Some Perspectives from 50 Years of Cotton Breeding

Fred Bourland

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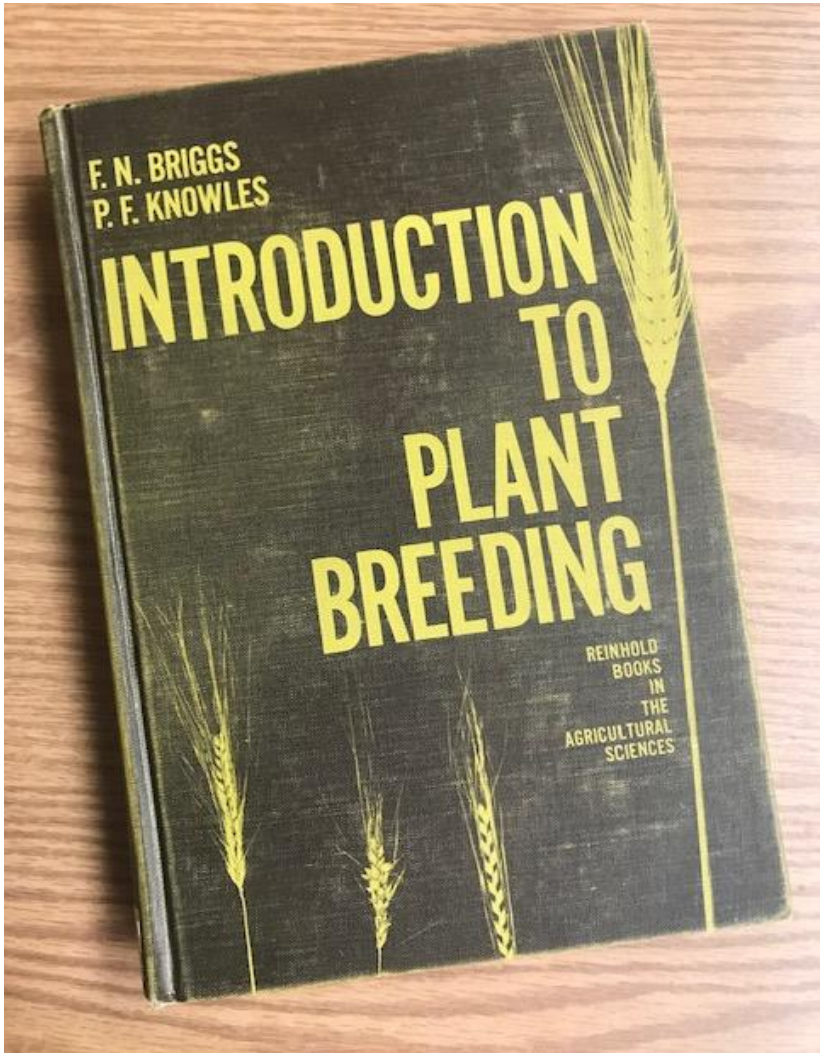
Two Life Changing Events - within one week in September 1969



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Cotton breeding chosen by coincidence!

1970 – learned to plant cotton plots, cross/self flowers, gin boll samples + many other cotton breeding tasks.

1970-73, M.S. at University of Arkansas – cotton breeding
1973-78, Ph.D. at Texas A&M University – cotton breeding
1978-88, Cotton Breeder, Mississippi State University
1988-97, Cotton Breeder, University of Arkansas – Fayetteville
1997-present, Cotton Breeder University of Arkansas – Keiser

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Some Perspectives from 50 Years of Cotton Breeding

What has changed?

I. Technology
II. Legislation
III. Cotton plant
IV. Cotton pests
V. Cotton yield
VI. Fiber quality
VII. Varieties

Photo taken 1976 – graduate student at Texas A&M University

Some Perspectives from 50 Years of Cotton Breeding

I. Technology Changes

1. No personal computers in 1970, thus, no electronic data entry/analysis (ANOVA by hand!), no word processing, no computer-generated labels/forms…

2. Limited computer-related devices in 1970, thus no seed counters, no harvest weigh systems, no HVI and AFIS…

3. Communication in 1970: No copiers, no e-mails, no texting, no cell phones, no on-line information, no on-line sources…

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II. Legislation Changes

1. PVP in 1970 – limited variety protection prior to 1970.
2. Cotton Incorporated founded in 1970.
3. State funding for cotton breeding has declined:
   - Less state funding for research.
     Little extramural funding required/expected in 1970 thru 1980's
   - Fewer state-funded cotton breeding programs.
     Mid-south: AR-2, LA, MS-2, MO, & TN, now 3 programs
4. Enhanced regulations associated environment (use of chemicals, pesticides) and employees.

