



Growing Strawberries

Why Strawberries?

- Popularity
- Reasonable labor requirements
- Relatively low investment
- High return per acre
- = Profitability



Strawberry Production

- U.S. acreage: 60,000
- California, Florida leaders (moving south)
- U.S. production: 2.8 billion lbs.
- Yields: 8,000 lbs./a (ME) ⇨ 60,000 lbs./a (CA)



Growing Berries

What Are Your Goals?

- Personal
- Financial
 - Berries = high risk crop
 - Invest wisely
 - Or not at all
- Scale
 - Home Garden/Hobby
 - Commercial



Growing Berries

What Are Your Goals?

- Philosophical
 - “Conventional”
 - Use synthetic fertilizer and pesticides as needed
 - “Organic”
 - Legal definition regulated by federal and states
 - Use only OMRI approved amendments
- Other- no legal definition
 - “Natural”
 - “No Spray”
 - IPM
 - etc.

Markets

What Are Your Markets?

- Yourself/family
 - How much can you use?
 - Will you preserve, process?



Marketing Options

Retail

Pick-Your-Own

- Location, accessibility
- Labor
- Parking
- Customer management
- Liability



Marketing Options

Retail

Farm stand/farmers markets

- Harvest labor
- Transport
- Storage
- Sales personnel
- Regulations



Marketing Options

Wholesale

Restaurants, institutions

- Work with chefs
 - Requirements
 - Organic, standards
- Harvest labor
- Storage
- Delivery
- Irregular schedule



Marketing Options

Wholesale

Grocers

- Harvest labor
- Storage
- Packaging specifications
- GAP requirements
- Delivery
- Invoice/payment schedule



Marketing Options

Value-Added

Processing: Jams, jellies, etc.

- Regulations
 - Must have a licensed kitchen
 - Contact MDACF and/or Cooperative Extension for information

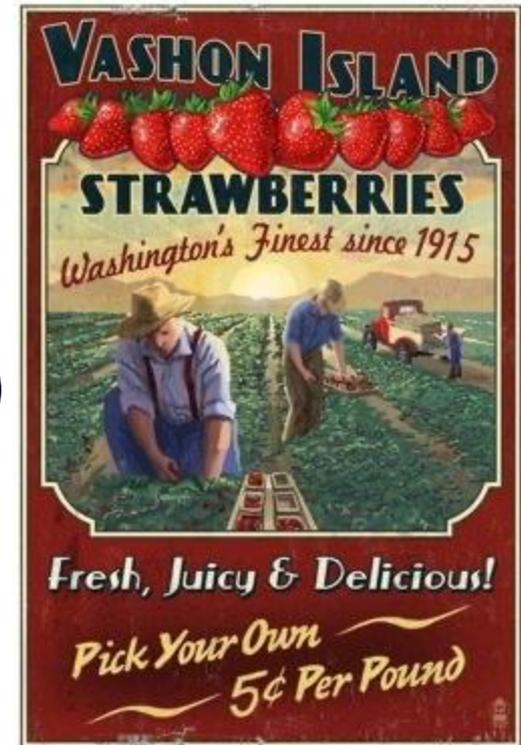


Marketing Options

Advertising: “What, When, Where”

Know your customer

- Use surveys at site
- Develop a mailing list (email, surface)
- Use the media
- Use social media
 - Keep it up to date & interesting
 - Be responsive



Maine Berries: Bottom Line

High Risk Crops

- High establishment costs
- High labor demands
- Winter injury likely
- Challenging pest complex
- Difficult to get high quality
- Questionable markets
- 1 to 5 years to production



Maine Berries: Bottom Line

- High establishment costs
 - 4,000-\$15,000/A
- High maintenance costs
 - \$2,000-5,000/year
 - Mostly labor
- Returns can be variable
 - \$0-10,000



Site Selection



Site Selection: Where to Plant

Location, location, location

- Accessibility
 - Customers, markets, labor
- Full sunlight
- Slope
 - Less than 8%
- Protected from winds
- Reliable source of water nearby,



Site Selection: Where to Plant

Location, location, location

- Well-drained soil with good organic matter
 - Avoid heavy clay soils, ledge
- Away from pest harbors
 - Wild brambles, strawberries
- No insurmountable weed issues



Site Selection - Weeds

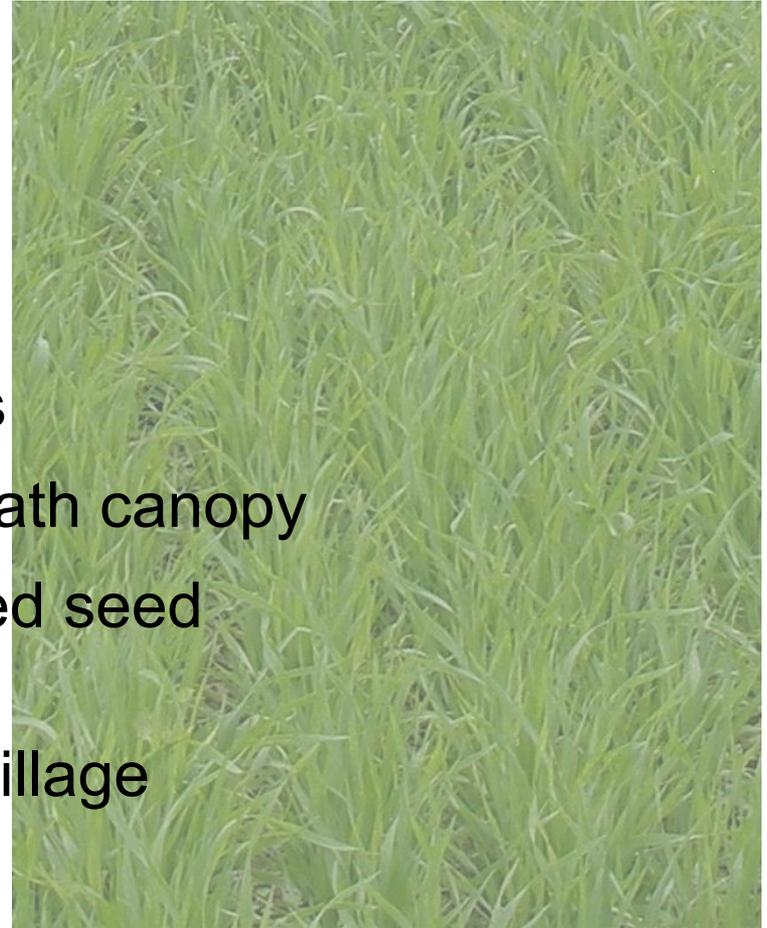
- Review site history
 - ✓ Previous crops
 - ✓ Weed history
 - ✓ Weed management history
- Examine site for existing weed species
 - ✓ Annual species
 - ✓ Perennial species



Site Preparation

Cover crops

- Build soil organic matter
- Improve soil structure
- Reduce weed pressure?
 - Shade out some species
 - Some may survive beneath canopy
 - Little impact on total weed seed population
 - Combine with repeated tillage
 - Use allelopathic species



Site Preparation

Cover Crops:

- Summer
 - Grasses, legumes, buckwheat,
 - Cash crops (pumpkins, corn, greens)
- Winter
 - Rye, Mustards



Site Preparation

Tarping

- Apply plastic tarps summer/fall before planting
 - Deplete annual weed seed bank
 - Deplete perennial plant reserves



Site Preparation

Herbicides

- Glyphosate
 - Apply fall prior to planting
- Gramoxone
 - Apply fall or spring prior to planting
 - Burn down only; won't control perennials



Site Preparation: Soil Testing

Have a soil test done!

Best if done the year before planting, or earlier

- Soil testing info at:
<http://umaine.edu/publications/2286e/>
- Results:
 - soil pH (best: 6.2-6.8)
 - nutrient levels (N, P, K, Ca, Mg)
 - organic matter (best 4%+)
- Correct any problems before planting



Site Preparation

Strawberry Nutrition

Soil Characteristic	Desirable Range
pH	6.2-6.8
Organic Matter	4% - 6%
Phosphorus	20-30 ppm
Potassium	120-180 ppm
	Base Saturation > 3.0
Magnesium	100-150 ppm
	Base Saturation > 5.0
Calcium	1000-1500 ppm
	Base Saturation > 50.0

Site Preparation

Soil Fertility

- Soil pH
 - Strong influence on nutrient availability
 - High pH
 - Reduces availability of Zn, Fe, Mn, Cu, B
 - Increases availability of Ca, Mg, Mo
 - Low pH
 - Reduces availability of N, P, K, Ca, Mg, Mo
 - Increases availability of Fe, Mn, B, Cu, Zn



Site Preparation: Fertilizer

Goal of Soil and Nutrient Management

- Supply sufficient nutrients to achieve realistic maximum yield based on site and cost



Site Preparation: Fertilizer

Goals of Soil and Nutrient Management

- Avoid excess application of nutrients that may be lost to leaching (N, P)
 - Wastes money
 - Can lower quality
 - Can lower yield
 - Environmental impacts
- Time nutrient application to crop demand
- Adjust pH to ensure optimal crop uptake



Site Preparation

Get the ground ready!

Soil Amendments:

- Use rates according to soil test
- Incorporate lime, compost, manures fall before planting



Site Preparation: Fertilizer

Apply granular fertilizers in spring before planting

- N-P-K
 - nitrogen, phosphorus, potassium
 - e.g. 10-10-10
 - = 10% N, P & K
 - Per 100 feet of row:
 - 1 lb. 10-10-10 or
 - Per acre: 500 lb. 10-10-10

Micro-nutrients? B, Mn, Fe



Site Preparation: Fertilizer

Organic Products

- Check label for nutrient %
- e.g. “Cheep Cheep[®]”
= 4-3-3
- Apply equivalent amount
- Usually slow release



Site Preparation



Raised Beds

- Improve drainage
- Reduce root diseases
- Increase drought
- irrigation
- Increase winter injury?

The Strawberry Plant

Fragaria x ananassa

- *F. virginiana* x *F. chiloensis*
 - *F. virginiana*:
 - Native to eastern U.S.
 - *F. chiloensis*:
 - Native to western Americas
 - Crossed in Europe, 1600's



The Strawberry Plant

Herbaceous perennial

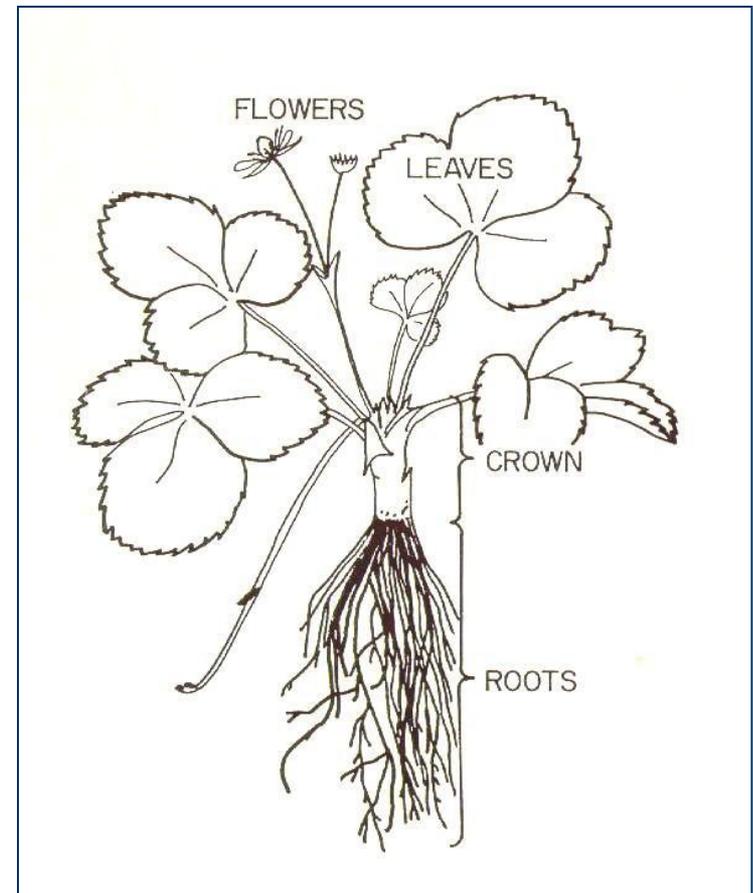
- Lives several to many years
- Lacks woody tissue
- Low-growing
- Reproduces sexually (seed)
- Reproduces vegetatively
 - Runners, branch crowns



