Row Cover Management, GDD's, and Frost / Freeze Protection

R. Allen Straw

Grower / Crop Consultant

Row Cover Management

- Three functions of row covers
  - Fall and winter – to promote plant development, especially if late transplanting
  - Winter / spring – to promote bud and bloom development, (use in fall when growing ‘Camarosa’)
  - Winter / spring – to provide protection from cold temperatures, wind, and frost
- Possible use of row covers
  - Manage row covers to extend the harvest season

Sources of Row Covers

- American AgriFabrics
- Berry Hill Irrigation
- Flo-Tech (formerly Atmore Industries)
- Hendrix and Dail
- KenBar
- Rain-Flo
- Reddick Fumigants
- Reemay Ag Fabrics
- Triple J Nursery
- Etc.

Row Covers

Weight	Light	Application	Cost
Polypropylene			
0.5 – 0.6 oz	85%	Growth	$700/A
0.9 – 1 oz	70%	Growth, Frost	$1,000/A
1.2 oz	60 - 65%	Frost	$1,250/A
1.5 oz	50%	Frost	$1,500/A
2 oz	30%	Frost	$2,000/A
Polyester			
0.6 oz	85%	Growth	$1,300/A
1.25 oz	75%	Growth. Frost	$1,800/A

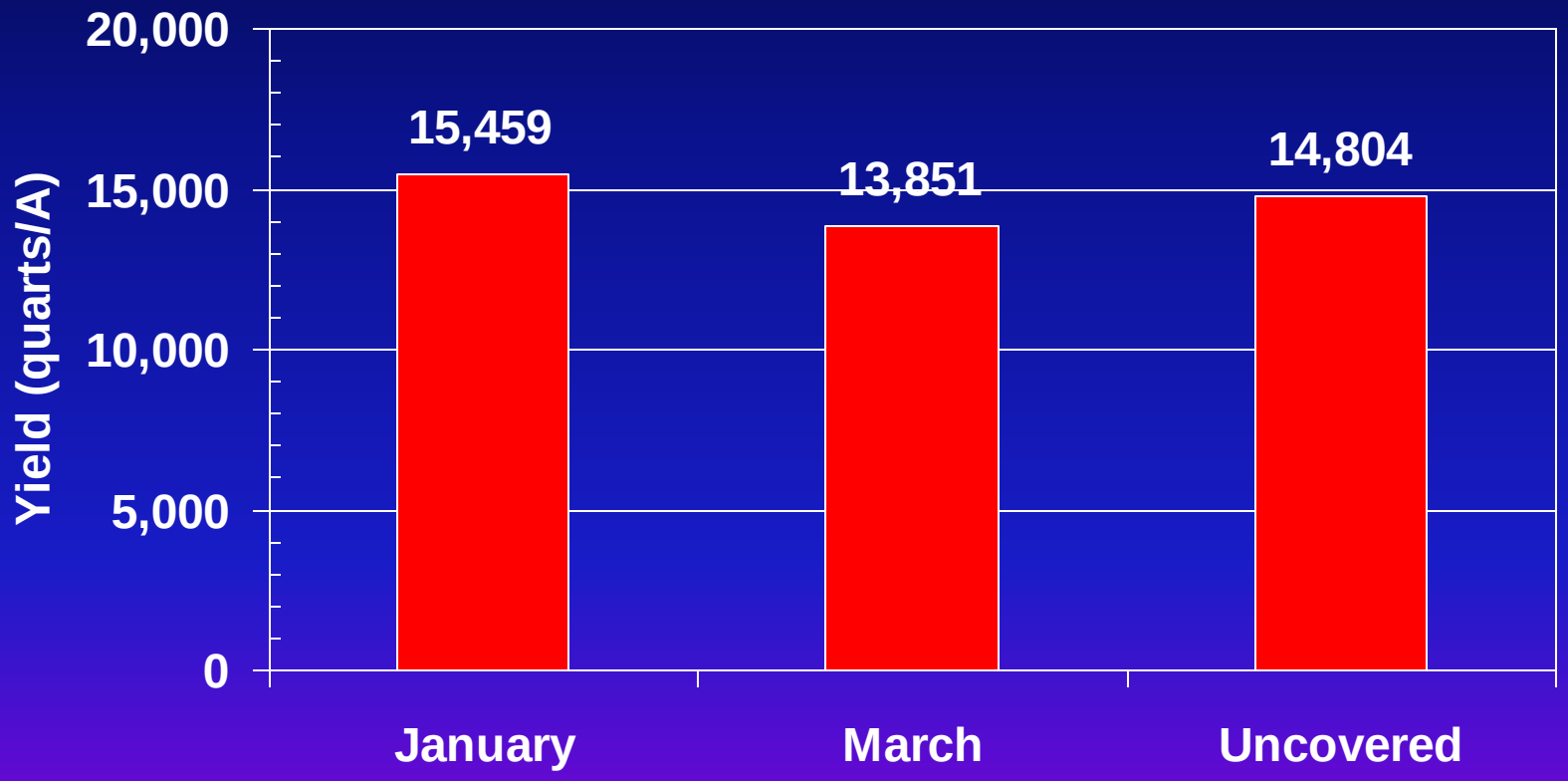
Timing of Row Cover

Covered in January

Uncovered

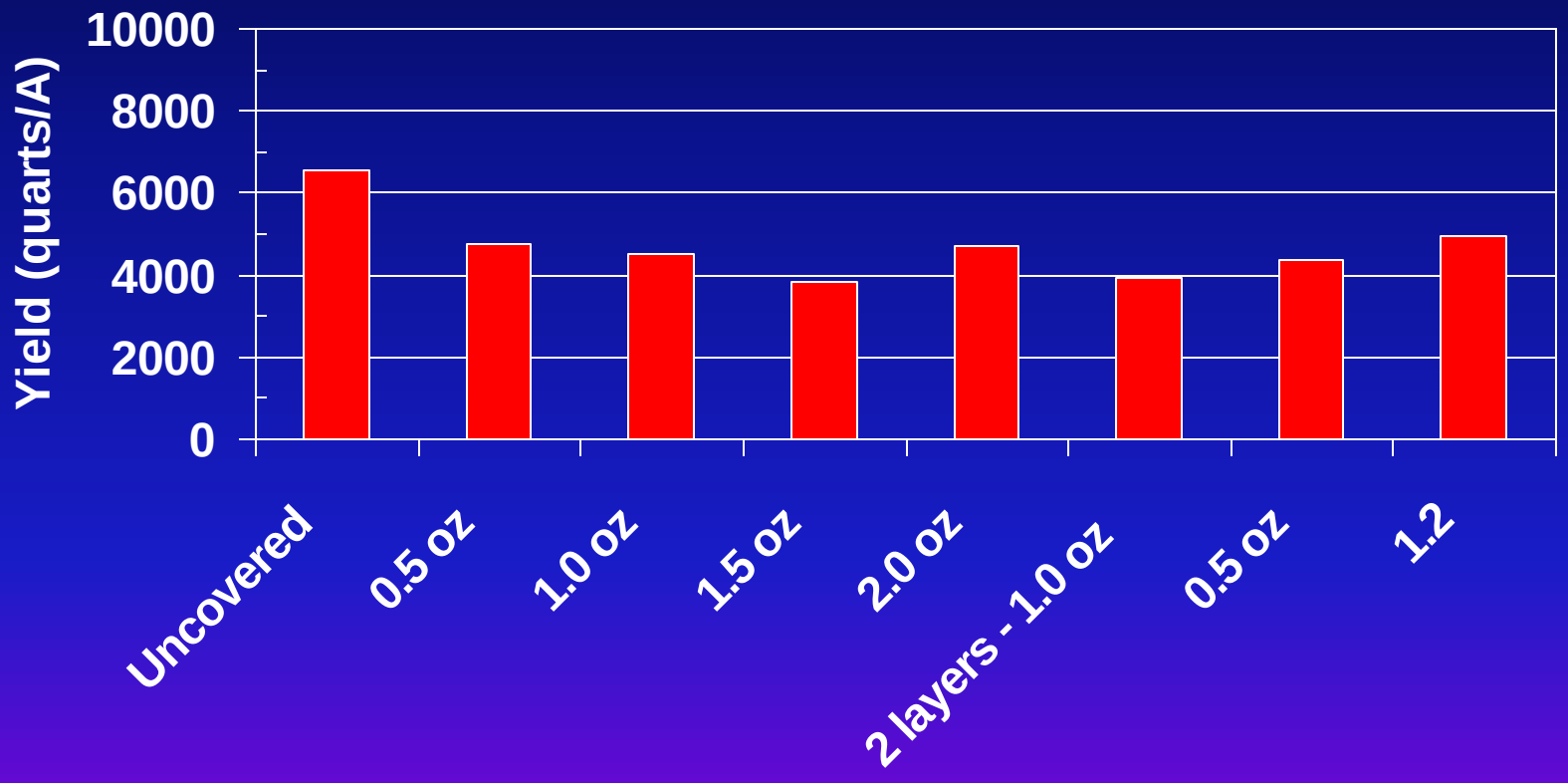
Photos taken mid-April, 2000

Row Cover Trials - 2000



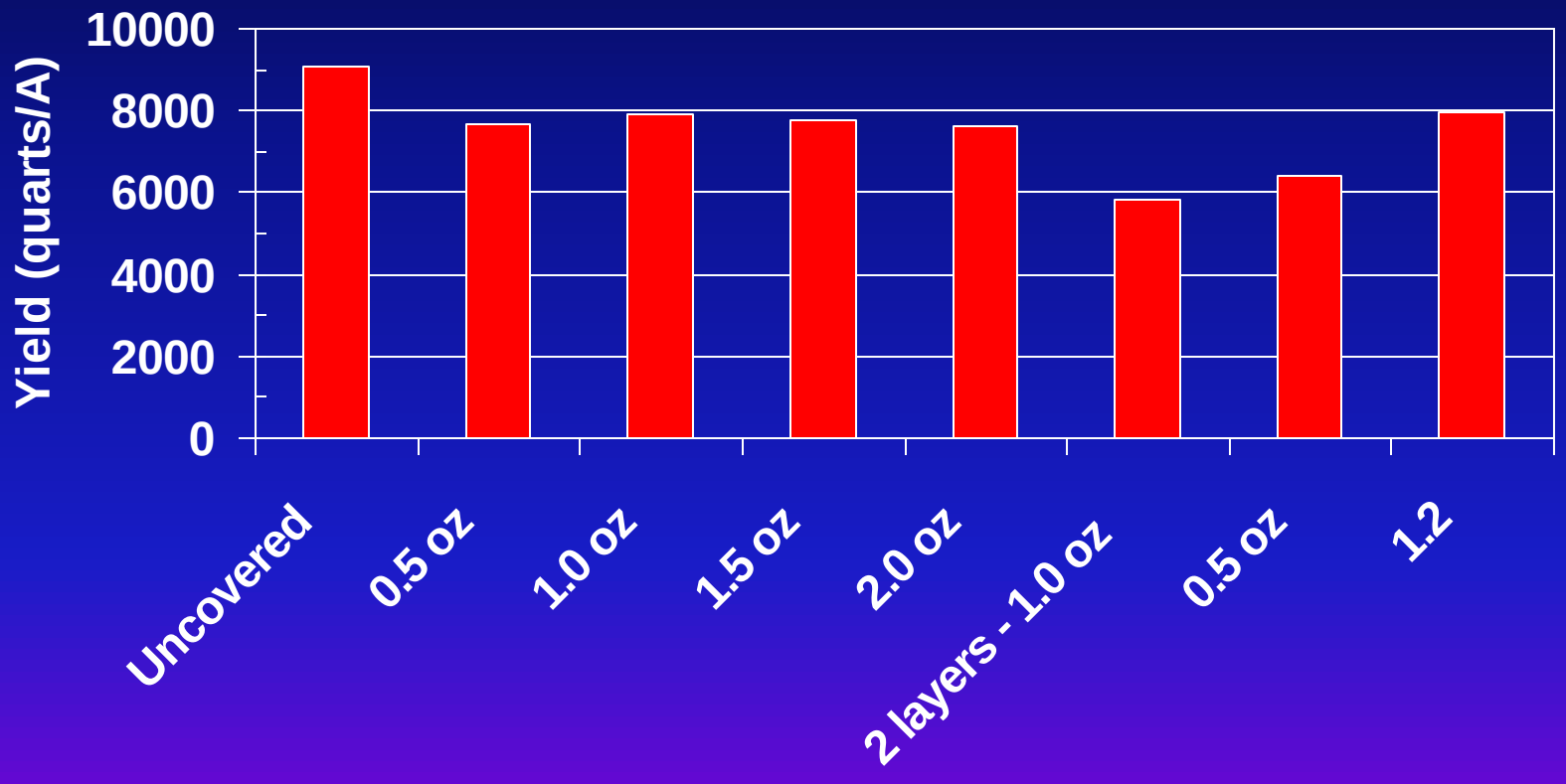
Yield based on 1.25 lb/quart

‘Sweet Charlie’ Yield - 2003



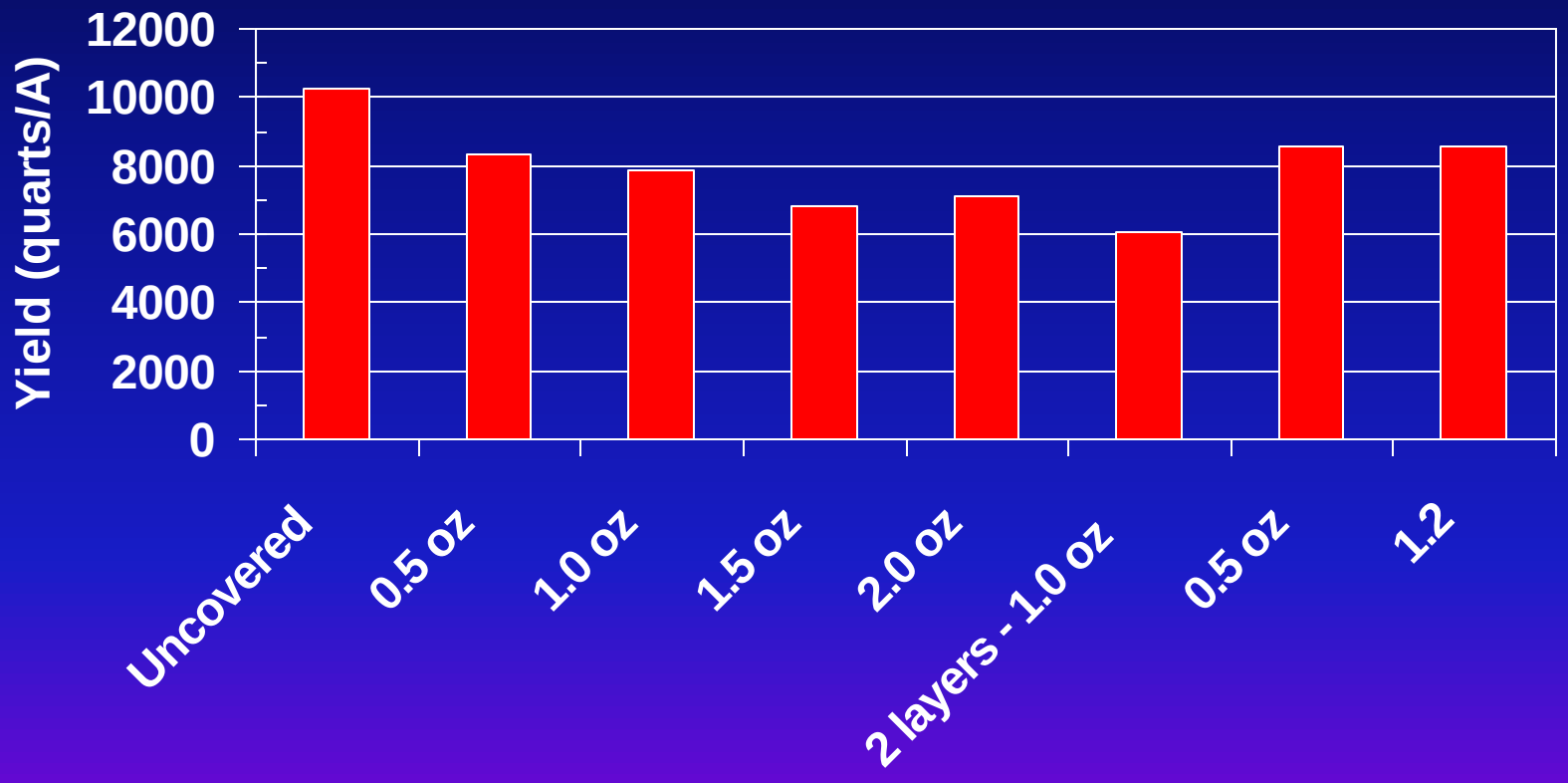
Yield based on 1.25 lb/quart

‘Chandler’ Yield - 2003



Yield based on 1.25 lb/quart

‘Camarosa’ Yield - 2003



Yield based on 1.25 lb/quart

Results - 2003

- Only 3 nights of frost / freeze protection
- Yield differences were not a result of differences in freeze protection
  - Likely,
    - Lack of light penetration
    - Crown development ?
- Lost temperature data due to equipment malfunction

Row Cover Management

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- Possible use of row covers
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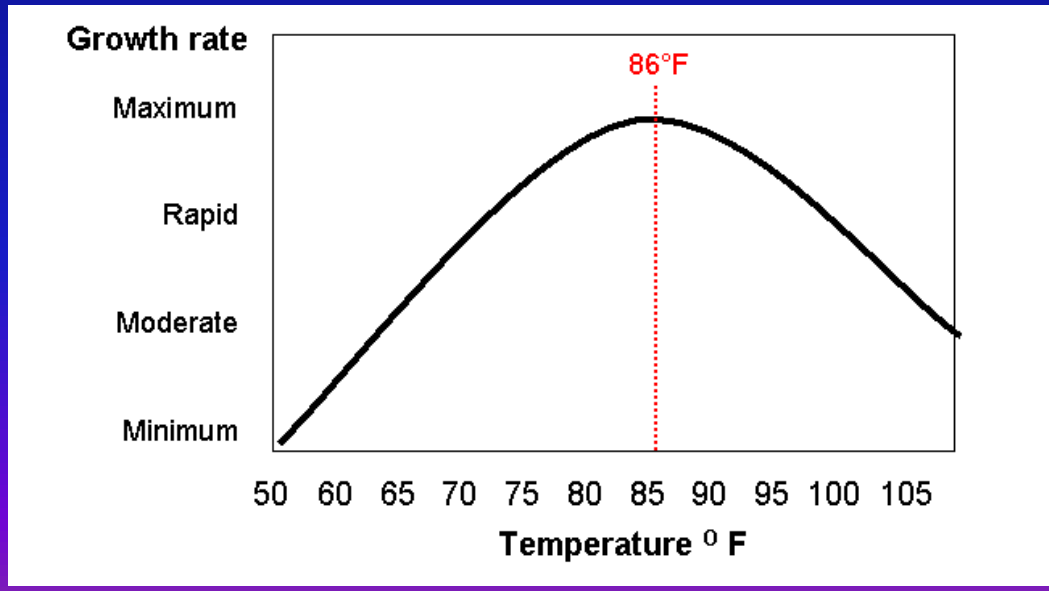
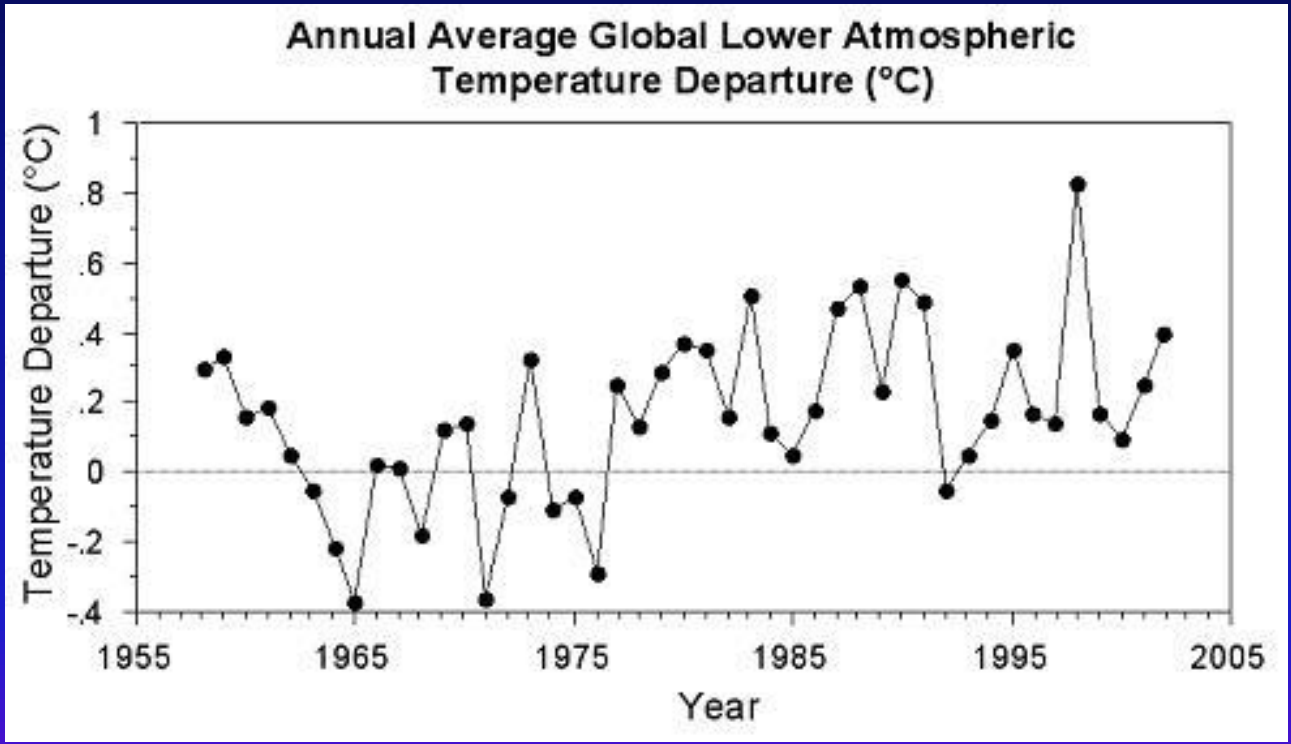
Jeremy Pattison