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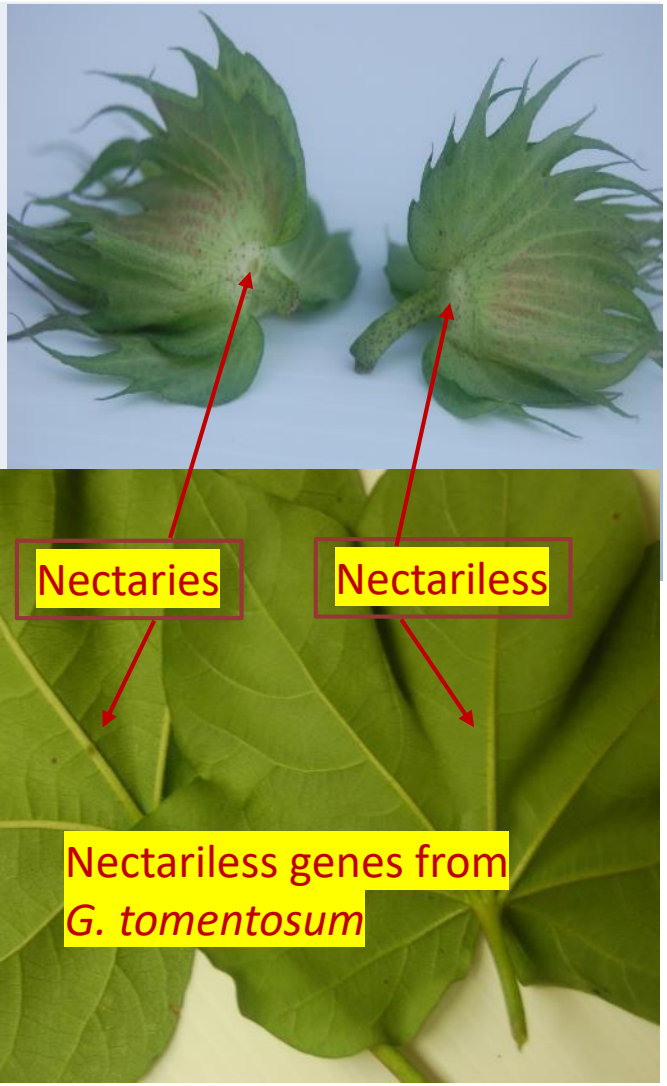
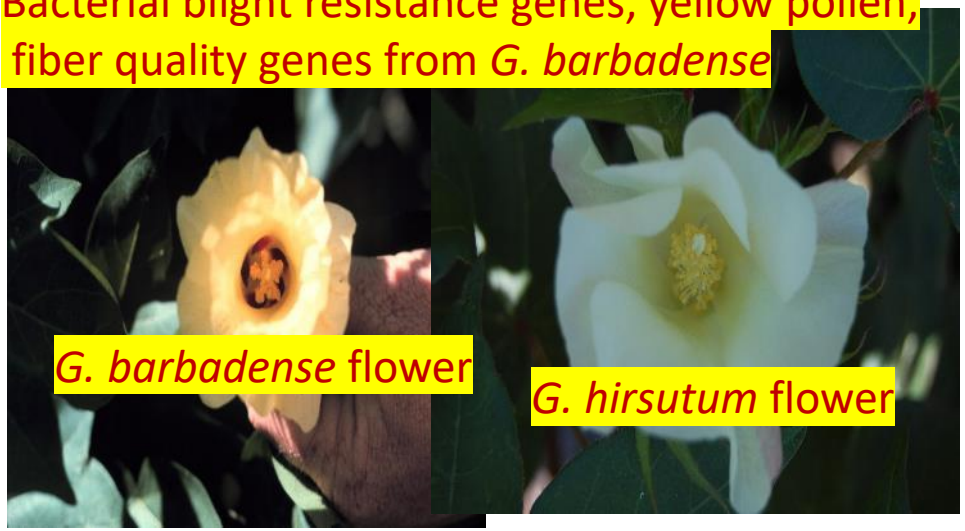
III. Cotton Plant Changes

1. Plant genetics (*Gossypium hirsutum* L.):
   - A. Same karyotype
   - B. Similar inheritance patterns
   - C. Some linkages broken
   - D. Genes from other Gossypium species
   - E. Transgenes from unrelated species
   - F. Molecular markers
   - G. Genome selection
   - H. Greater understanding of gene action



Bacterial blight resistance genes, yellow pollen, fiber quality genes from *G. barbadense*



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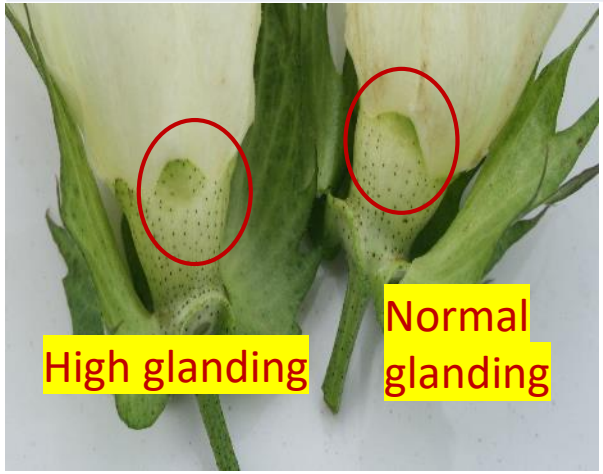
III. Cotton Plant Changes

2. Plant development
   - A. Similar flowering intervals, VFI and HFI
   - B. Fewer monopodia (vegetative branches)
   - C. Lower and more uniform plant density
   - D. Morphological traits (mostly HPR):
     - Nectariless
     - Okra-leaf (open canopy)
     - Frego bract
     - Red leaf color
     - High glanding vs. glandless
     - Smooth leaf vs. hairy leaf (pilose)



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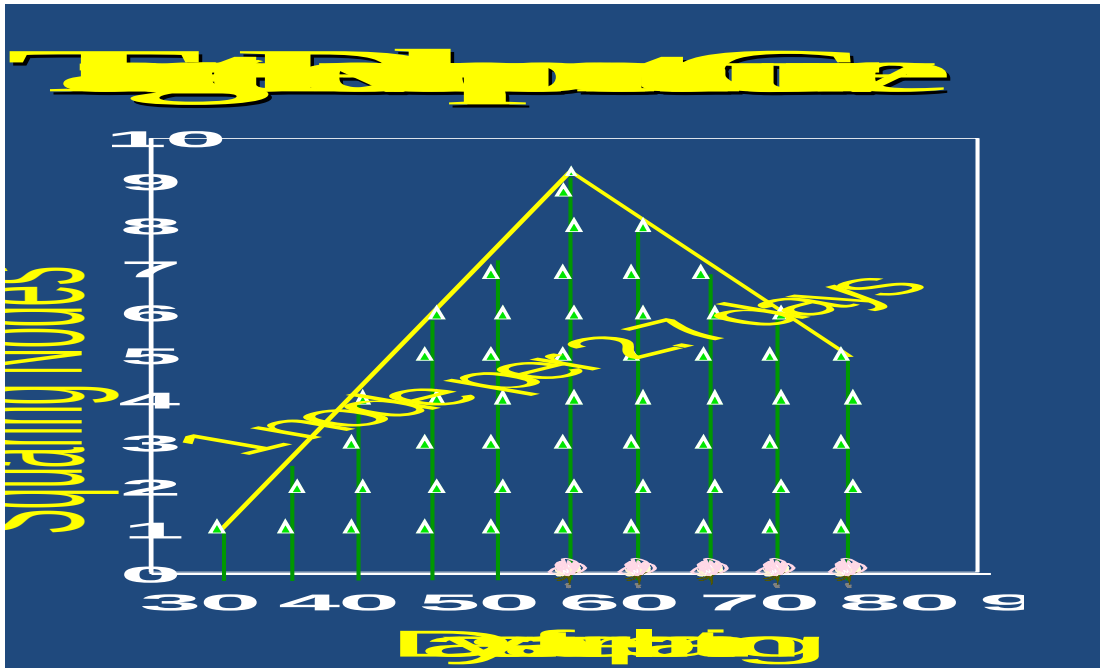
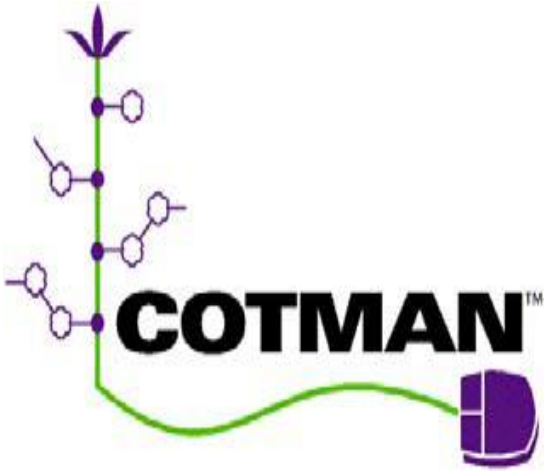
III. Cotton Plant Changes

