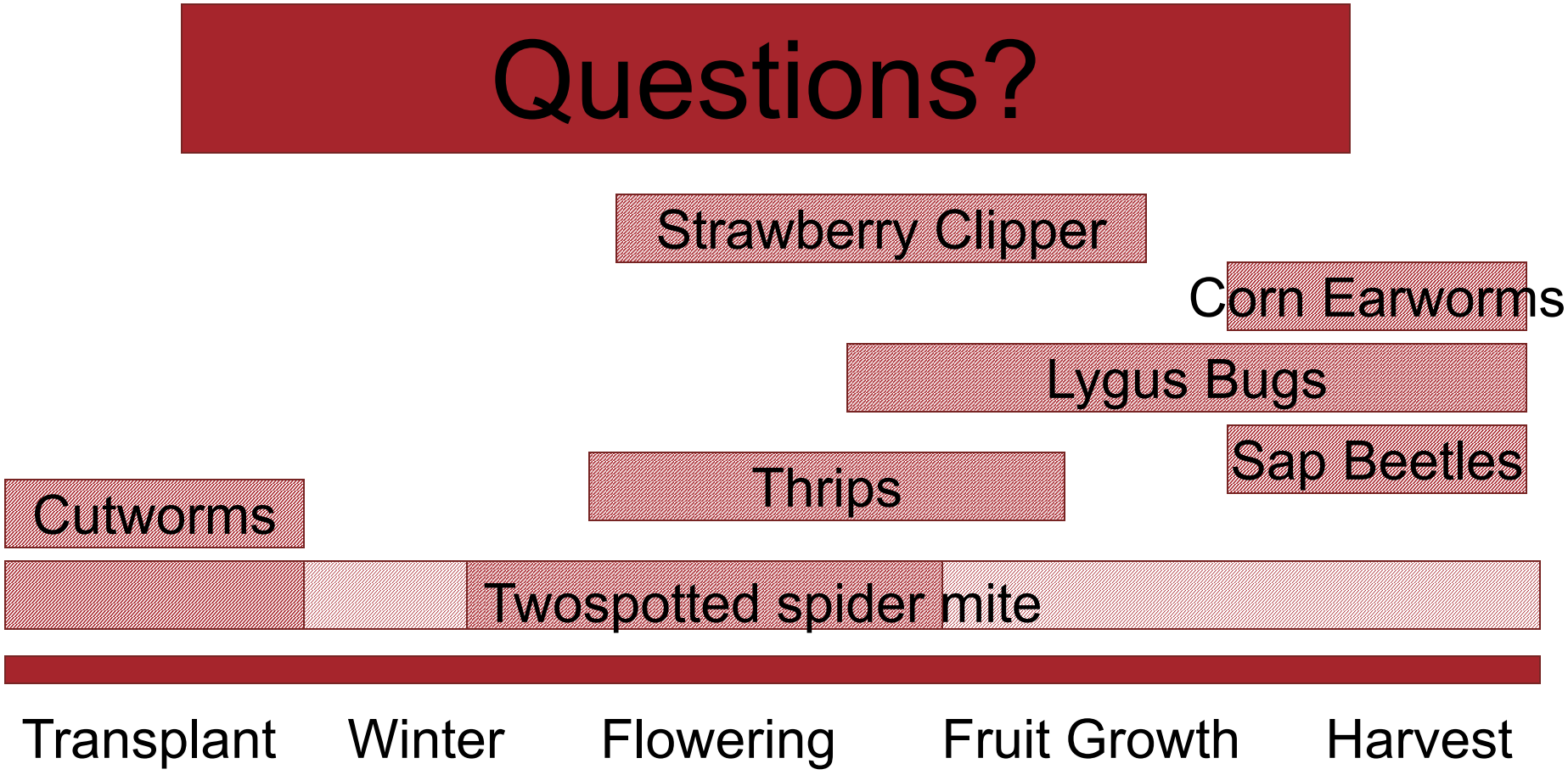
Lygus Bug Threshold and Monitoring

- Threshold 1 Lygus/20 plants
- Sampling: Using a beat sheet, sample 20 ft sections at a time
- Also observe nearby weeds
- Lygus are more prevalent in summer, so summer plantings/day neutrals are more likely to experience damage