The Strawberry Plant

Herbaceous Perennial

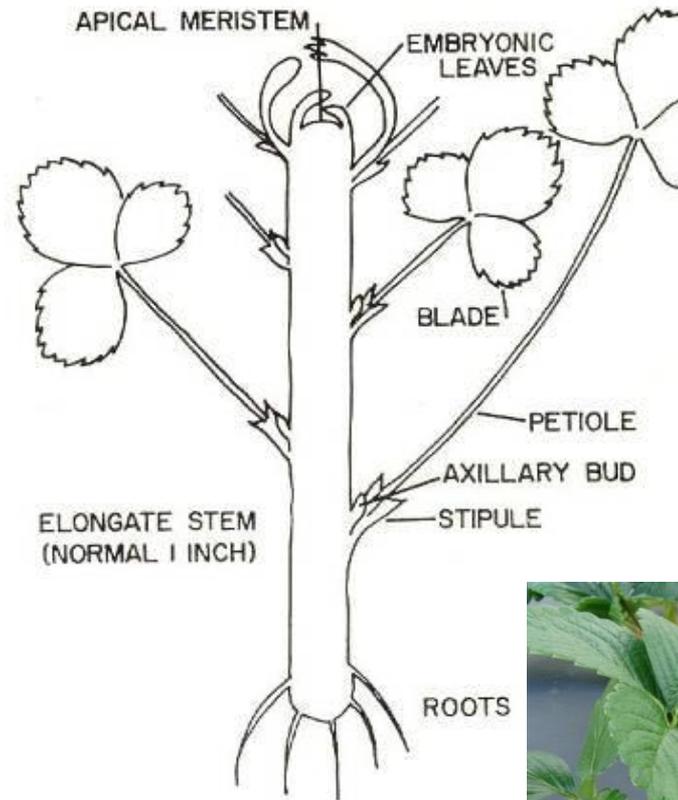
- Main stem: crown
 - Compressed stem
- Buds form other parts:
 - Leaves, flowers, runners, branch crowns, roots
 - Spiral arrangement



The Strawberry Plant

Strawberry Crown

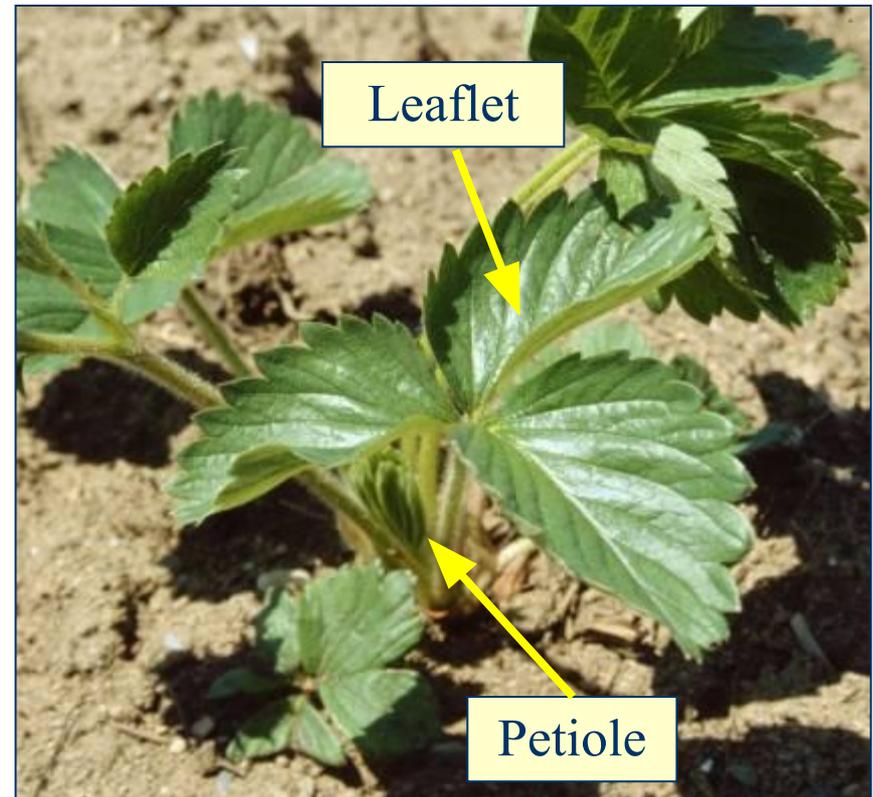
- Apical Meristem
 - Leaves
 - Flowers
- Axillary Buds:
 - Stolons
 - Branch crowns



The Strawberry Plant

Leaves

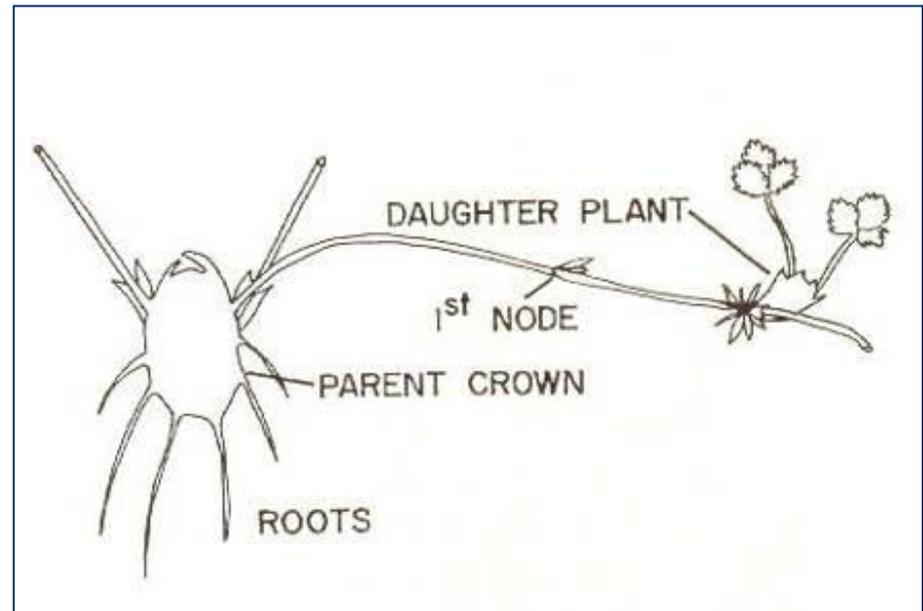
- Trifoliate
 - 3 leaflets/leaf
 - Serrated, waxy cuticle
- Long petioles
- Spiral arrangement
 - 6th leaf above the 1st
- Regenerate annually



The Strawberry Plant

Runners

- Stolons (shoots)
- From axillary buds
- Usually two nodes
- Environmental cues
 - Warm Temperatures
 - Long day length
 - Variety differences



The Strawberry Plant

Runner Plants (Daughters)

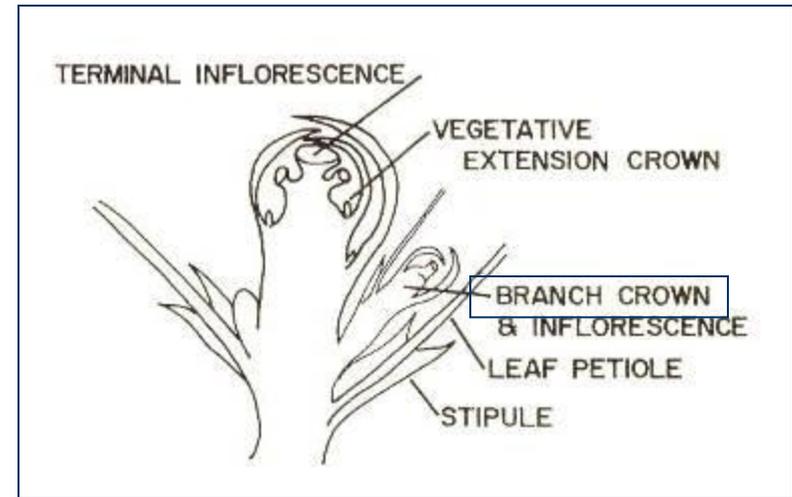
- Primary
 - Direct from mother plant
- Secondary, tertiary, etc.
 - From other runner plants
- Rooting
 - Moisture
 - Stability (no wind)
 - Independence from mother plant
- Inter-plant competition



The Strawberry Plant

Branch Crowns

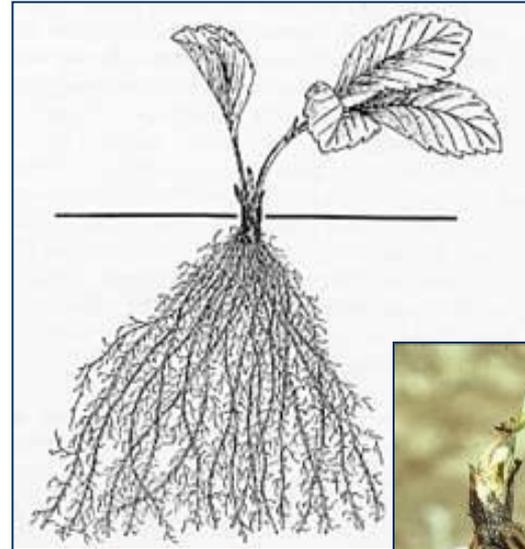
- Shoots
 - Similar to main crown
- From axillary buds
- Environmental cues
 - Cool temperatures
 - Short day length
- Intra-plant competition
 - Reduced fruit size



The Strawberry Plant

Roots

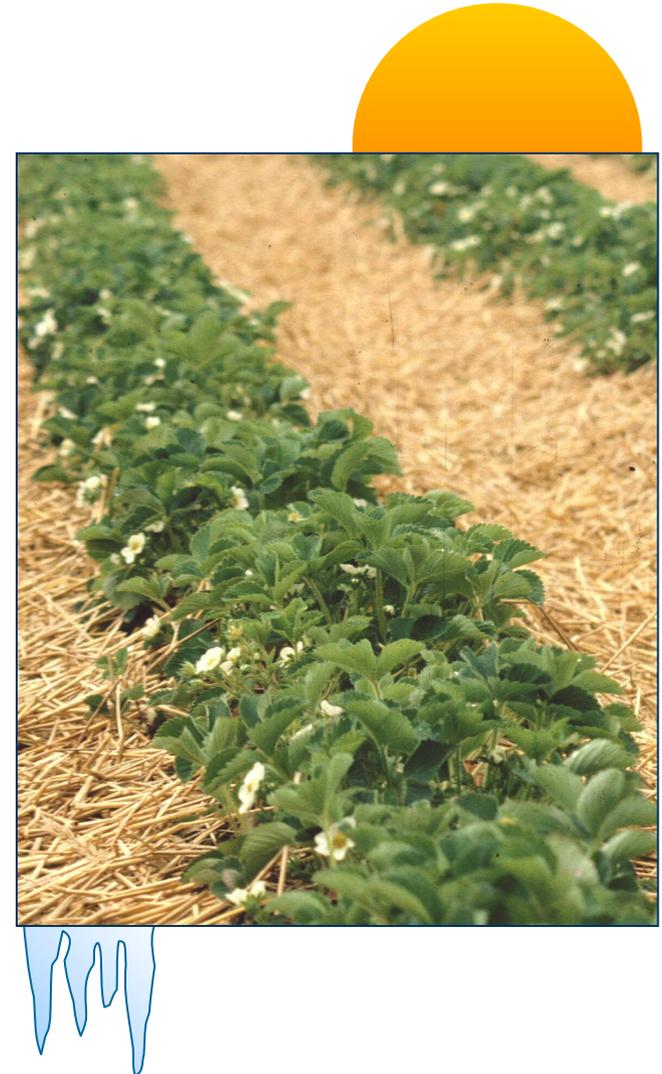
- Adventitious or Primary
 - 20-30 per crown
 - Average 4-6" length
 - Live 2-3 years
- Lateral
 - Branch from primaries
 - Live 1-2 years
- Root hairs
 - Branch from laterals
 - Short-lived
- Mycorrhizae