3. Plant management
   - A. Vacuum planters (plant-to-stand), no thinning (except in research)
   - B. More irrigation, particularly after 1980 drought
   - C. PGR's (defoliants/dessicants as harvest aids; mepiquat choride to control plant height; boll openers to facilitate once-over harvest)
   - D. Increase monitoring of plant development





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IV. Cotton Pest Changes

1. Diseases
   - A. Less seedling disease due to enhanced seed quality, seed treatments, and seed handling. Increase resistance?
   - B. Bacterial blight – High resistance, molecular markers
   - C. Less boll rots due to earliness, PGR's, boll openers, and bacterial blight resistance.
   - D. Less Verticillium wilt due to increased tolerance?
   - E. More nematode problems; improved resistance

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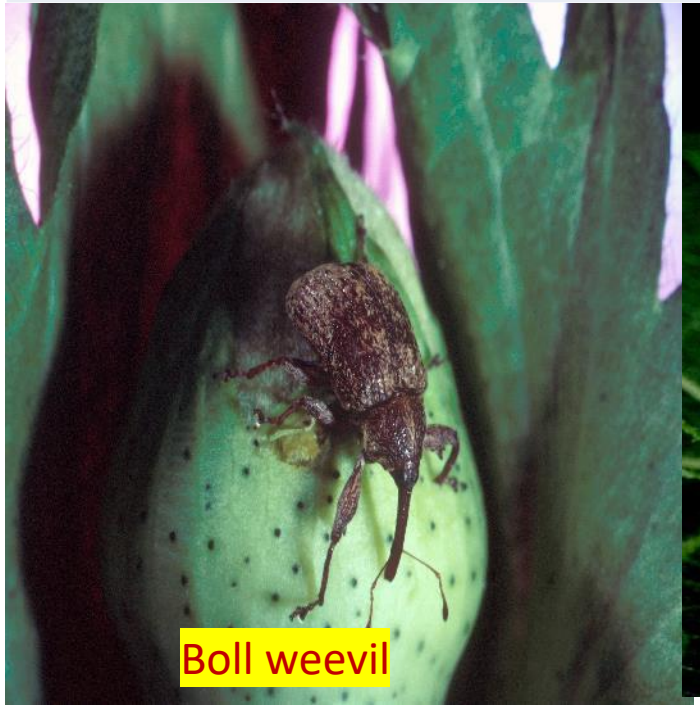
IV. Cotton Pest Changes

2. Insects
   - A. Boll weevil essentially eradicated in U.S.
   - B. Cotton bollworm/tobacco budworm complex – morphological traits in 1970's, low resistance, Bt cottons in 1990's
   - C. Tarnished plant bugs – limited pest in 1970's, now major pest



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IV. Cotton Pest Changes

3. Weeds
   - A. Limited herbicides in 1970, relied heavily on mechanical control.
   - B. Now: Management system dictated by transgenes & herbicides → Less grasses, more resistant broadleaf weeds, less root damage to cotton plant by incorporated herbicides.

