When the Growing Season Ends Before the Corn Crop is Mature

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ILLINOIS

Crop Sciences

COLLEGE OF AGRICULTURAL, CONSUMER & ENVIRONMENTAL SCIENCES

From Cornell comes this:

SPEEDY RECOVERY ...

New corn performs better in cold

New strain of corn recovers much more quickly after a cold snap

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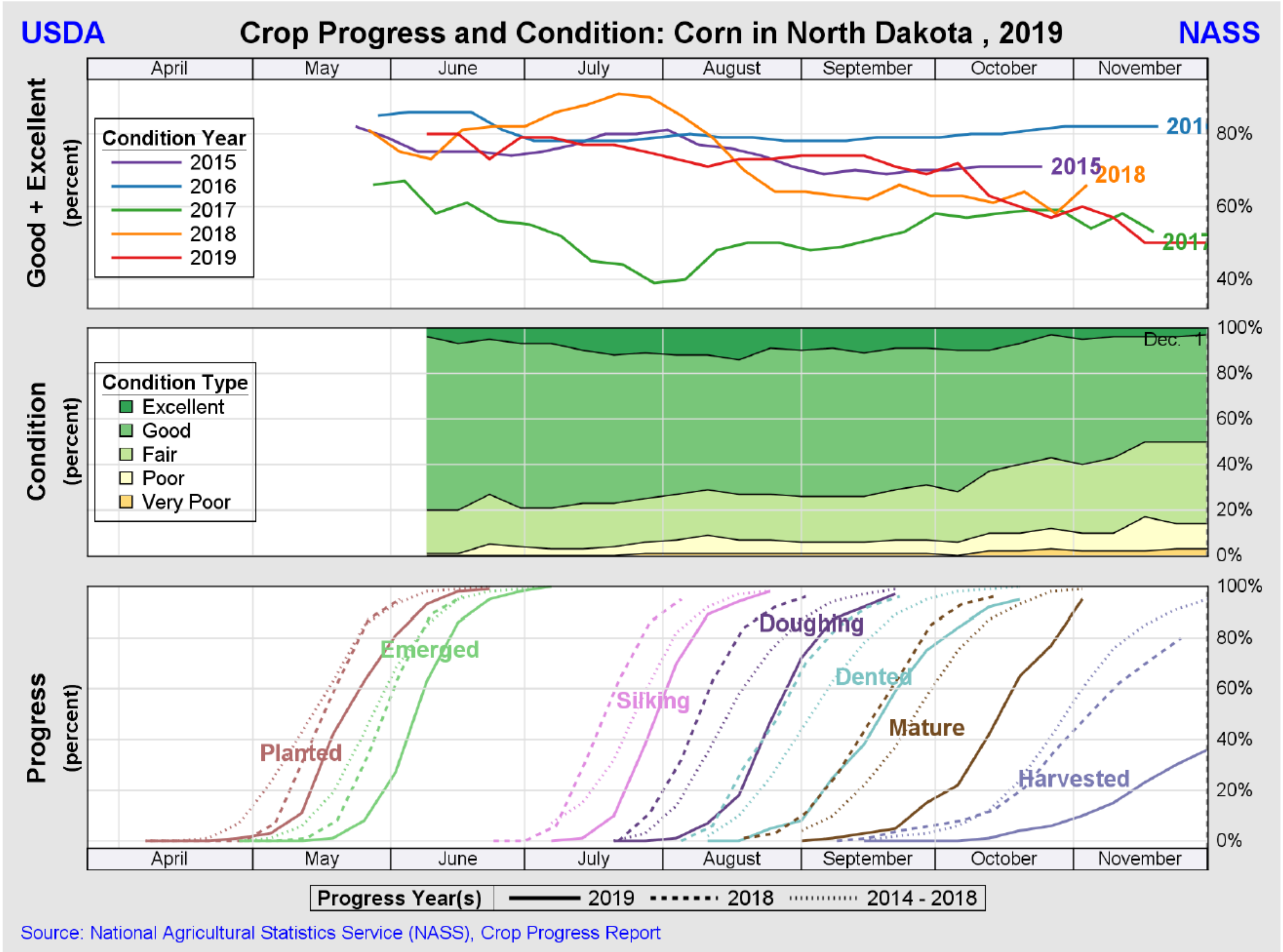
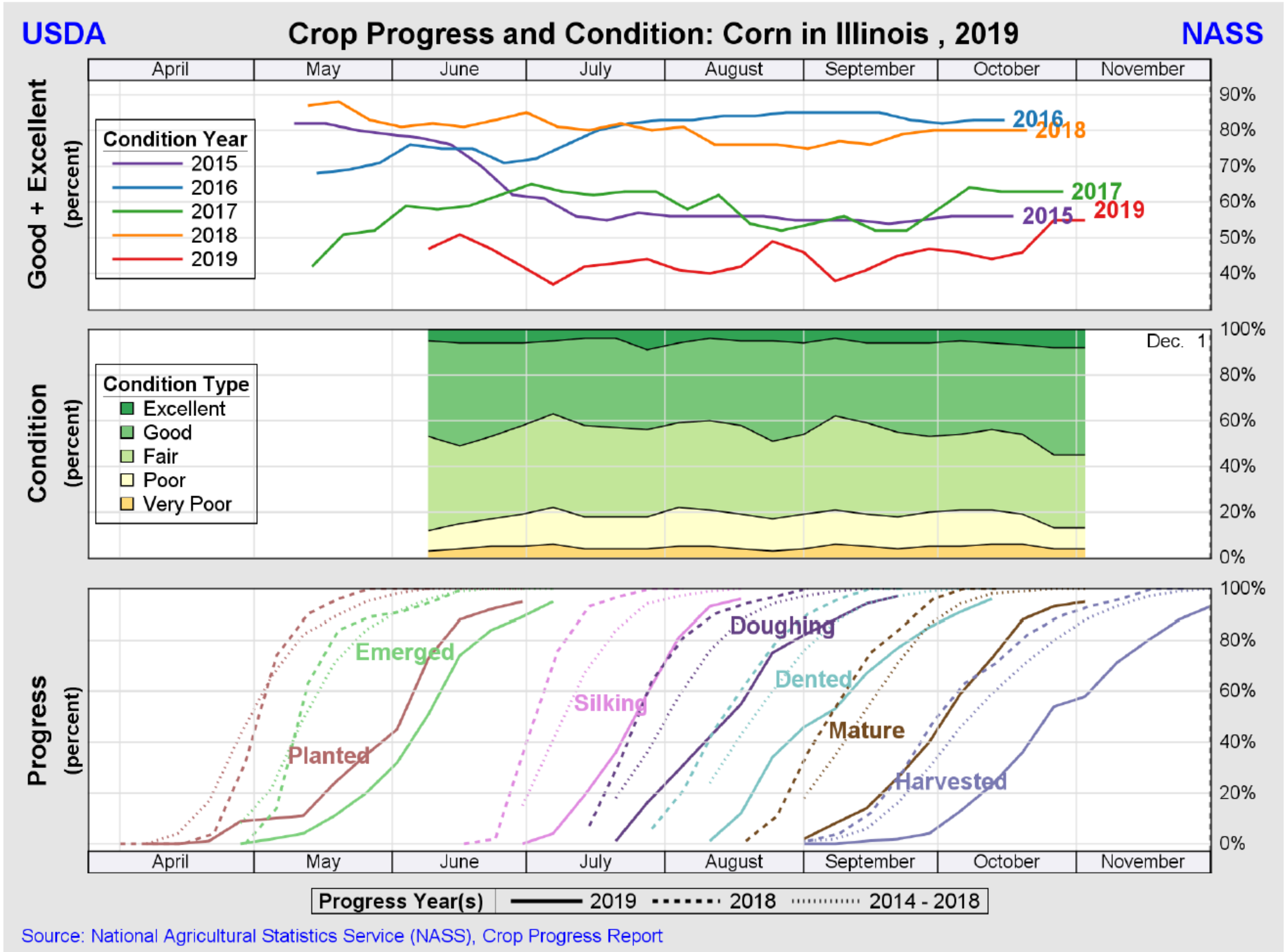
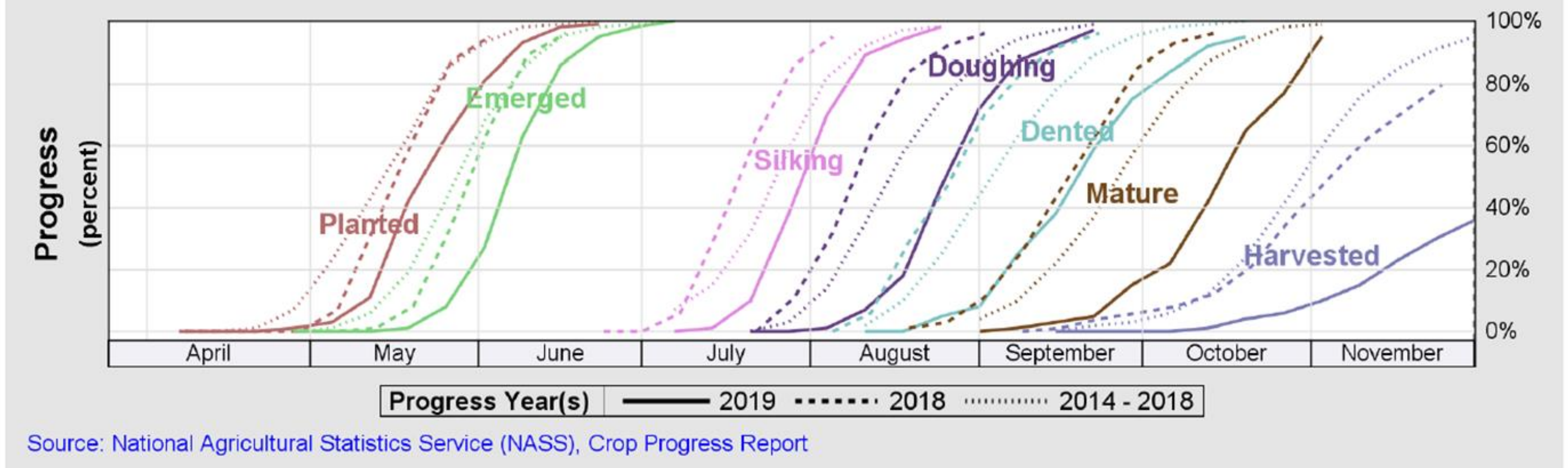


USDA
Crop Progress and Condition: Corn in North Dakota , 2019
NASS
April
May
June
July
August
September
October
November
Good + Excellent
(percent)
Condition Year
2015
2016
2017
2018
2019
80%
60%
40%
Condition
(percent)
Condition Type
Excellent
Good
Fair
Poor
Very Poor
Dec. 1
100%
80%
60%
40%
20%
0%
Progress
(percent)
Planted
Emerged
Silking
Doughing
Dented
Mature
Harvested
Progress Year(s)
2019
2018
2014 - 2018
Source: National Agricultural Statistics Service (NASS), Crop Progress Report

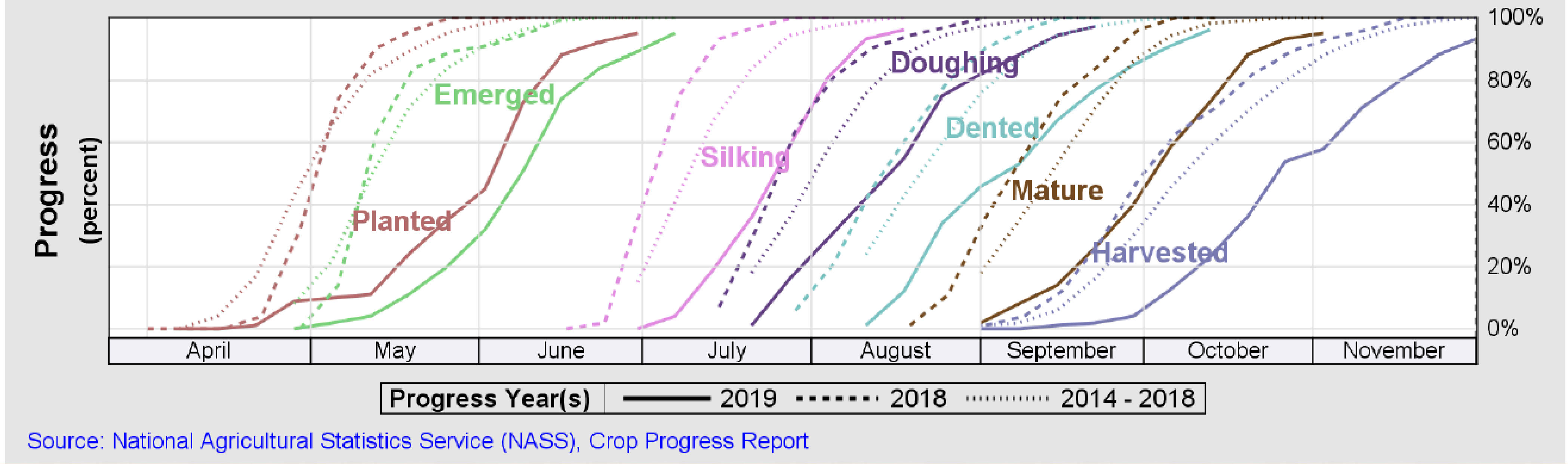


USDA
Crop Progress and Condition: Corn in Illinois , 2019
NASS
April May June July August September October November
Good + Excellent (percent)
Condition Year
2015
2016
2017
2018
2019
90% 80% 70% 60% 50% 40%
Condition (percent)
Condition Type
Excellent
Good
Fair
Poor
Very Poor
Dec. 1
100% 80% 60% 40% 20% 0%
Progress (percent)
Planted
Emerged
Silking
Doughing
Dented
Mature
Harvested
Progress Year(s) 2019 2018 2014 - 2018
Source: National Agricultural Statistics Service (NASS), Crop Progress Report