The Strawberry Plant

Flower Development

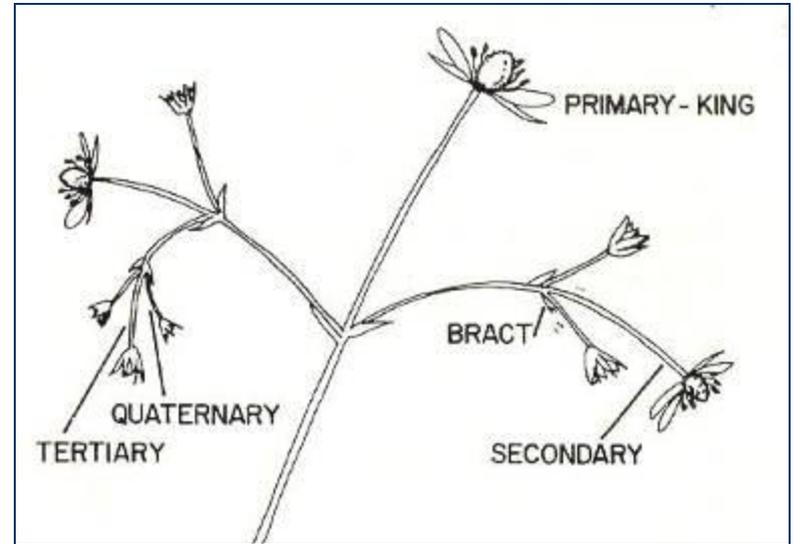
- Environmental cues
 - Short day length
 - Cool temperatures
- = Fall & Spring
- Exception: day-neutral plants
- Measured by leaves
 - Mulch late, remove early to encourage more flowers



The Strawberry Plant

Flowers

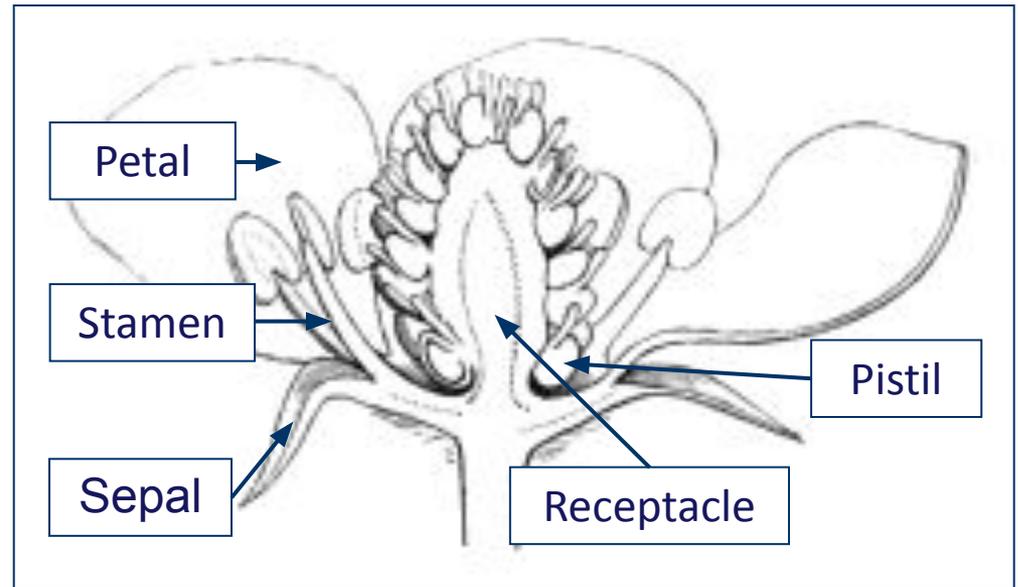
- From terminal bud
 - Primary or branch crown
- Modified Stem
 - Terminated by primary blossom (“King”)
 - Branches arise at nodes
 - Secondary, tertiary, quaternary blossoms



The Strawberry Plant

Blossoms

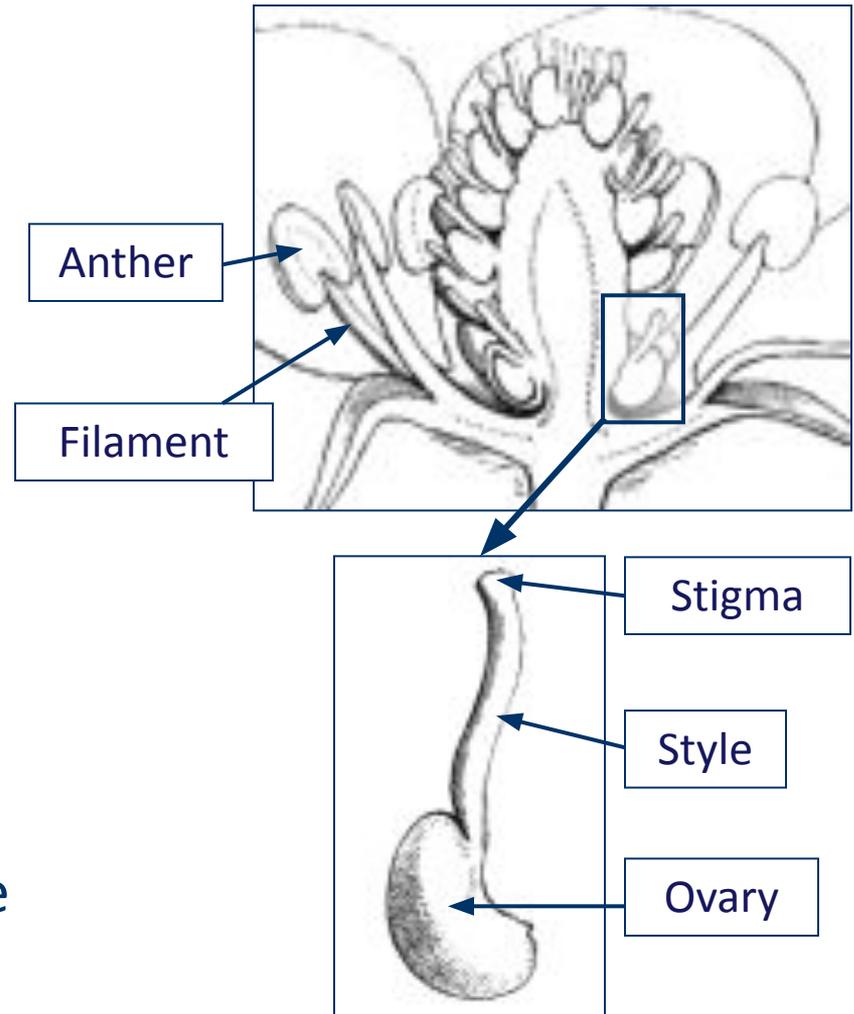
- ~ 10 sepals
- ~ 5 petals
- ~ 20-40 stamens
 - Pollen
- Receptacle
- 60 - 600 pistils
 - Primaries most, quaternaries least



The Strawberry Plant

Blossoms

- Stamens
 - Anthers
 - Carry pollen
 - supported by filaments
- Pistils
 - Stigma
 - Pollen reception
 - Style
 - Ovary
 - Carpel with single ovule
 - Achene



The Strawberry Plant

Pollination

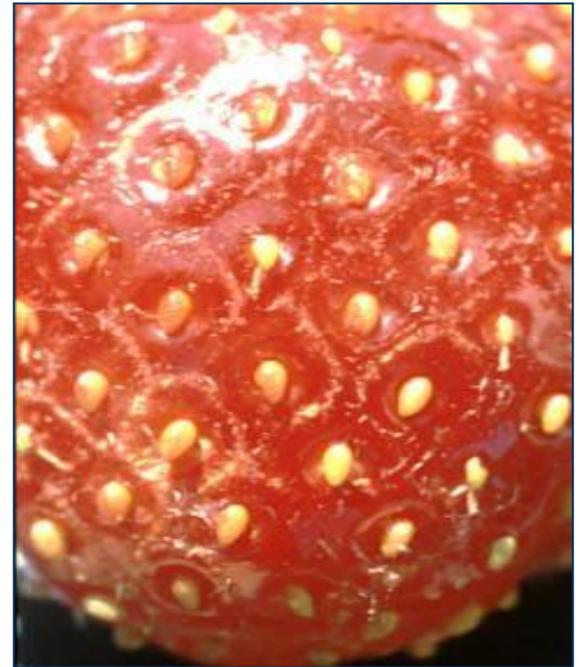
- Most strawberries self-fertile
 - Some exceptions: *F. chiloensis*
 - Cross-pollination improves yield
- Stigmas receptive prior to pollen release
 - Encourages cross-pollination
- Post-pollination
 - Fruit (achene) development: embryo, endosperm
 - Synthesis and translocation of auxin



The Strawberry Plant

Fruit Development

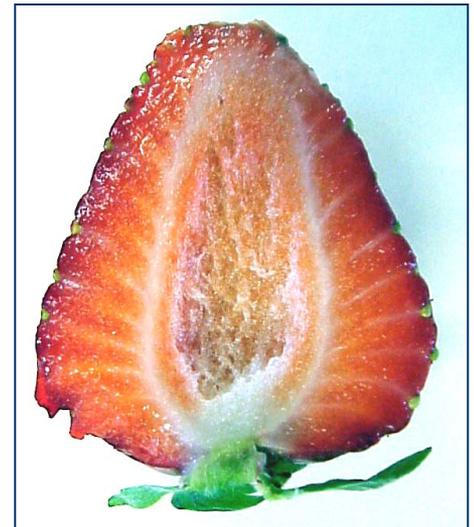
- Achenes
 - True fruit of the strawberry
 - Together with receptacle forms an *aggregate*
 - Not a true “berry”, botanically
- Bloom ⇨ Fruit Ripening ~ 30 days



The Strawberry Plant

Fruit Development

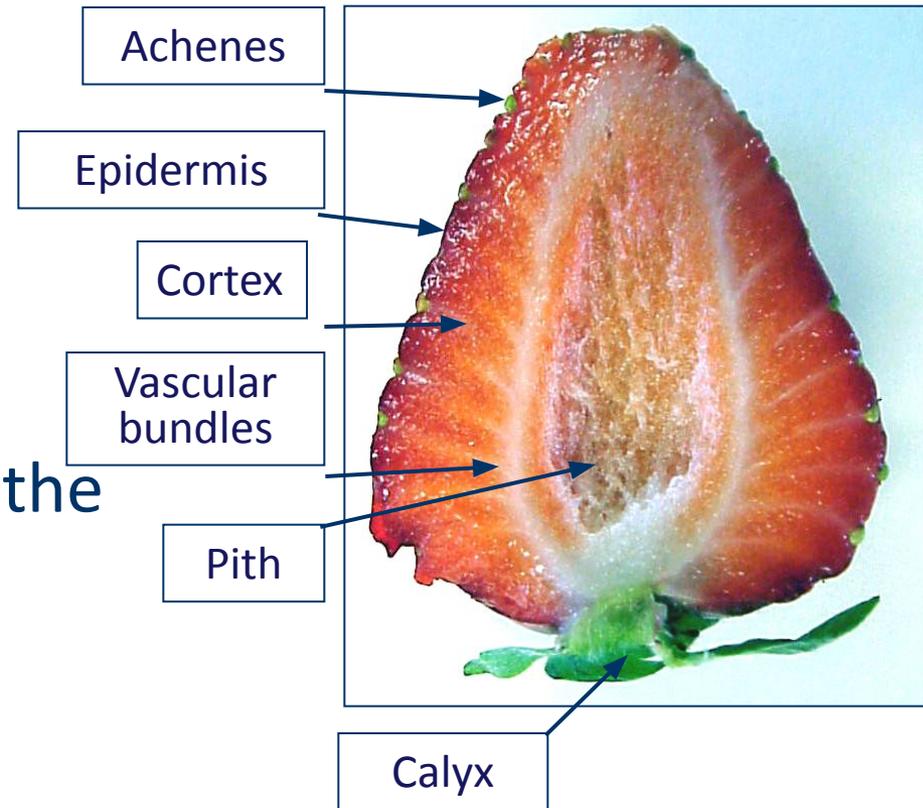
- Development of receptacle
 - Auxin synthesized in endosperm
 - Translocated to receptacle tissue
 - via vascular bundles
 - Cells in receptacle elongate
 - Form edible flesh of the “berry”
 - Nearly all growth following pollination is due to cell elongation
 - Very little cell division