- The next several slides are from Jeremy and the work he has done at NC State.
  - Planting Dates
  - Timing of Row Covers
  - GGD Model

Optimum Plant Growth and Development: Time and Temperature Dependent

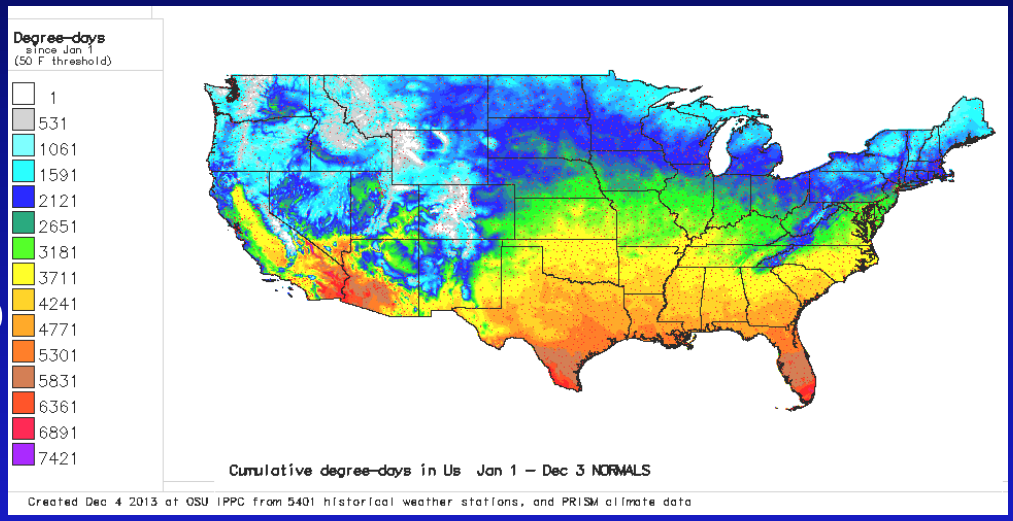


Over Time, Temperature Varies!



Degree Days: Measures the Heat Accumulation Over Time!

- Plant growth can be inhibited at high and low temps
  - The temp at which very little plant growth occurs is the base temp
- Vary by crop
  - Strawberry cool season crop
  - Corn and cotton like it hot
- So, how do we measure **relevant** heat accumulation over time…



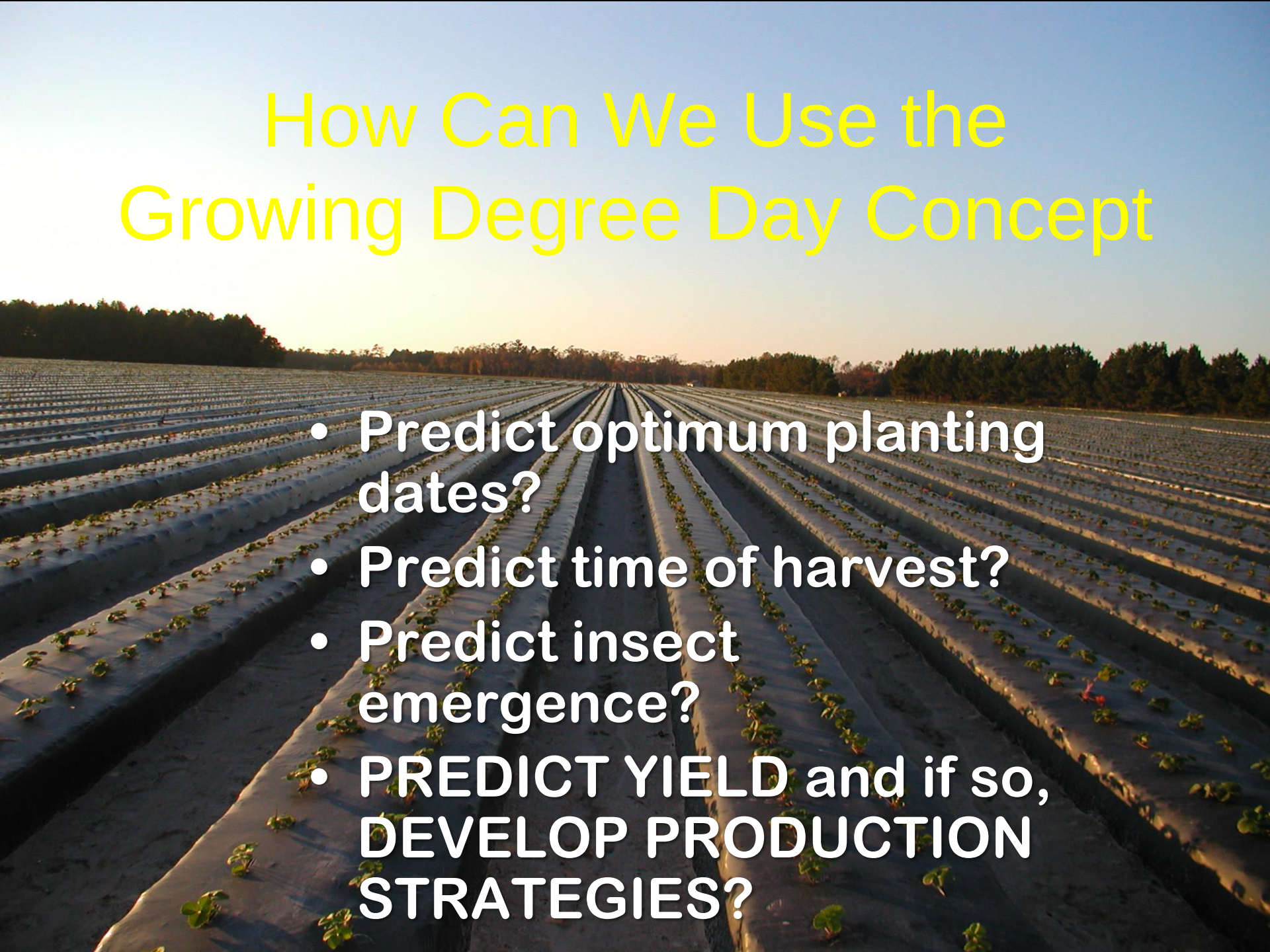
(Tmax+Tmin)/2 – baseTemp

Ex. (63+54)/2 – 50 = 8.5

Predicting growth stages of cotton

Growth Stage	Days	Heat Units – DD60s
Planting to Emergence	4 to 9	50 to 60
Emergence to First Square	27 to 38	425 to 475
Square to Flower	20 to 25	300 to 350
Planting to First Flower	60 to 70	775 to 850
Flower to Open Boll	45 to 65	850 to 950
Planting to Harvest Ready	130 to 160	2200 to 2600

How Can We Use the Growing Degree Day Concept



- Predict optimum planting dates?
- Predict time of harvest?
- Predict insect emergence?
- PREDICT YIELD and if so, DEVELOP PRODUCTION STRATEGIES?