N Dakota



Illinois



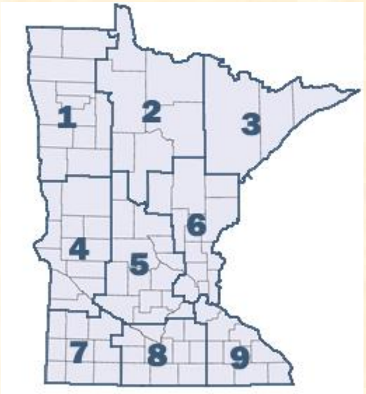
Climate Division Data by State between Two Dates
From Midwestern Regional Climate Center

Minnesota

5/ 1/2019 to 10/31/2019

Modified Growing Degree Days, Base 50 - Ceiling 86

cd	DD	Normal	Departure	Percent
1	2095	2294	-199	91
2	1950	2114	-164	92
3	1691	1850	-160	91
4	2455	2608	-153	94
5	2449	2629	-179	93
6	2297	2433	-136	94
7	2544	2708	-164	94
8	2602	2757	-155	94
9	2580	2701	-120	96
State	2235	2397	-163	93

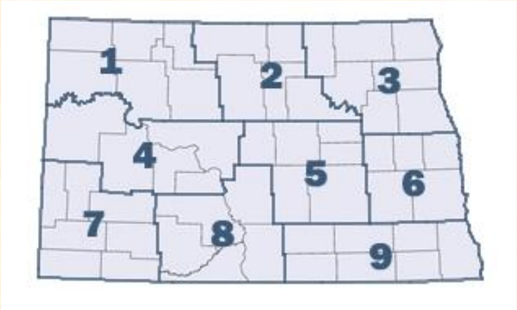


North Dakota

5/ 1/2019 to 10/31/2019

Modified Growing Degree Days, Base 50 - Ceiling 86

cd	DD	Normal	Departure	Percent
1	2078	2178	-100	95
2	1997	2208	-212	90
3	2022	2201	-179	92
4	2094	2325	-232	90
5	2133	2364	-231	90
6	2185	2414	-229	91
7	2120	2360	-240	90
8	2221	2475	-254	90
9	2279	2507	-228	91
State	2115	2323	-208	91



Climate Division Data by State between Two Dates
From Midwestern Regional Climate Center

Iowa

5/ 1/2019 to 10/31/2019

Modified Growing Degree Days, Base 50 - Ceiling 86

cd	DD	Normal	Departure	Percent
1	2734	2851	-117	96
2	2687	2838	-151	95
3	2718	2816	-98	97
4	2935	3088	-153	95
5	2915	2979	-65	98
6	3049	3065	-16	99
7	3203	3236	-33	99
8	3127	3178	-51	98
9	3221	3270	-48	99
State	2938	3023	-85	97

Illinois

5/ 1/2019 to 10/31/2019

Modified Growing Degree Days, Base 50 - Ceiling 86

cd	DD	Normal	Departure	Percent
1	3030	3002	29	101
2	2992	2970	22	101
3	3406	3327	79	102
4	3319	3259	60	102
5	3301	3209	92	103
6	3583	3466	117	103
7	3666	3491	174	105
8	3838	3632	206	106
9	3903	3673	230	106
State	3430	3322	108	103

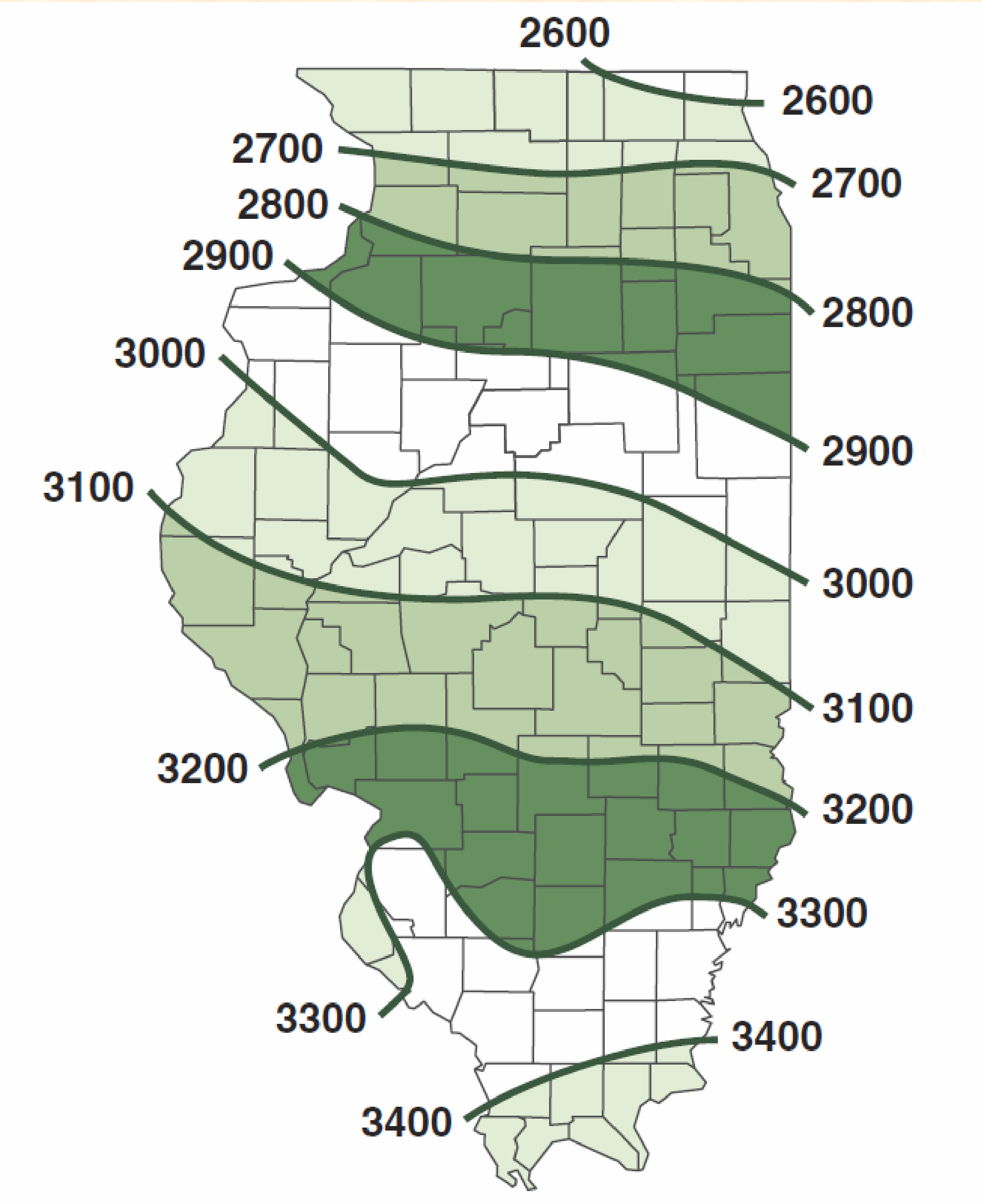
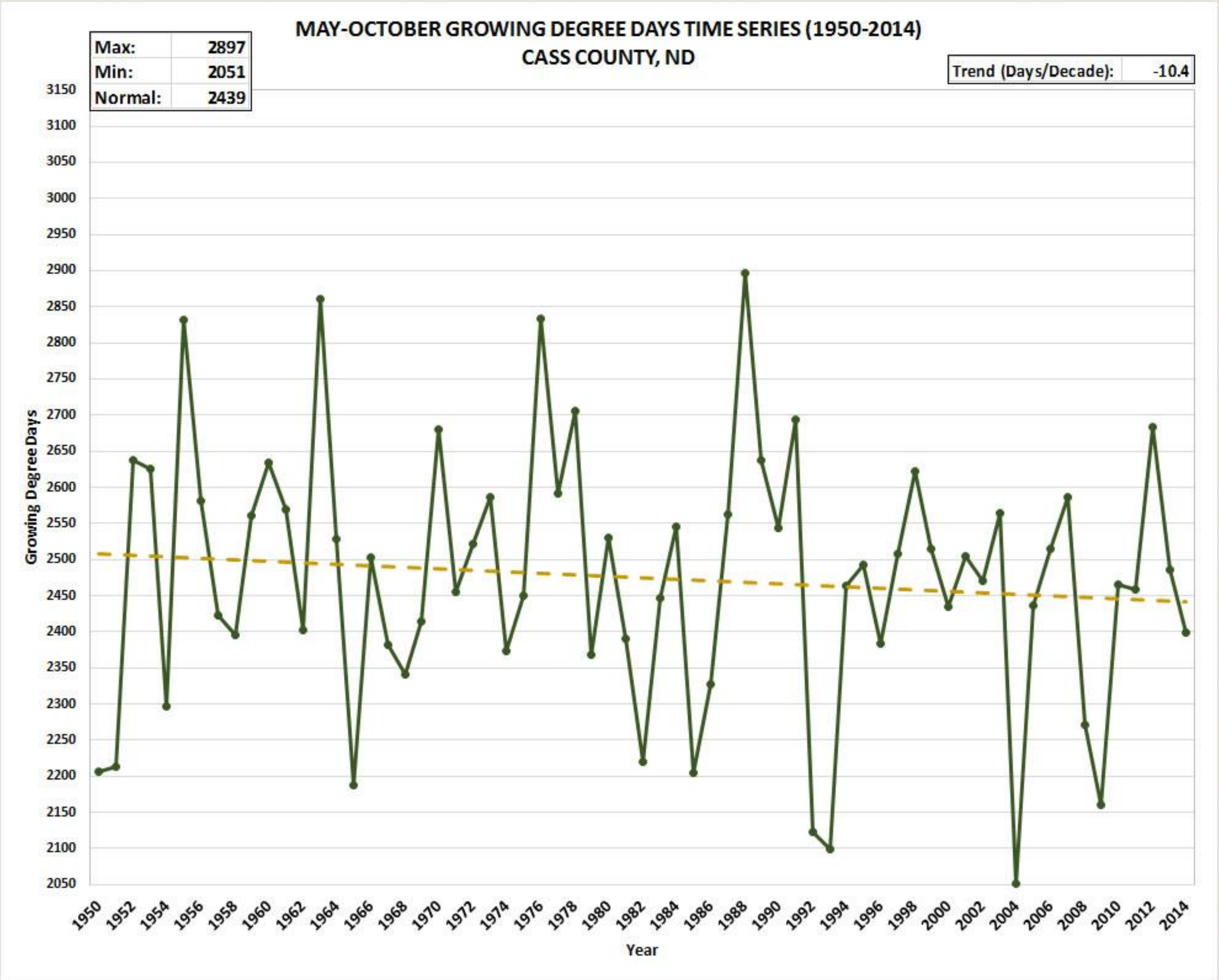
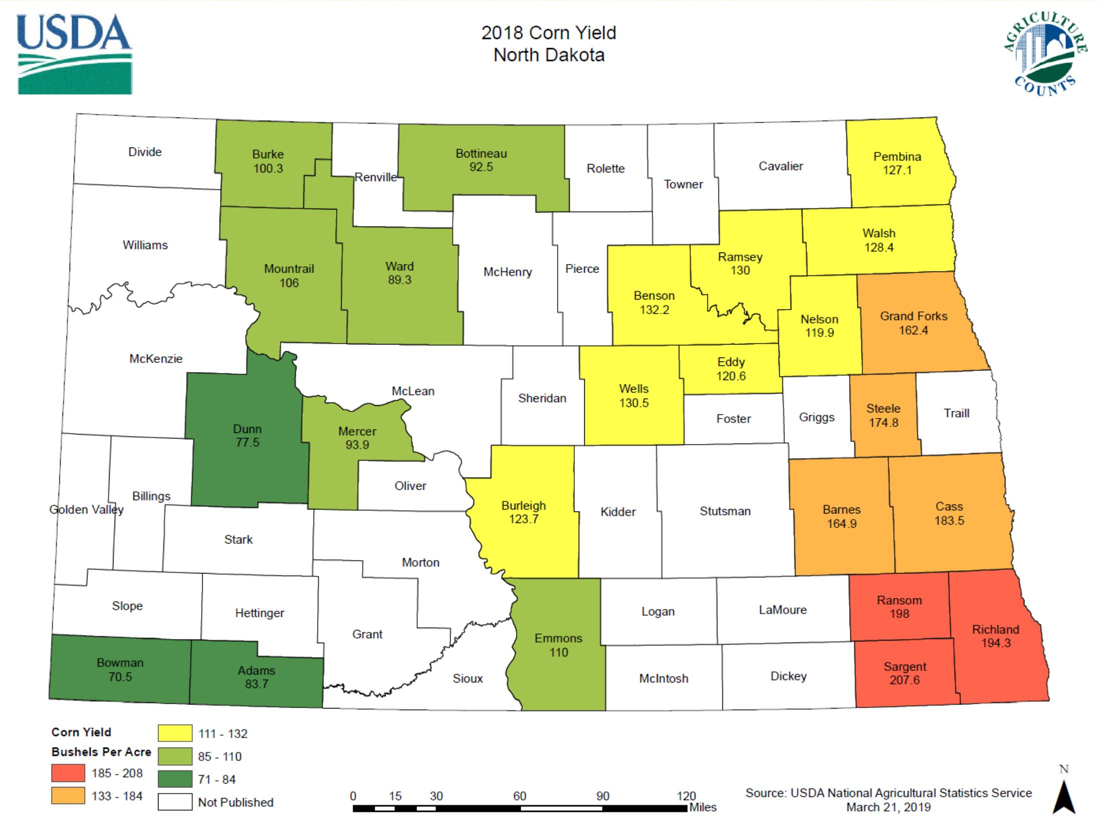
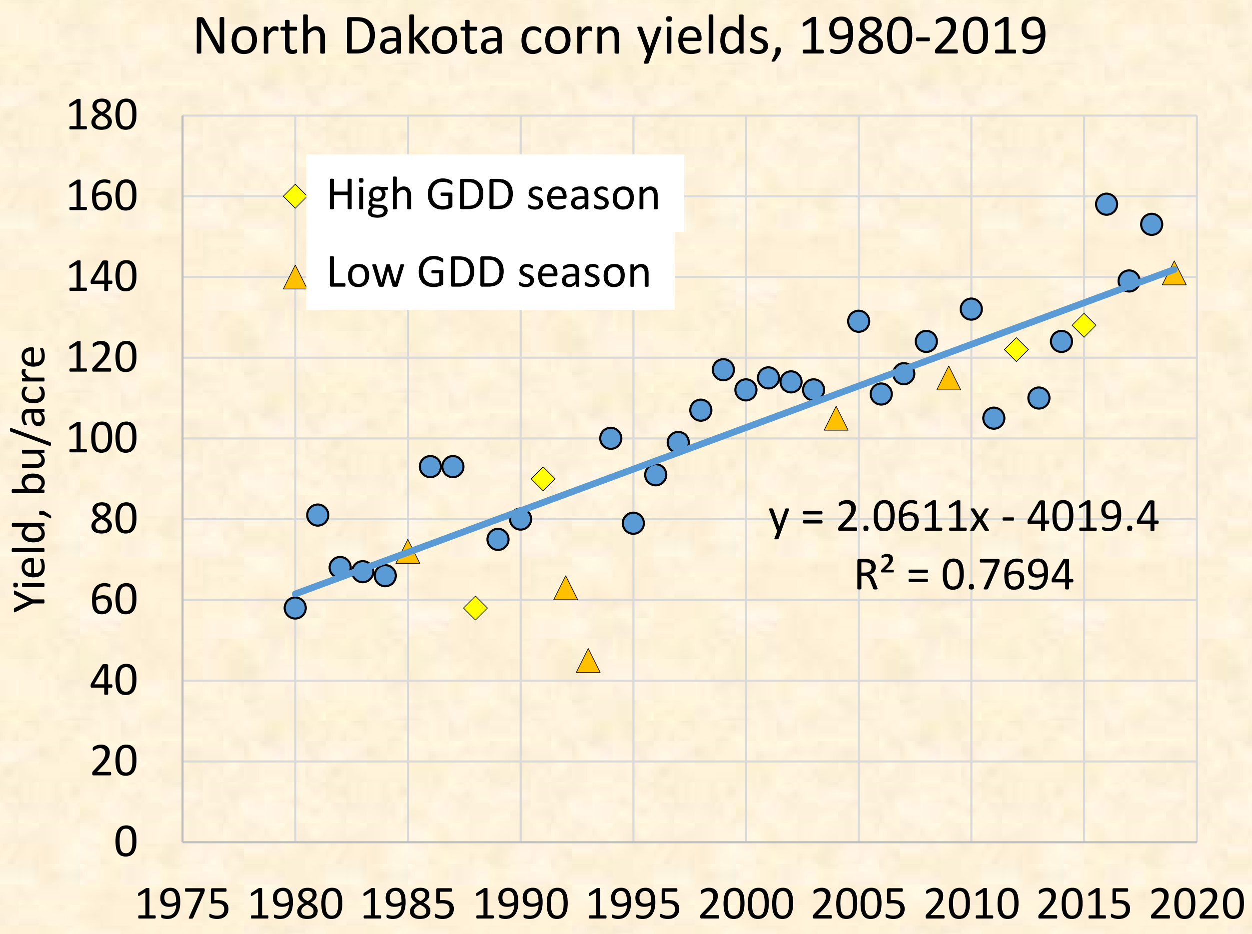
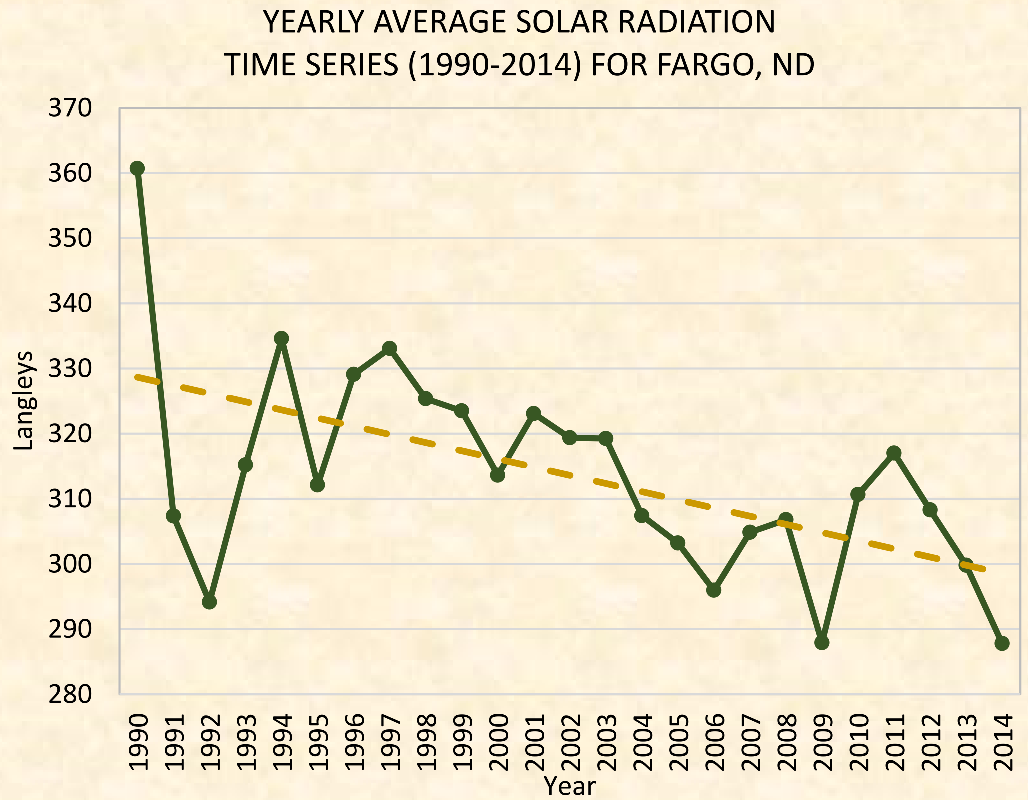