The Strawberry Plant

Strawberry Anatomy

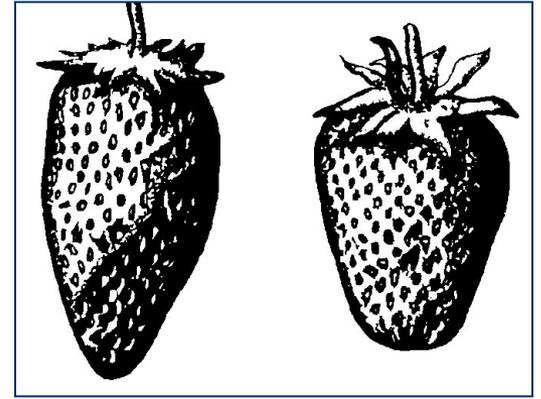
- Achenes
- Epidermis
- Cortex
- Vascular bundles
- Pith
 - Most growth occurs in the cortex & pith
- Calyx



The Strawberry Plant

Strawberry Development

- Shape & Size
 - Number of achenes
 - Distribution of achenes
 - Number of cells in receptacle
- Blossom Order
 - Primary ⇨ secondary ⇨ tertiary
- Variety (genetics)



The Strawberry Plant

Fruiting Problems

- Pollination
- Frost
- Insects



The Strawberry Plant

Fruiting Potential

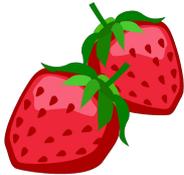
- Yield per plant:
 - Number of fruit per plant
 - Number of crowns
 - Number of blossoms/stalk
 - Size of fruit
- Yield per acre:
 - Yield per plant
 - ↕
 - Number of plants per acre
- Variety (genetics)



The Strawberry Plant

Fruiting Potential

Inter & intra plant competition impact on yield



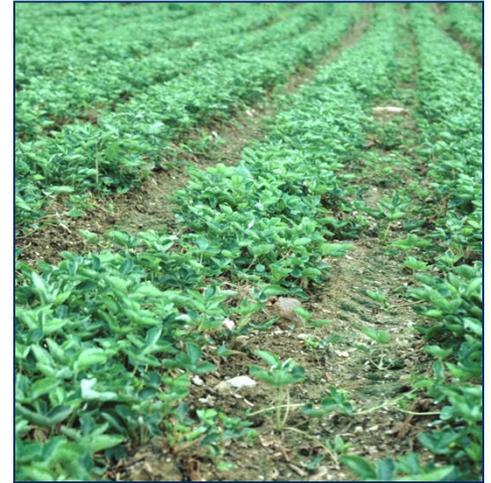
	Number of fruit	Size of Fruit	Yield / plant	Yield / acre
Plants/ acre	□	□	□	□*
Crowns/ plant	□	□	□	■*

*Total yield; marketable yield may be reduced

The Strawberry Plant

Nature vs. Nurture

- Production systems vs. plant habit
 - Design systems to optimize plant's nature
 - Matted row
 - Design plants to fit optimum system
 - Plasticulture, Greenhouse
- Best compromise for a climate



The Strawberry Plant

Berries need:

- Well-drained soil with good organic matter
- Good light exposure
- Source of water nearby
- Soil pH: 6.0 to 6.5
- No weed competition



Site Preparation: Soil Testing

Have a soil test done!

Best if done the year before planting, or earlier

- Soil testing info at:
<http://umaine.edu/publications/2286e/>
- Results:
 - soil pH (best: 6.2-6.8)
 - nutrient levels (N, P, K, Ca, Mg)
 - organic matter (best 4%+)
- Correct any problems before planting



Site Preparation

Get the ground ready!

Soil Amendments:

- Use rates according to soil test
- Incorporate lime, compost, manures fall before planting



Site Preparation: Fertilizer

Granular Fertilizers

- Apply in spring before planting
- N-P-K
 - nitrogen, phosphorus, potassium
 - e.g. 14-14-14
 - = 14% N, P & K



Site Preparation: Fertilizer

Organic Products

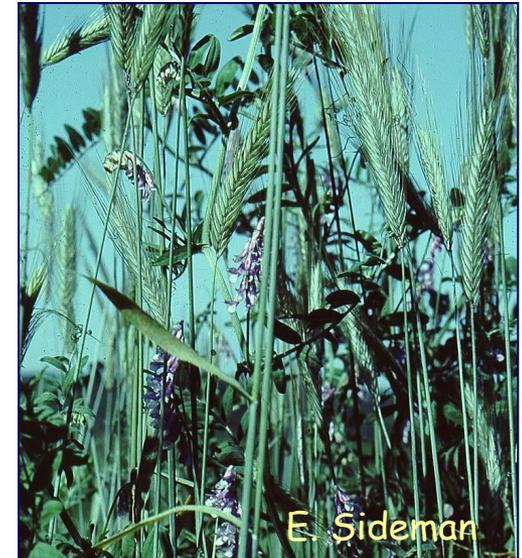
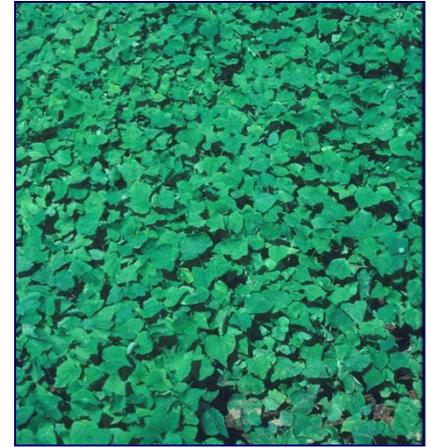
- Check label for nutrient %
- e.g. “Cheep Cheep[®]”
= 4-3-3
- Apply equivalent amount
- Usually slow release



Site Preparation

Crop Rotation

- Maintain soil structure and microbial activity
- Sustain reservoirs of plant nutrients
- Inhibit build-up of pests: weeds, diseases
- Strawberries: *in for 1-3 years, out for 4-5*
- Rotation Crops:
 - Summer: grasses, legumes, buckwheat
 - Cash crops?
 - Winter: rye, Mustards



Strawberry Varieties



What's important?

- Yield
- Harvest season
- Fruit quality
 - Size
 - Color
 - Firmness
 - Flavor
- Plant durability
 - Winter hardiness
 - Disease resistance
 - Longevity
- Personal taste

Strawberry Varieties

- Wendy
 - Galletta
 - Flavorfest
 - Cavendish
 - Jewel
 - Cabot
 - Valley Sunset
- Early
- Late



Strawberry Varieties

Early

Wendy, Annapolis, Galletta

Early Mid-season

Flavorfest, Cavendish, Yambu

Mid-Season

Jewel, Darselect, Dickens

Mid-Late

Cabot, Keepsake

Late

Valley Sunset, Malwina



Strawberry Varieties

Wendy

- Early
- Good yield
- Medium fruit size
 - Declines quickly
- Disease susceptibility
- Good flavor



Strawberry Varieties

Annapolis

- Early
- Good yield
- Med-large fruit size
 - Declines quickly
- May be tender
- Good flavor



Strawberry Varieties

Flavorfest

- Early-midseason
- Good yield
- Good fruit size
- Firm
- Nice appearance
- Good flavor
- Disease resistance



Strawberry Varieties

Cavendish

- Early-midseason
- Long harvest window
- Very good yield
- Good fruit size
- Coloring issues
- Good flavor
- Disease resistance



Strawberry Varieties

Yambu

- Early-midseason
- Long harvest window
- Very good yield
- Good fruit size
- Good flavor



Strawberry Varieties

Archer

- Early-midseason
- Fair yield
- Very good fruit size
- Good flavor



Strawberry Varieties

Jewel

- Midseason
- Very good yield
- Fair fruit size
- Nice appearance
- Firm



Strawberry Varieties

Sonata

- Midseason
- Good yield
- Fair fruit size
- Firm
- Nice appearance
- Fair flavor



Strawberry Varieties

Darselect

- Mid-season
- Good yield
- Large, uniform fruit
- Good flavor



Strawberry Varieties

Keepsake

- Late-midseason
- Good yield
- Good fruit size
- Good appearance
- Good flavor
- Long shelf life



Strawberry Varieties

Dickens

- Late-mid season
- Good plant survival & yield
- Large fruit size
- Good appearance
- Good flavor



Strawberry Varieties

Cabot

- Late-mid season
- Large fruit size
- Good appearance
- Good flavor
- Susceptible to rot
- Short lived plants



Strawberry Varieties

Valley Sunset

- Late season
- Large fruit size
- Good appearance
- Good flavor
- Susceptible to rot
- Short lived plants



Strawberry Varieties

Malwina

- Very late season
- Medium-large fruit size
- Dark color
- Firm
- Good flavor



Planting Strawberries

Dormant Crowns

- Compressed Stems
- Look For:
 - Healthy, yellow roots
 - White crown tissue
 - No mold



Planting Strawberries

Dormant Crowns

- Plant April - May
- Planting Depth
 - half way up the crown



Planting Strawberries

Delayed Planting/Stale Seedbed

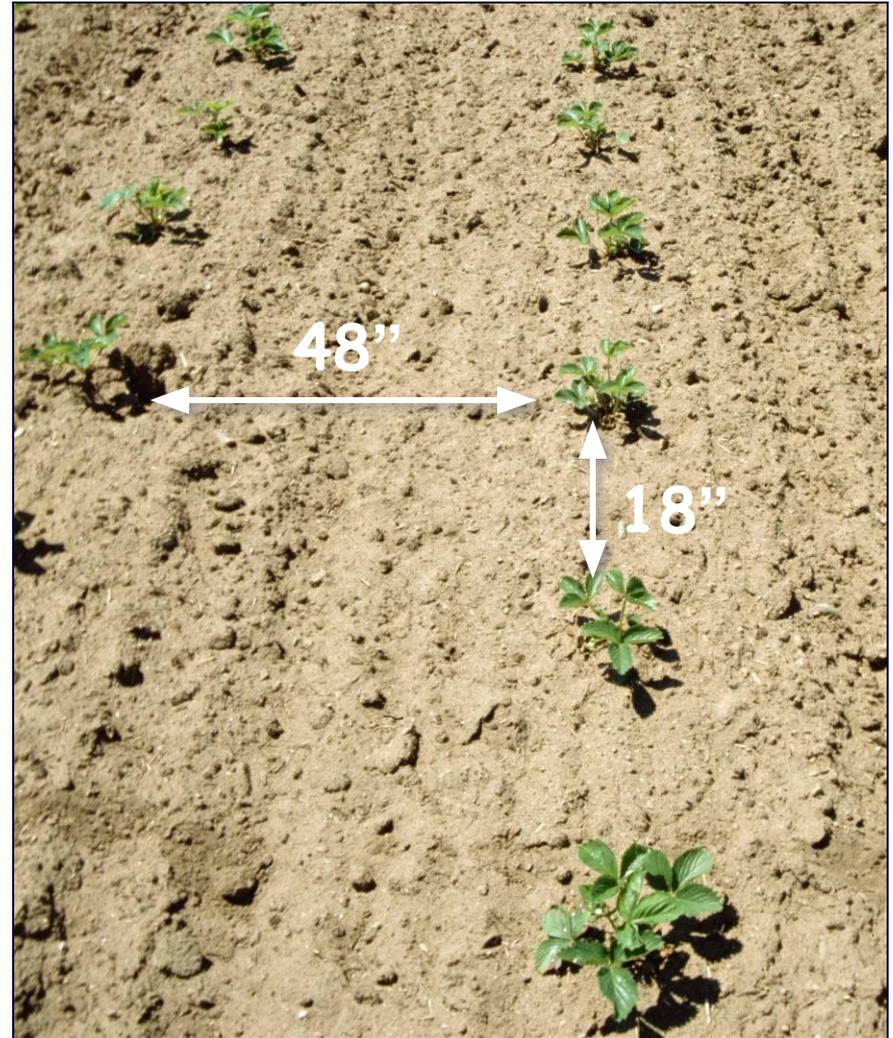
- Plant in mid-late June
 - Prepare ground in fall or early spring
 - Allow weed seeds to germinate 2-4 wks
 - Spray or flame or lightly till,
 - Disturb soil as little as possible
- Advantages:
 - **weed control**, labor distribution
- Disadvantages:
 - Plant quality, availability, irrigation