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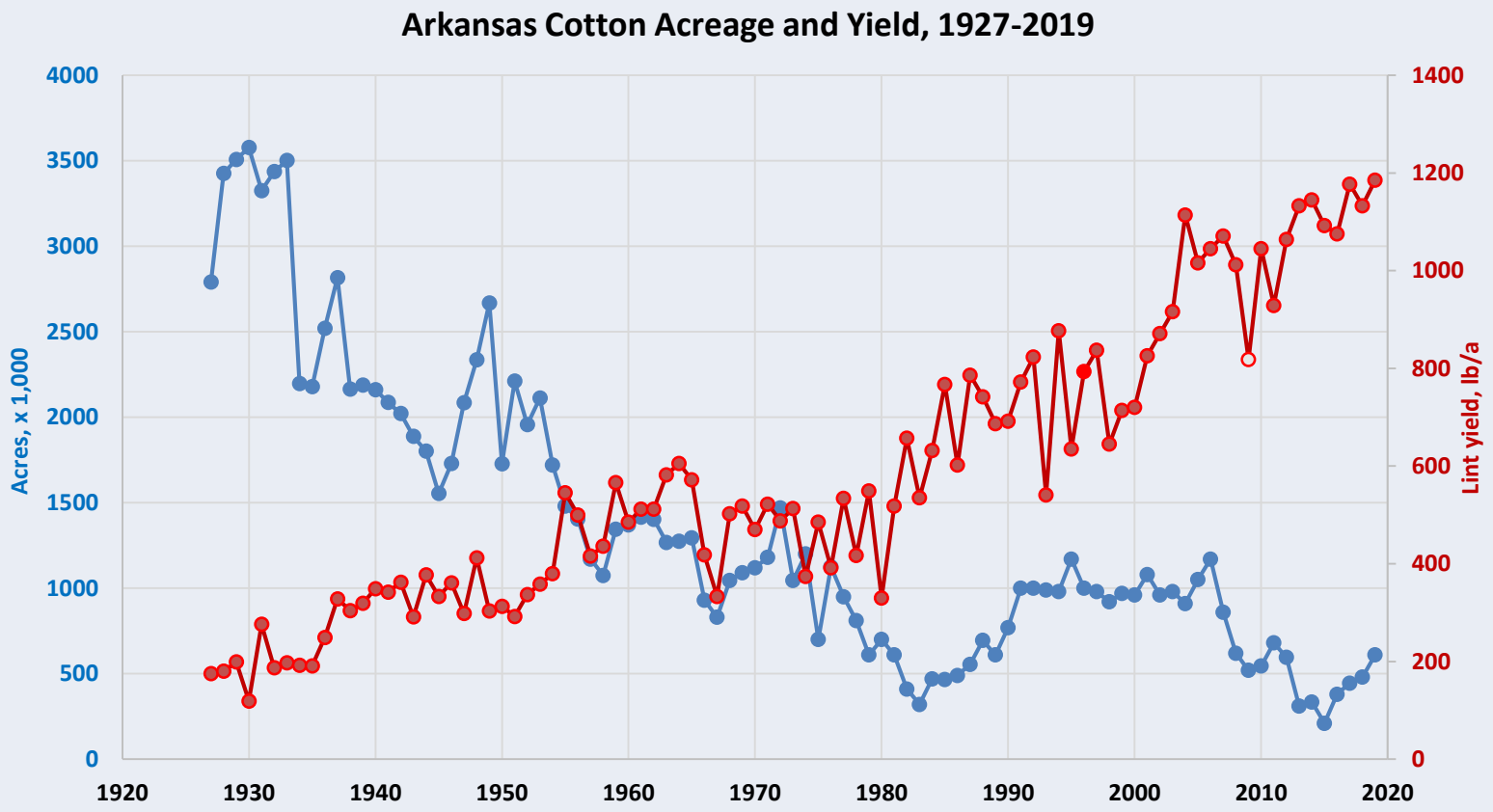
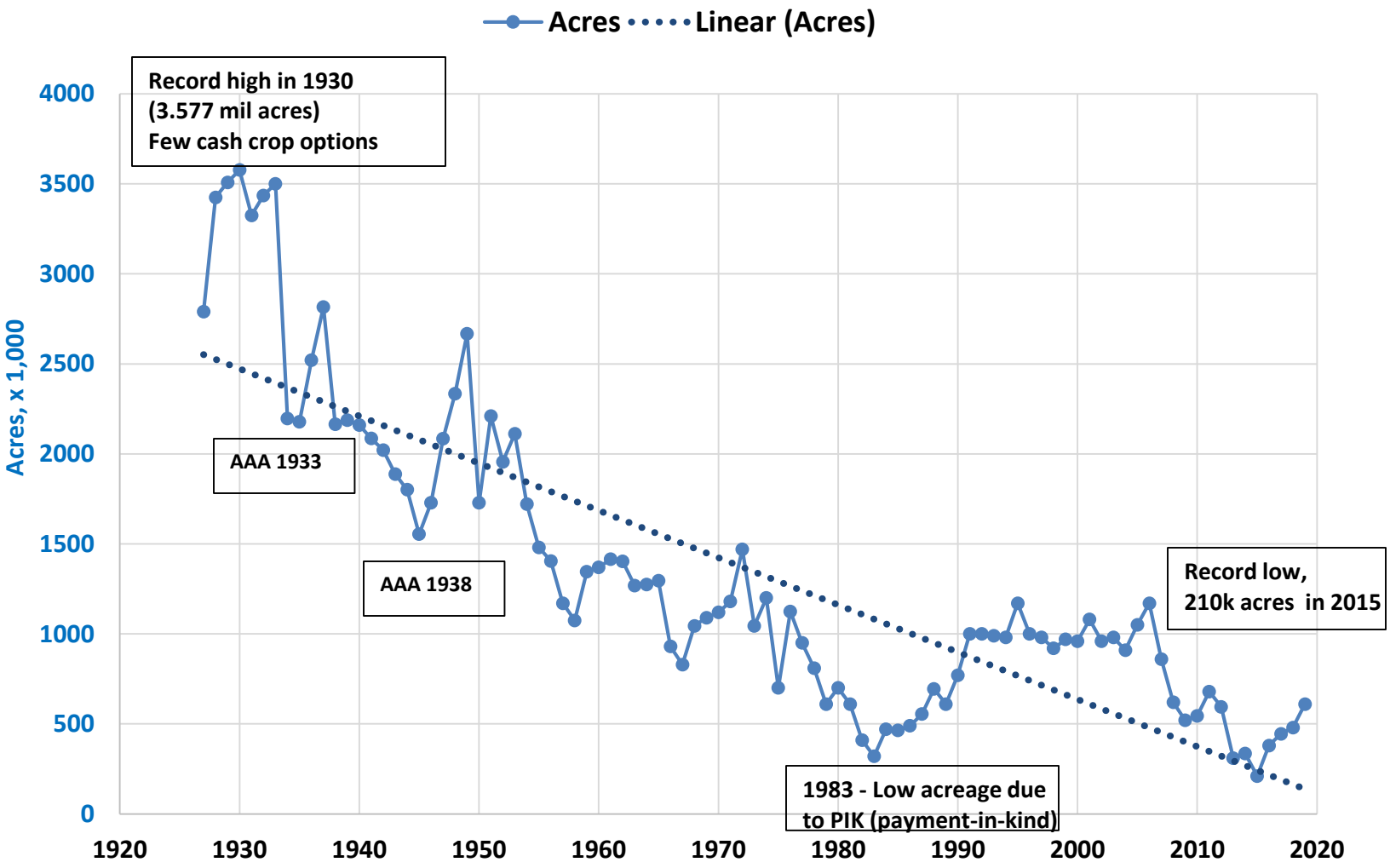
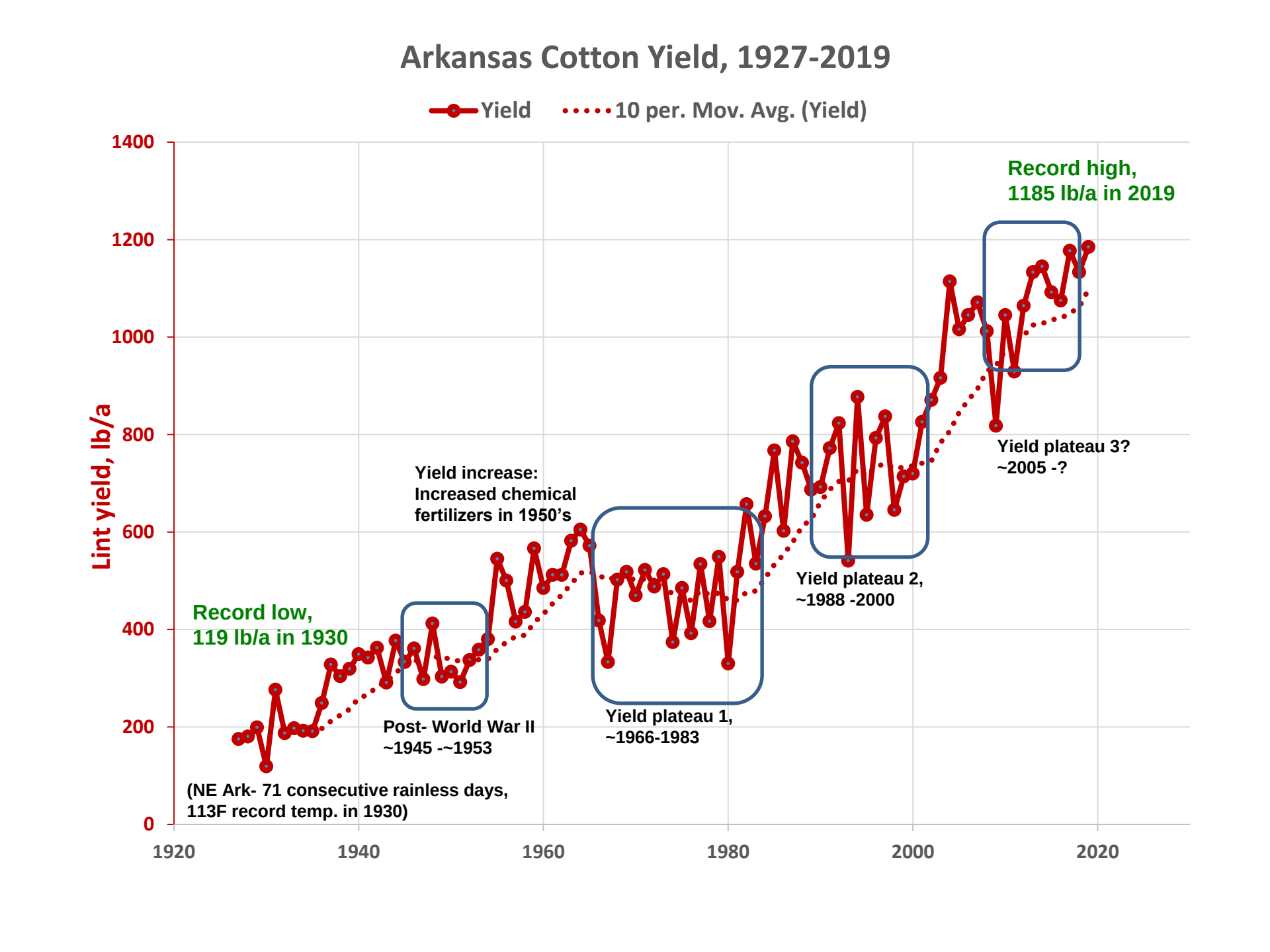
V. Cotton Yield Changes



