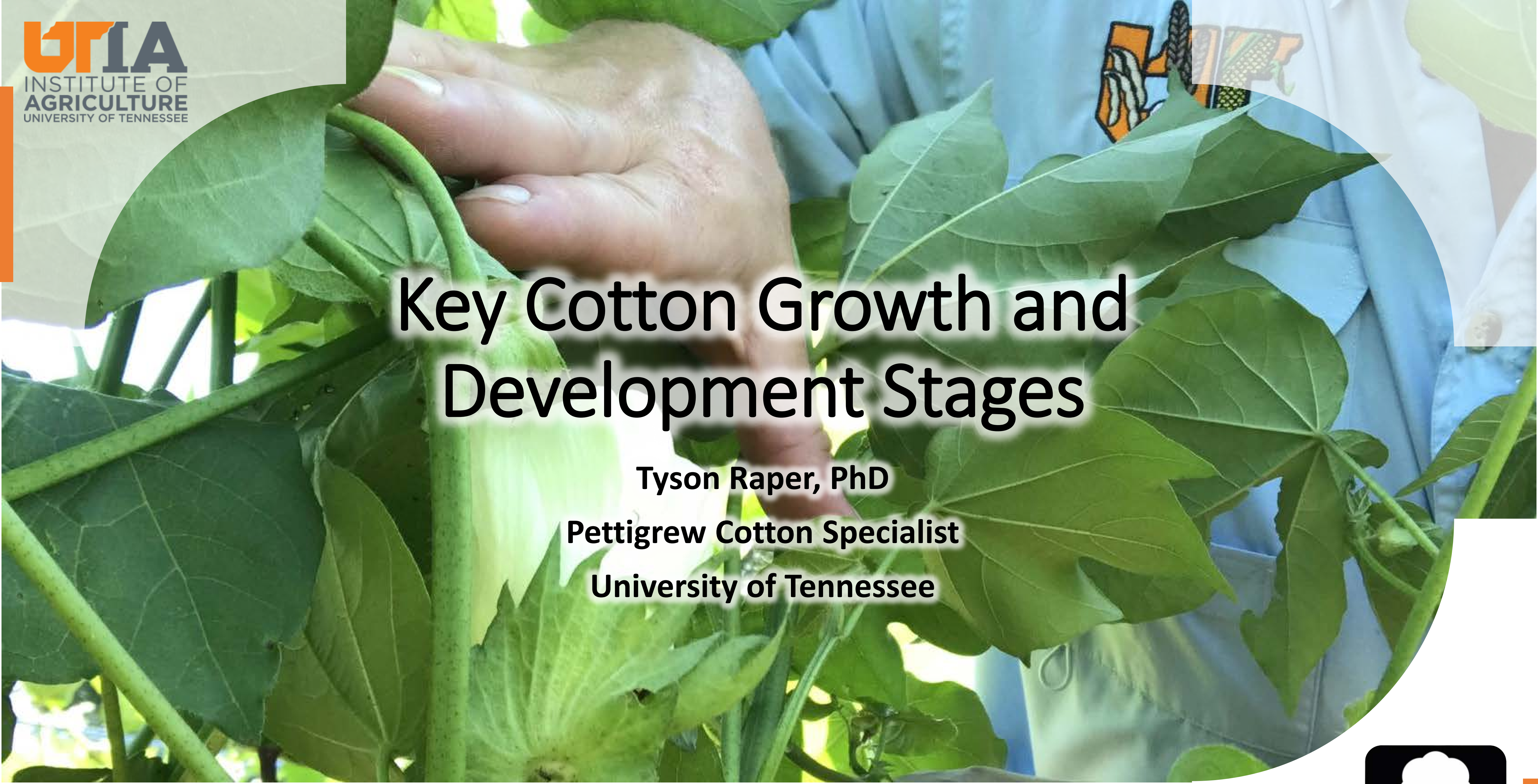


Key Cotton Growth and Development Stages

Tyson Raper, PhD

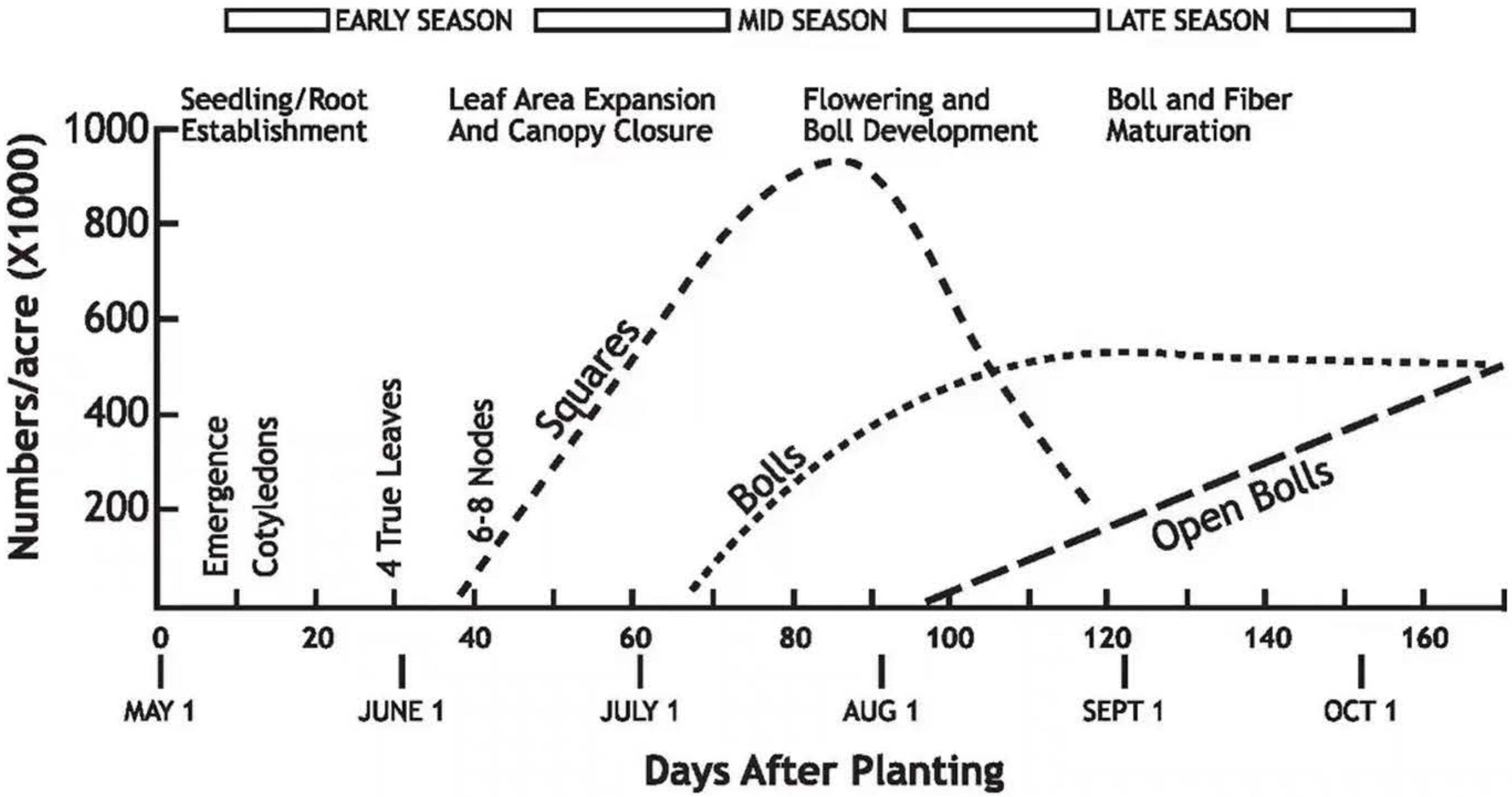
Pettigrew Cotton Specialist

University of Tennessee

UTIA INSTITUTE OF AGRICULTURE UNIVERSITY OF TENNESSEE

cotton

Season Overview



Images courtesy the National Cotton Council:
https://www.cotton.org/tech/ace2/images/growth-fig-1_2.jpg

Fruiting Body Development

Image courtesy Madison Cartwright
Twitter: @MadlCartwright

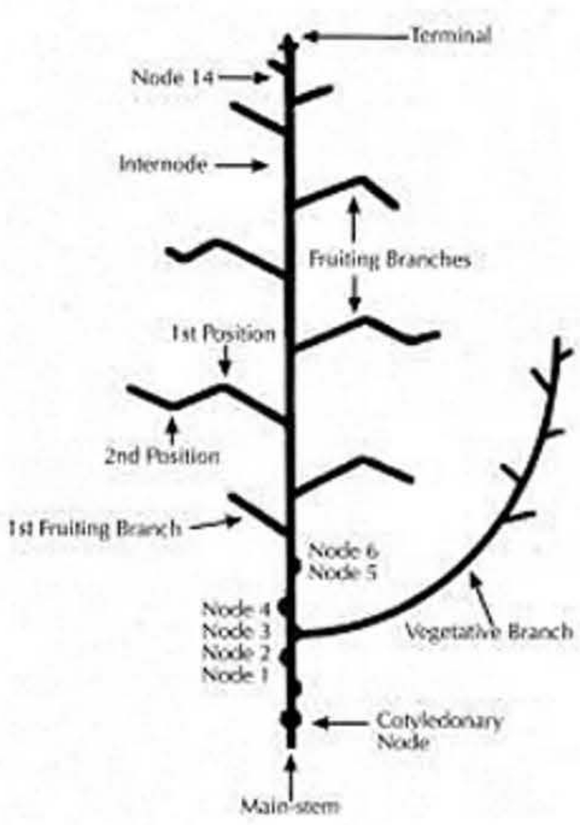


Image courtesy the National Cotton Council:
https://www.cotton.org/tech/ace2/images/growth-fig-1_2.jpg

Data collection

- Six key growth stages
  - Emergence
    - Date at which 50% of seeds planted within a 10’ span have cracked the ground and begun to slough seed coat
  - First week of squaring
    - Date at which 50% of 10 consecutive plants have a match-head square
  - First week of flowering
    - Date at which 50% of 10 consecutive plants have a flower
  - Cutout
    - Date at which 50% of 10 consecutive plants reach NAWF 5
  - First week of cracked boll
    - Date at which 50% of 10 consecutive plants have a cracked boll
  - 60% open boll
    - Date at which rated % open reaches 60%

Last Effective Bloom Date

- Last calendar day that we can expect a white flower to form a harvestable boll (not necessarily of the highest quality).