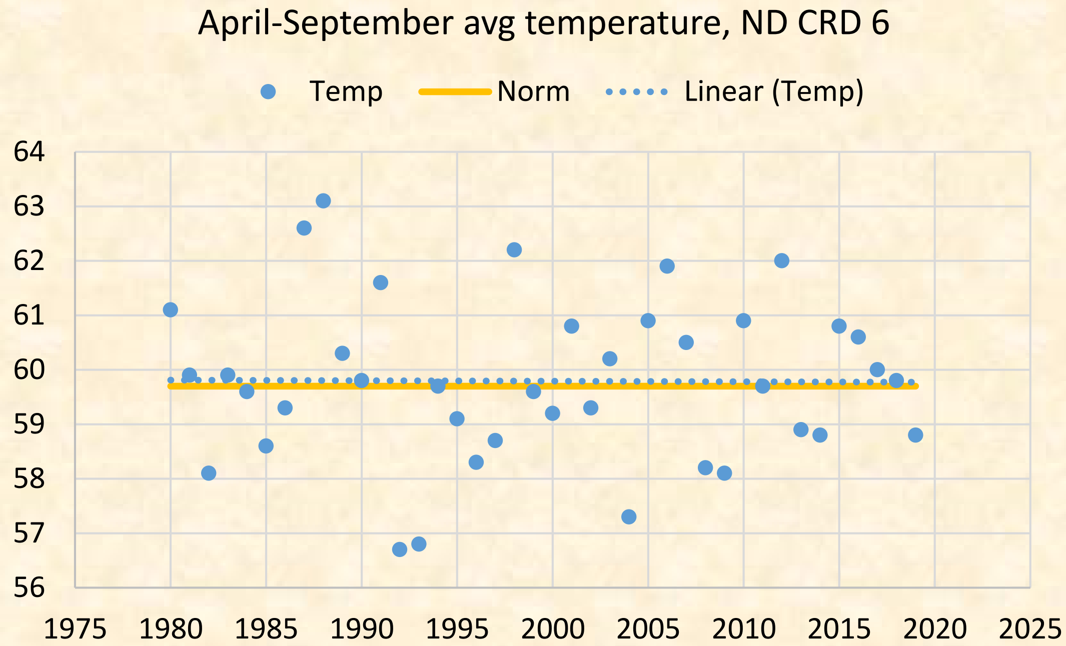
Figure 2.4. Average number of growing degree-days in Illinois, May 1 to September 30, based on 1971–2000 data. Map provided by the Illinois State Climatologist Office, Illinois State Water Survey.

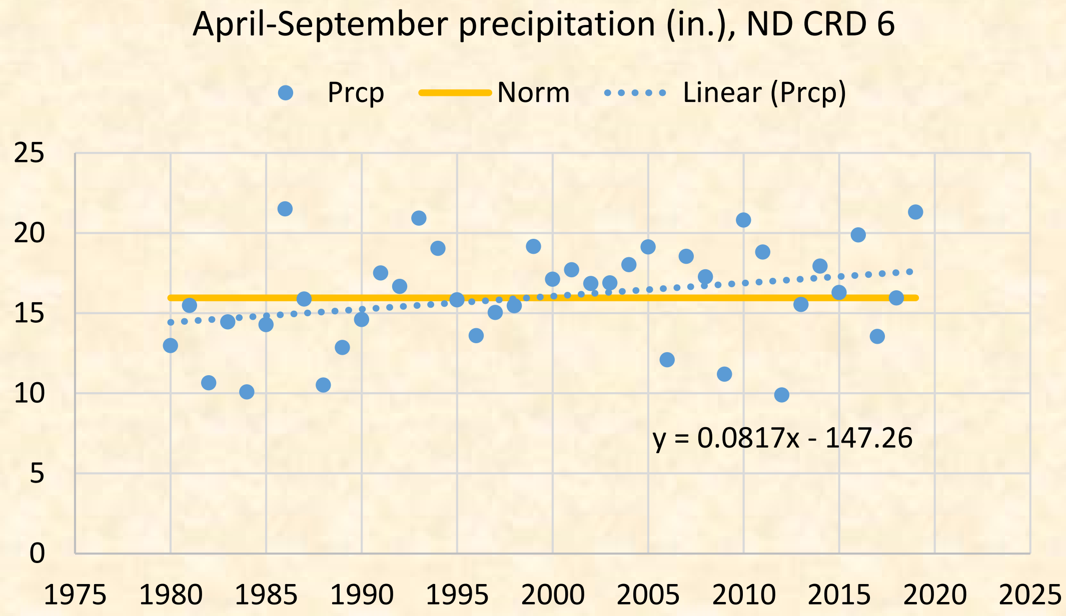



USDA
2018 Corn Yield
North Dakota
AGRICULTURE COUNTS
Divide
Burke 100.3
Renville
Bottineau 92.5
Rolette
Towner
Cavalier
Pembina 127.1
Williams
Mountrail 106
Ward 89.3
McHenry
Pierce
Benson 132.2
Ramsey 130
Walsh 128.4
Nelson 119.9
Grand Forks 162.4
McKenzie
McLean
Sheridan
Wells 130.5
Eddy 120.6
Foster
Griggs
Steele 174.8
Traill
Dunn 77.5
Mercer 93.9
Oliver
Burleigh 123.7
Kidder
Stutsman
Barnes 164.9
Cass 183.5
Golden Valley
Billings
Stark
Morton
Slope
Hettinger
Grant
Emmons 110
Logan
LaMoure
Ransom 198
Richland 194.3
Bowman 70.5
Adams 83.7
Sioux
McIntosh
Dickey
Sargent 207.6
Corn Yield
Bushels Per Acre
185 - 208
133 - 184
111 - 132
85 - 110
71 - 84
Not Published
0 15 30 60 90 120 Miles
Source: USDA National Agricultural Statistics Service
March 21, 2019
N


North Dakota corn yields, 1980-2019
Yield, bu/acre
0
20
40
60
80
100
120
140
160
180
1975 1980 1985 1990 1995 2000 2005 2010 2015 2020
High GDD season
Low GDD season
y = 2.0611x - 4019.4
R² = 0.7694







North Dakota weather and corn production:

- Growing season rainfall is increasing
- More precipitation means more clouds
- More clouds means less sunshine
- Growing season temperatures show little trend