Arkansas Cotton Acreage and Yield, 1927-2019




Arkansas Cotton Yield, 1927-2019
Yield
10 per. Mov. Avg. (Yield)
Lint yield, lb/a
1400
1200
1000
800
600
400
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0
1920
1940
1960
1980
2000
2020
Record high,
1185 lb/a in 2019
Yield plateau 3?
~2005 -?
Yield increase:
Increased chemical
fertilizers in 1950's
Yield plateau 2,
~1988 -2000
Record low,
119 lb/a in 1930
Post- World War II
~1945 -~1953
Yield plateau 1,
~1966-1983
(NE Ark- 71 consecutive rainless days,
113F record temp. in 1930)

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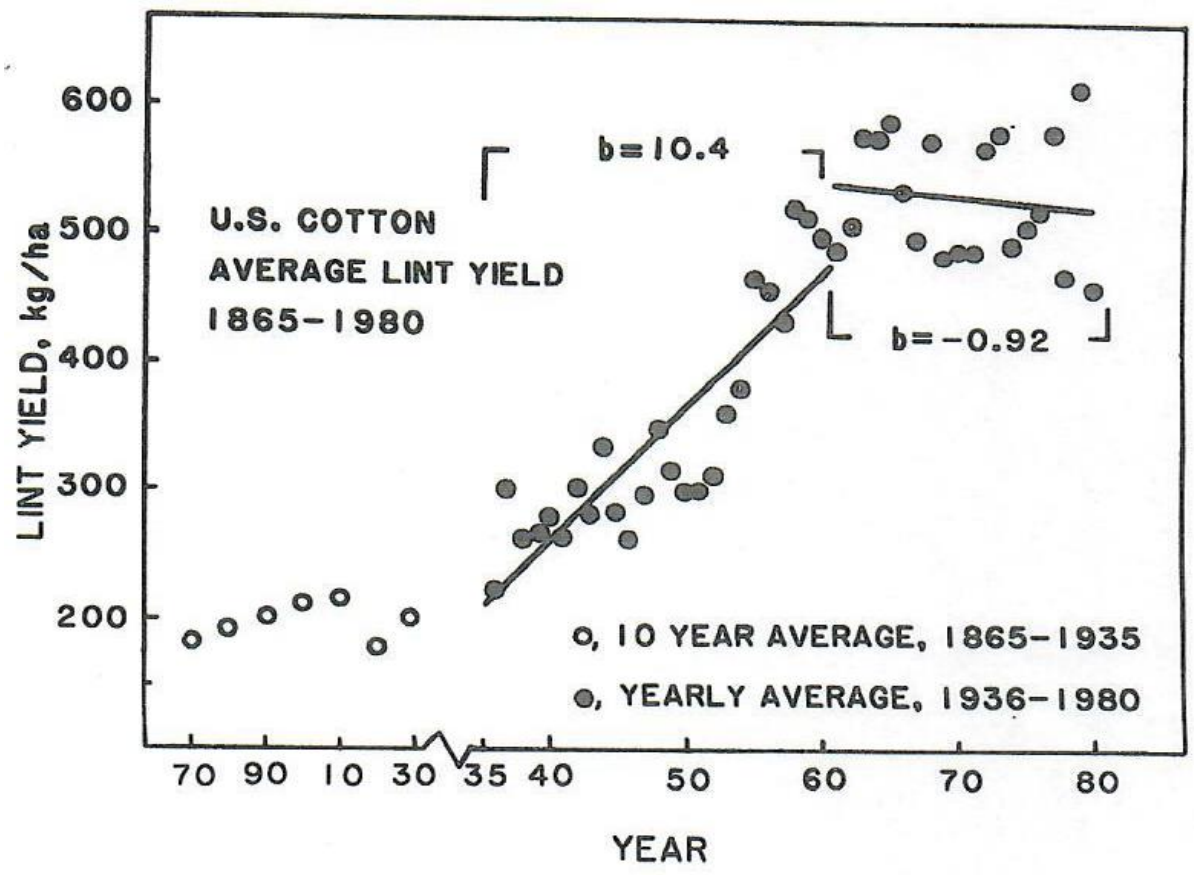
V. Cotton Yield Changes – Yield Plateau 1