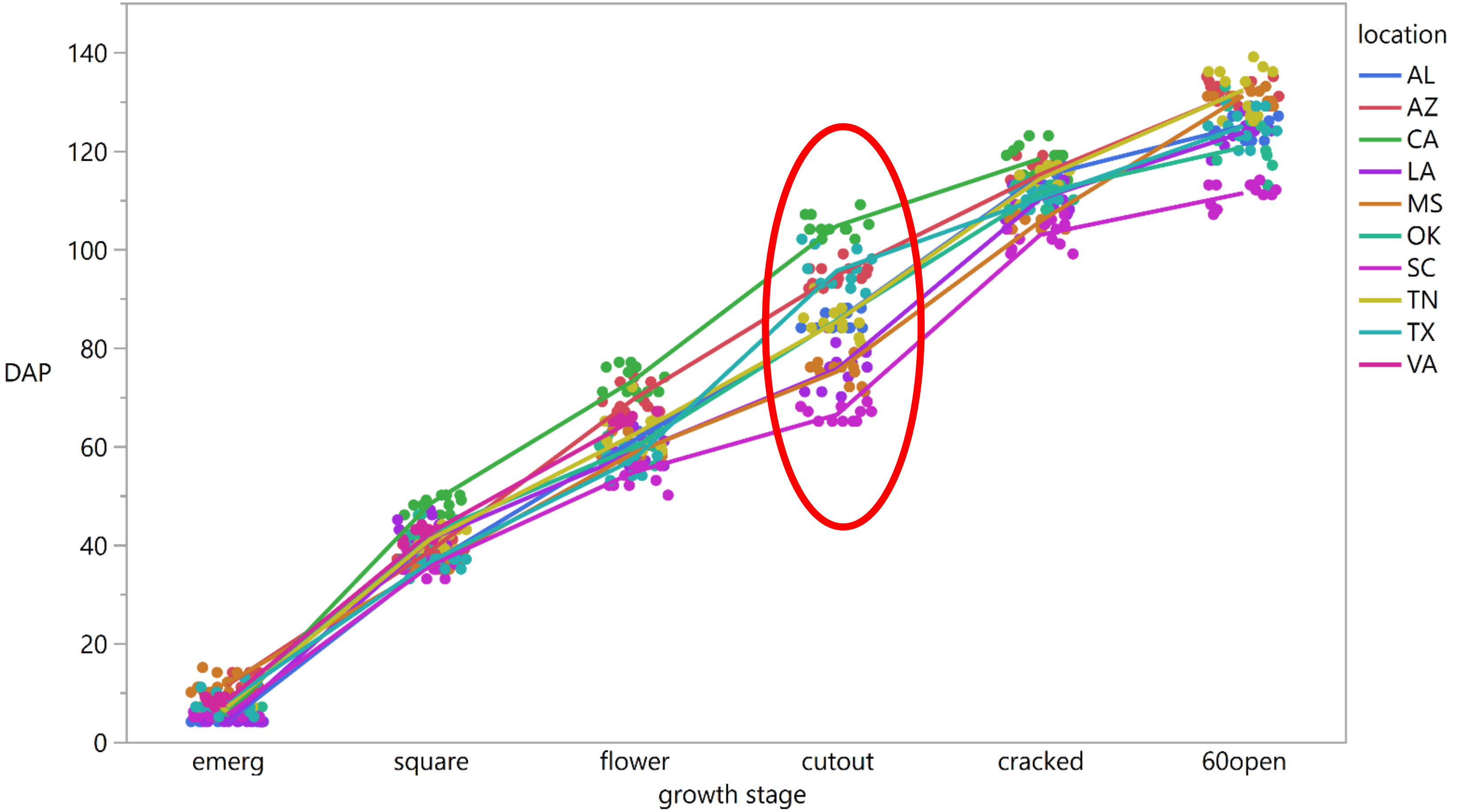
- Days needed to accumulate minimum heat units to go from white flower to open boll, prior to killing freeze (sub-30)

- Goodwell 2009 – 2019 average last effective bloom date:
- **August 6th**
- Range:
- **July 24th – Aug. 15th**

- Amarillo 2007 – 2019 average last effective bloom date:
- **August 8th**
- Range:
- **July 25th – Aug. 15th**

Days After Planting Ranges for Growth Stages

Stage	DAP
Emergence	7-10
Square	40-45
Flower	60-65
Cutout	75-95
Cracked Boll	105-120
60% Open	120-140



History of DD60 use in cotton

- Daily average, base of 60F selected by Extension Cotton Specialist Working Group in 1983
  - Prior to selection of base 60F and daily averaging, many other approaches and bases were common
  - Many Beltwide presentations in early 80s evaluating heat unit accumulations
- Since then, several adjustments in guidelines have been proposed within states
- Some states have adopted alternative calculations
  - Notably, Arizona and the 86/55 HUAP forced sine curve approach
  - Initially used for estimation of pink boll worm emergence

Understanding and Using Heat Units

James R. Supak, Extension Agronomist-Cotton
Texas Agricultural Extension Service
Lubbock, Texas

Heat Unit Concept

Cotton Growth and Development Patterns

J.C. Silvertooth, E.R. Norton, and P.W. Brown

Abstract

Summaries of cotton crop phenology, as a function of heat units (HU, 86/55°F limits) have been developed across a wide range of production conditions in Arizona. Basic phenological events such as the occurrence of pinhead squares, squares susceptible to pink bollworm, and first bloom are described in terms of HU accumulations since planting (HUAP). Fruit retention guidelines and height: node ratios, which measure a crop's vegetative/reproductive balance, are developed as a function of HUAP. Similarly, the rate of canopy closure is described in terms of HUAP. The use of the number of nodes above the top white bloom to the terminal (NAWB) is developed as a measure of a crops progression towards cut-out. Also, the expected ranges of HU's accumulated since planting that are required to accomplish crop cut-out are shown for Upland and Pima cotton.

Introduction

Plants are biological organisms that respond in direct relation to the temperature and environmental conditions to which they are exposed. Therefore, it has been shown for many different crop plants (and insects) that growth and development can be described much more accurately and predictably by the use of some measure of thermal conditions. As a result, various types of heat unit (HU) systems have been developed to assist in predicting and/or projecting plant and insect development. By using HUs, one can describe thermal conditions for specific locations or specific seasons and not assume consistency for locations or years on a calendar basis.

The cotton (Gossypium spp.) producing areas of the desert southwest offer many diverse settings. In Arizona, these areas range from elevations less than 100 feet above sea level to over 4,000 feet. Most of the Arizona cotton acreage is situated geographically so that a rather long growing season can be employed. Important stages in the development of many crops are often described as a range of calendar dates. For example the times for optimum planting are often described as a range of calendar dates, and important crop development stages are described as number of days after planting (DAP).

Relationships describing both cotton crop and pink bollworm (Pectinophora gossypiella (Saunders)) development have been formulated to some extent (Fry, 1983; Brown et al., 1990; Silvertooth et al., 1989; Silvertooth and Terry, 1989; Silvertooth et al., 1990; Silvertooth et al., 1991a, and Silvertooth et al., 1991b). The HU terms most often used in this case were with 86 and 55°F, upper and lower limits, respectively. The purpose of this paper is to outline the phenological description of cotton crop development on a HU basis and update baselines offered in earlier papers (Silvertooth et al., 1992; Silvertooth et al., 1993; and Silvertooth, 1994). Information resulting from the development of these type of growth descriptions can serve as reference points or baselines in the development of management techniques oriented at ultimately improving cotton production efficiency in Arizona and the irrigated southwest.