Planting Strawberries

Matted Row System

- perennial
- runners fill out rows
- Plant April - May
- 12-24" between plants
- 42-60" between rows
- 7000-8000 plants/acre



Planting Strawberries



New Plant Establishment

- Water in, water often
- Trickle irrigation?
 - Bury 3 inches
 - raised beds



Site Preparation



Raised Beds

- Improve drainage
- Reduce root diseases
- Increase drought
 - irrigation
- Increase winter injury?

Planting Strawberries

New Plant Establishment

- Cultivation



Planting Year Care

Flower removal (planting year only!)

- Pinch clusters at bud stage
- 3-4 times over 2-3 weeks
- Encourages runner growth
- Reduces plant stress
- Reduces disease potential



Flower truss removal

Planting Year Care

Set runner plants

- Runner emergence July-Sept.
- Root between mother plants
- Allow 2' row width
- Use primary runners
- Hold in place with soil, etc.
- Moisture stimulates rooting



Planting Year Care

- Runners rooted by mid Sept.
- Final row width = 2 feet
- Remove excess/late runners
 - Secondary, tertiary
- Light fertilizer sidedress
 - early-mid August
 - 1 lb. N/1000ft²
 - 30-40 lbs./acre





Winter Care

Mulch

- Apply when plants are dormant
 - Leaves red and wilted
 - November-December



Winter Care

Mulch

- Materials
 - Clean straw (not hay)
 - 3-5 tons/acre
 - \$1,000-1,500/acre
 - 6-10" thick
 - Sawdust, shavings



Season Extension

Rowcover Options:

1. Apply cover in September

- Remove and apply straw when dormant (or not)
- Remove straw in March or
- Remove cover at bloom

2. Mulch as usual Nov.- Dec.

- Remove straw in March
- Apply cover
- Remove cover at bloom



Season Extension

Rowcovers:

- Advantages:
 - Harvest 1-2 weeks earlier
 - Increase in yield
 - Less insect damage
- Disadvantages:
 - Cost (\$1000-\$2000/acre)
 - Early bloom = frost injury
 - Insufficient winter protection



Springtime Care

- Remove mulch late March-April
 - place under & around plants
 - Keep flowers & fruit dry
- Fertilize *very lightly*
 - 15-25 lb. N/acre (CaNO_3)
 - 1-2 lb. B/acre (Solubor)
- Pest management
 - Weeds, insects, diseases
- Frost control



Springtime Care

Protect buds & flowers from frost

- cover at night
- irrigation



Frost injury

Frost Protection

Irrigation

- Set up sprinklers
- Arrange for complete coverage
- ~24 inch risers, frost nozzles
- Check pumps, pipes
- Apply when 33°F at bud height
 - Frost alarms
- Turn off when ice has melted



Harvest Time

- ~3 weeks after bloom
 - mid June - mid July
- Harvest fruit fully ripe
 - pick regularly & often
- Remove rotten fruit
 - source of diseases
- Irrigate between harvests



Harvest Time

Customer Management

- Signs, neat and easy to read
- Plenty of parking
- Field access free of hazards
- Transport available
- Picking rules & instructions posted
- Friendly, knowledgeable help
- Plenty of picking containers available
- Clean restrooms, shade, seating & drinks available
- Fast, efficient checkouts



Bed Renovation

- Start at the end of harvest
 - mid July - early August
- Bed thinning and renewal process
 - every harvest year for the life of the bed
- Evaluate the bed:
 - If health is declining
 - Check pest problems
 - Check fertility
 - Start new bed next spring



Bed Renovation

Step I

- Remove all in-row weeds



Bed Renovation

Step II

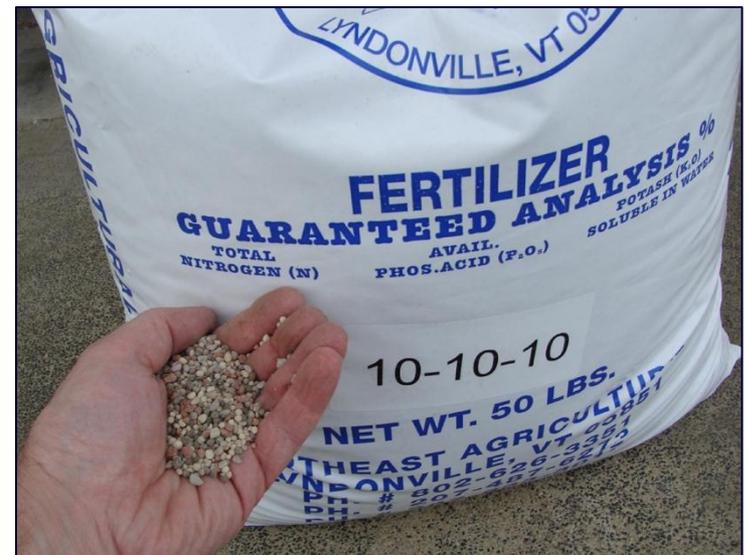
- Mow off leaves
 - ~2" above crowns
 - Skip if plants are stressed (drought)
 - incorporate into soil
 - see step IV



Bed Renovation

Step III

- Apply soil nutrients
 - soil test recommendation
 - maintenance rate N, P, K
 - 30-40 lb. of NPK per acre
 - granular, compost, etc.



Bed Renovation

Step IV

- Till the sides of the rows
 - narrow row to a 10" width
 - leaving row centers
- Incorporates fertilizer, leaves
- Throw ~1" soil over row center
 - provides base for new roots



Bed Renovation



Bed Renovation

Reduced Renovation

“No-Tilling” Approach

- Reduce weed pressure
- Mow & fertilize as usual
- No tilling to narrow row
 - post-emergent herbicides or flaming to narrow rows
 - Apply pre-emergent herbicides as usual, or use flaming



Bed Renovation

Reduced Renovation

- Weed/Runner control throughout summer with post & pre-emergent herbicides
- No cultivation/tillage
 - Prevents germination of weed seed
- No soil applied over plants
 - Increased winter injury?
 - Apply compost alternative?



Bed Renovation

Step V

- Water
 - encourages new growth
 - “activates” fertilizer
 - plants need 1-2” water/week



Summer Care

Post-Renovation

- Water (again)
 - plants need 1-2"/week
- Weed, weed, weed
 - Cultivation, herbicides
- Fertilize mid-late August
 - 1/2 renovation rate
 - 20 lb. N/acre



Strawberry Nutrition

Nitrogen

- Planting year
 - 20-40 lbs./acre pre-plant
 - 30 lbs./acre late June-early July
 - 20 lbs./acre late August-early Sept.
- Established beds
 - 70 lbs./acre at renovation
 - Immediately after fruiting
 - 30 lbs./acre late August-mid Sept.

Strawberry Nutrition

Phosphorus

- Strawberries don't have high P demand
 - Deficiencies fairly rare in NE
 - 20-30 ppm optimal
 - Monitor with soil tests
- Slowly available
- Should be soil-incorporated
- Doesn't leach readily
- Low pH decreases availability

P

Strawberry Nutrition

Potassium

- Strawberries have a high K demand
 - Important component of the fruit
- Deficiencies fairly rare in NE
- 120-180 ppm optimal
- Monitor with soil tests
- Slowly available
- Should be soil-incorporated
- Balance with Mg
 - $K:Mg = 4:1$

K

Strawberry Nutrition

Magnesium

- Soil levels variable
- 100-150 ppm optimal
- Deficiencies not uncommon
- Reduced availability if pH is low
- Dolomitic limestone primary source
 - Should be soil-incorporated
- Epsom salts soluble form (MgSO₄)
 - Can be applied as a foliar spray

Mg

Strawberry Nutrition

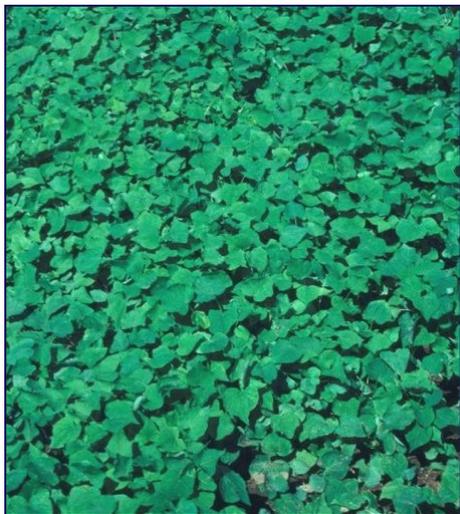
Boron

- Micro-nutrient
 - Essential for good root growth and pollination
 - Easily leached from soil (no ionic charge)
 - Commonly deficient in NE
 - Normal: 60 ppm in leaves
 - Toxic to plants at excessive levels (100 ppm)
 - Apply no more than one lb. actual B per season
 - Apply B in blend with other nutrients at renovation

B

Cover Crops

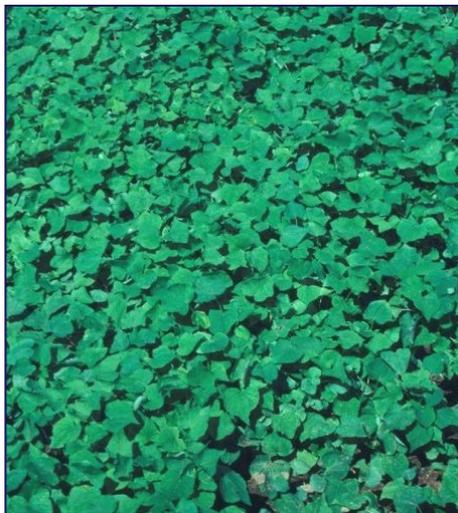
- Maintain soil structure and microbial activity
- Sustain reservoirs of plant nutrients
- Inhibit build-up of pests
 - weeds, diseases, insects
- Strawberries: in for 1-3 years, out for 4-5



Crop Rotation

Rotation Crops:

- Summer
 - Grasses, legumes, buckwheat,
 - Cash crops (pumpkins, corn, greens)
- Winter
 - Rye, Mustards



Matted Row Strawberries

- Average bed life 3-6 years
- Most common reason for early bed failure: **Weeds**
- Renovate every year after harvest (not planting year)
- Start new bed one year before plowing up old bed (no fruit in planting year)



Strawberry Plasticulture



Strawberry Plasticulture

Year One

- Soil & bed prep
- Mulch application
 - Tickle irrigation
- Planting (July-Sept.)
- Flower removal
- Runner control
- Winter protection