Lygus Bug Management Methods

- Lygus are very difficult to control, and few registered materials are effective, so before treating, be certain that Lygus are present in damaging numbers
- Weed control is important to minimize Lygus populations

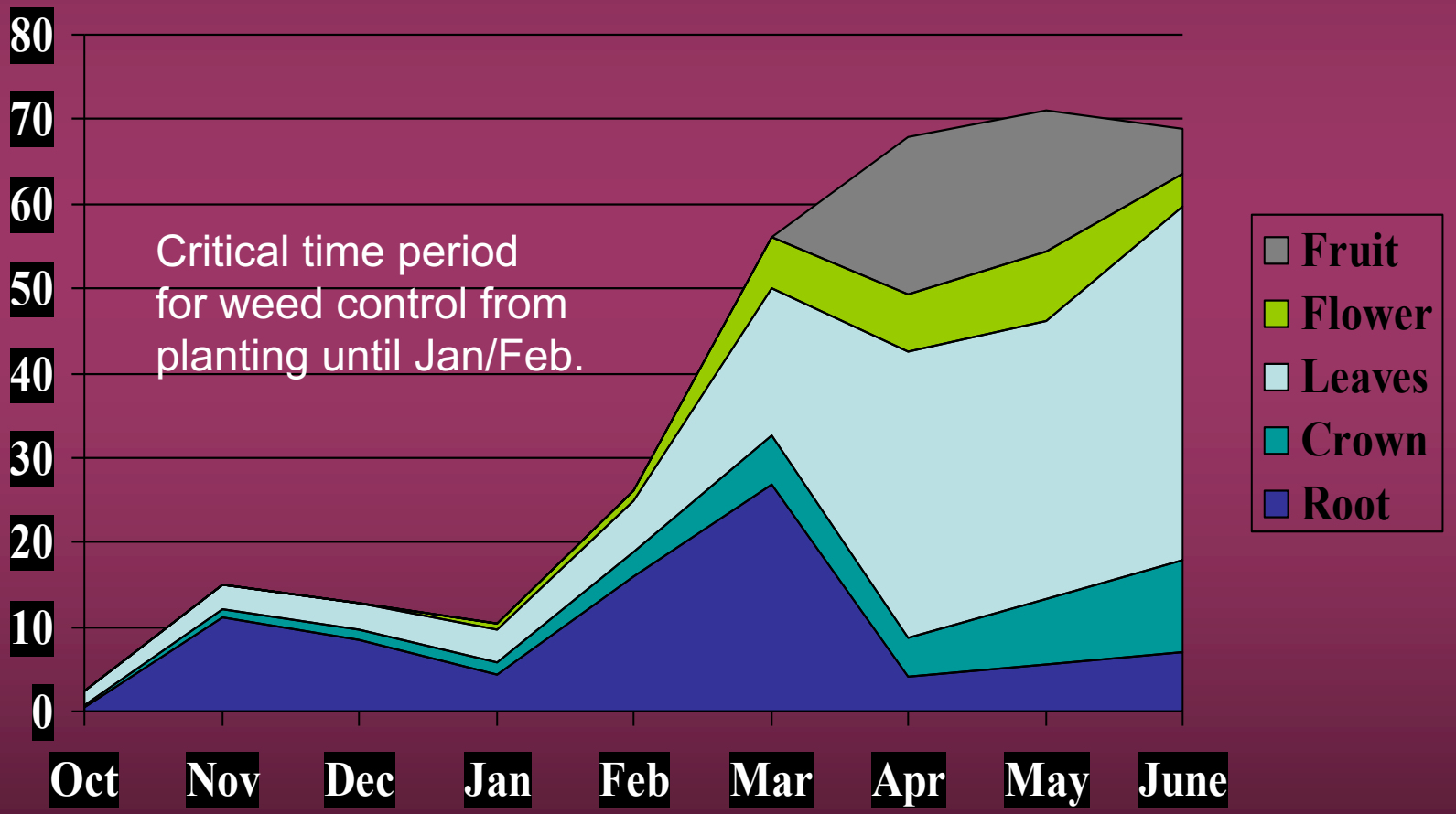
Strawberry Insect Pest Timeline



Weed Management in Strawberry

Katie Jennings
North Carolina State University
Dept. of Horticultural Science

Strawberry Growth (dry wt g)