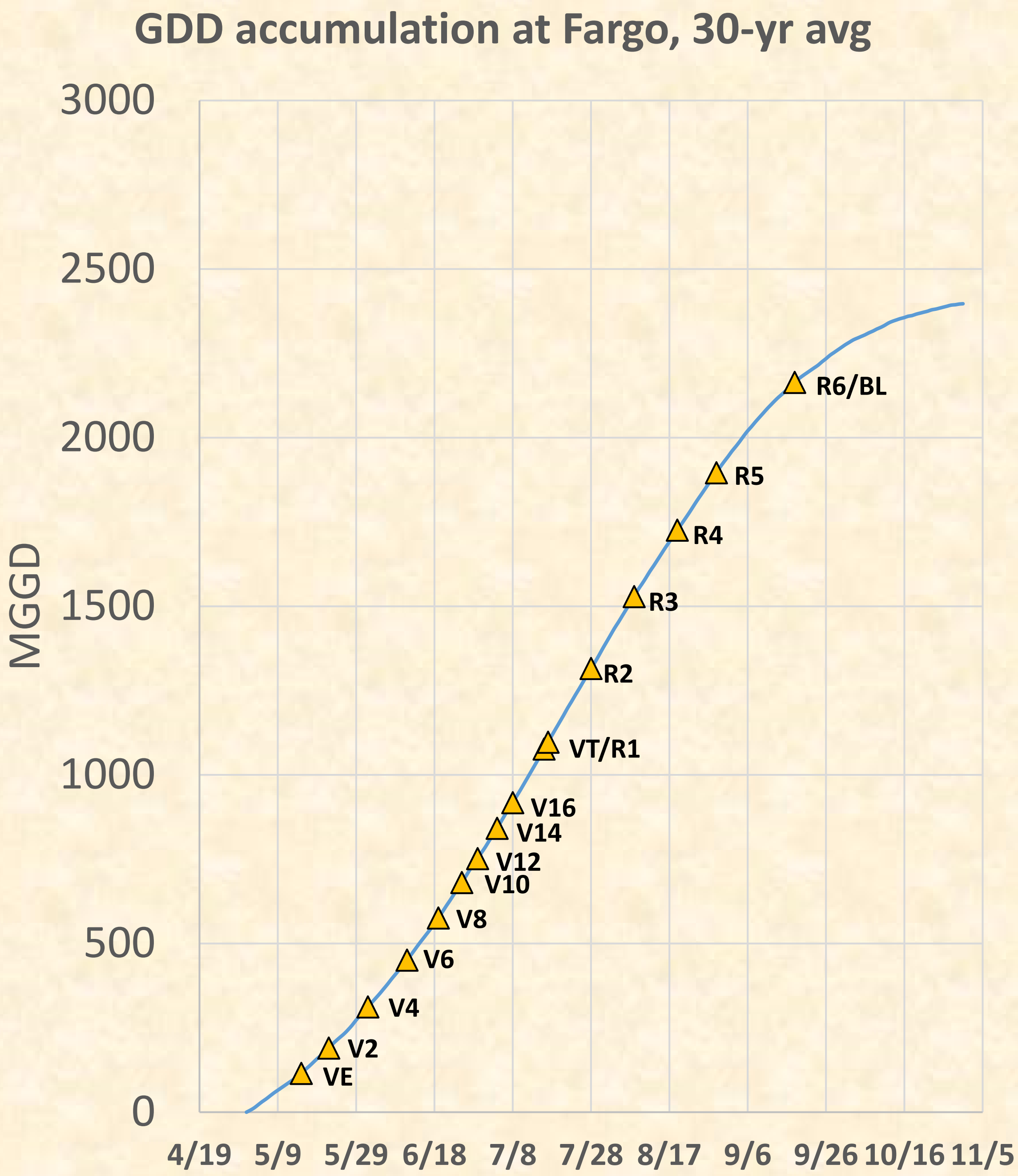
Corn Development and GDD

	Approx. no. from planting	
Stage	MGGD*	Days**
VE	115	10
V2	235	19
V4	395	29
V6	555	38
V8	715	46
V10	845	52
V12	945	56
V14	1045	61
V16	1140	65

	Approx. no. from planting	
Stage	MGGD*	Days**
VT (tassel)	1350	73
R1 (silk)	1400	75
R2 (blister)	1660	86
R3 (milk)	1925	96
R4 (dough)	2190	108
R5 (dent)	**2450?**	**119**
R6 (mature)	2700	132

* MGGD = modified growing degree days

**When planted May 1 in central Illinois, 111-day hybrid



GDD and development of a 90-day hybrid planted May 1 at Fargo, ND

	Approx. no. from planting	
Stage	MGGD	Days
VE	115	14
V2	188	21
V4	316	31
V6	444	41
V8	572	49
V10	676	55
V12	756	59
V14	836	64
V16	912	68
VT (tassel)	1090	76
R1 (silk)	1110	77
R2 (blister)	1328	88
R3 (milk)	1540	99
R4 (dough)	1725	110
R5 (dent)	**1900**	**120**
R6 (mature)	2160	140

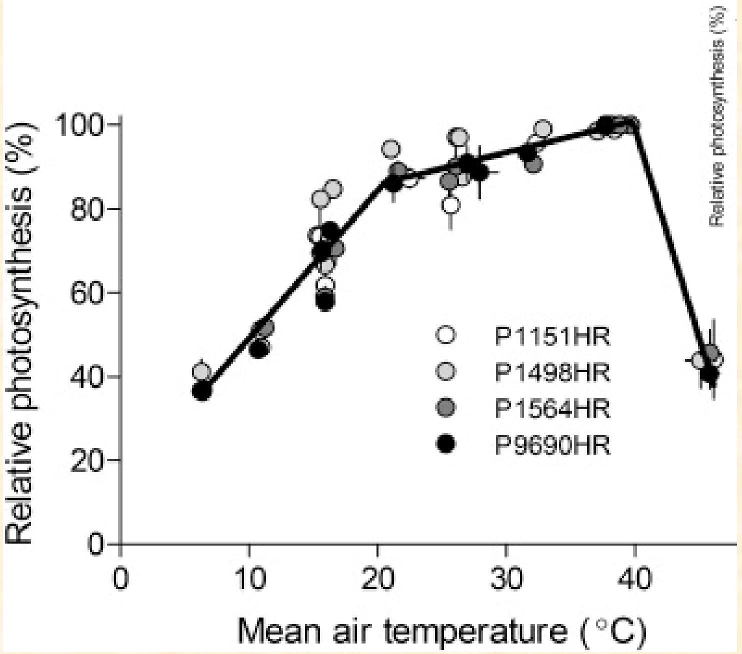
Comparing Illinois and North Dakota growing seasons

- ND is much cooler, with normal May-October GDD accumulations about 1,000 higher in IL, 3300 to 2300
  - The GDD cushion to allow for later planting or cooler temps is also much larger in IL: roughly 3100 – 2700 = 400 in IL; maybe 2,300 – 2100 = 200 in ND
  - GDD in ND is decreasing slowly
- Days are longer during the spring and summer in ND – May-Aug about 40 minutes longer per day in Fargo than in Peoria, or 80 hours total
- ND has less rain so more average daily solar radiation than IL
- So, a “good day” for photosynthesis is as good in ND as in IL, but between dryness and low temps, ND does not have as many such days

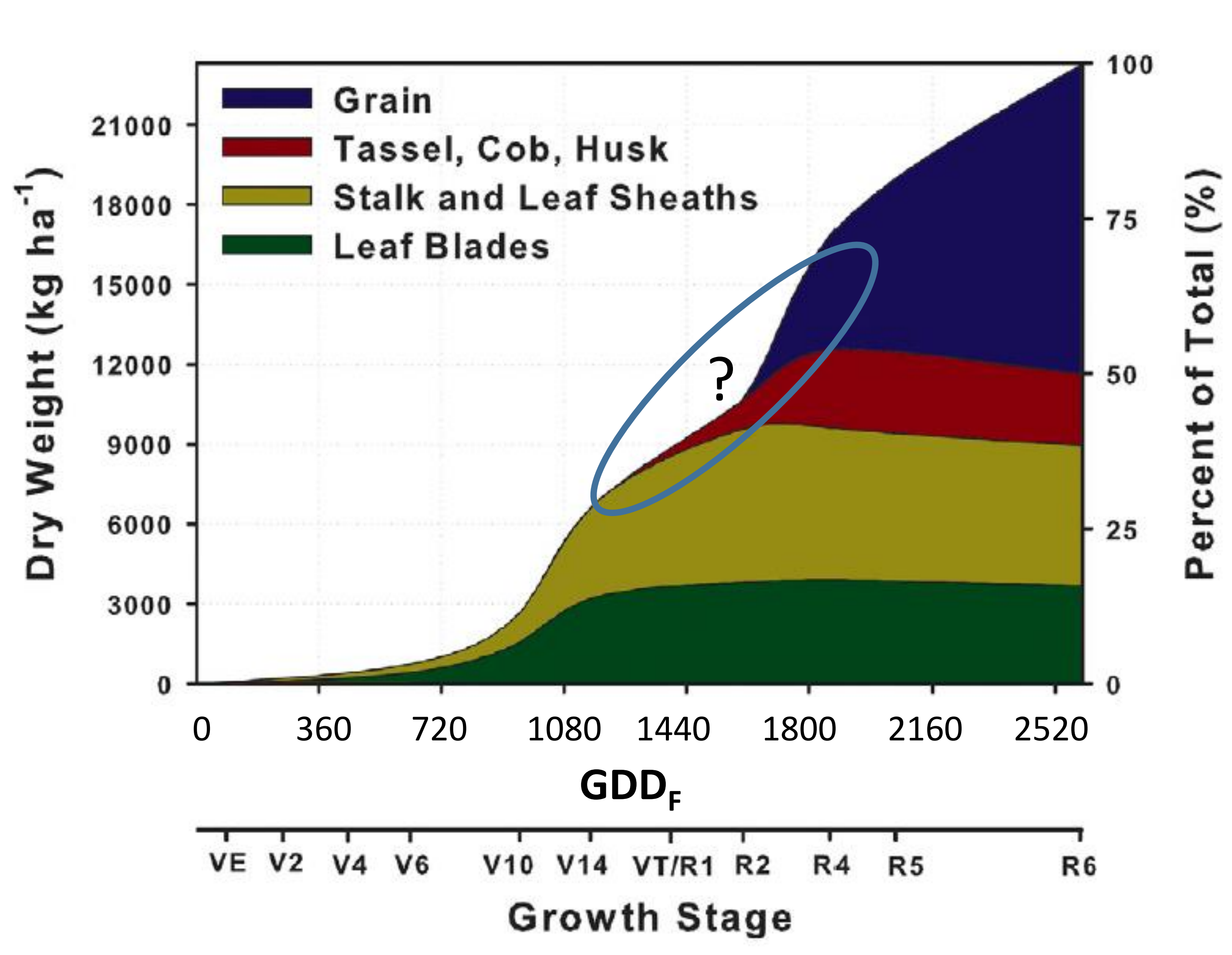
A note on growing degree days and corn development

- This system was arrived at by taking a lot of temperature and crop stage data; it's not "theoretical"
- The "modified" GDD in the US:
  - 50° as the base temp implies no growth or Ps below 50
  - 86° as the high temperature "cutoff" implies that growth/Ps rates above that are the same as at 86
- Corn photosynthesis increases with temperature, up to maybe 100°; the cutoff is because factors like drought (and maybe night temps) often restrict plant development in the field
- But it's altogether possible that the crop grows faster at 65/98 than at 65/88, even though MGGD are the same
  - Under long days in ND, could the amount of growth/day be higher at the same temps and sunlight as it is in Illinois?

Have you seen pre-tassel corn "sit still" when under drought stress and accumulate GDD without adding new leaves?