Year Two

- Remove winter cover
- Frost protection
- Pest control
- Harvest
- Remove plastic
- Plow down
- Plant cover crop



Strawberry Plasticulture

Plant Types: Plugs vs. Crowns



Strawberry Plasticulture

Plant Type: Plugs vs. Crowns

Dormant Crowns

- Inexpensive
- Early planting
 - June-July
- Good variety selection
- Flower removal
- Runner Removal
- No disease issues
- Heat stress

Plugs (runner tips)

- Expensive, availability
- Late Planting
 - September-November
- Limited varieties (Chandler)
- No flower removal
- No runner removal
- Disease issues
- Inadequate establishment time

Strawberry Plasticulture



Prepping the beds

- Incorporate slow-release fertilizer
- Beds are pre-formed 5-6' on center
- 24" - 42" wide, 6" - 10" high
- Top crowned to shed water
- Insert 1-2 rows drip tape 6" deep

Strawberry Plasticulture



Laying plastic mulch

- Lay plastic fall or spring
- Black embossed plastic mulch
 - White plastic?
- Mark rows for planting



Strawberry Plasticulture

Dormant Crowns

- Prepare ground, apply mulch in fall or spring
- Plant through plastic June-July
- Remove flowers
 - May crop some varieties



Strawberry Plasticulture

Dormant crowns

- Remove runners July-September
- Cover for cold/winter protection September-October



Strawberry Plasticulture

Dormant Crowns

- Remove covers April-May
 - Frost protection
- Harvest June-July
- Remove plastic, plow down
- Plant rotation crop



Strawberry Plasticulture

Plugs

- Prepare ground, apply mulch spring/summer
- Plant plugs through plastic late August-late September



Strawberry Plasticulture



Plug Plants - Transplanting

- Young rooted runner plants
- Plant late summer - early fall (late July-early September)
- Plant with water wheel type planter
- Use rowcovers for late growth
 - Allows late planting
- Difficult to get plants established
- Difficult to get plugs for early planting.



Strawberry Plasticulture

Plug Plants – Winter Protection

- Cover for cold/winter protection September-October
- Heavy weight fabric rowcovers



Strawberry Plasticulture

Plug Plants

- Remove covers April-May
 - Frost protection
- Harvest June-July
- Remove plastic, plow down
- Plant rotation crop



Strawberry Plasticulture

Day-Neutral Plants

- Fruit spring & fall
- Similar to “everbearing” types (e.g. Ozark Beauty)
- Grow for off-season fruit
- Often grown as an annual



Strawberry Plasticulture

Day Neutral Varieties

- Seascape: early
- Albion: midseason
- San Andreas: midseason



Strawberry Plasticulture

Day-Neutral Plants

- Start from dormant crowns
 - some plug plant culture in Canada
- Prepare ground, apply mulch in fall or spring



Strawberry Plasticulture

Day Neutral Plants

- Plant crowns in early spring
 - Plugs mid-summer
- Plant on raised beds (6-10")
- Plant close together
 - 8"-10" between plants
 - Double rows 1' apart



Strawberry Plasticulture

Day-Neutral Plants

- Pinch flowers for four weeks
- Encourages root establishment



Strawberry Plasticulture

Day-Neutral Plants

- Remove all runners
 - Increases yield, fruit size
 - Cut while still small
 - Don't allow to root
- Labor intensive



Strawberry Plasticulture

Day-Neutral Plants

- Rowcovers for frost protection September-October
- Can irrigate over rowcovers for more protection



Strawberry Plasticulture

Day-Neutral Plants

- Harvest August-October
- Twice/week
- Extended ripening time
 - Not concentrated



Strawberry Plasticulture

Day-Neutral Plants

- Remove plastic, plow down in late fall
or
- Cover for winter, take spring crop in June
- Remove plastic, plow down
- Plant rotation crop



Strawberry Plasticulture

Plant Nutrition

- Pre-plant incorporate
 - P, K, Mg, etc.
 - ~45 kg slow release N
- Liquid feed through trickle lines
 - 1.25 kg N/acre/week, *if needed*
 - Check growth
 - Leaf color, petiole length
 - Leaf analysis
 - 3% N



Strawberry Plasticulture

Renovation of plasticulture beds

- Mow off leaves after harvest
- Remove/incorporate waste
- Fertilize through trickle irrigation
- Remove runners throughout summer



Strawberry Plasticulture

Renovation of plasticulture beds

Problems:

- Too many crowns in second year
 - Small fruit size
- Disease issues
 - Anthracnose, Botrytis, mildew
- Runner removal
 - Labor costs too high



Strawberries in Tunnels



Spain

Strawberries in Tunnels



Republic of Georgia

Strawberries in Tunnels



North Carolina

Strawberries in Tunnels



New Hampshire

Strawberries in Tunnels



Low Tunnels

Strawberry Pests

Weeds

Diseases

- Red Stele Root Rot
- *Verticillium* Wilt
- Gray Mold

Insects

- Tarnished Plant Bug
- Strawberry Bud Weevil (Chigger)



Pesticides

The pesticide label is the law – read it!

- Users must follow all instructions and precautions
 - Both the pest and the host plant should be listed
 - Wear proper protective clothing
 - Follow recommended concentrations and rates
 - Observe days to re-enter and days to harvest
- If selling produce, you must obtain a Pesticide Applicator license.
- <https://extension.umaine.edu/ipm/pesticide-safety/>

Weed Management



Weeds

Weed Management

Most common reason for early bed failure: **Weeds**

- Pre-plant management
- Rotation, rotation, rotation



Weeds

Weeds are often the most significant pest problem

What Makes a Plant a Weed?

Competition for resources

- light
- water
- nutrients



Weed Identification

Identification is key to effective management

- Grass
- Broadleaf
- Annual
- Winter Annual
- Biennial
- Perennial



Pre-plant Weed Management

Pre-plant weed control is the cornerstone of a successful weed management program

- Should begin 1-3 years pre-planting
- Site selection
- Soil amendments
- Cover Crops
- Fallowing
- Stale seedbed/Strip tillage



Weeds – Site Selection

Site selection

- Review site history
 - Previous crops
 - Weed history
 - Weed management history
- Examine site for existing weed problems



Weed Management

Soil Amendments

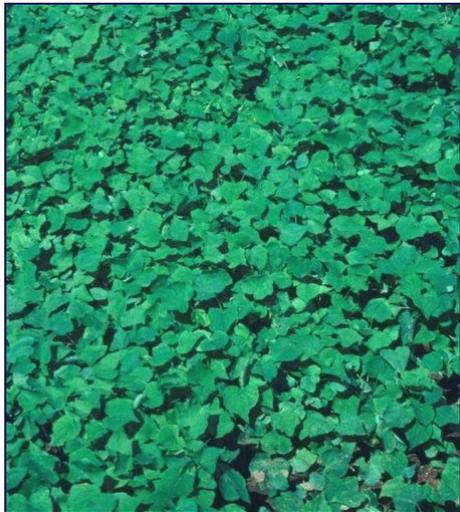
- Animal Manures
 - Often contain weed seed
- Compost
 - May contain weed seed
 - Should be “finished”
 - Hot enough to destroy seeds
 - Cover piles to prevent weed seed contamination



Weed Management

Crop Rotation can be an effective weed reduction practice

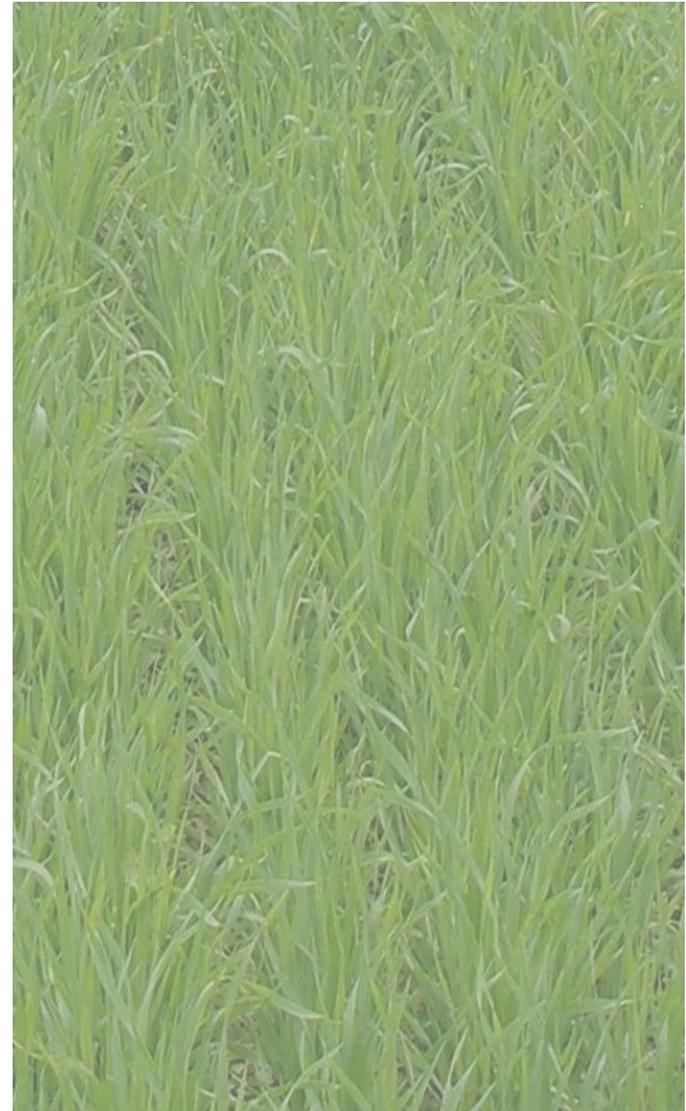
- Maintain soil structure and microbial activity
- Sustain reservoirs of plant nutrients
- Inhibit build-up of perennial weeds and weed seed bank
- Strawberries: in for 1 – 3 years, rotate out for 4 - 5



Weed Management

Cover crops

- Improve soil structure
- Reduce weed pressure?
 - Shade out some species
 - Use allelopathic species
 - Inhibit weed seed growth
 - Sorghum/Sudan grass



Weed Management

Crop options:

- Summer
 - Grasses, legumes, buckwheat,
 - Cash crops (pumpkins, corn, greens)
- Winter
 - Rye, Mustards



Weed Management Strategies

Crop Rotation

Organic matted row:

Year One:

- Soil Prep
- Spring Planting
- Flower Removal
- Set Runners
- Winter Protection

Year Two:

- Mulch Removal
- Frost Protection
- Harvest
- Plow Down
- Plant Rotation Crop



Weed Management Strategies

Fallowing

- Repeated tillage throughout growing season
 - Deplete annual weed seed bank
 - Deplete perennial plant reserves
- Problems
 - Energy intensive
 - Soil structure
 - Erosion



Weed Management Strategies

Stale Seedbeds

- Prepare ground in fall or early spring
- Allow weed seeds to germinate 2-4 weeks
- Kill weeds with contact herbicide or flaming
 - Do not disturb soil surface
 - Prevents new weed seeds from surfacing
- Plant, keep soil disturbance to a minimum
 - Slows new weeds by days-weeks

Weeds



Management Strategies

Increase crop plant density

- Less space for weeds to grow
- Avoid intra-crop competition
 - Crops can be weeds too
 - Yield per plant vs yield per acre

Planting Year

Delayed Planting

- Plant in mid-late June
 - Allow spring weeds to germinate
 - Lightly till, spray or flame
 - Disturb soil as little as possible
- Advantages:
 - **weed control**, labor distribution
- Disadvantages:
 - Plant quality, availability, irrigation