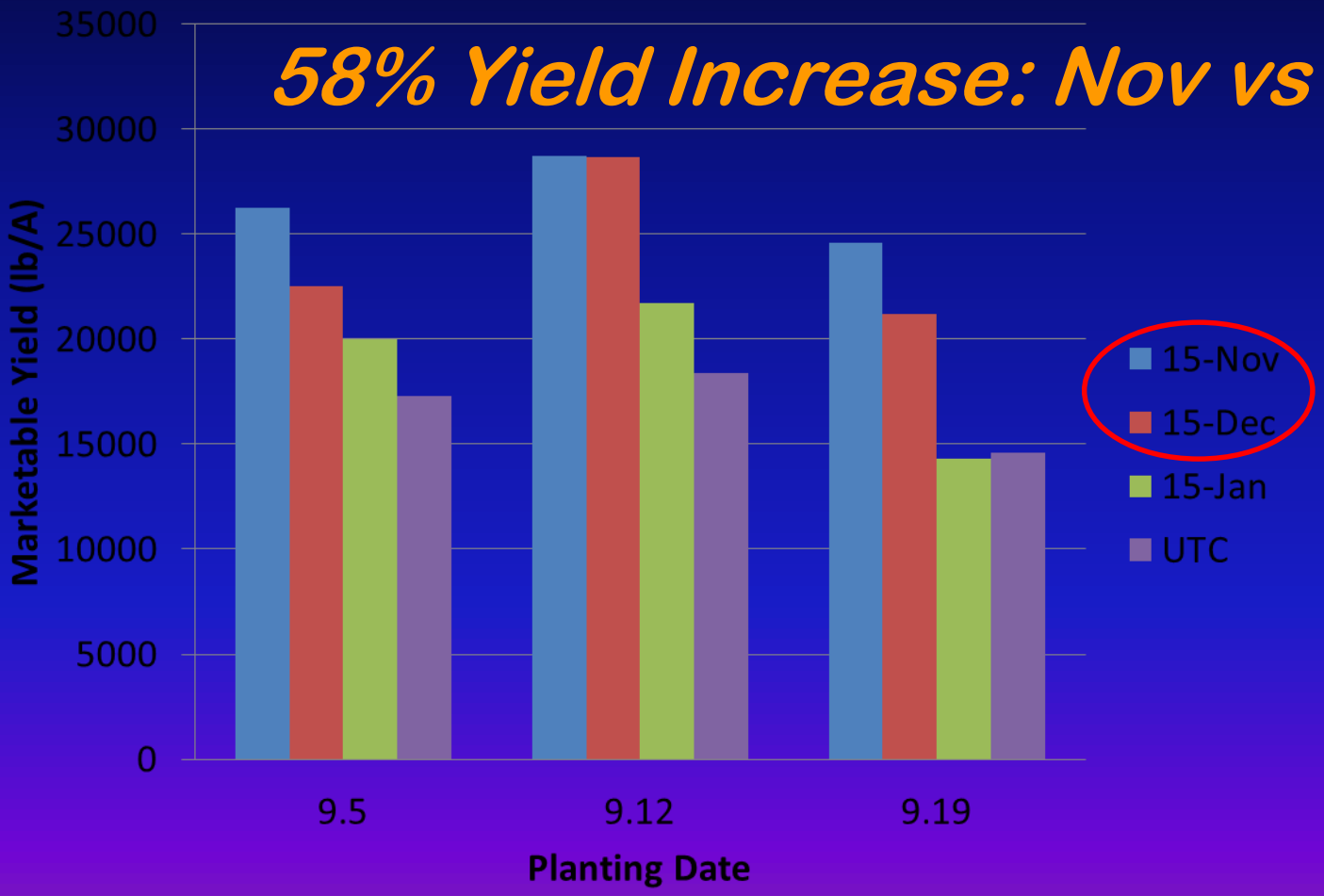
Common Row Cover Use

- **Fall:** Correct for off-target planting dates
  - Enhance growth and development
  - Timing???
- **Winter:** protection from sub-lethal temps
  - Hardiness varies based on physiological state
  - < 15 F start a conversation
  - Protect from desiccation

Optimum fall/winter timing to maximize yield???

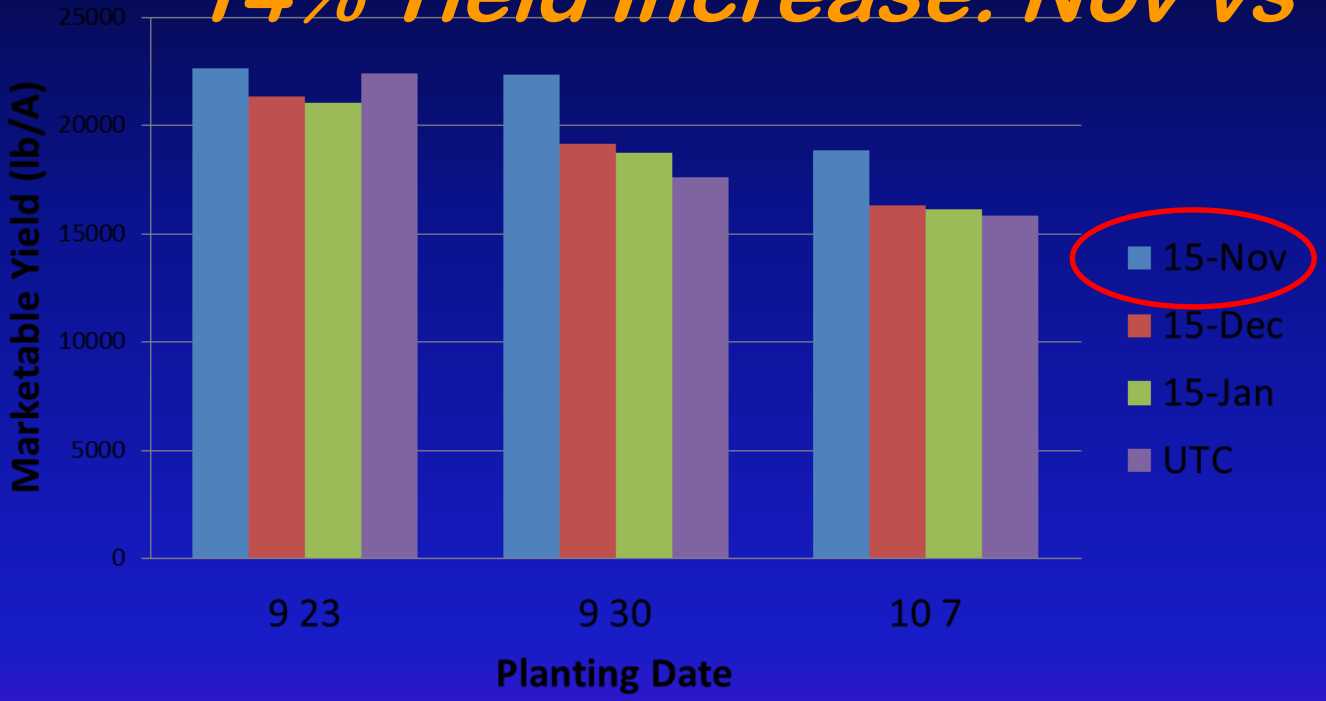
“Calendar Farming”
Chandler Mountains, NC

2007-08, 2009-10



"Calendar Farming"
Camarosa Piedmont, NC,
2009-10, 2010-11

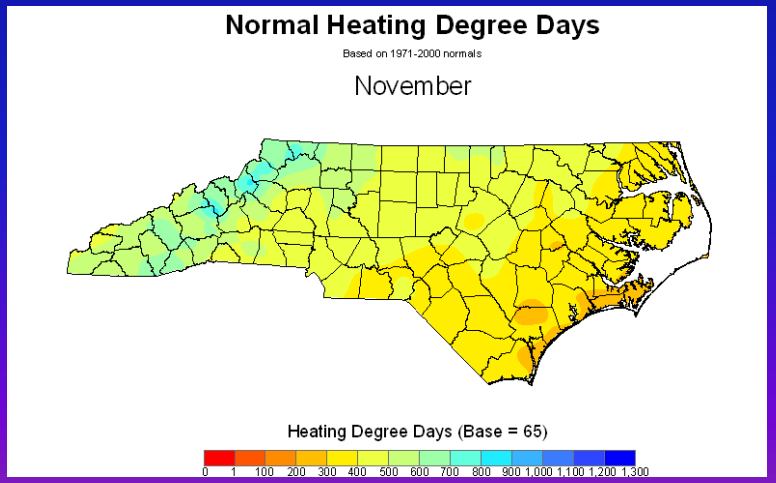
14% Yield Increase: Nov vs UTC



- **Planting date and year** largest contributors to yield variation
- 2nd and 3rd planting dates did benefit from covers
  - But only with the Nov 15th cover date
  - Suggesting that winter protection is not as essential as we thought

How to Incorporate Temperature / Time to Identify the Optimum Degree Days?

- The 1st 90 days are critical
- Race to build adequate branch crowns with optimum flower buds
  - PD can control crown # and covers help with flower numbers
  - Alternatives to calendar farming to optimize performance
- Are certain environmental factors correlated with yield?
  - Critical growth periods
    - Floral bud development
- What's the relationship with yield?
  - To develop strategies to better manage environmental variation