Meredith. 1982. The cotton yield problem: Changes in cotton yields since 1950. p. 35-38. In Proc. Beltwide Cotton Prod.- Mech. Conf.

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V. Cotton Yield Changes

Yield Plateau 1, ~1966 -1983

- 1977 Beltwide Cotton Production-Mechanization Conference, Special Session (15 papers) titled "What is happening to cotton yields".
- 1982 Beltwide Cotton Production-Mechanization Conference, Special Session (6 papers) titled. "The cotton yield problem".

Meredith, 1982. "The circumstantial evidence from this investigation strongly suggests the cause of decreased cotton yields is largely due to our misuse of technology."

Yield Plateau 1 attributed to TECHNOLOGY DRAG

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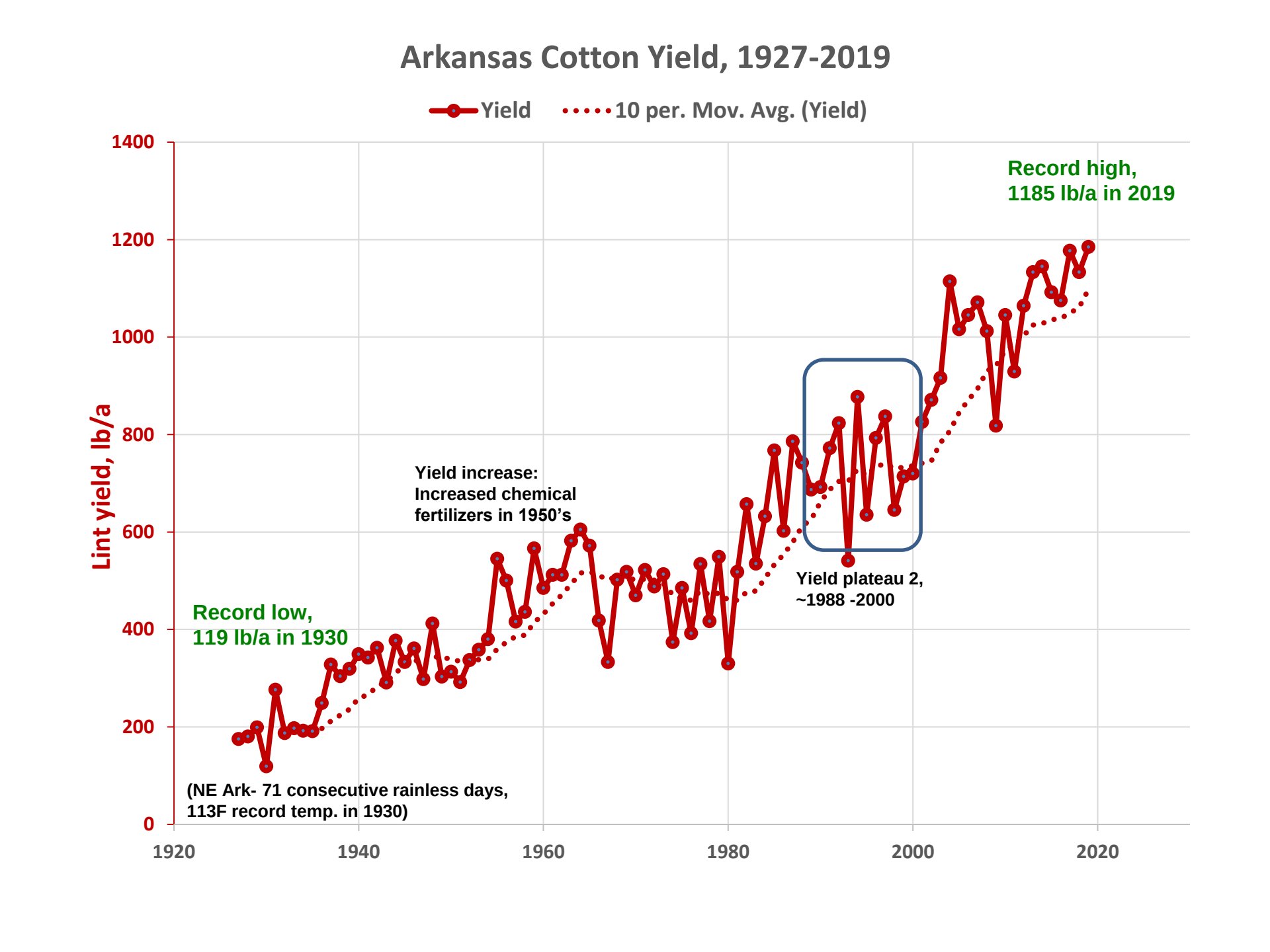
V. Cotton Yield Changes

Recovery from Yield Plateau 1:

A. Adopted short-season systems (shift to earlier maturing varieties)
B. Decreased plant populations (enabled by acid-delinted → improved seed quality and seed treatments for seedling disease control).
C. Increased in irrigation (particularly triggered by drought of 1980, and shift to short-season varieties).
D. Improved N management (petiole analysis).
E. Improved insect control (“killing bugs” to IPM).
F. Improved herbicide technology (improved herbicides, placement, rates).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V. Cotton Yield Changes

Yield Plateau 2, ~1988-2000, attributed to:

- Early plateau due to resistance of worms to insecticides – control failure - **TECHNOLOGY DRAG.**
- Late plateau due to transgenes introduced, breeding efforts to backcross transgenes in older genetics – **GENETIC DRAG**.