Weeds

Management strategies

Delayed planting

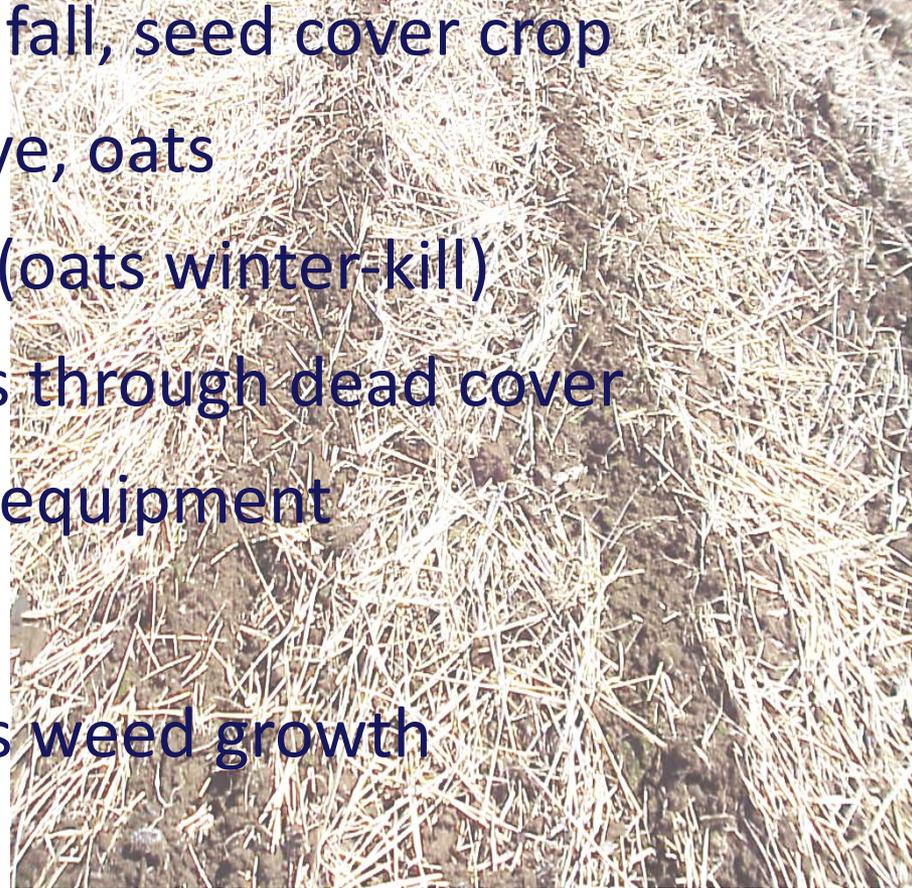
- Plant in mid-late June
 - Allow spring weeds to germinate
 - Lightly till, spray or flame
 - Disturb soil as little as possible
- Advantages:
 - weed control, labor distribution
- Disadvantages:
 - Shorter season, irrigation



Weed Management Strategies

Strip Tillage

- Prepare ground in early fall, seed cover crop
 - Winter rye, annual rye, oats
- Kill cover crop in spring (oats winter-kill)
- Till narrow (8-16") strips through dead cover
 - Requires specialized equipment
- Plant crop into strips
- Dead vegetation inhibits weed growth



Weed Management Strategies



Strip tillage

- Specialized equipment (\$)
- Horsepower
- Cool soil
- Weeds within rows

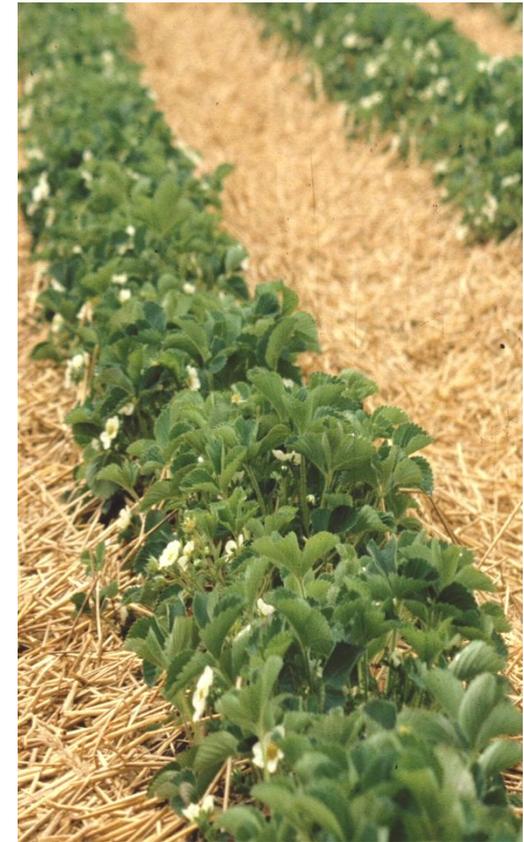
Photo: U. Mass.

Weed Management Strategies

Mulch

Prevents weed seed germination

- Place under & around plants
- Straw, chips, shavings
- Plastic



Weed Management Strategies

Cultivation

- Tines, blades, etc.
- Disturb weed roots
- Best when weeds very small
- Disturb soil as little as possible



Some hand weeding will be needed



Cultivation

“Finger” Cultivators



Buddingh



Regi

E. Sideman

Cultivation

Tine “Blind” Cultivator



Weed Management Strategies

Herbicides

- Pre-Emergent
- Post-Emergent
 - Costly
 - Won't control all weeds
 - May injure crop plants
 - Requires specialized equipment
 - Follow all label directions and precautions



Strawberry Diseases



Disease Management

Disease problems

What's required:

- Disease organism
 - fungus, bacteria, virus
- Proper environment
- Suitable host plant
- Time



Management

- Reduce or eliminate one or more of the requirements

Gray Mold

Botrytis cineria

Symptoms:

- Gray, fuzzy mold on fruit

Management

- Good air circulation, drying
 - narrow plant rows
 - raised beds
 - mulch
- Fungicides applied during bloom

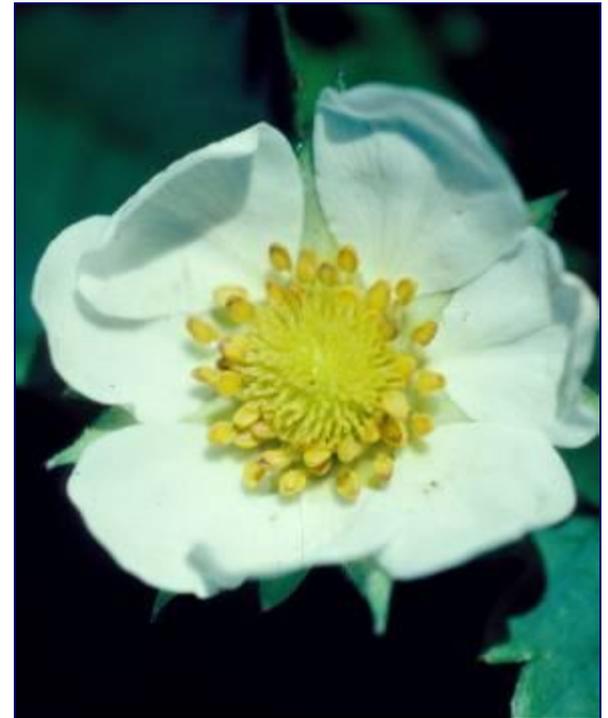


Strawberry Pests

Gray Mold (*Botrytis cineria*)

Fungicides applied during bloom: 10%, full, post?

- Captan
- Thiram
- Captevate
- Pristine
- Switch
- Double Nickle
- Elevate
- Topsin-M



Leather Rot

Phytophthora cactorum



Photo: Wayne Wilcox

Strawberry Pests

Leather Rot

Management

- Good soil drainage
- Good air circulation, drying, prevent splashing of spores
- mulch
- narrow plant rows
- raised beds
- Fungicides applied 10% bloom, wet weather

- Ridomil Gold
- Aliette
- Phostrol

Leather Rot

Management

- Good soil drainage
- Good air circulation, drying, prevent splashing of spores
- mulch
- narrow plant rows
- raised beds
- Fungicides applied 10% bloom, wet weather



Anthracnose

Anthracnose



Strawberry Pests

Anthracnose

Management

- Good soil drainage
- Good air circulation, drying
- Straw mulch, prevent splashing
- raised beds
- narrow plant rows
- Fungicides applied before disease develops (pre-bloom)



- Cabrio
- Abound
- Captan
- Thiram



Anthracnose

Management

- Good soil drainage
- Good air circulation, drying
- Straw mulch, prevent splashing
- raised beds
- narrow plant rows
- Fungicides applied before disease develops (pre-bloom)



Leaf Diseases



Strawberry Leaf Spot



Strawberry Leaf Scorch

Strawberry Pests

Leaf Spot & Leaf Scorch

Management

- Good air circulation, drying
- narrow plant rows
- sanitation
- Fungicides

- Captan
- Thiram
- Topsin-M
- Pristine
- Rally
- Syllit
- Cabrio
- Kocide



Foliar Diseases

Leaf Spot & Leaf Scorch

Management

- Good air circulation, drying
- narrow plant rows
- sanitation
- Fungicides



Powdery Mildew



Strawberry Pests

Powdery Mildew

Management

- Good air circulation, drying
- narrow plant rows
- sanitation
- Fungicides

- Abound
- Rally
- Pristine
- Topsin-M + Captan
- Procure



Powdery Mildew

Management

- Good air circulation, drying
 - narrow plant rows
 - sanitation
- Fungicides



Strawberry Pests

Bacterial Angular Leaf Spot

Encouraged by wet & cold, frost protection

Management

- Good air circulation, drying
- narrow plant rows
- sanitation
- Fungicides

- Copper (Kocide, etc.)
 - Watch for plant injury
 - Don't apply after bloom
- Oxidate
- Double Nickel



Bacterial Angular Leaf Spot

Encouraged by wet & cold, frost protection

Management

- Good air circulation, drying
- narrow plant rows
- sanitation
- Fungicides



Red Stele Root Rot

Phytophthora fragaria



Strawberry Pests

Red Stele Root Rot

Management

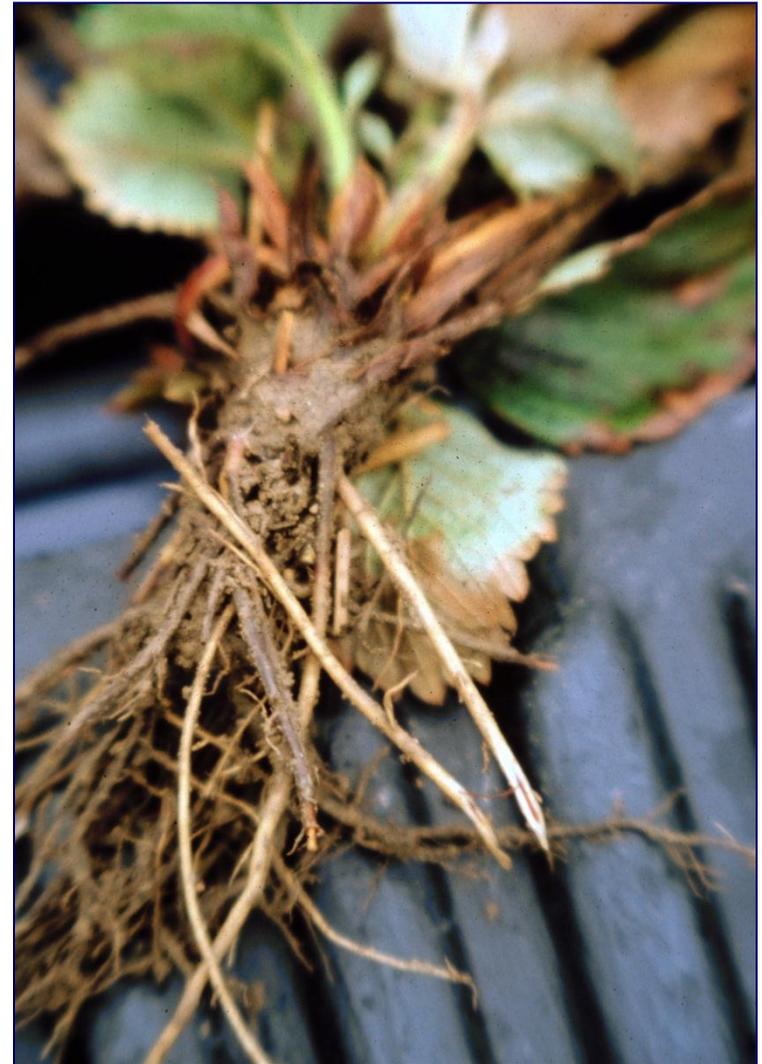
- Good soil drainage
 - tiling
 - raised beds
 - optimum organic matter
 - gypsum
- Resistant varieties
- Fungicides
 - Ridomil Gold
 - Aliette
 - Phostrol



Red Stele Root Rot

Management

- Good soil drainage
 - tiling
 - raised beds
 - optimum organic matter
 - gypsum
- Resistant varieties
- Fungicides



Verticillium Wilt

Symptoms

- Plants wilt in heat
- Outer leaves die
- Roots blackened



Verticillium Wilt

Management

- Good soil drainage
- Optimum organic matter
- Irrigation during dry periods in summer
- Resistant varieties
- Do not rotate with nightshade crops



Strawberry Insects, etc.