From Bender et al., Agron J. (Illinois)

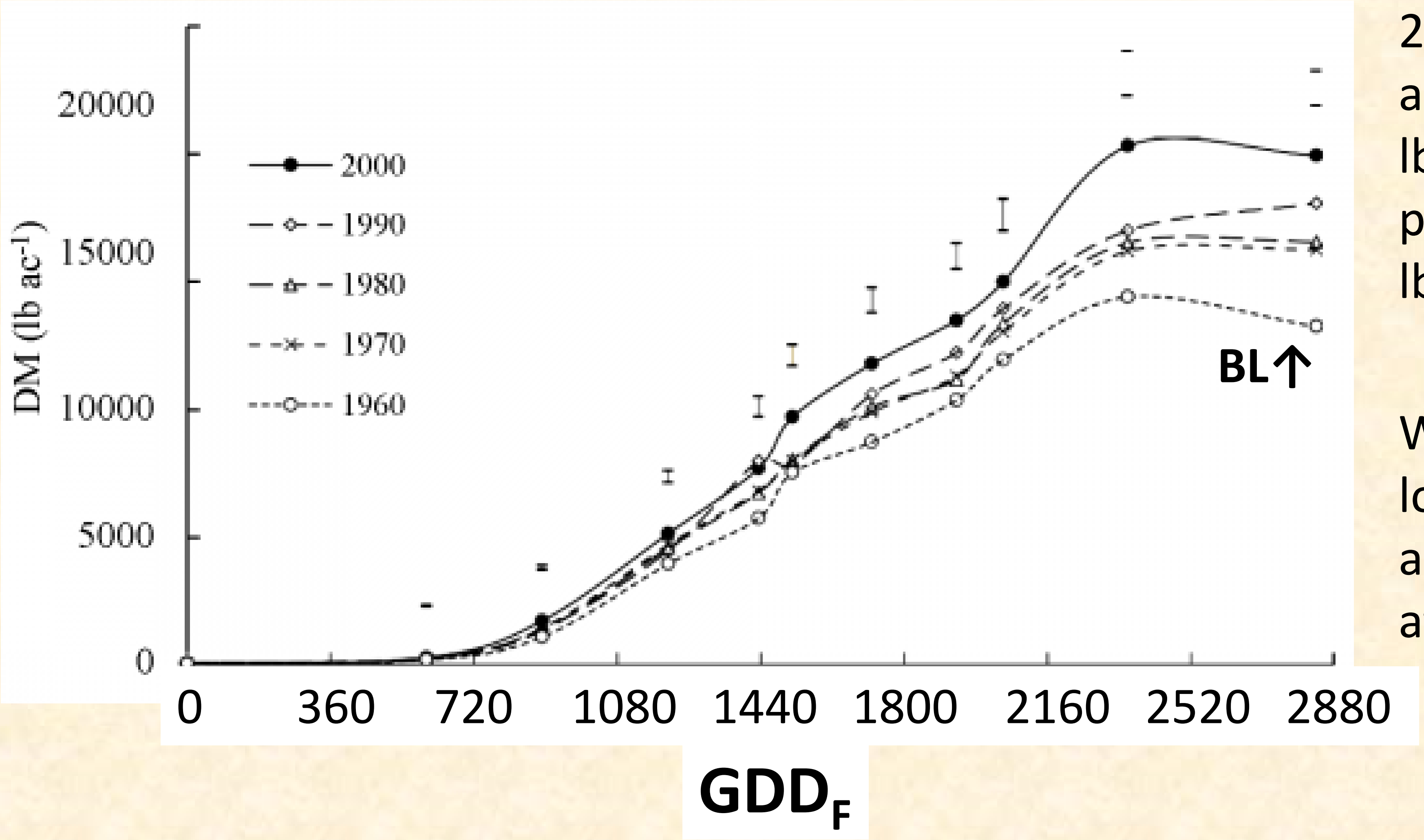


? The “dent” in dry weight accumulation has not been found in most studies

And, having the rate linear between R5 and R6 is not the way most have reported this

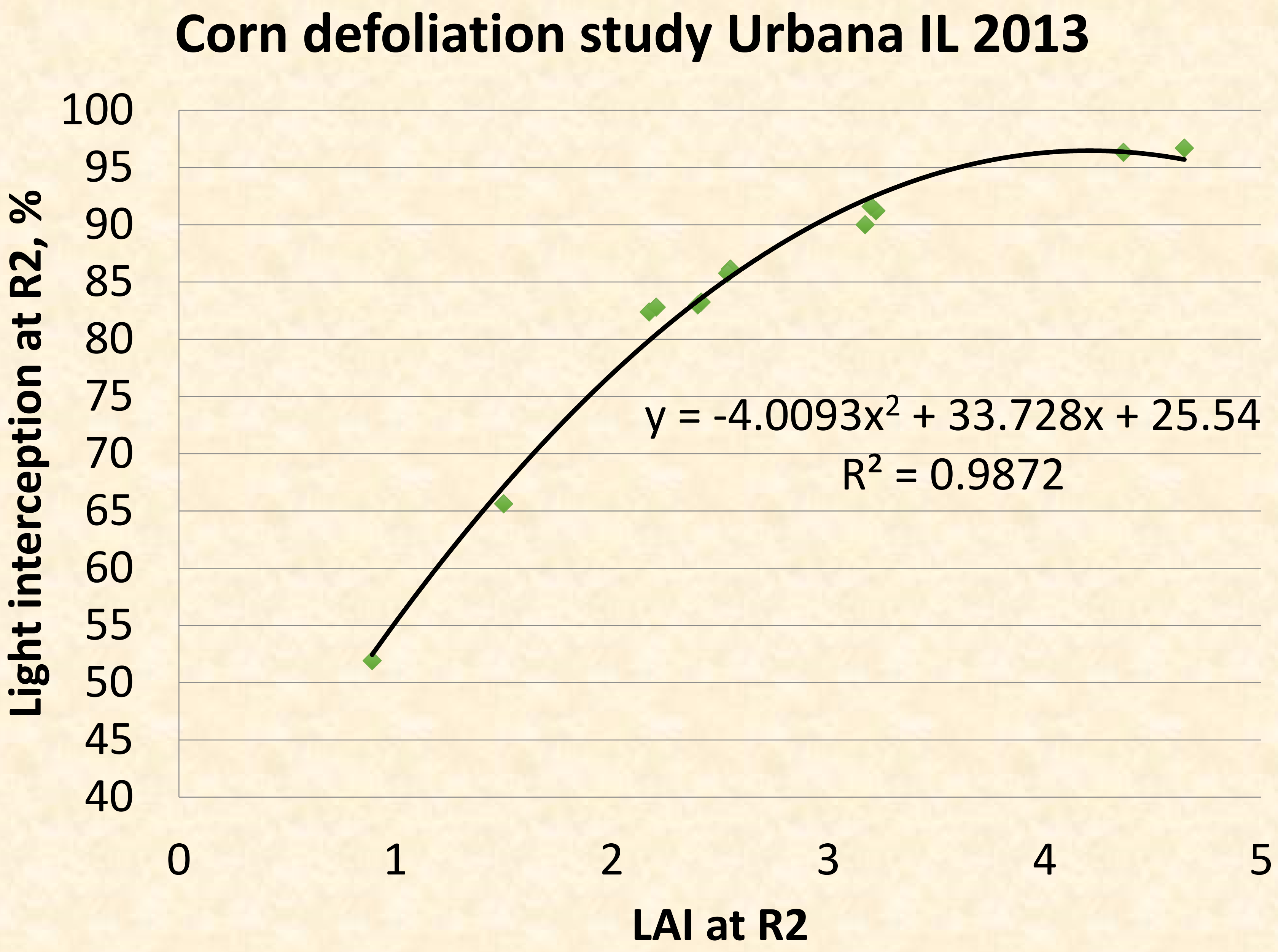
From Elmore and others, Iowa State U.

-Compare different "era" hybrids; 2 hybrids per era x 2 years



From V6 to R5, the 2000-era hybrids accumulated about 20 lb dry matter per acre per GDD, or about 500 lb per (warm) day.

Why do you think it looks like DM accumulation stopped at about R5?


Corn defoliation study Urbana IL 2013
Light interception at R2, %
100
95
90
85
80
75
70
65
60
55
50
45
40
0
1
2
3
4
5
LAI at R2
y = -4.0093x2 + 33.728x + 25.54
R² = 0.9872

Corn defoliation study Urbana IL 2013

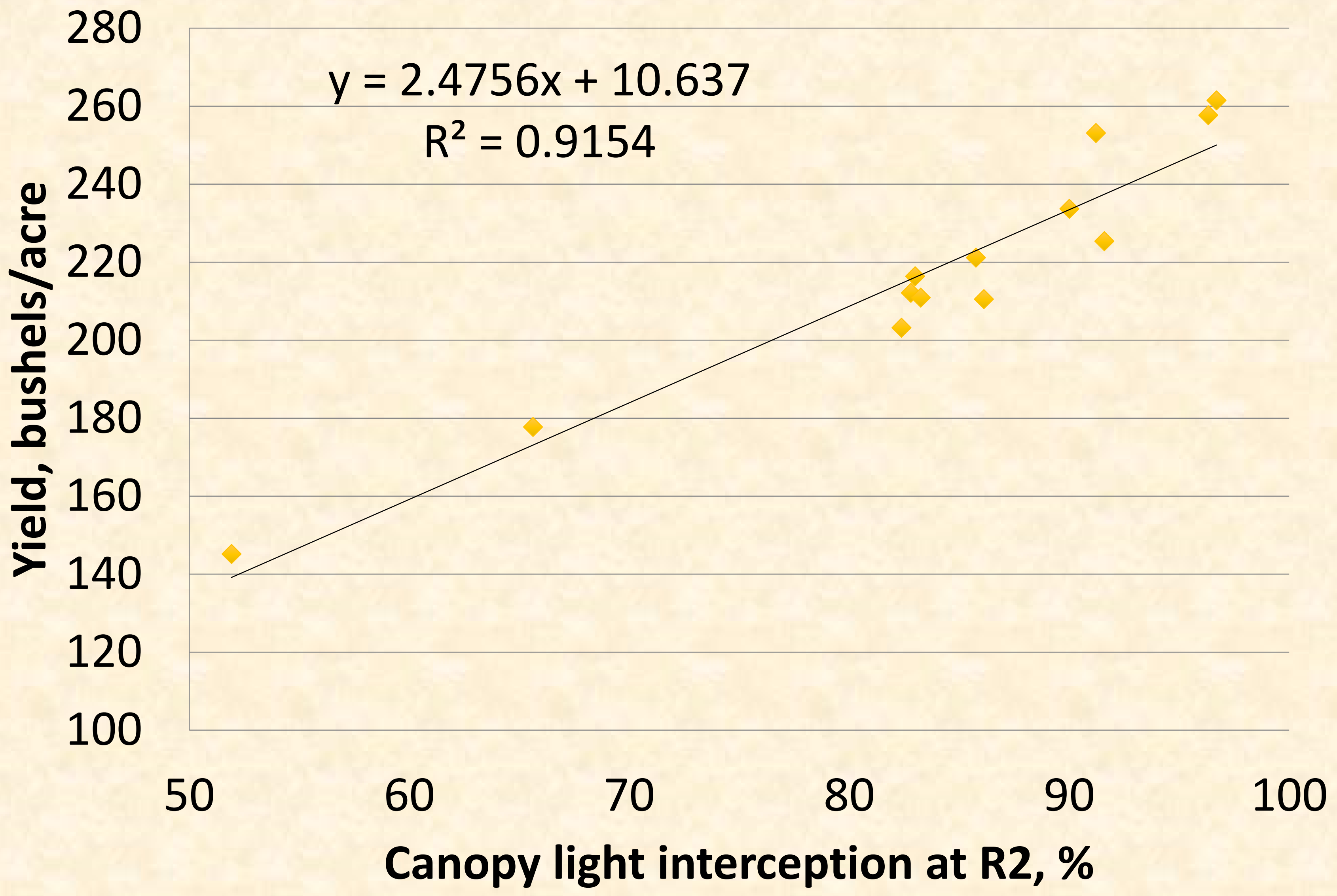


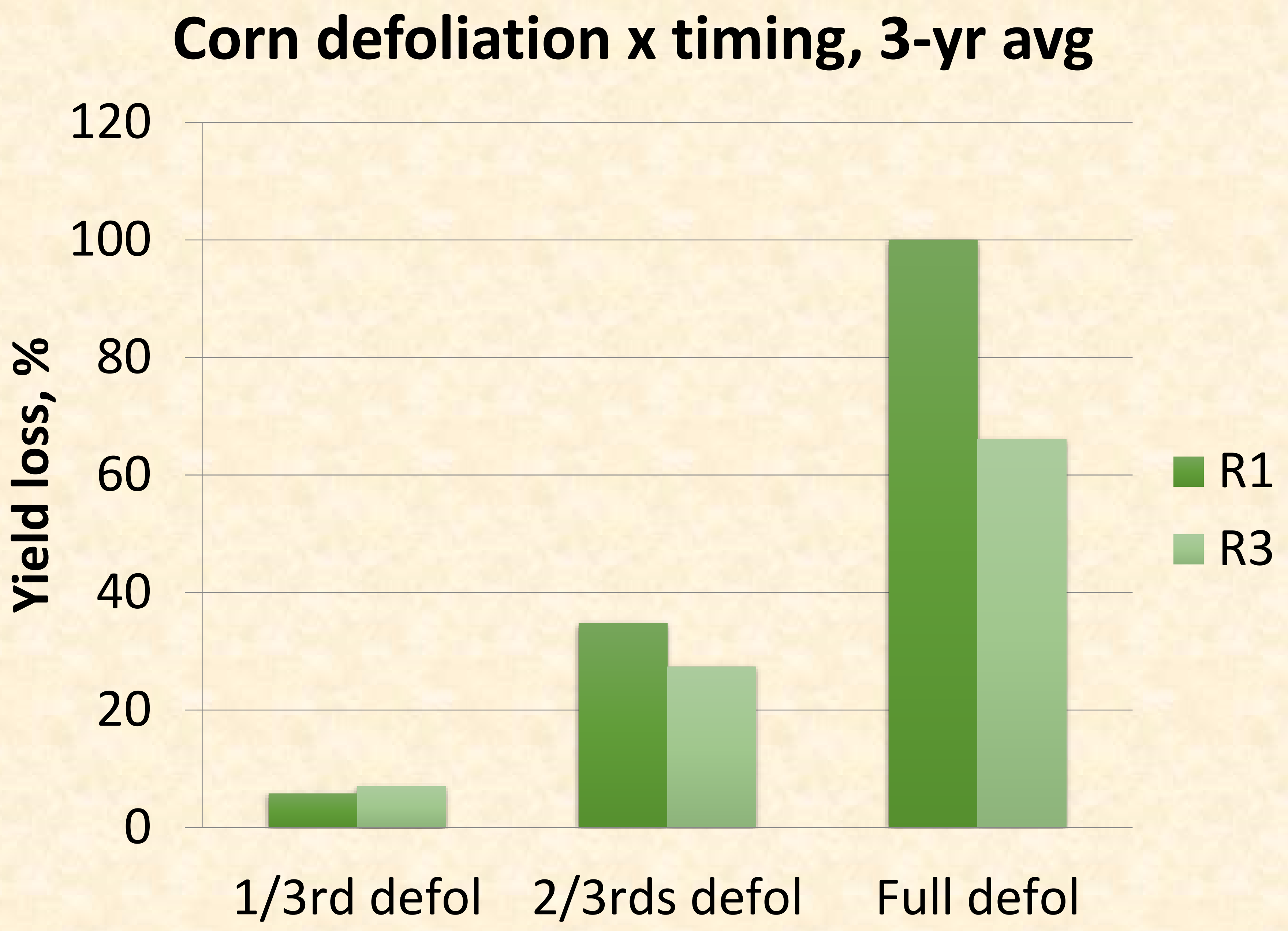
Table 1. Estimated percent corn yield loss due to defoliation occurring at various stages of growth.