75

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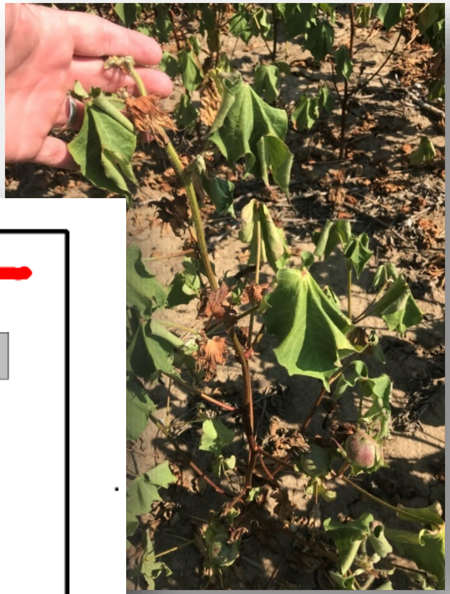
Issues with the Heat Unit approach

- Plant growth and development is assumed to be driven by temperature alone.
  - Water stress, nutrient deficiencies, solar radiation. . .
- Relationship between plant growth and temperature is considered linear.
  - Response to temperature is likely more curvilinear than linear
- The lower threshold temperature is constant throughout the season.
  - Cold stress early not the same as cold stress late
- An upper threshold is not typically included within the calculation.
  - Plant growth and development accelerates at 100F?
  - Growth rate declining near 86F



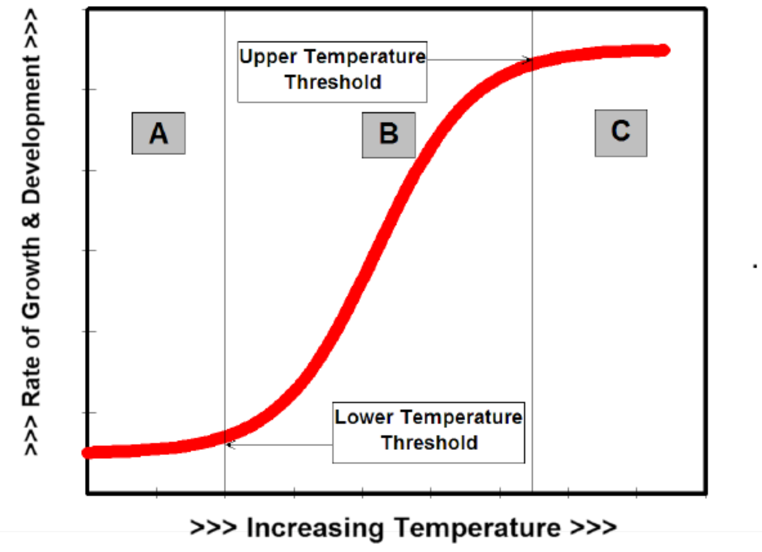
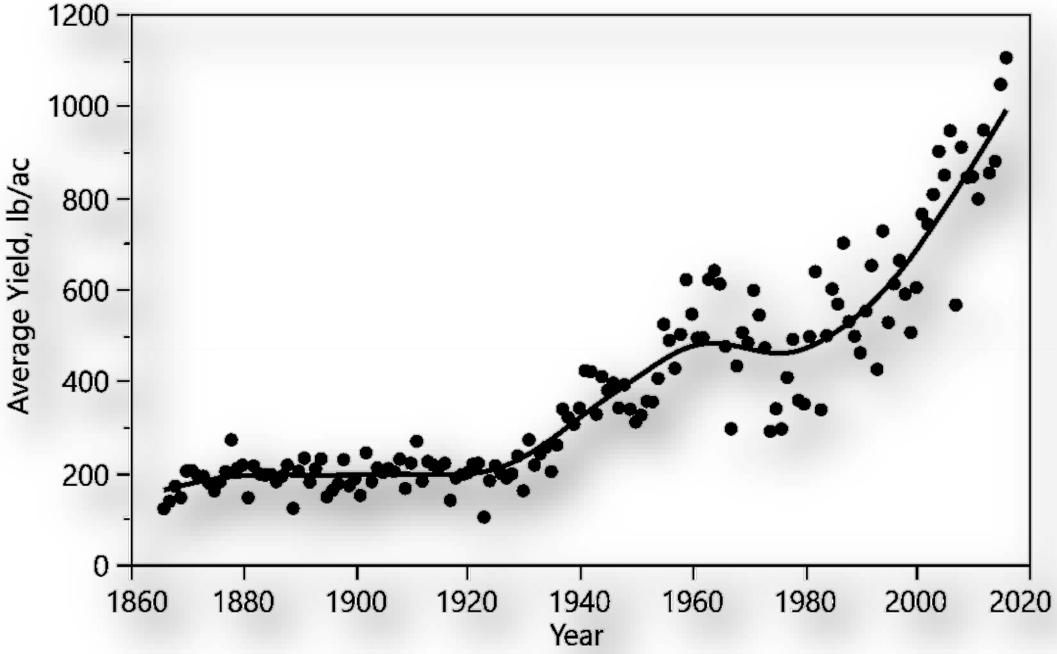
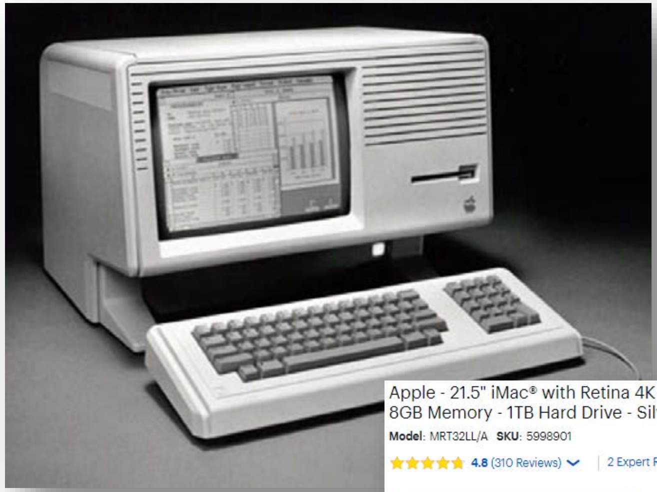


Figure 1. The relationship between organism growth and development and temperature often follows a sigmoid or S-shaped curve. Growth and development ceases when temperatures decline below the lower temperature threshold (A) or increase above the upper temperature threshold (C). Growth and development increases rapidly when temperatures fall between the lower and upper temperature thresholds (B).