Strawberry Pests

White Grubs

Symptoms:

- Plants wilt, weak growth
- Death

Management

- Don't plant after sod
- Control grass weeds
- Nematodes?
- Insecticides
 - Admire Pro (15), Platinum (50)



White Grubs

Larvae of June beetles, Japanese beetles and others

Symptoms:

- Plants wilt, weak growth
- Death



White Grubs

Management

- Don't plant after sod
- Control grass weeds
- Nematodes
- Insecticides



Strawberry Bud Weevil

Anthonomus signatus “Clipper”

Symptoms:

- flower buds clipped
- poor yield



Strawberry Bud Weevil

Management

- rotate planting
- remove alternate hosts
 - wild strawberries, brambles
- Insecticides pre-bloom



Strawberry Pests

“Clipper” Feeding Indications



Strawberry Pests

Clipper scouting



Tarnished Plant Bug

Lygus lineolaris

Symptoms:

- Fruit with seedy ends
- Catfacing



Tarnished Plant Bug

Management

- Remove alternate hosts
 - flowering weeds
- Don't mow during bloom
- Insecticides pre- and post-bloom



Scouting - Initiate at Bud Stage



Strawberry Pests

Tarnished plant bug

- Threshold: 4 out of 30 clusters infested
- Insecticides pre- and post-bloom
- Danitol (2)
- Brigade (0)
- PyGanic (0)
- Dibrom (1)
- Malathion (3)
- Assail (1)



Potato Leafhopper

Empoasca fabae



Actual Size: 1/16" – 1/8"

Strawberry Pests

Hopper burn

- Worse on new plantings
- Scout undersides of leaves
- Insecticides
 - Sevin
 - Provado
 - Assail



Potato Leafhopper

Hopper burn

- Worse on new plantings
- Scout undersides of leaves
- Insecticides



Spittlebug



Actual Size: ~ 1/8"

Spittlebug



- Worse in weedy plantings
- Scout leaf petioles
- Threshold: 1 spit/foot
- Insecticides
- Need good coverage
- Brigade
- Malathion
- Danitol
- Provado, Assail
- PyGanic

Sap Beetles / Picnic Beetles



- Harvest regularly
- Remove over-ripe fruit
- Traps w/ fruit or bread bait
- Insecticides
- Watch days to harvest
- Brigade (0)
- Danitol (2)
- PyGanic (0)
- Malathion (3)
- Dibrom (1)
- Assail (1)

Root Weevils

Black Vine Weevil & Strawberry Root Weevil



Root Weevils

Leaf notching from adult feeding



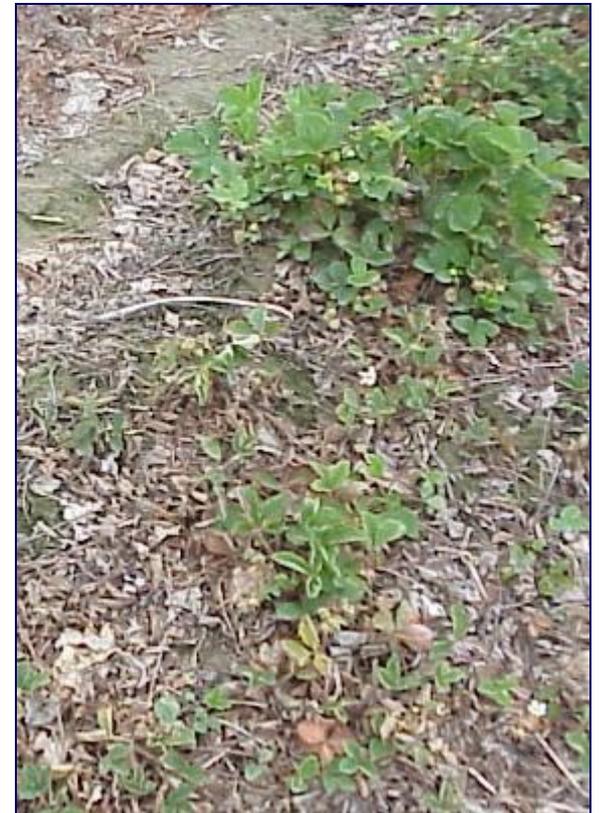
Root Weevils

Strawberry Root Weevil Grubs



Root Weevils

Root Weevil Damage



Root Weevils

Root Weevil Management

- Crop Rotation
 - Plant non-host crops for 3+ years
- Sanitation
 - Clean your equipment!
 - Avoid soil movement between fields
- Insecticides
 - Adults/early summer
 - Larvae/late summer
- Nematodes
 - Spring/early fall



Root Weevil Management

- Destroy infested plantings
 - Fallow, turn ground repeatedly
 - Fall Plowing
- Foliar Spray (adult weevils)
 - Early-mid summer
 - Brigade 8-16 oz. at night
- Insecticide drench (small grubs)
 - Mid-late summer
 - Platinum 5-12 oz./acre
- Nematodes
 - *Heterohabditis bacteriophoba* at 1/2 billion/acre or *Steinernem feltiae* at 1 b/A (~\$120)
 - Mid-May and/or Mid-August

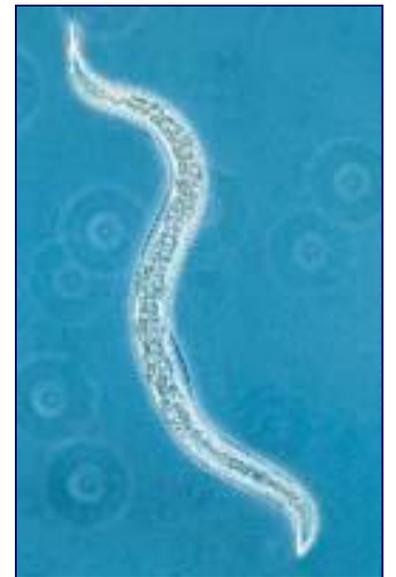


Photo: USDA

Spotted Wing Drosophila

- Adults lay eggs in ripening fruit
 - Larvae (maggots) cause fruit rot
 - 14 days/ generation
 - 12 generations/season
- Monitor with traps
- Insecticides
 - Must be applied frequently
- Sanitation
 - Remove all rotten fruit from field



Two-Spotted Spider Mites

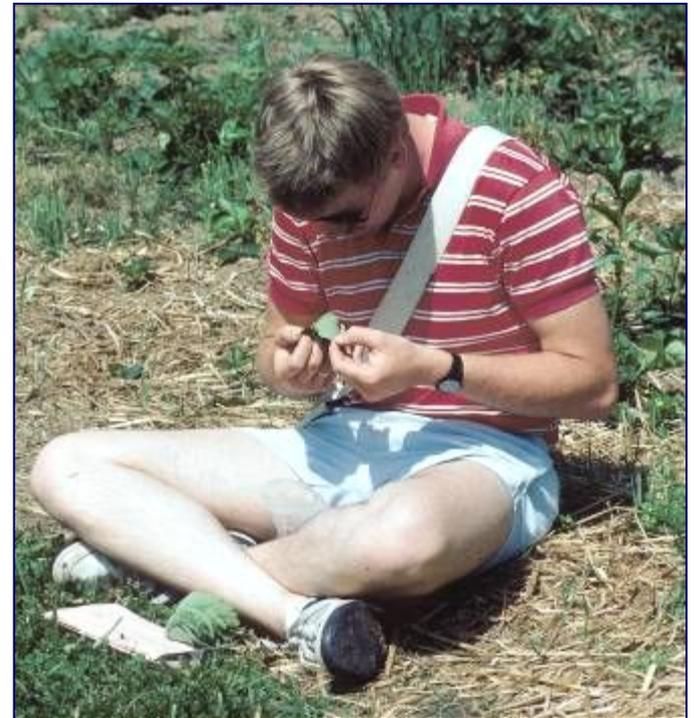


Threshold: 25% of leaves infested

Two-spotted Spider Mites

Monitoring: Randomly harvest 60 leaves from throughout the field. Check for the presence of mites (mites do not have to be counted.)

Threshold: 15 leaves infested per 60 leaf sample (25%)



Strawberry Pests

Two-spotted Spider Mites

Miticides

- Oils (Sunspray, Stylet)
- Bifenture (0)
- Agri-Mek (3)
- Savey/Zeal (3)
- Vendex (1)
- Acramite (1)
- Oberon (3)

Predatory Mites

- 5,000-10,000 *Neoseiulus fallacis*/acre



Two-Spotted Spider Mites

Management

Miticides

- Oils

Predatory Mites

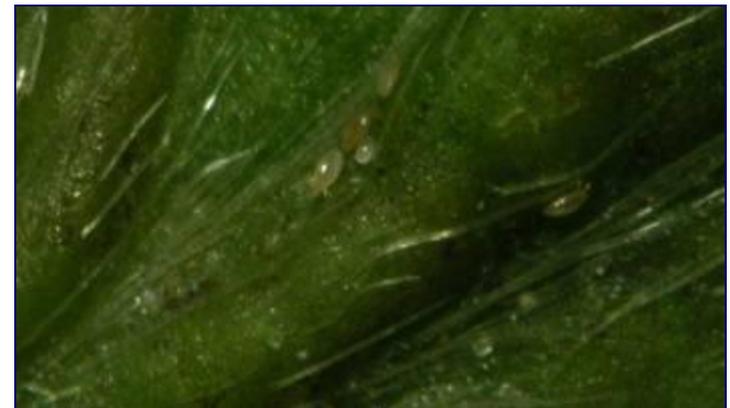
- 5,000-10,000 *Neoseiulus fallacis*/acre



Strawberry Pests

Cyclamen Mites

- Generally come in on nursery stock
- Plants are weak with twisted, crinkled leaves
- Mites very small need at least 20X to see them
- Reside in crown
- Control with miticide drench
 - Must reach within crown



Cyclamen Mites

- Come in on nursery stock
- Plants are weak with twisted, crinkled leaves
- Mites very small; need 20X to see them
- Reside in crown
- Control with miticide drench
 - Must reach within crown
- Predatory mites?



Slugs

Slugs

- Keep fields dry
- Traps/Baits
- Pesticides
 - Deadline
 - Sluggo
 - Diatomaceous Earth?



Resources

- Cornell Berry Diagnostic Tool:
 - <https://blogs.cornell.edu/berrytool/>
- New England Small Fruit Management Guide
 - <https://ag.umass.edu/fruit/ne-small-fruit-management-guide>



Further Study

<http://extensionpubs.umext.maine.edu/>

- Strawberry Production Guide
<https://scholars.unh.edu/extension/1670>
- Strawberries: Organic Production
<http://attra.ncat.org/attra-pub/PDF/strawberry.pdf>
- New England Small Fruit Pest Management Guide
<http://https://ag.umass.edu/fruit/ne-small-fruit-management-guide>