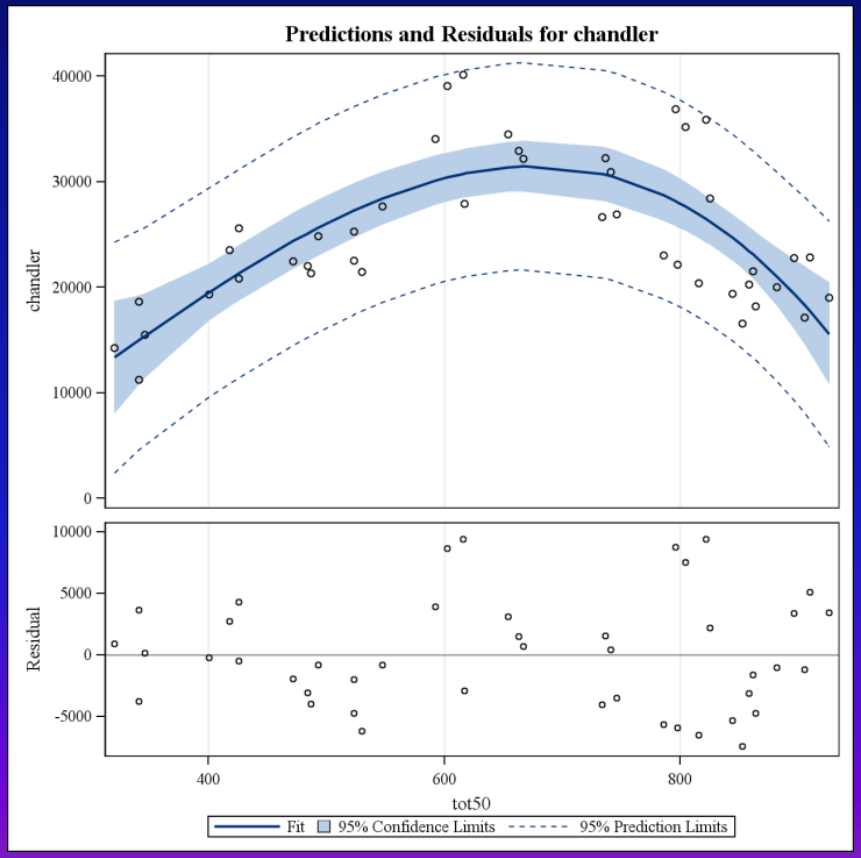


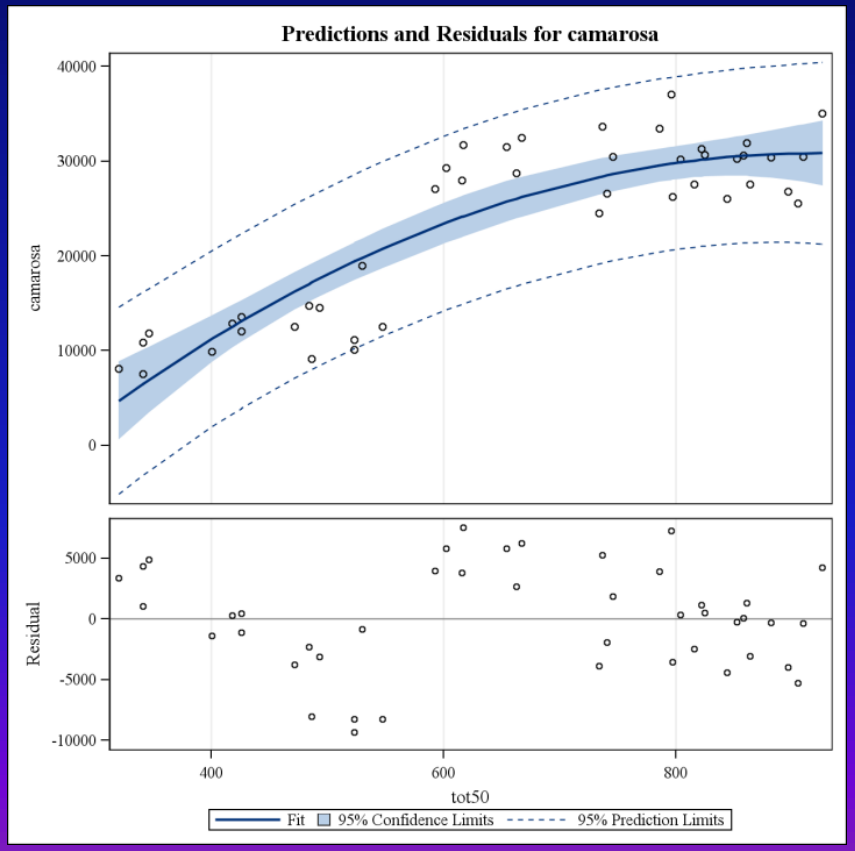
Mechanism of Yield Increase

- *Planting date impacts # of Branch Crowns ($p<0.0001$)*
- *Appears that **row covers** are NOT increasing # of Branch Crowns ($p=0.39$)*
  - *Increases in # of flowers / Branch Crown*
- *Row covers are increasing floral bud initiation during the fall, NOT in the winter!*

Chandler: yield peaks at 600 units (R^2=0.56, P<.0001)
Camarosa: yield peaks at 800 units (R^2=0.78, p<.0001)

Total GDD (50F) Oct, Nov, Dec (90 days)





How can we monitor GDD's?

- Calculator
- NC Cronos
  - http://www.nc-climate.ncsu.edu/cronos
- Weather Channel
- Smart phone apps
  - Farm Progress growing degree day
- Field data loggers
  - Precise farm measurements
- New tools in development

AgroClimate Agroclimate.org

Tools for Managing Climate Risk in Agriculture

Find location

Chapel Hill 2 W
Orange County (NC)

Select base temperature

Select projected period

Graph options

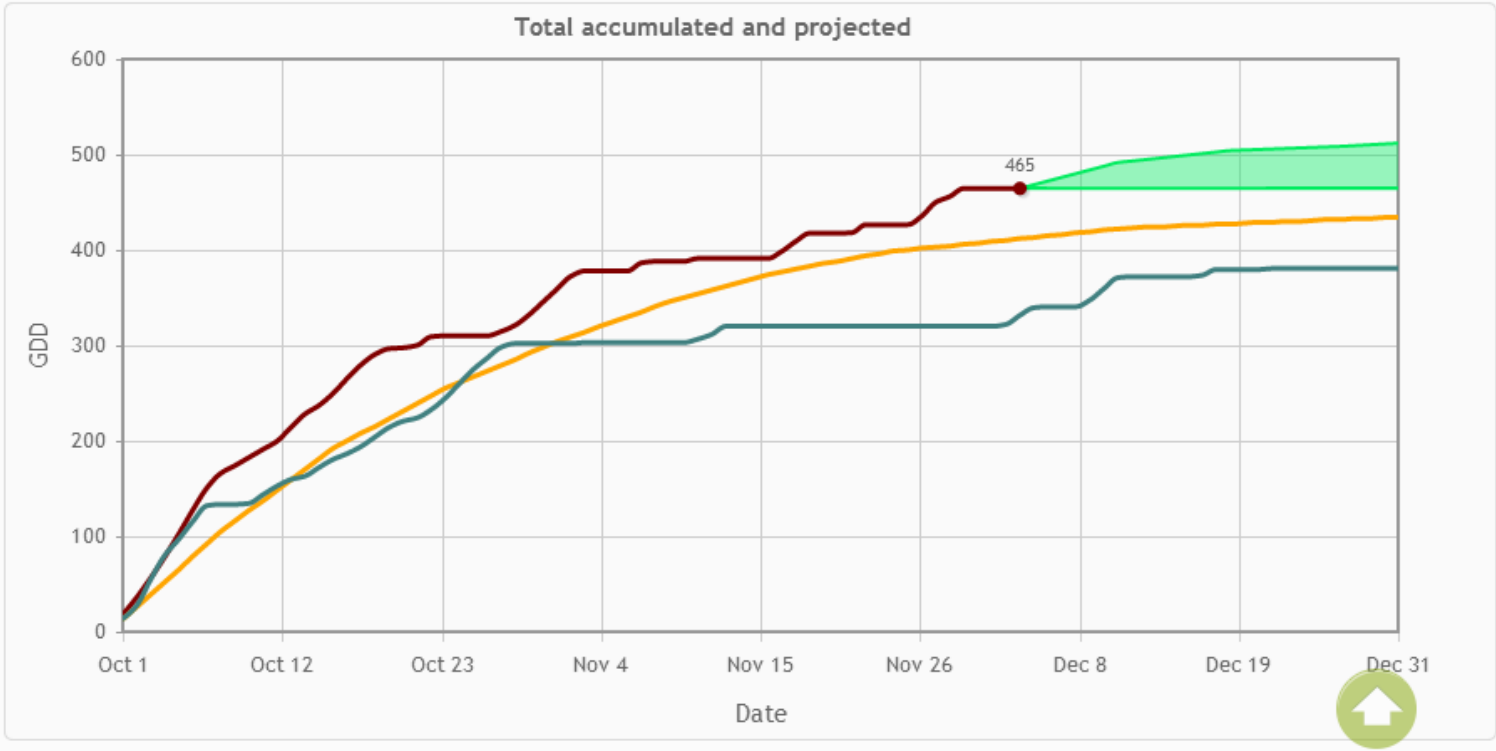
About GDD

Map | Total Accumulated and Projected | Accumulated by Period

Model: 50 °F - Orange County (NC)

Period [Oct 1 - Dec 4]:		
	This season	465 GDD
	Last season	332 GDD
	Historic average	412 GDD

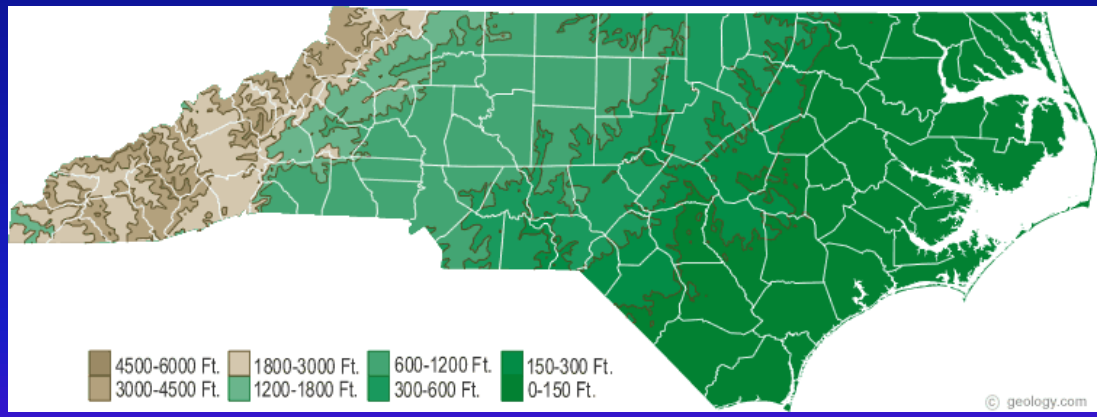
Current accumulation
Historic Average
Last season
Neutral years, long-term climatology



Cover Recommendations By Region and Cultivar

Mountains (USDA Zone 6 or colder):

- Chandler
  - Fall and Winter use is essential
  - Apply in the fall (60F) and remove when plants break dormancy
- Camarosa (questionable)



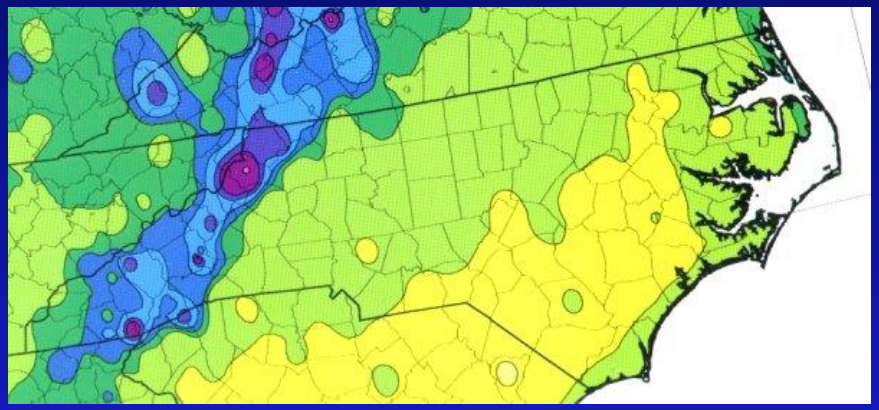
W. Piedmont (zone 7):

- Chandler
  - Fall covers w/ late planting
  - Winter protection (<15F)
- Camarosa
  - Fall covers essential (60F)
  - Remove if plants break bud early
  - Winter protection (<15F)

Row Cover Recommendations:

Eastern Piedmont (zone 7):

- Chandler
  - Fall covers w/ late planting
  - Winter protection (<15F)
- Camarosa
  - Fall covers may enhance yield certain years
  - Monitor GDD's and apply as needed
  - Winter protection (<15F)



Coastal Plain (zone 7 to 8):