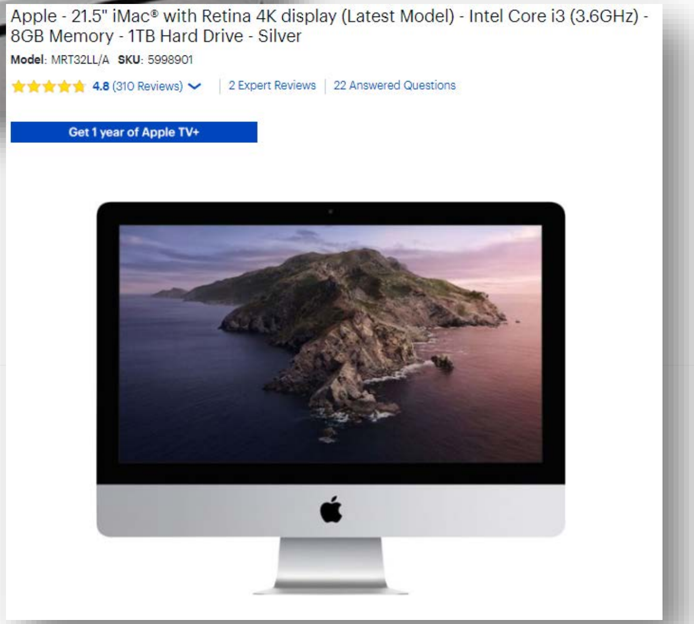
Time to re-evaluate?

- Use of DD60s decided in 1983
  - Consider technological advancements over the past 36 year
  - Consider yield increases over the past 36 years





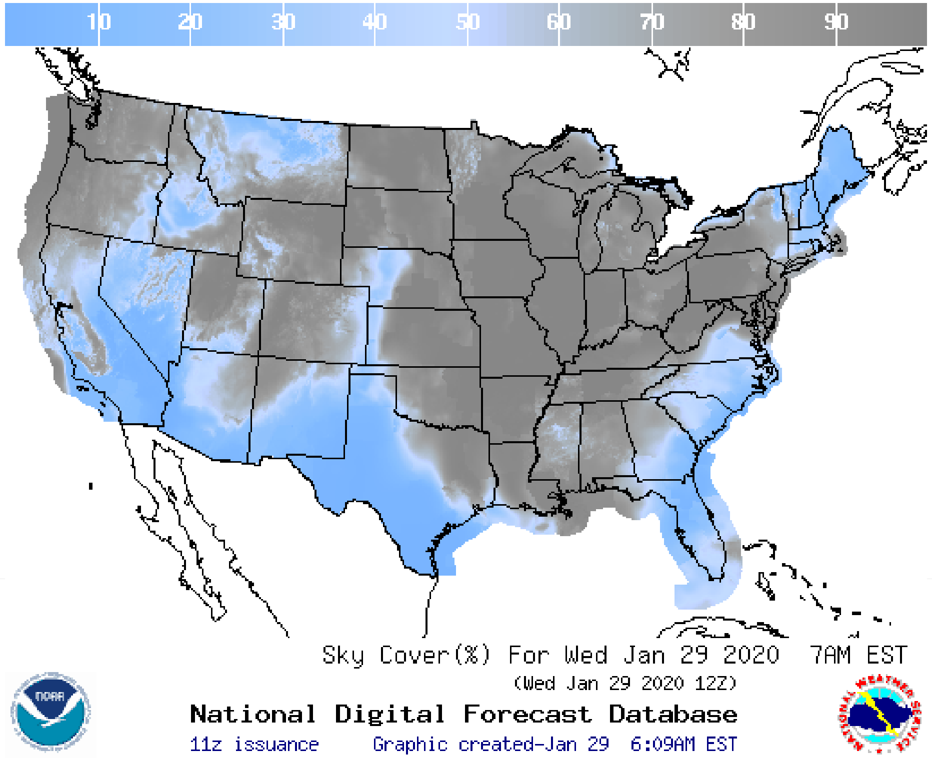
www.computerhistory.org



Opportunities for improvement?

Possible refinement of DD60 calculation, guidelines

- Are DD60 guidelines changing?
  - Higher yielding cultivars may reach key growth stages faster
  - Observations at 4-5 NACB
- Is base 60 still appropriate? Is an upper threshold appropriate? Should these change through the year?
- Should heat units early have more value than heat units late?



Development of a novel approach

- With additional computing power, more complex calculations can be completed with ease
  - Weather station networks easy to access
  - Opportunity to pull other parameters into calculation
  - Solar radiation? Cloud cover?