Fernandez and Louws

Herbicide Options for Preemergence Weed Control in the Row

Goal PRE

- Apply 1 to 2 pt/A to soil surface of pre-formed bed at least 30 days before transplanting.
- Controls annual broadleaf weeds including Carolina geranium and cutleaf eveningprimrose.
- Plastic mulch should be applied soon after application.
- Avoid soil disturbance for best results.

Chateau PRE

- Apply 3 oz/A to pre-formed bed prior to laying plastic.
- Apply at least 30 days prior to transplanting.
- Controls cutleaf eveningprimrose, henbit, chickweed, pigweeds, wild radish.

Ultra Blazer PRE

- Apply 0.5 to 1.5 pt/A to pre-formed bed.
- Avoid soil disturbance after application for best results.
- Plastic mulch should be applied soon after application.
- No thirty day restriction.
- Weed spectrum similar to Goal.

Devrinol PRE

- Apply 8 qt or 8 lb to pre-formed bed prior to laying plastic. Incorporate or spray on surface.
- If bed is dry irrigate in with enough water to soak bed 2 to 4”.
- Subject to photodegradation. About 50% is lost after 4 days on the soil surface in the summer.
- Controls annual grasses and small seeded broadleaf weeds.
- Potential for injury – limited work in NC.

What about applying Sinbar PRE in the Row?

NOT LABELED IN NORTH CAROLINA

- Injury has been observed in NC on our sandy soils.
- Some years we have seen minimal injury. However, other years injury has been pretty great.

Herbicide Options for Postemergence Weed Control in the Row

Stinger
Clopyr available in some states

- Rate: .33 to 0.5 pt/A
- DO NOT apply within 30 days of harvest. DO NOT use surfactant with Stinger.
- DO NOT tank mix with other pesticides.
- POST for clover, vetch, dock, cocklebur, dandelion, sowthistle, thistle, and nightshade.

Vetch Control with Stinger

- Annual weed that is problematic in strawberry.
- Contaminant in straw. Know your source!