- Chandler
  - Not needed when planted on time
  - Winter protection (<15F)
- Camarosa
  - Fall overs may enhance yield certain years
  - Monitor GDD's and apply as needed
  - Winter protection (<15F)

Negative Effects of Row Covers: Winter flowering

- Unusually mild late fall
  Nov and **Dec**
- Counted green fruit, open and unopened flowers
- Covers removed January 10th PRS, CH
- Not an issue at UMRS

Type 3 Tests of Fixed Effects

Effect	Num DF	Den DF	F Value	Pr > F
cv	1	9	55.61	<.0001
rc	3	36	27.35	<.0001
cv*rc	3	36	12.25	<.0001
pd	2	96	80.51	<.0001
cv*pd	2	96	11.60	<.0001
rc*pd	6	96	2.76	0.0162
cv*rc*pd	6	96	0.71	0.6433
loc	1	9	800.33	<.0001
loc*cv	1	9	77.17	<.0001
loc*rc	3	36	0.95	0.4289
loc*pd	2	96	18.35	<.0001
loc*cv*rc	3	36	3.60	0.0226
loc*cv*pd	2	96	10.23	<.0001
loc*rc*pd	6	96	1.30	0.2646
loc*cv*rc*pd	6	96	1.33	0.2501

Final Thoughts… GDD

- Optimum yield is a result of adequate branch crowns and flower numbers/crown
  - Planting date controls branch crown #
  - Fall row covers promote floral development
- Temperature appears to be a good “trigger” to deploy covers
  - Now have fall GDD targets… Camarosa > Chandler
  - Monitor heat units in the field or locally and be responsive to past and forecasted weather to hit targets
  - May not need fall covers in some years

Frost and Freeze Protection

- Transitional Zone
  - Significant freezes during fruiting
- Don’t grow strawberries without frost protection
  - Difference between 15% of potential yield to 90% of potential yield
- High-dollar insurance
- No! It is a necessary investment!

Frost & Freeze

- Frost
  - Can occur with an air temp above 32ºF and very low dew point
  - Radiation heat transfer to black sky can cause moisture in the air to form frost
- Freeze
  - Air temp drops to freezing or below
  - Frost usually occurs with freeze

Two Types of Freeze Conditions

- Radiation Freeze
  - Heat from air is lost to black, cloudless sky with little or no wind conditions
  - Best case for freeze protection
- Advection Freeze
  - Horizontal movement of cold air into area with wind
  - Worst case for freeze protection

Frost/Freeze Protection Theory

- Not just an insulation effect
  - However, this is important
- Latent heat of fusion
  - As water freezes144 btu per pound of water is released to the environment
- Sensible heat
  - Liquid water cools and releases heat to environment

Sources of Heat

- Liquid water
  - Heat released from water
    - Sensible
    - Latent
- Heat in the soil
  - Water absorbs and holds heat from soil
  - Ice insulates soil heat
    - Little effect if off the soil surface

Heat Transfer

- Air to Water
  - Latent heat of vaporization, evaporative cooling, 1,044 btu per lb of water
  - This is a problem at beginning of water flow
- Water to Air
  - Once air is saturated, sensible heat is transferred to the air
  - 1 btu per pound of water per ºF

Heat Transfer (cont.)

- Water to Plant
  - Heat of fusion
    - Transfers some heat to plant surface
    - Transfers some heat to air
- Convection
  - Warm air rises
- Advection
  - Air moves from high pressure to low pressure

Engineering Issues

- Selection of Sprinklers
  - Uniformity
  - Application rate
  - Freezing of heads
- Selection of Pipe Size
  - Friction loss
  - Volume of water
- Sprinkler Layout
  - Overlap of wetted zone
- Selection of Pressure Source (Pump)
  - Elevation
  - Distance
  - Pressure at nozzles

Critical Temperatures

- Different phases of crop growth has different critical temperatures
  - Crown (buds concealed) $10^{o}F$
  - Buds (buds emerged, closed) $27^{o}F$
  - Blooms open $30^{o}F$
  - Fruit $28^{o}F$
- We need more information!!
  - Buds (partially emerged) $15^{o}F$- $25^{o}F$ (?)

Generally Speaking

- As a rule, we do not desire for the crop to drop below 30ºF
  - Remember evaporative cooling
  - Need to start system at 34 to 35ºF
- Application rate of 0.15 inch per hour
  - With no-wind, protection to 22ºF
  - Liquid water should always be available

Water Application Rates (in./hr)

Wind Speed (mph)

Temp.	0 - 1	2 - 4	5 - 8	10-14	18-22
27°F	0.10	0.10	0.10	0.10	0.20
26°F	0.10	0.10	0.14	0.30	0.40
24°F	0.10	0.16	0.30	0.40	0.80
22°F	0.12	0.24	0.50	0.60	---
20°F	0.16	0.30	0.60	0.80	---
18°F	0.20	0.40	0.70	1.00	---
15°F	0.26	0.50	0.90	---	---

Volume of Water

- At 0.15 inch per hour
  - 68 gpm per acre
  - 40,800 gallons per acre per 10 hour event
- How many events ?
  - Better plan on 20 - 10 hour events
  - 815,000 gallons per acre of strawberries
  - 2.5 ac-ft of water per acre of crop

Layout of System

- Sprinkler Spacing
  - Traditional spacing is 60’ by 60’
    - Not as many sprinklers required
    - Takes longer for sprinkler to cover area
  - The Closer, The Better
    - 40’ by 40’ is a compromise
    - 30’ by 30’ is best
  - Function of sprinkler type and available water pressure

Types of Sprinklers

- Traditional Impacts
  - Higher pressure
  - Rigid construction
  - Large selection

- Wobblers
  - Excellent uniformity
  - Fast rotation
  - Limited range

Impacts vs. Wobblers

- Impacts
  - Solid body construction
  - Higher pressure requirement, wide range of flow selection
  - Wide range of wetted-diameters
  - Rigid pipe layout, mostly coupled-aluminum
  - More likely to freeze-up (18^{o}F)

Wobblers vs. Impacts

- Wobblers
  - Installation similar to micro-irrigation system
  - Lower pressure, limited wetted diameter
  - For small acreage, same pump and infrastructure can be used for both trickle irrigation and freeze protection
  - Uses more water per head
  - Plastic body

Water Application

Impacts

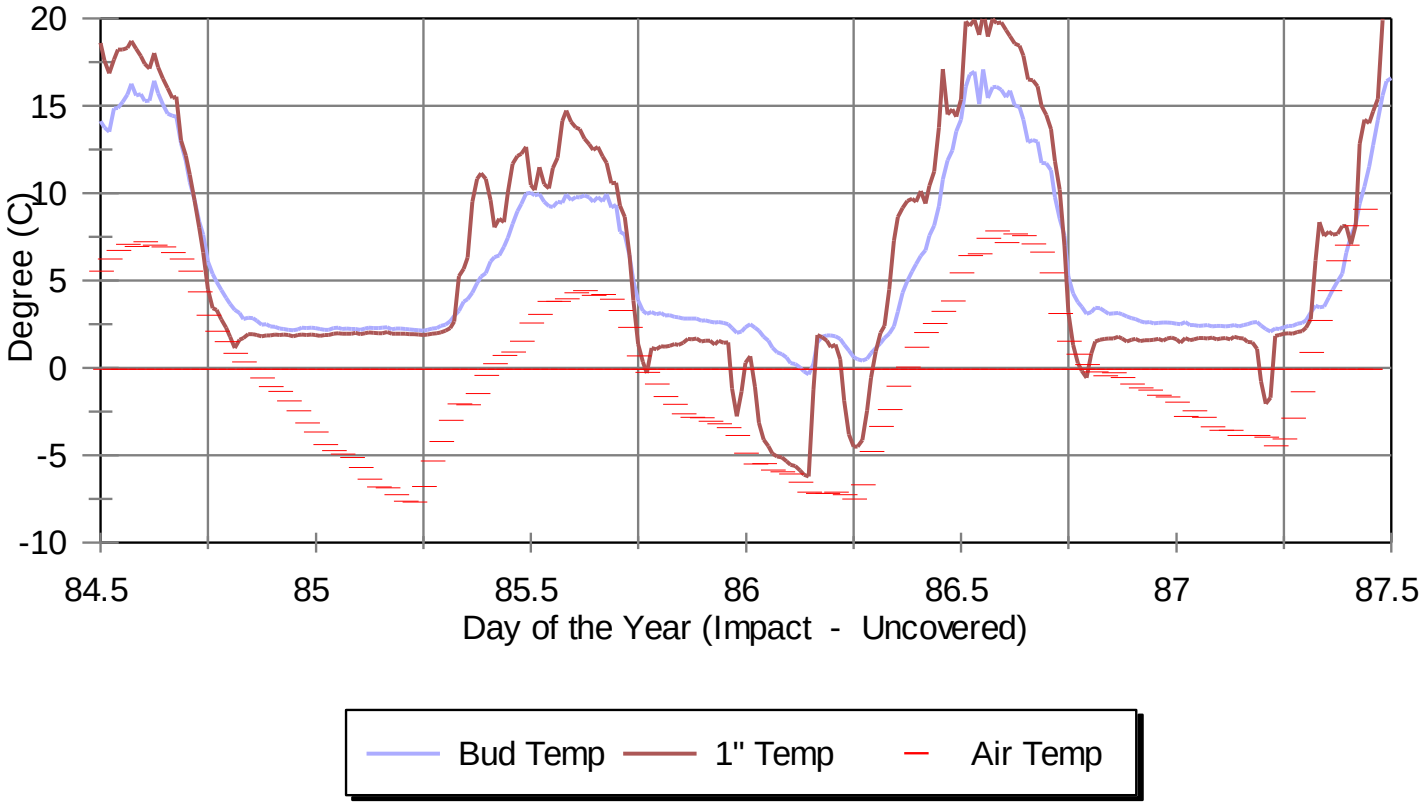
- High spray angle
- Flow is concentrated