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Locations

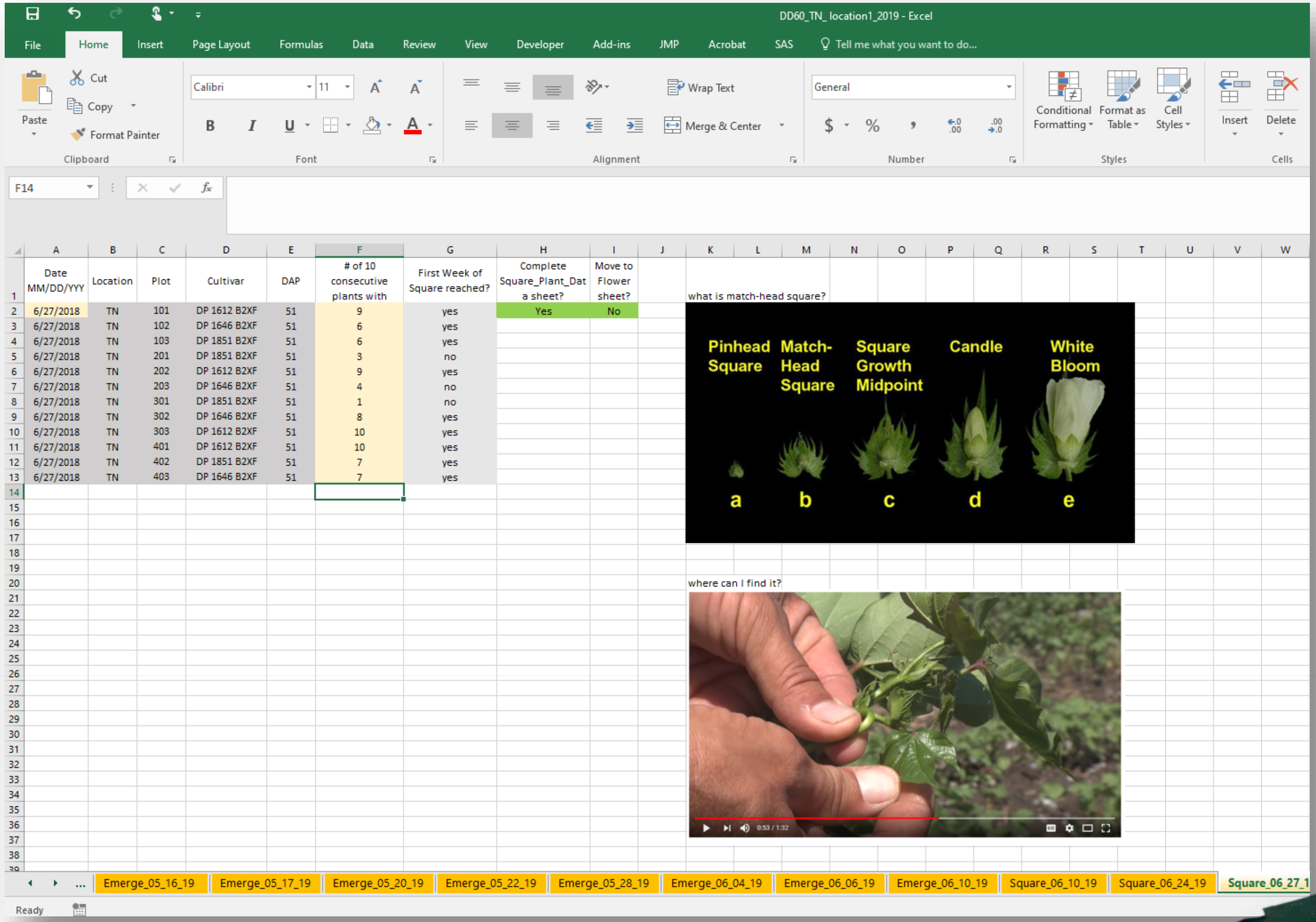
1. Tennessee (Tyson Raper)
2. Mississippi (Darrin Dodds)
3. Virginia (Hunter Frame)
4. Oklahoma (Seth Byrd)
5. California (Bob Hutmacher)
6. Arizona (Randy Norton)
7. South Carolina (Mike Jones)
8. Louisiana (Dan Fromme)
9. Texas (Murilo Maeda)
10. Texas (James Griffin)
11. Georgia (Jared Whitaker/John Snider)
12. North Carolina (Keith Edmisten)
13. Missouri (Cal Meeks)
14. Alabama (Steve Brown/Tyler Sandlin)

Refining the DD60 Model

- Trial Design
  - Minimum of two 38” or 40” rows, 30’ in length
  - Four replicates