Vetch

Stinger @ 2/3 pint

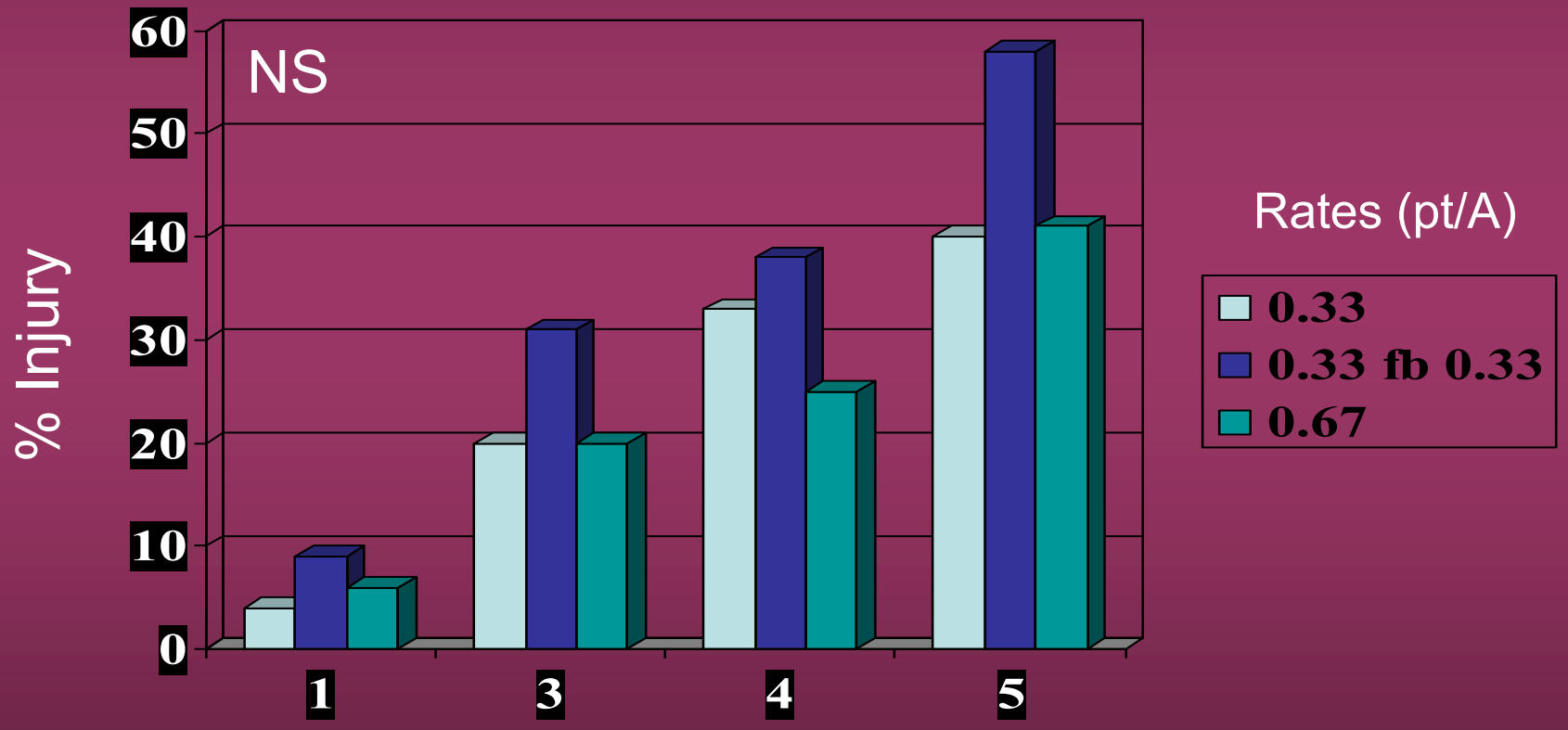
Can I Plant Vegetables Following the Application of Stinger?

Stinger Carryover to Vegetable Crops

- Tomato and pepper
  - Crop injury on foliage.
  - Misshapen fruit.
  - Reduction in yield.