Stage of growth	Percent leaf area destroyed				
	20	40	60	80	100
Tassel	7	21	42	68	100
Silked	7	20	39	65	97
Blister	5	16	30	50	73
Milk	3	12	24	41	59
Dough	2	8	17	29	41
Dent	0	4	10	17	23
Black layer	0	0	0	0	0

derived from Vorst (1990)

Recent work has shown that these losses are likely similar for current hybrids

When during each stage loss occurs is important, though


Corn defoliation x timing, 3-yr avg
Yield loss, %
0
20
40
60
80
100
120
1/3rd defol
2/3rds defol
Full defol
R1
R3

R5 Stage: Dent

R5 Stage: Dent

- All or most kernels show some dent in the crown
- Cob is mature color (red, white, pink)
- Kernels ~60% moisture: moisture loss accelerates
- Sugars pour into the kernels, where they are converted into starch, and the starch begins to "pack" into endosperm cells and to lose water
- A starch line (packed starch at the crown, less and "looser" starch below) appears early in R5, starting at the top of the kernel and proceeding down to the cob

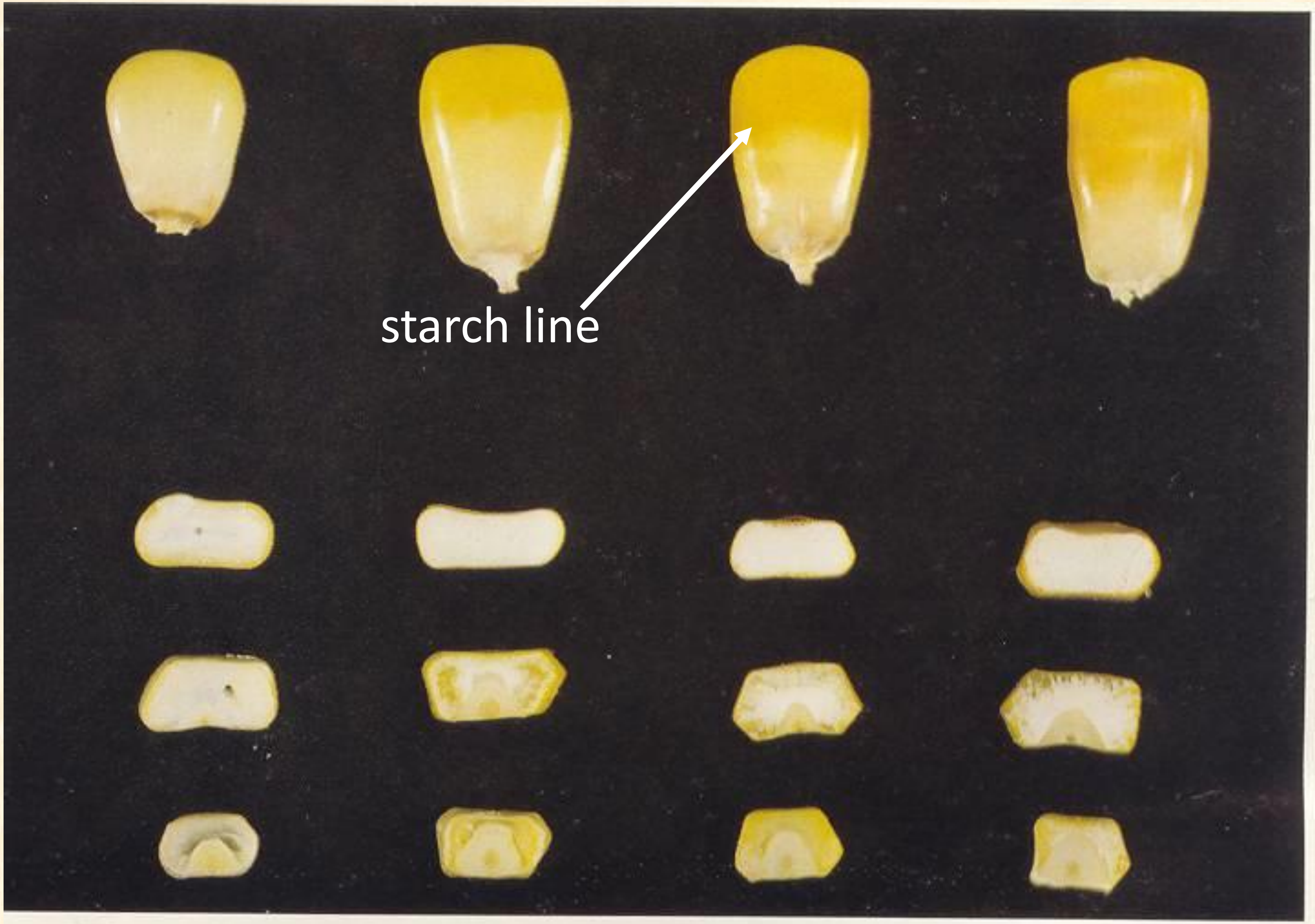
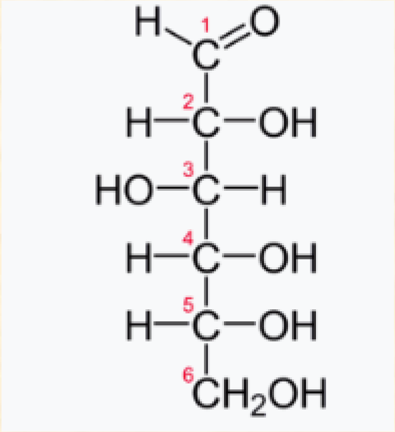


Fig. 49. Kernel starch line development.

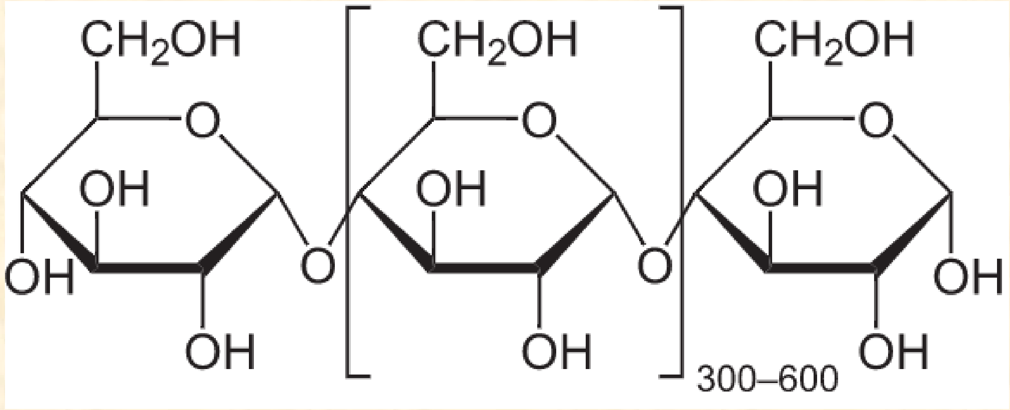
The “main event” during R5

- More than half of kernel dry weight is deposited during R5
- Sugars produced in the leaves and moving out of the stalk are “pulled into” the kernels, where they are converted into starch
- This conversion to starch is critically important:
    - It keeps the (sugars) in the kernel
    - And taking sugar out of solution lowers the osmotic strength of the cell, creating a “pull” for more sugars to come in
- A starch line appears at R5, starting at the top of the kernel and proceeding down to the cob; accumulated starch is hard above the starch line and soft below it

Hundreds of glucose molecules



Starch synthase enzyme



This is amylose (unbranched)

Amylopectin (branched) is another form

Breaking down R5:

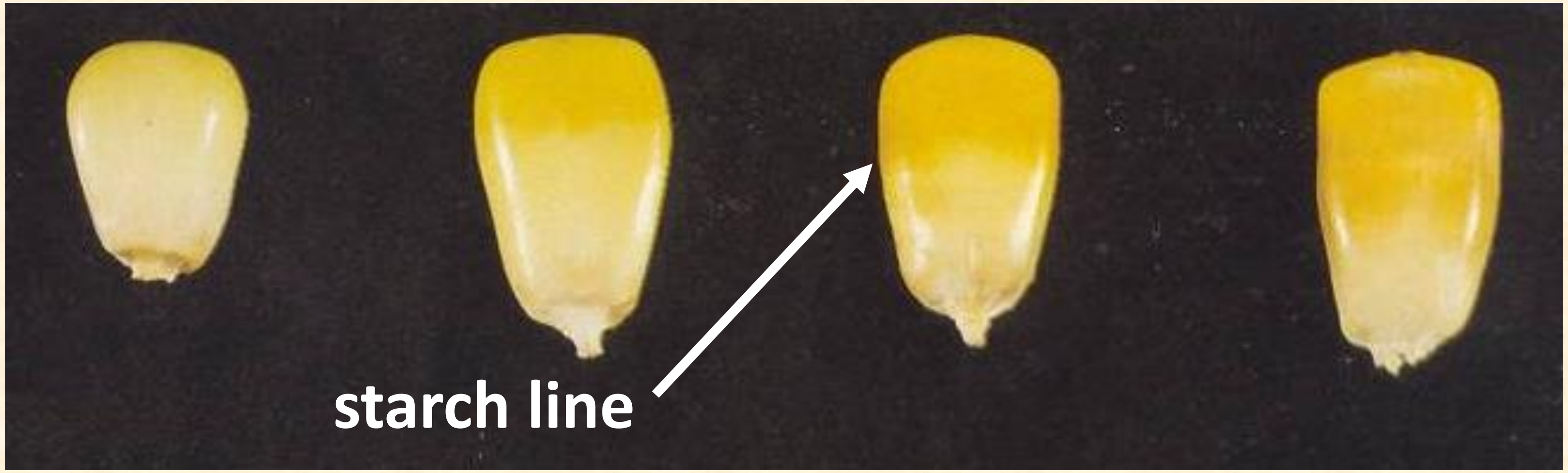
- Iowa State Guide PMR 1009 (2009)

R stage	% moisture	Dry wt*	For stage: GDD accum	For stage: Days
R5.0	60%	45%	75	3
R5.25	52%	65%	120	6
R5.5	40%	90%	175	10
R5.75	37%	97%	205	14
R6.0	35%	100%		
Total for R5		55%	575	33

* Total of final kernel DW at the start of stage indicated.

Things that can go wrong during R5

- The supply of sugars in the plant starts to run out, caused by:
  - Slow photosynthesis due to
    - Too cool
    - Too cloudy
    - Leaf disease or loss to hail or frost
    - Lack of water in the soil
  - Interrupted movement of sugars from leaves to the stalk or stalk to the cob then to the kernels
    - Stalk breakage (near the ear is worse)
    - Stalk diseases
    - Not enough water in the plant for transport through the phloem
- The demand by kernels is low or diminishes, caused by:
  - Lack of adequate kernel numbers – “sink” too small
  - Slow conversion of sugars to starch (rare, but lack of P?)
  - Kernel diseases