Wobblers

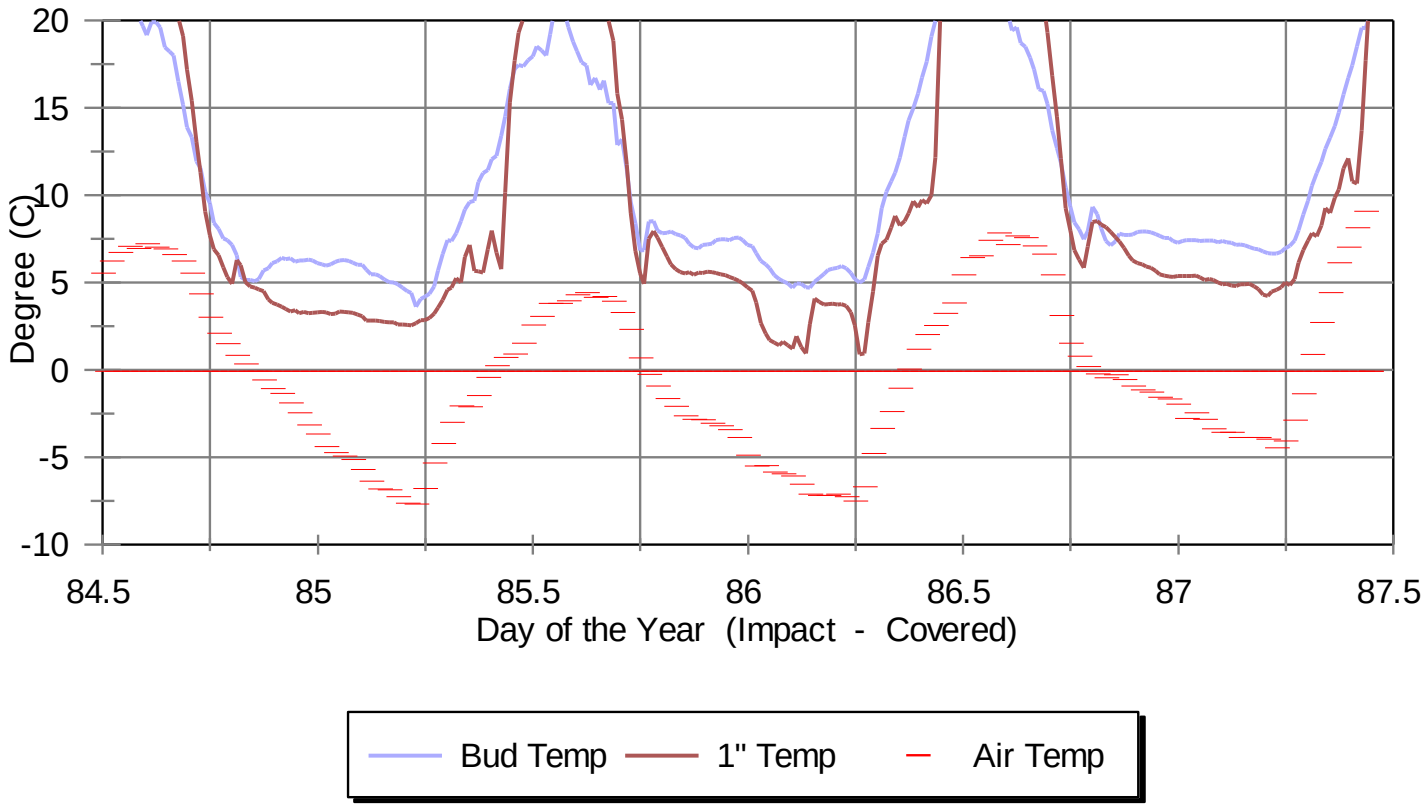
- Low spray angle
- Fast rotation

Combination:
Row Covers and Irrigation

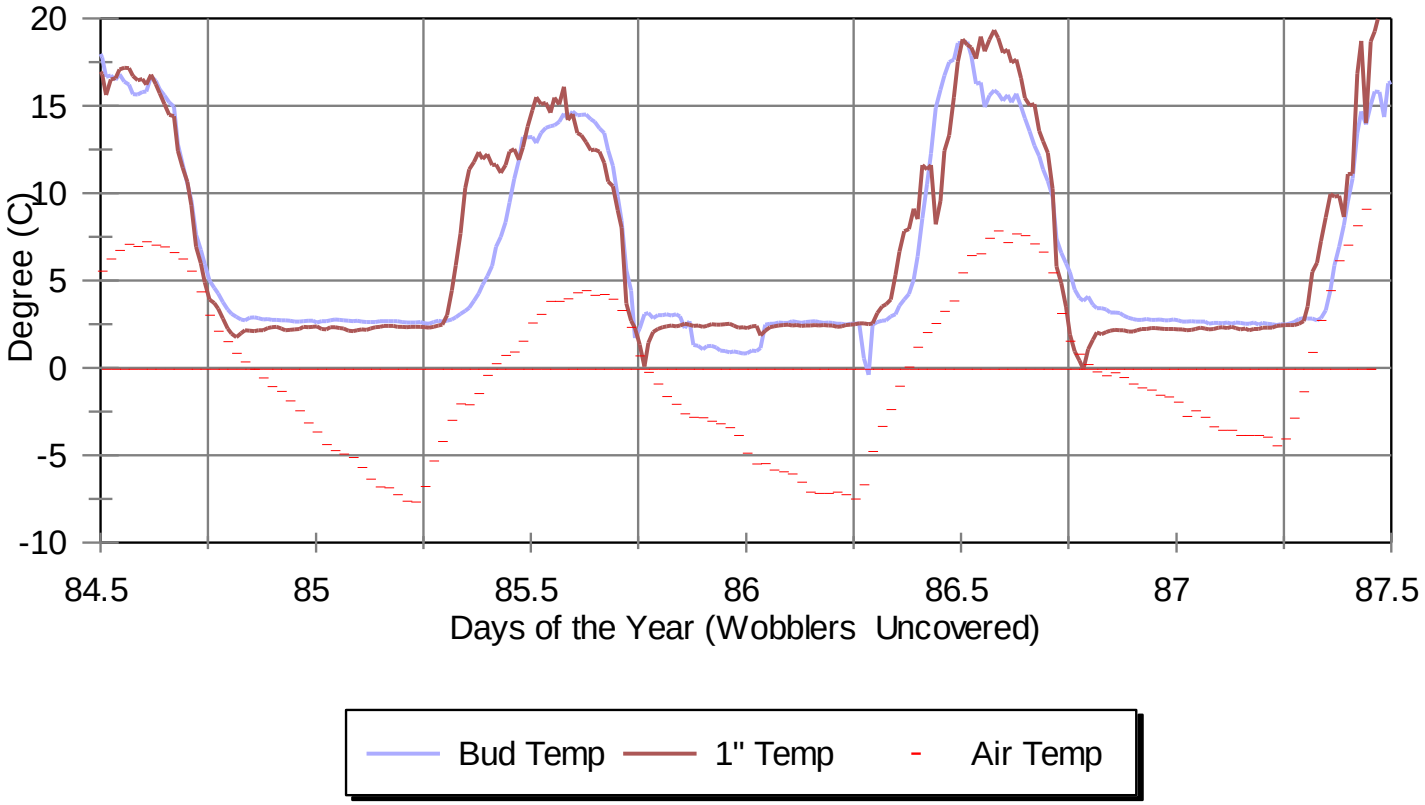
Impact - Uncovered



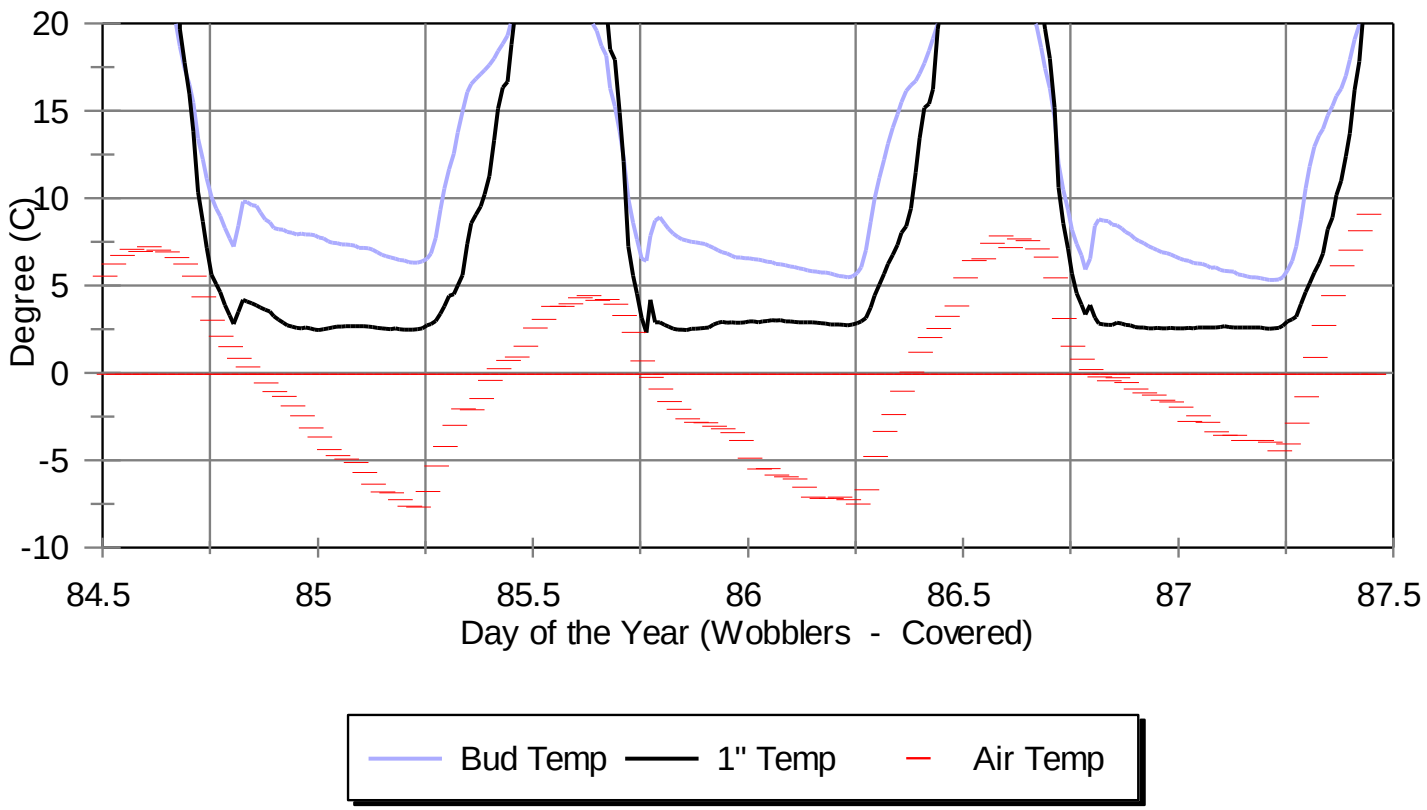
Impact - Covered



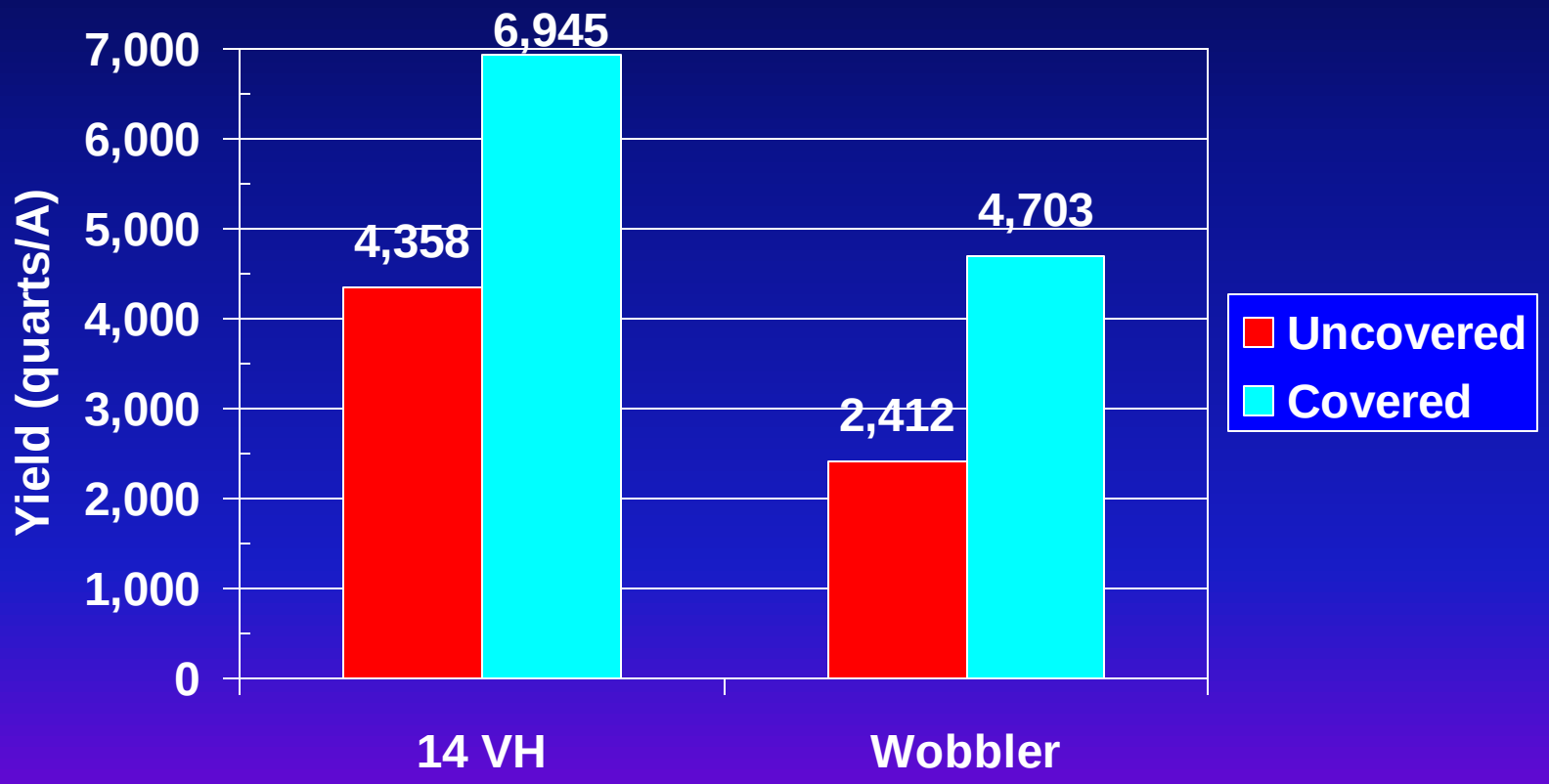
Wobblers - Uncovered



Wobblers - Covered



Yield Data - 2001



Yield based on 1.25 lb/quart

Grower Experiences - 2001

- Valley Home Farm
  - Nancy Edwards and Bob Potts
  - Bedford Co. (Southeast of Nashville)
- Wobblers
  - 30’ X 30’ Spacing
  - 3/32” Nozzles (#6 – Gold)
- Six Nights of Frost Protection
  - **March 24 – March 27**
  - April 17 – April 18

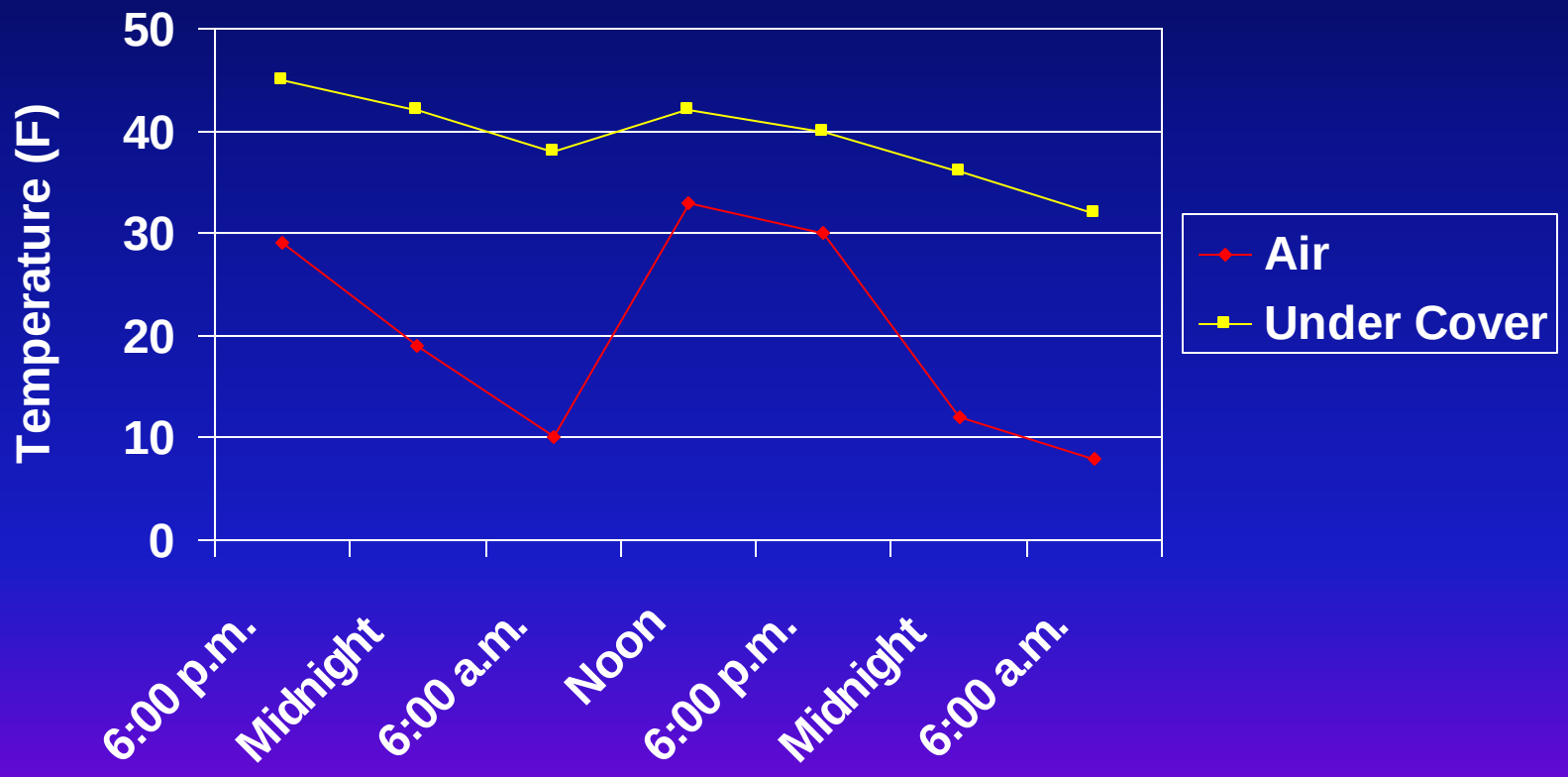
Grower Data - 2001

Temp. / Press.	3/24	3/25	3/26	3/27
Air Temp @ Startup (^{o}F)	32	30	24	27
Blossom Temp @ Startup (^{o}F)	34	33	32	33
Average Blossom Temp after Icing (^{o}F)	39	38-40	40	40
Low Temp (^{o}F)	27	20	16	18
Pressure @ Head (PSI)	20	15	30	25
Application Rate (in./A)	0.12	0.10	0.14	0.13

Grower Experiences - 2002

- Valley Home Farm
  - Nancy Edwards and Bob Potts
  - Bedford Co. (Southeast of Nashville)
- Wobblers
  - 30’ X 30’ Spacing
  - 3/32” Nozzles (#6 – Gold)
  - 27 -28 psi (0.13 in./hr)