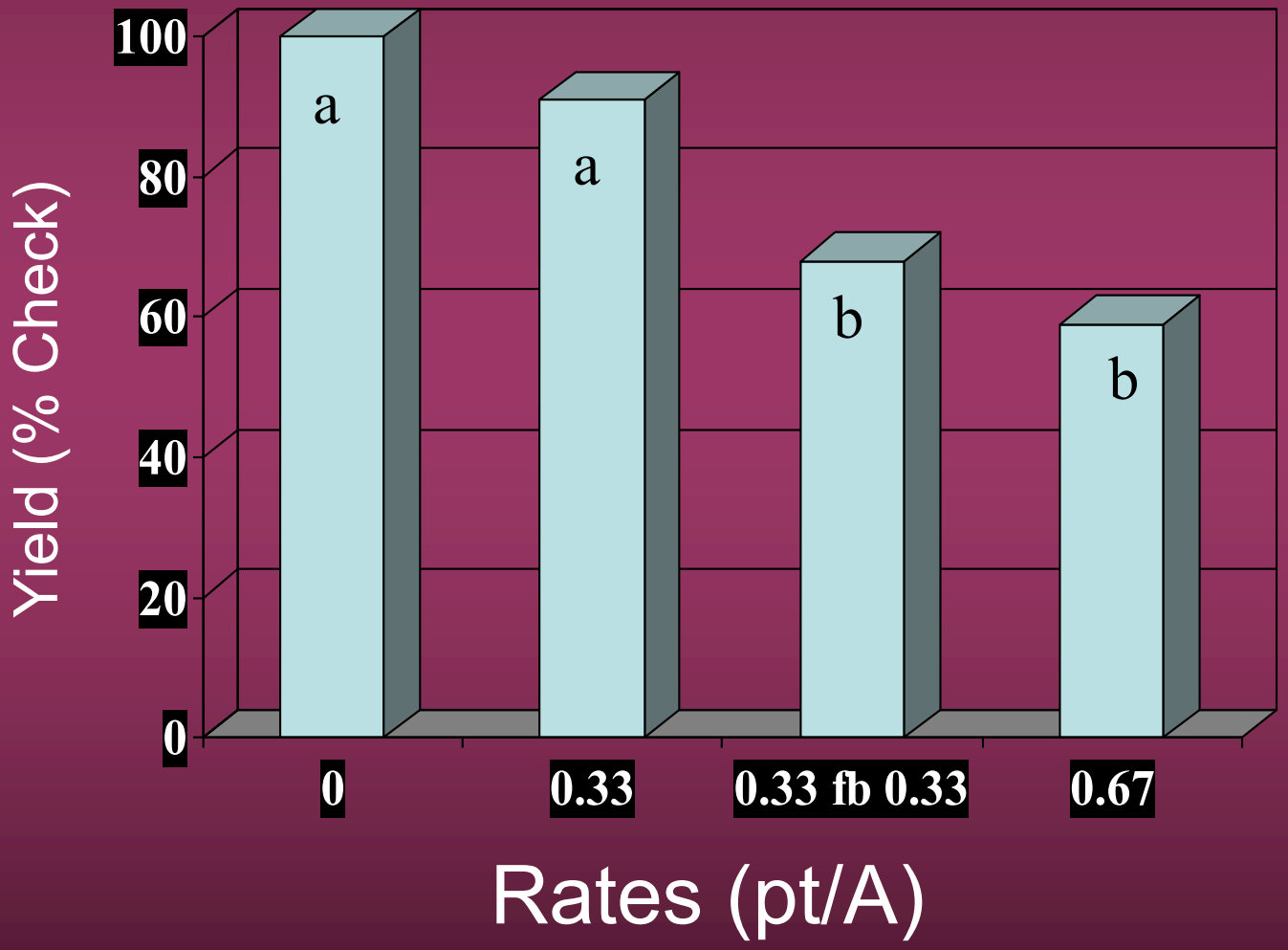
- Cantaloupe
  - No visual injury.
  - No effect on yield.

Effect of Stinger on Tomato Injury



NC

Effect of Stinger on Marketable Tomato Yield



GA

Effect of Stinger on Tomato Fruit

Herbicide Options for Postemergence Grass Control in the Row

Select/Arrow

- POST for annual and perennial grasses.
- Rate: 6 to 8 oz/A.
- Newly planted or established plantings.
- Use high rate and sequential applications for perennial grasses (bermudagrass or johnsongrass).
- Total use during season can not exceed 32 oz per acre per year.
- Do not apply within 4 days of harvest.