- Cultivars
  - Early- DP 1612 B2XF
  - Mid- DP 1646 B2XF
  - Late- DP 1851 B3XF

Data collection/initial analysis

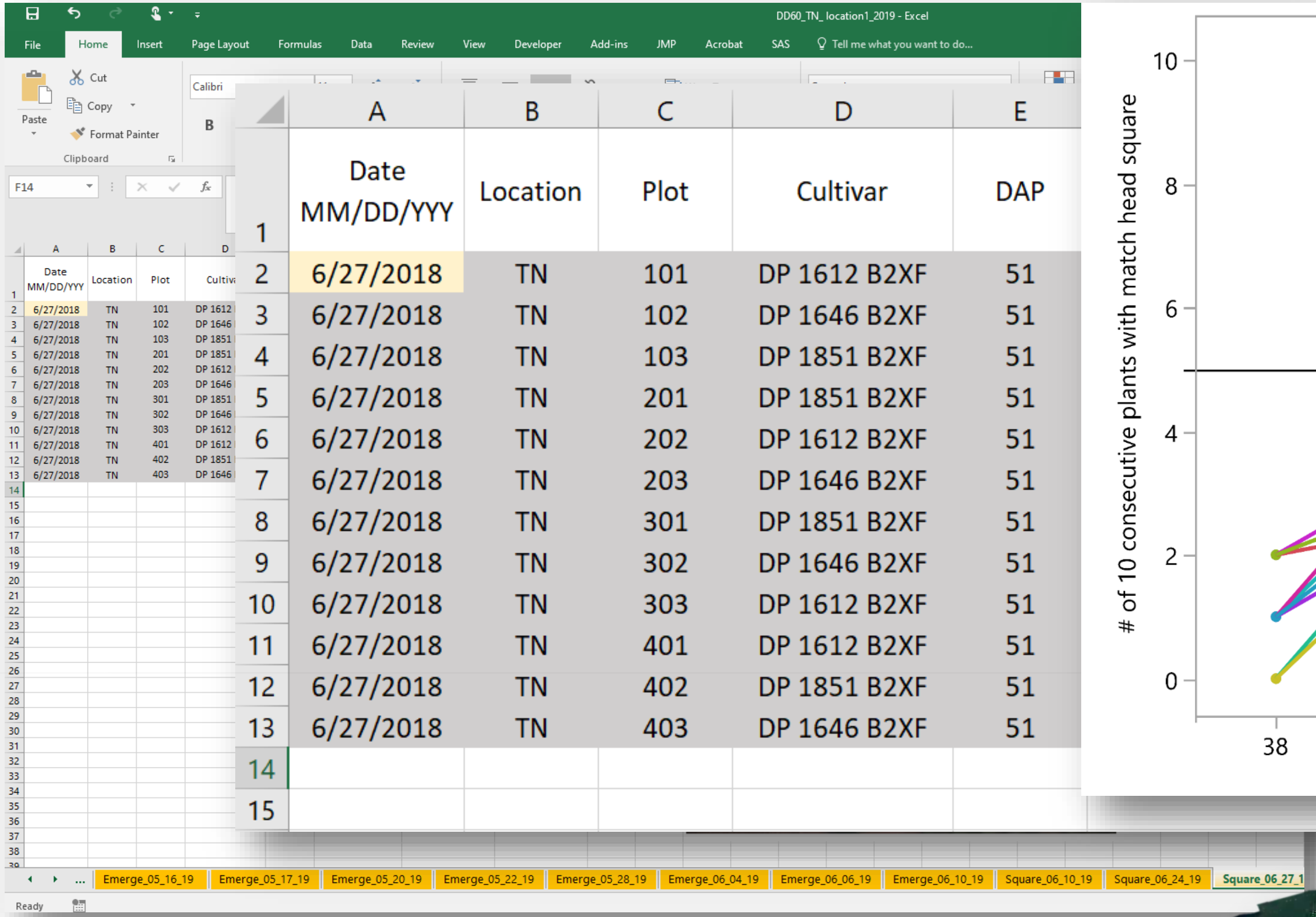


Date MM/DD/YYY	Location	Plot	Cultivar	DAP	# of 10 consecutive plants with	First Week of Square reached?	Complete Square_Plant_Data sheet?	Move to Flower sheet?
6/27/2018	TN	101	DP 1612 B2XF	51	9	yes	Yes	No
6/27/2018	TN	102	DP 1646 B2XF	51	6	yes		
6/27/2018	TN	103	DP 1851 B2XF	51	6	yes		
6/27/2018	TN	201	DP 1851 B2XF	51	3	no		
6/27/2018	TN	202	DP 1612 B2XF	51	9	yes		
6/27/2018	TN	203	DP 1646 B2XF	51	4	no		
6/27/2018	TN	301	DP 1851 B2XF	51	1	no		
6/27/2018	TN	302	DP 1646 B2XF	51	8	yes		
6/27/2018	TN	303	DP 1612 B2XF	51	10	yes		
6/27/2018	TN	401	DP 1612 B2XF	51	10	yes		
6/27/2018	TN	402	DP 1851 B2XF	51	7	yes		
6/27/2018	TN	403	DP 1646 B2XF	51	7	yes		

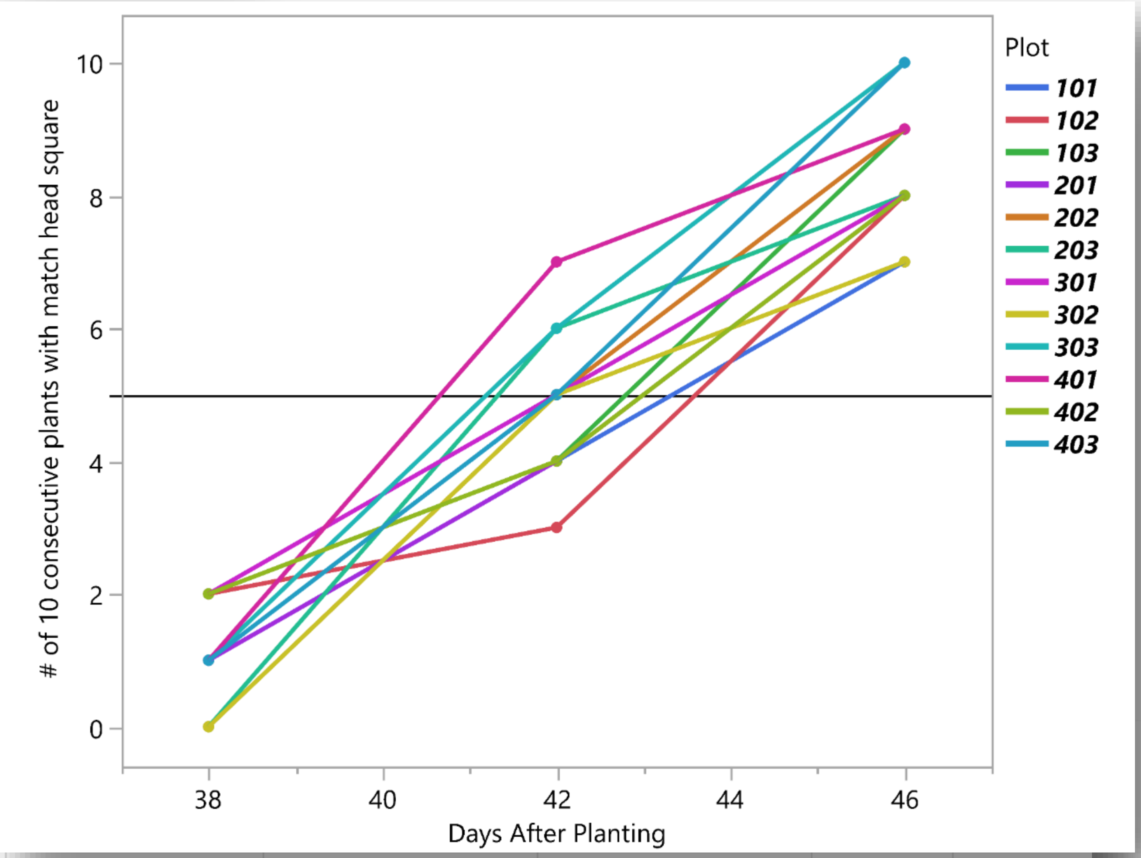
Data collection/initial analysis

Date MM/DD/YYY	Location	Plot	Cultivar	DAP	# of 10 consecutive plants with match head square	First Week of Square reached?	Complete Square_Plant_Data sheet?	Move to Flower sheet?
6/27/2018	TN	101	DP 1612 B2XF	51	9	yes	Yes	No
6/27/2018	TN	102	DP 1646 B2XF	51	6	yes		
6/27/2018	TN	103	DP 1851 B2XF	51	6	yes		
6/27/2018	TN	201	DP 1851 B2XF	51	3	no		
6/27/2018	TN	202	DP 1612 B2XF	51	9	yes		
6/27/2018	TN	203	DP 1646 B2XF	51	4	no		
6/27/2018	TN	301	DP 1851 B2XF	51	1	no		
6/27/2018	TN	302	DP 1646 B2XF	51	8	yes		
6/27/2018	TN	303	DP 1612 B2XF	51	10	yes		
6/27/2018	TN	401	DP 1612 B2XF	51	10	yes		
6/27/2018	TN	402	DP 1851 B2XF	51	7	yes		
6/27/2018	TN	403	DP 1646 B2XF	51	7	yes		