85%	**65%**	**55%**	**40%**
“milk”	**milk**	**milk**	**milk**

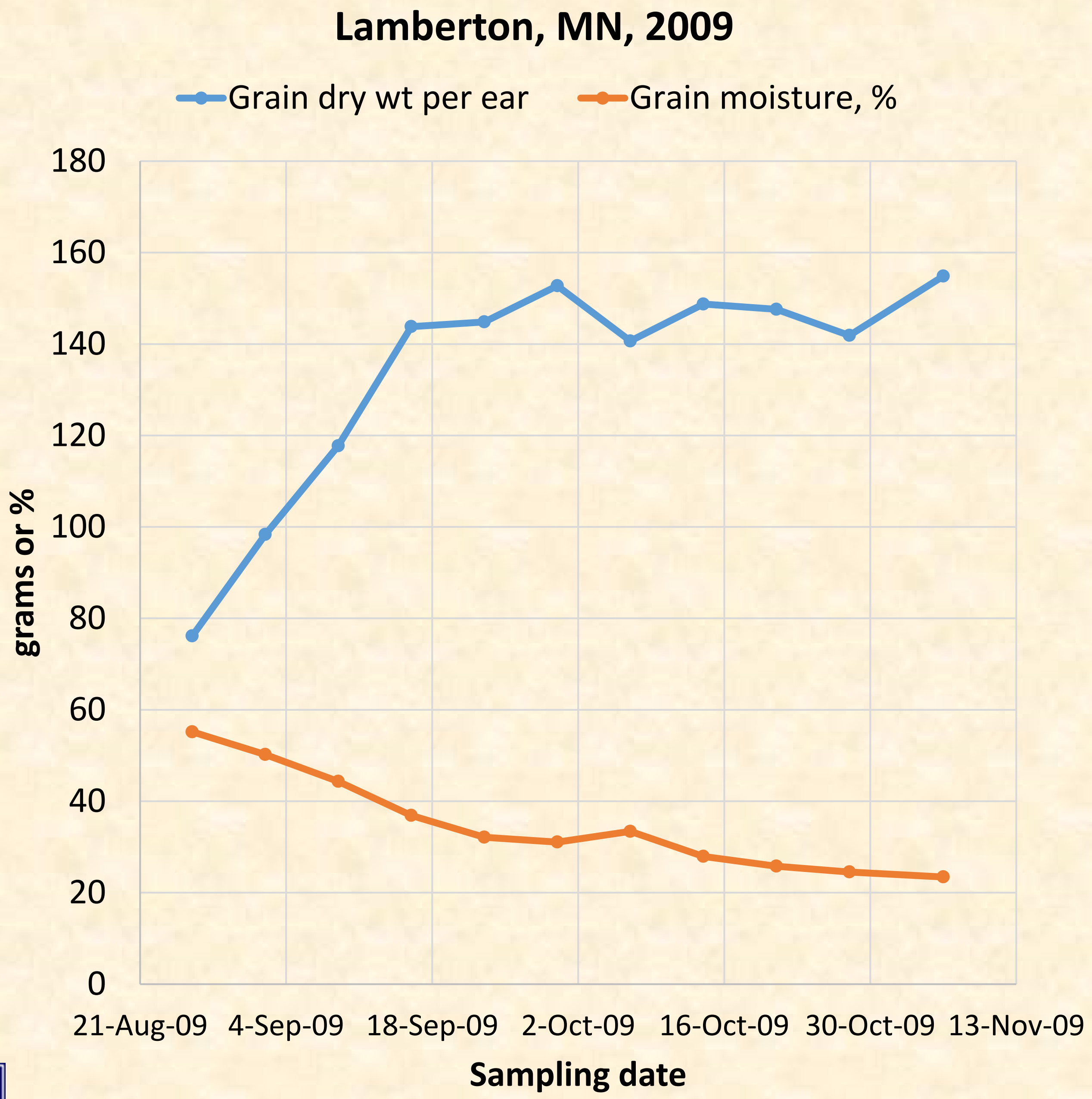
Source: Iowa State University

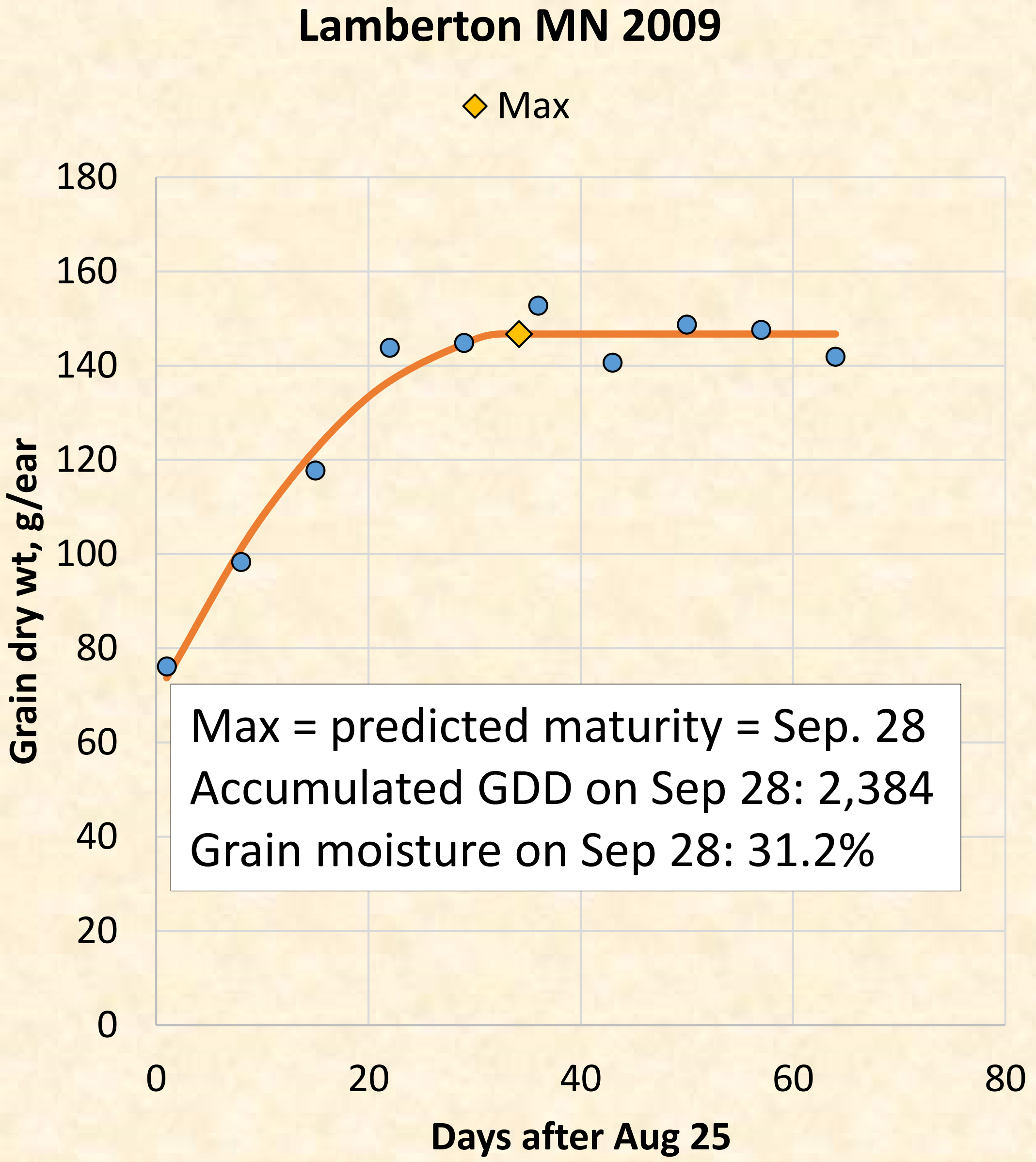
Starch Line Location vs. Grain Yield

Starch line 20% down on August 3

Starch line 50% down on August 17

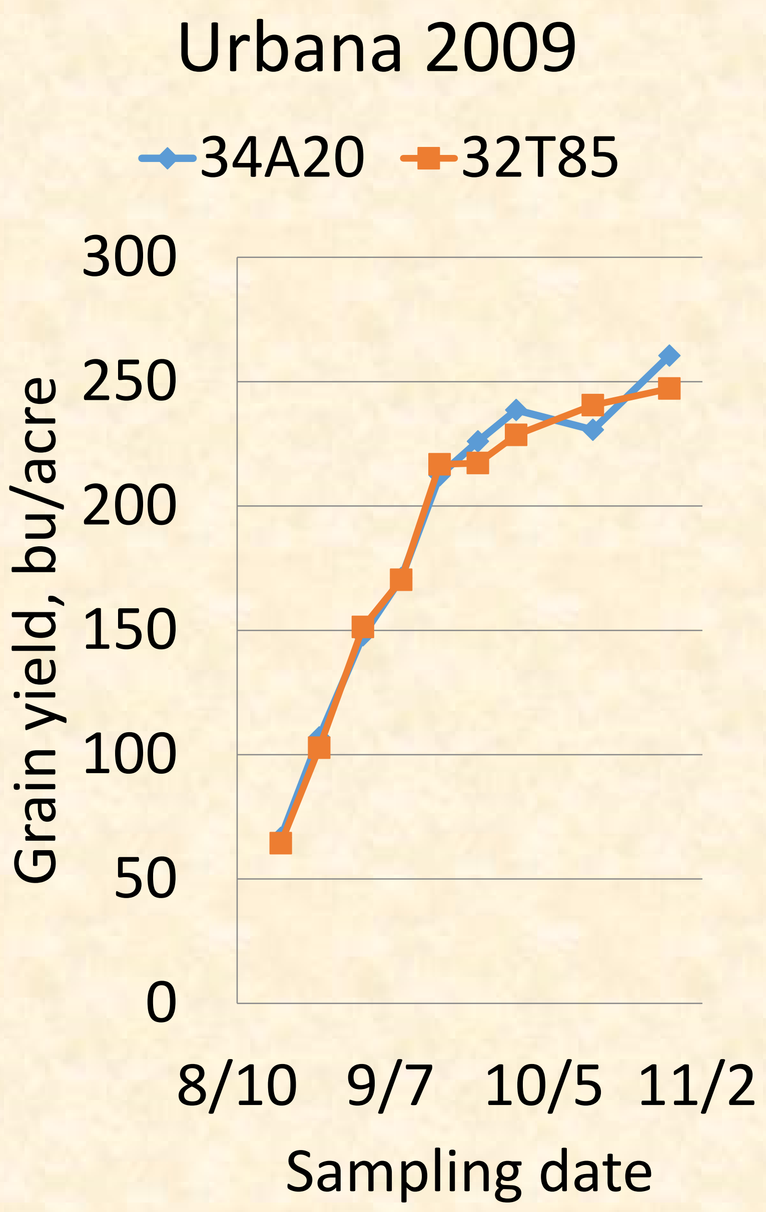
Source: Jeff Coulter, U Minn.

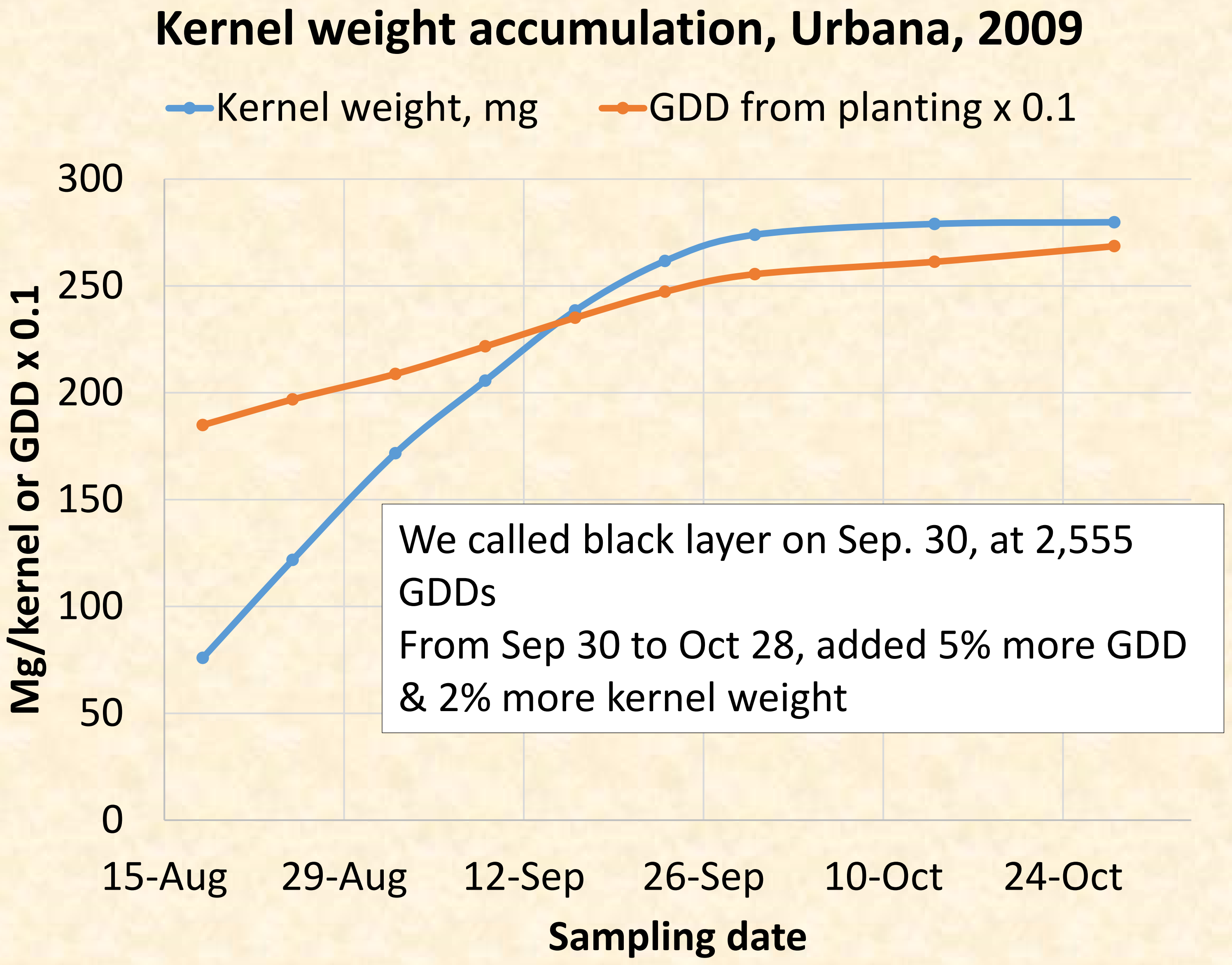

Lamberton, MN, 2009
Grain dry wt per ear
Grain moisture, %
grams or %
0
20
40
60
80
100
120
140
160
180
21-Aug-09
4-Sep-09
18-Sep-09
2-Oct-09
16-Oct-09
30-Oct-09
13-Nov-09
Sampling date