Select Max

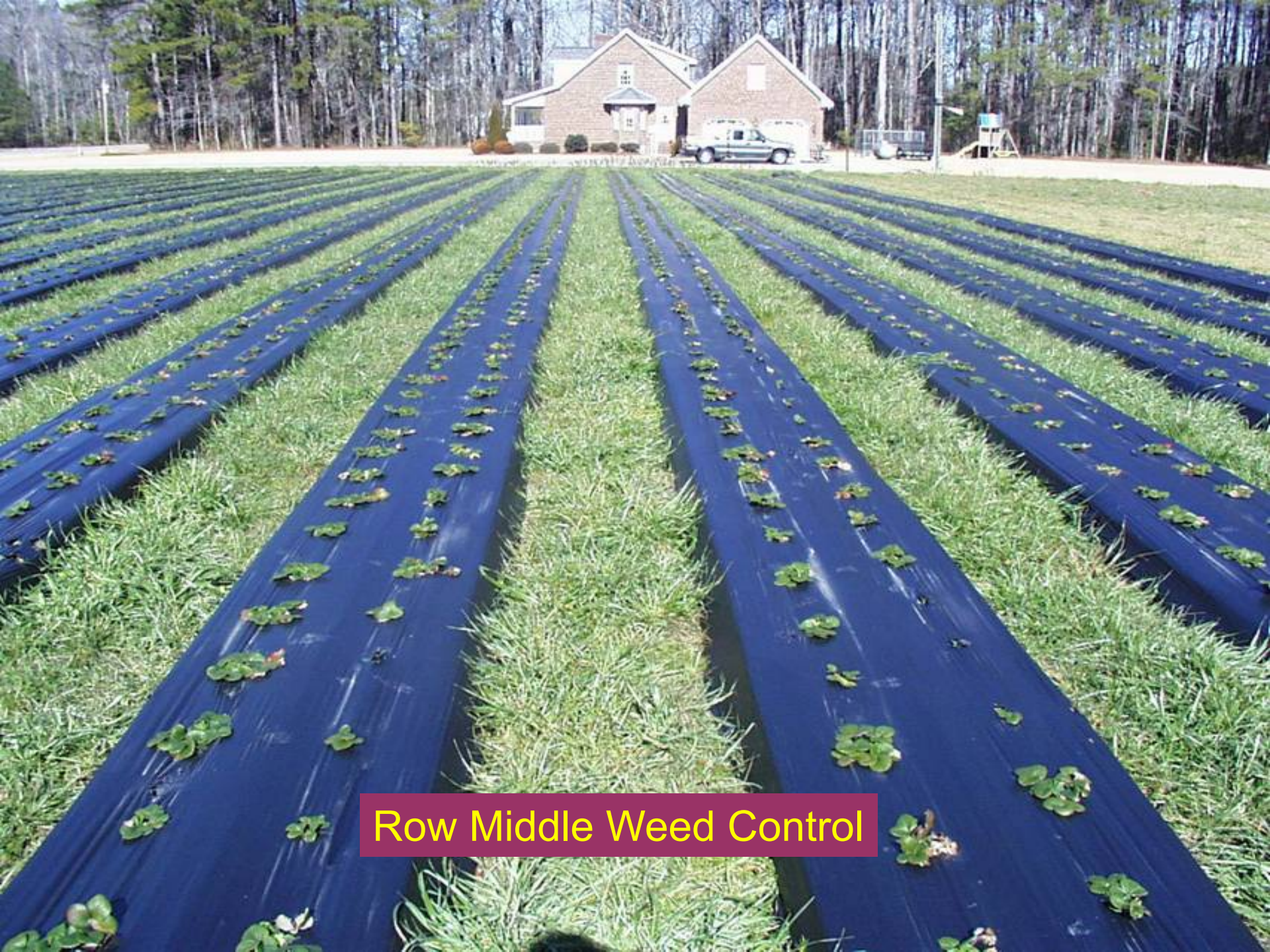
- POST for annual and perennial grasses.
- Rate: 12 to 16 oz/A.
- Nonionic surfactant or COC
- Newly planted or established plantings.
- Use high rate and sequential applications for perennial grasses (bermudagrass or johnsongrass).
- Total use during season can not exceed 32 oz per acre per year.
- Do not apply within 4 days of harvest.

Poast

- POST for annual and perennial grasses.
- Rate: 1 to 1.5 pt/A
- Sequential applications necessary for perennial grass control.
- Do not apply within 7 days of harvest.
- Do not exceed 2.5 pt/A per year.

Poast

- Some recent questions about slowing down the ryegrass in row middles.
- Recommend spraying Poast at about 5 oz/A without crop oil.
- Hard to say what will happen – hopefully will slow down and not kill the ryegrass completely. If it doesn't slow it down enough spray again 10 days later.
- Downside – lower rates select for resistant ryegrass.