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V. Cotton Yield Changes

Recovery from Yield Plateau 2:

A. Eradicated the boll weevil.
B. Adopted Bt cotton for controlling boll/bud worm.
   Rapid shift to transgenic cotton varieties:
   Arkansas: 1995 = 0.3% transgenic; 2000 = 88.5% transgenic
C. Improved genetics/varieties (transgenes = catalyst for more breeding, not directly related to yield increase)
D. Decreased acreage.
E. Improved crop management (Pix, fertilizer rates, varieties, plant monitoring….)

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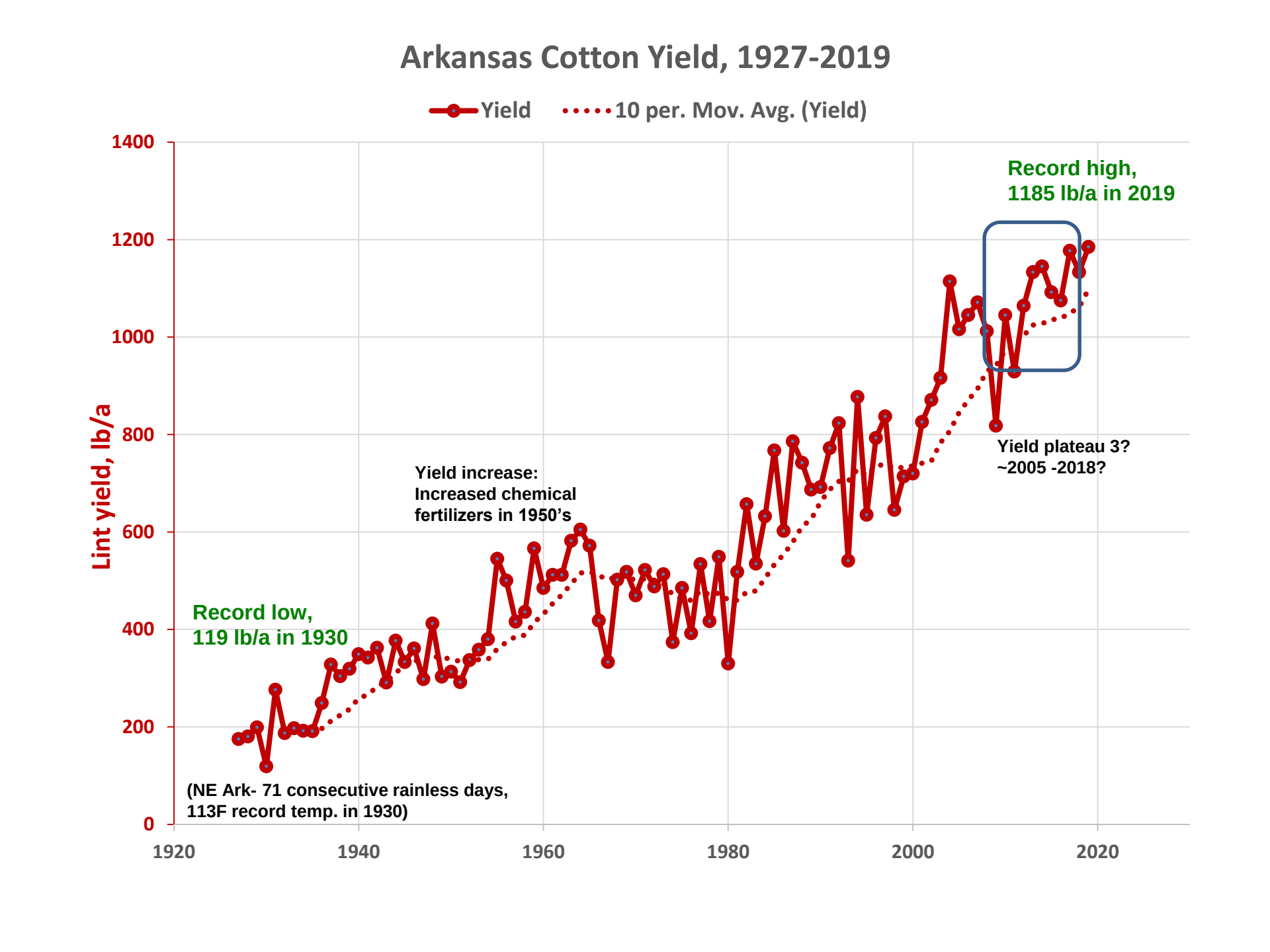
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Yield plateau 3?
~2005 -2018?
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V. Cotton Yield Changes

Yield Plateau 3?, ~2010 - 2018?

- **Shift in varieties** as new transgenes introduced, but new transgenes backcrossed into older genetics – **GENETIC DRAG.**
- Difficult to increase high yields, particularly with climate in mid-south region – **CLIMATIC LIMITS DRAG**.

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V. Cotton Yield Changes

Recovery from Yield Plateau 3:

A. Less genetic drag than experienced earlier released transgenes.

B. Physiological yield limits?

In the musical “Oklahoma”, cowboy Will Parker returned from Kansas City and sang: ”They've gone about as fur as they c'n go!”

C. New genetic, physiological and/or production system breakthroughs may be needed?

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VI. Cotton Fiber Quality Changes

Fiber quality at Keiser, Clk/JH, Marianna, & Rohwer:

1970: 14 varieties, 4 loc., Fiber tested by U.S. Testing Co., Memphis. TN
1986: 22 varieties, 4 loc. Fiber tested by USDA-AMS Classing Office, Little Rock, AR
2002: 37 varieties, 4 loc., Fiber tested by Starlab, Knoxville, TN
2018: 21 varieties, 4 loc. Fiber tested by LSU Fiber Lab, Baton Rouge, LA
2019: 50 varieties, 4 loc. Fiber tested by LSU Fiber Lab, Baton Rouge, LA

Trait		1970	1986	2002	2018	2019
Strength	Mean	88.0 psi	26.7	30.9	31.1	30.9
(g/tex)	High	94.5 psi	30.1	35.5	34.2	35.5
	Low	84.5 psi	23.4	27.6	28.5	26.5
Length	Mean	1.11	1.16	1.17	1.21	1.20
(in.)	High	1.14	1.21	1.25	1.29	1.28
	Low	1.09	1.09	1.11	1.14	1.13
Micronaire	Mean	4.7	4.5	4.3	4.5	4.2
	High	5.0	5.1	5.1	5.0	4.9
	Low	4.3	4.1	3.8	4.1	3.5