- Cold Snap – Late February
  - Buds emerging from crowns
  - Forecast low teens

Grower Data - 2002



February 26 – 28, 2002

Evidence

Overall Results - 2002

- Impacts Only
  - Froze at 18°F
  - Lost 5 to 20% of yield
- Impacts / Covers
  - Froze at 18°F
  - Minor losses
- Wobblers / Cover
  - No loss

Frost / Freeze Protection Recommendations

- Frost above freezing
  - Water or row covers alone
- Temperatures mid- to high 20's
  - Water or row covers alone
- Temperatures low 20's
  - Use both water and row covers
- I believe we could protect fruit to $0^{o}F$

Other “Tricks”

- One grower has all of the nozzles to fit the Wobblers, he changes them based on the forecast.
- Two growers have limited water supplies:
  - Run the system until ice forms
  - Turn it off (one by-passes the water leaving the pump running)

Row Covers / Freeze Protection Management

- Row Covers from this point on:
  - Maturity Enhancement
  - Frost /Freeze Protection
    - Emerged Buds and Flowers
- Overhead Water
  - Frost/Freeze Protection
- Use the combination of row covers and overhead water when:
  - Deploying wet row covers
  - Extremely cold temperatures are forecast
  - Windy conditions / advective freeze situation

Questions ?