Row Middle Weed Control

Several Options for Middles

- Non chemical
  Annual ryegrass
- Chemical options
  - Preemergence
    - Chateau
    - Dacthal
    - Devrinol
  - Postemergence
    - Poast
    - Select/Select Max
    - Stinger
    - Ultra Blazer
    - Aim
    - Gramoxone Inteon
    - Roundup WeatherMax

Ryegrass in the Middles

Resistant Ryegrass

- Two sources
  - Seed source.
  - Seed bank - introduced seed planted in row middles in strawberries in previous years.
  - Seed moving in from wheat-growing areas that have Hoelon resistant ryegrass.

What Can a Grower use for Row Middles with Ryegrass?

Preemergence

- Chateau - NO
- Dacthal - NO
- Devrinol – NO

Postemergence

- Poast - NO
- Select/Select Max - NO
- Stinger - YES
- Ultra Blazer - NO
- Gramoxone Inteon – May need to use as a spot treatment.
- Roundup WeatherMax - May need to use as a spot treatment.
- Aim - May need to use as a spot treatment.

What Can a Grower use for Row Middles with Ryegrass?

Postemergence

- Stinger - YES
- Gramoxone Inteon – May need to use as a spot treatment.
- Roundup WeatherMax - May need to use as a spot treatment.
- Aim - May need to use as a spot treatment.


Herbicide Options for Weed Control
in Row Middles

Chateau PRE to Row Middles

- Use hooded or directed sprayer.
- DO NOT spray over strawberries.
- DO NOT apply after fruit set – spotting.
- May add COC or NIS to help control emerged weeds.
- Avoid drift – spotting may occur on fruit or foliage.
- Potential to injure ryegrass PRE and will burn ryegrass if already emerged.

CHATEAU Applied POST to Row and Row Middle

Injury caused by POST over-the-top application of Chateau.

Dacthal

- PRE to the row middles.
- Annual grasses and small seeded broadleaf weeds.
- Rate: 8 to 12 lb
- Fall application can injure ryegrass (emerged and not emerged).
- Rainfall or overhead irrigation is needed within 24 hours of application for herbicide activation.

Devrinol

- Direct to the row middles for PRE weed control.
- Annual grasses and small seeded broadleaf weeds.
- Rate: 8 qt or 8 lb
- Fall application can injure ryegrass (emerged and not emerged).
- Rainfall or overhead irrigation is needed within 24 hours of application for herbicide activation.

Ultra Blazer POST to Row Middles

- Directed spray between mulched beds.
- Avoid contact with strawberries – WILL BURN
- Weed spectrum similar to Goal.
- Rate: 0.5 to 1.5 pt/A
- Plastic mulch should be applied soon after application.
- Avoid soil disturbance after application for best results.

Stinger POST to Row Middles

- Rate: .33 to 0.67 pt/A
- POST for clover, vetch, dock, cocklebur, dandelion, sowthistle, thistle, galinsoga, and nightshade.
- Very narrow weed spectrum.
- DO NOT apply within 30 days of harvest. DO NOT use surfactant with Stinger.
- DO NOT tank mix with other pesticides.

Roundup

- POST non-selective.
- Rate: 11 to 22 oz
- Hooded spray or wiper applicator.
- To prevent SEVERE crop injury prevent contact with any portion of the crop or plastic.
- Strawberries are most susceptible to Roundup damage in the fall.
- Do not apply within 14 days of harvest.

Gramoxone Inteon

- POST non-selective weed control.
- Rate: 2 pt/A with hooded sprayer.
- Do not allow drift or spray solution to contact crop or severe injury or crop death will occur.
- Do not make more than 3 applications per year.

Aim

- POST for broadleaf weeds.
- Rate: Up to 2 oz/A with hooded sprayer.
- Contact herbicide with minimal residual activity.
- Coverage is essential for satisfactory performance.
- Apply to actively growing weeds up to 4 inches tall and rosettes less than 3 inches across.
- Crop injury will occur when spray is allowed to come in contact with green stem tissue, leaves, flowers or fruit.

Contact Information

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