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VII. Varieties – 3 shifts:

1. **Full-season to short-season varieties (early 1980's).**
2. Conventional to transgenic varieties, ~1996
3. Old transgenes to new transgenes, ~2005, ~2017

% Arkansas cotton acreage in two (3) varieties

Year	ST 213	DP 16	DP 61	Total
1974	51	40	-	91
1975	59	35	-	94
1976	59	34	1	94
1977	60	28	5	93
1978	56	17	18	91
1979	52	10	23	85
1980	39	3	18	60
1981	29	1	15	45
1982	16	-	9	25
1983	6	-	5	11

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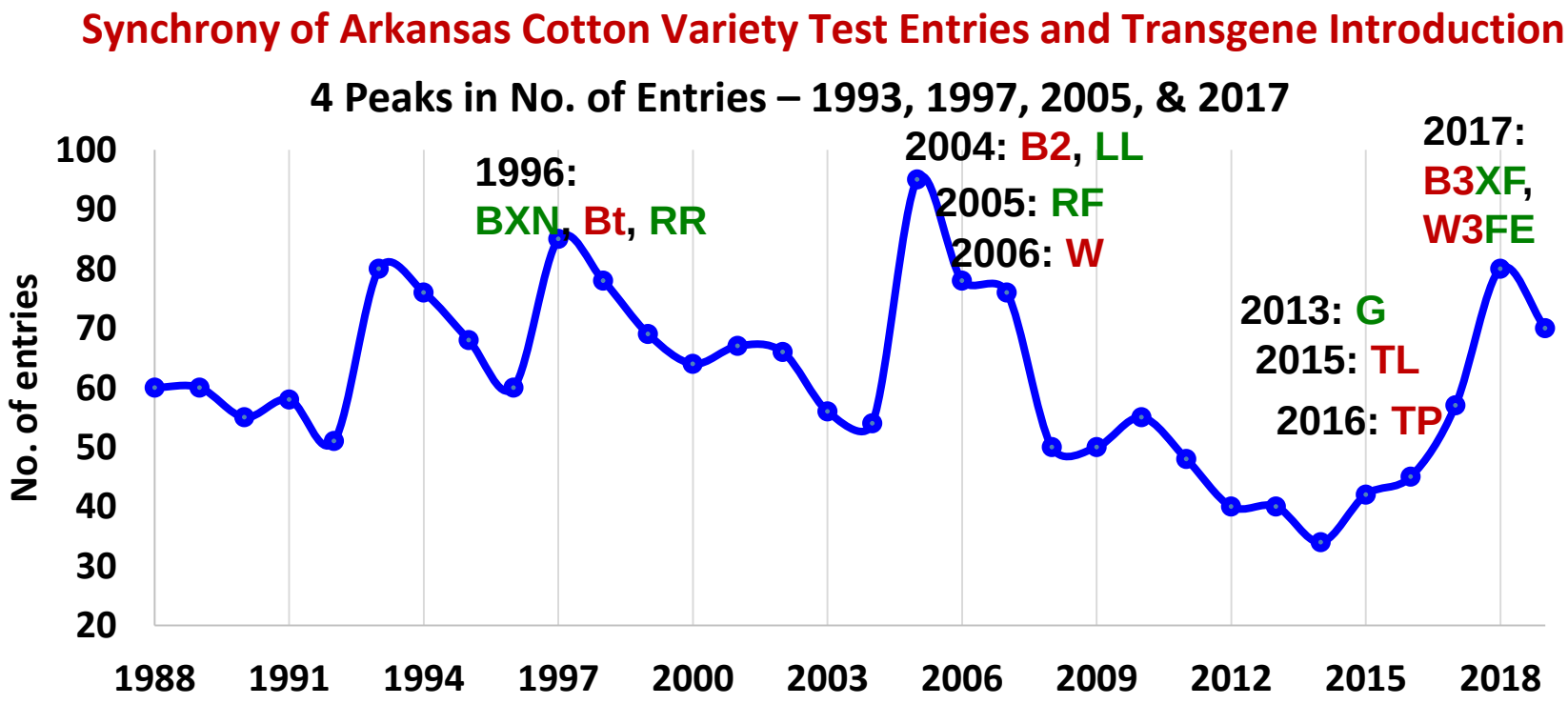
VII. Varieties – 3 shifts

1. Full-season to short-season varieties (releases began in 1978).
2. **Conventional to transgenic varieties, ~1996**
3. **Old transgenes to new transgenes, ~2005, ~2017**



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VII. Varieties – Production Without Transgenes?

Disease control:

- No transgenes for diseases

Insect control:

- Boll weevil - eradicated, no transgenes
- Worm control -
  - Bt genes: B, B2, B3, W, W3, TL, TP
    - Improved insecticides = BT genes?
    - Stacking vertical resistance genes?
- Plant bugs – no transgenes currently available

Weed control:

- Single: BXN, RR, RF, LL
- Stacked: XF (RF, LL & dicamba)
- Stacked: FE (RF, LL & 2,4D)

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VII. Varieties - Production Without Transgenes?

Yield:

No transgenes for increased yield

Fiber quality:

No transgenes for enhanced fiber quality

Production costs:

Lower seed costs without technology fees

Insect control costs?

Weed control costs?

Transgenes = "NASA" effect: Efforts and funding for NASA were catalyst for great strikes in computer & material sciences.

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Top 10 Cotton Production Changes, 1970-2020

1. Short-season varieties → earlier maturity, system approach
2. Improved seed quality →Plant-to-stand, optimum plant densities
3. Expanded irrigation → > yield, > yield stability, < crop disasters
4. Plant growth control → > uniform height, > boll retention
5. Boll weevil eradication → revolutionized insect management
6. Transgenes → improved (changed) insect and weed control
7. Boll openers → once-over harvest
8. Fiber length & strength → Increased & combined with high yield
9. Planting & harvest equipment → faster, > acreages
10. Lint yields → 2 ½ fold increase in Arkansas state averages,

We have come a long way. THE FUTURE?

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”… gone about as fur as they c'n go!” ??