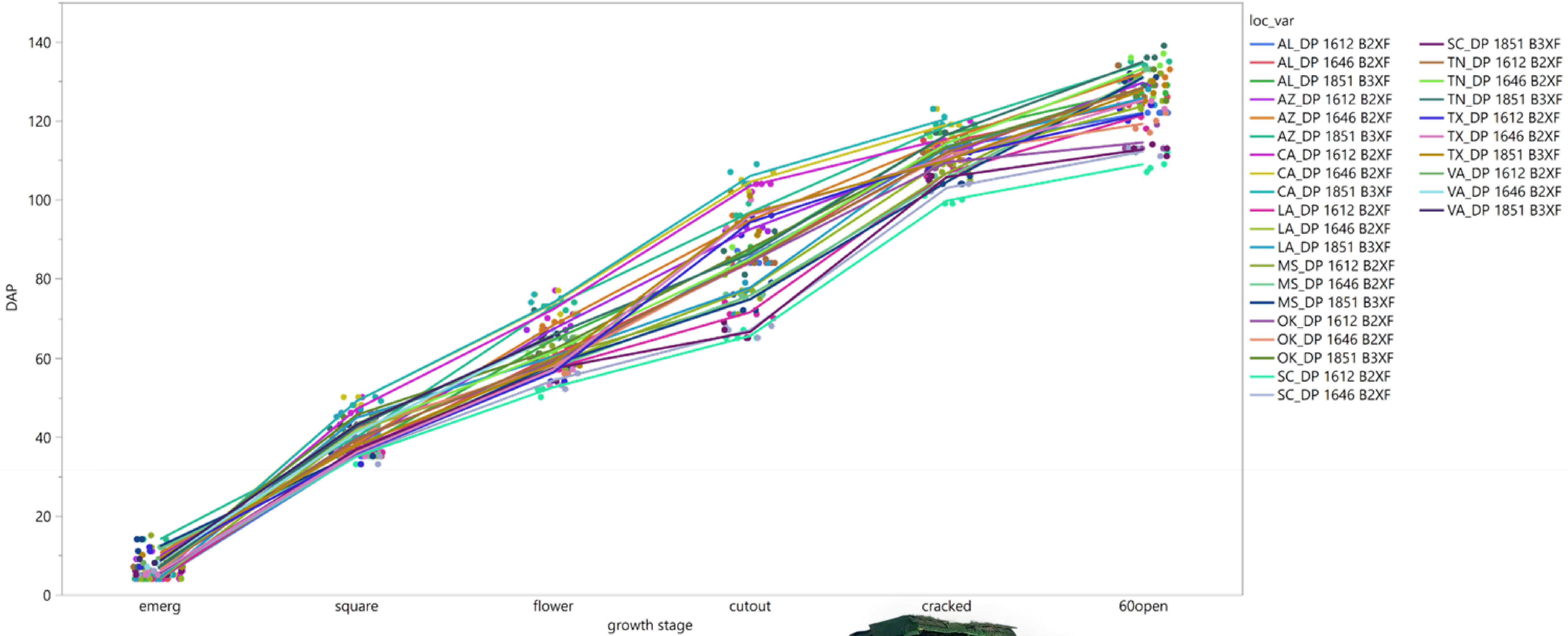
Data collection/initial analysis

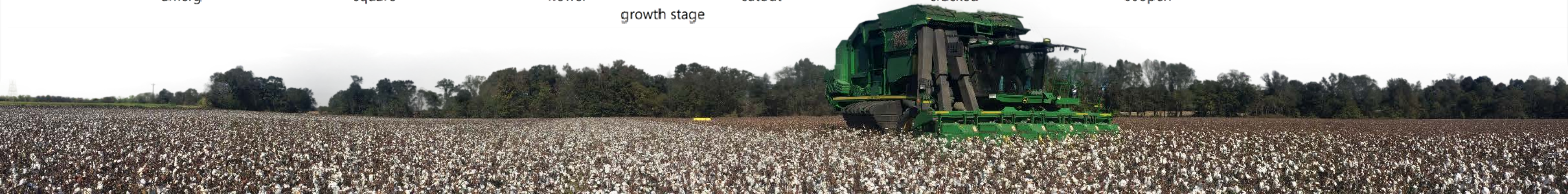


Date MM/DD/YYY	Location	Plot	Cultivar	DAP
6/27/2018	TN	101	DP 1612 B2XF	51
6/27/2018	TN	102	DP 1646 B2XF	51
6/27/2018	TN	103	DP 1851 B2XF	51
6/27/2018	TN	201	DP 1851 B2XF	51
6/27/2018	TN	202	DP 1612 B2XF	51
6/27/2018	TN	203	DP 1646 B2XF	51
6/27/2018	TN	301	DP 1851 B2XF	51
6/27/2018	TN	302	DP 1646 B2XF	51
6/27/2018	TN	303	DP 1612 B2XF	51
6/27/2018	TN	401	DP 1612 B2XF	51
6/27/2018	TN	402	DP 1851 B2XF	51
6/27/2018	TN	403	DP 1646 B2XF	51



Days After Planting- 2018 Beltwide Data





Refining the DD60 Model, Tian et al. 2020

TABLES & FIGURES

Table 1. Optimized T_{base} (°F) considering all or specific cultivars and years.

	Cultivar			
Year	**All**	**DP 1612 B2XF**	**DP 1646 B2XF**	**DP 1851 B3XF**
Both	55	60	59	58
2018	57	61	57	57
2019	56	61	58	57

Table 2. Optimized T_{up} (°F) considering all or specific cultivars and years using T_{base} = 55 °F.

	Cultivar			
Year	**All cultivars**	**DP 1612 B2XF**	**DP 1646 B2XF**	**DP 1851 B3XF**
Both	87	83	83	83
2018	96	83	87	91
2019	80	81	80	80

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Anonymous. 2019. How to manage pests: Degree-days. University of California Agriculture and Natural Resources Statewide Integrated Pest Management Program. Accessed online at http://ipm.ucanr.edu/WEATHER/ddconcepts.html

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