Lamberton MN 2009
Max
Grain dry wt, g/ear
0
20
40
60
80
100
120
140
160
180
0
20
40
60
80
Days after Aug 25
Max = predicted maturity = Sep. 28
Accumulated GDD on Sep 28: 2,384
Grain moisture on Sep 28: 31.2%

Summary - Maturity Line Weight Study

Kernel stage	Milk in kernel	Average yield underestimate with maturity line weight method	Current "yield factor" for maturity line weight method	Average observed "yield factor" in our trials
1/4	≥75%	44%	7.1	12.7
1/2	50 - 74%	35%	7.5	11.5
3/4	25 - 49%	30%	8.0	11.5
Doughy	5 - 24%	26%	8.5	11.6
Extended	1 - 4%	1%	10.6	10.8


Urbana 2009
34A20
32T85
Grain yield, bu/acre
300
250
200
150
100
50
0
8/10
9/7
10/5
11/2
Sampling date


Kernel weight accumulation, Urbana, 2009
Kernel weight, mg
GDD from planting x 0.1
Mg/kernel or GDD x 0.1
300
250
200
150
100
50
0
15-Aug
29-Aug
12-Sep
26-Sep
10-Oct
24-Oct
Sampling date
We called black layer on Sep. 30, at 2,555 GDDs
From Sep 30 to Oct 28, added 5% more GDD & 2% more kernel weight

	P0916XR (109 RM)		P1395XR (113 RM)	
Date	% ML advance	Yield to reach max	% ML advance	Yield to reach max
		bu/ac		bu/ac
27-Jul	0	143	0	151
3-Aug	16	76	10	90
10-Aug	51	33	45	45
17-Aug	73	7	58	-1
24-Aug	100	-11	100	-4

Grainfilling Rates During "Linear" Phase, 2010

	Monmouth		Urbana	
Week	109-day	113-day	109-day	113-day
	--------------bu per acre per day---------------			
1	10.2	8.0	9.6	8.8
2	5.1	8.4	6.2	6.4
3	7.5	9.0	3.7	6.5
4	4.2	2.4	2.5	0.4
5	0.0	3.9	-3.9	-0.9

Effective Filling Period, days, 2010

Monmouth		Urbana	
109-day	113-day	109-day	113-day
29	33	31	32

In 2009 the EFP was about 50 days, at about 5 bu/ac/day, at both locations.

Does corn grain lose dry matter as it dries in the field?

- This first came from Bob Nielsen at Purdue, who in the early 1990s suggested a loss of 1 bushel per point of moisture, from the high 20s to 15%; this was later dropped to ½ bu per %
- Work at a number of universities was unable to show this; at the UI, we did a 3-year study that showed a 1.2% increase in kernel weight going from 29 to 20% moisture
- Some seed companies claimed that hybrids differ in the tendency to do this, with some showing no loss
- Some farmers feel strongly that this is real, and harvest early and pay to dry to prevent it
- While no one can say it never happens, there is no known physiological reason for it, outside of the possibility for ear rots and loss of ears to droppage
- Because so much "proof" of this comes from yield monitors, some believe that it's mostly a consequence of subtle differences in how yield monitors sense moisture and weigh between grain at high v low moisture

Proportion of final dry weight

50%	90%	100%

R4 – L. Dough **R5.5 – mid-Dent** **R6 - Mature**

Management considerations during grainfill

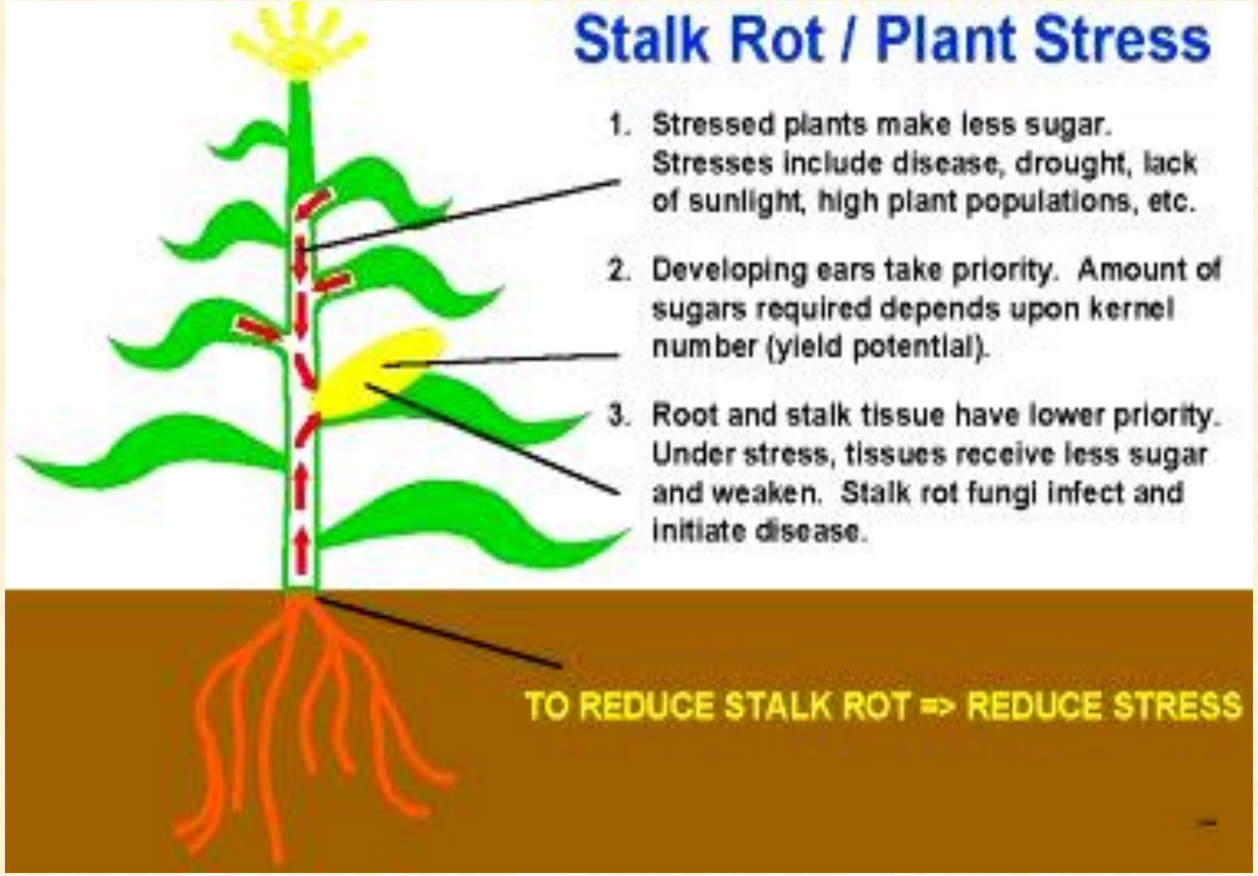
- If pollination wasn't very successful or there was a lot of kernel abortion, so that kernel number per acre less than 10,000,000, keeping a healthy canopy to maturity might have a limited effect on yield:
    - At 80,000 k/bu, yield ay 10M k = 125
    - At 70,000 k/bu, yield = 143
- If kernel numbers are high, every day with full light interception (at max fill rate) can add 10-11 bushels of yield
- Leaf loss after pollination is irreversible, but disease or insect control may be cost-effective, depending on how much damage there is and how early it was detected and treated

Point to ponder:

A chemical company says that using its foliar fungicide at R1 will help leaves stay green longer, which will mean higher corn yield

- Do you think that having leaves stay green up to black layer would always increase yields?
- If not, when might that not happen?
- What would you tell a farmer (if you don't work for the chemical company?)
    - And if you do work for the chemical company?

Lodging problems in corn and assimilate translocation



Point to ponder:

The same chemical company says that using its foliar fungicide at R1 will improve corn standability, even though we know that stalk diseases aren't (much) controlled by foliar fungicide

- Why would having leaves stay green longer (let's assume this happens) make stronger stalks?
- Does it matter that standability is not so often a problem?
- Under what conditions might corn lodge even though fungicide was used?
- What cost for fungicide do you think would justified if it affected only (or mostly) standability?

R6 Stage: Maturity

- Black layer: Black abscission layer formed because the starch line has advanced all the way to the cob
- Kernels have (usually*) reached maximum dry weight
- Leaves/husks are often–but not always—brown; stalk may be green
- Kernels 32-35% moisture (varies from <30 to >35)
- Harvesting now means high drying costs and possible grain damage
- Drydown rate depends on temperature, husk cover, etc.

*We have found instances of “bonus fill”, with what we think is sugars accumulating in the cob and moving into kernels even though the conducting cell layer is dark/dead

When maturity is late: the view from the kernel

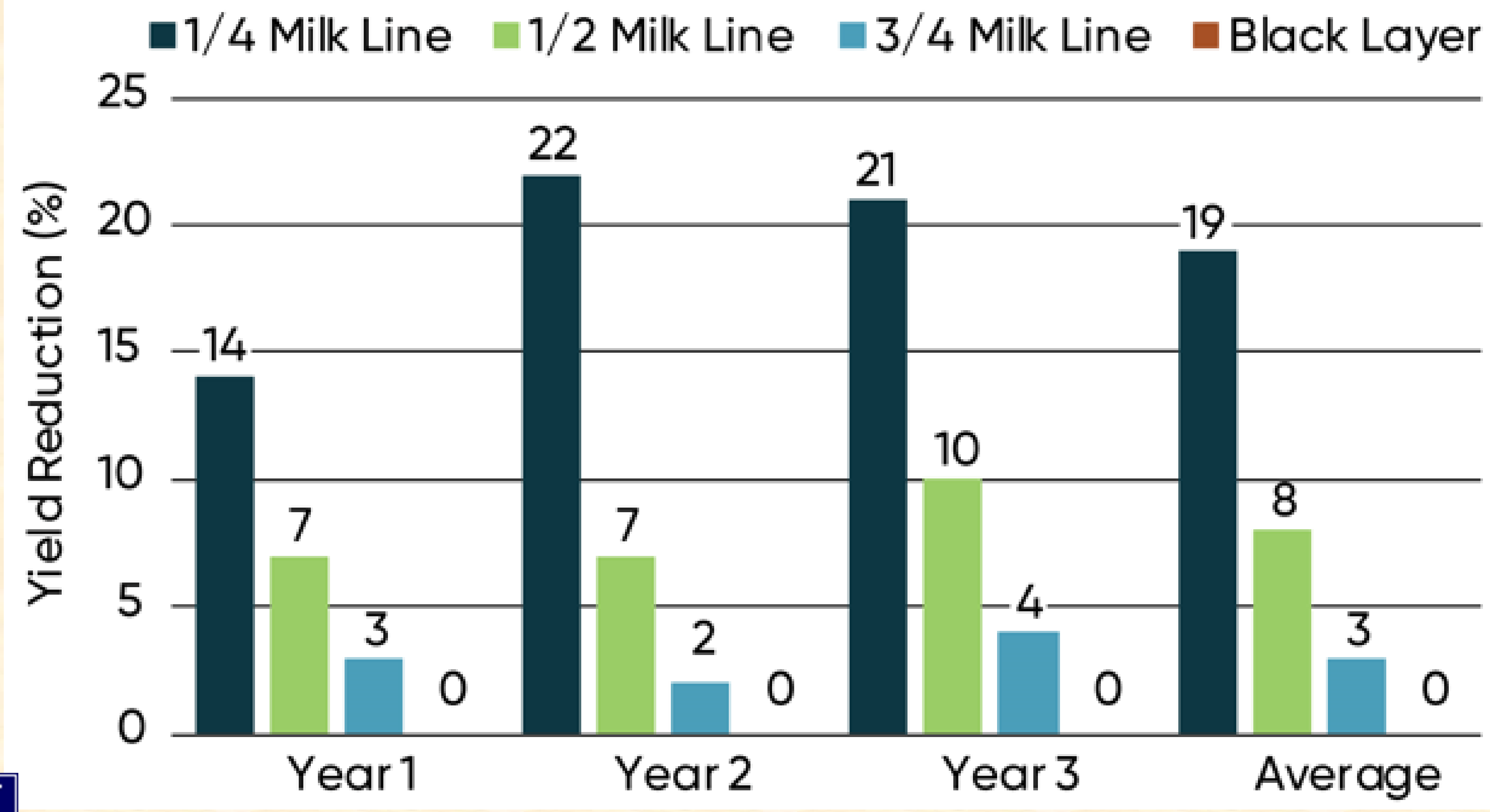
- Having GDD accumulations drop to low or to zero slows/stops Ps and with it the chance to add more dry weight to kernels even if there is still some green leaf area
- If GDD accumulation has been enough to allow kernels to black-layer normally, moisture is usually 32-34%, but can be outside this range

If sugar import stops <u>before</u> natural maturity:

- Black layer may form slowly and not be very dark: this is moot when there's no more sugars in the "pipeline" anyway
- Kernel weight and yield will be lowered, but not by much if GDD totals are within 200 or so of PM (~90% of total)
- Grain moisture will be high, and:
  - Sugars often remain in the base of kernel not converted to starch; this will slow drying (more solubles means water is "held" more tightly)
  - With less starch present, the base of the kernel will shrink as it dries
  - Sugars brown at high temperatures, so drying can increase kernel damage (and dockage)
  - Lower endosperm density and kernels whose shape doesn't allow them to fit together as well means lower test weight, even after grain is dried

From Pioneer Field Facts

Avg of 6 hybrids; removed all leaves and stalk above the ear



Days from:

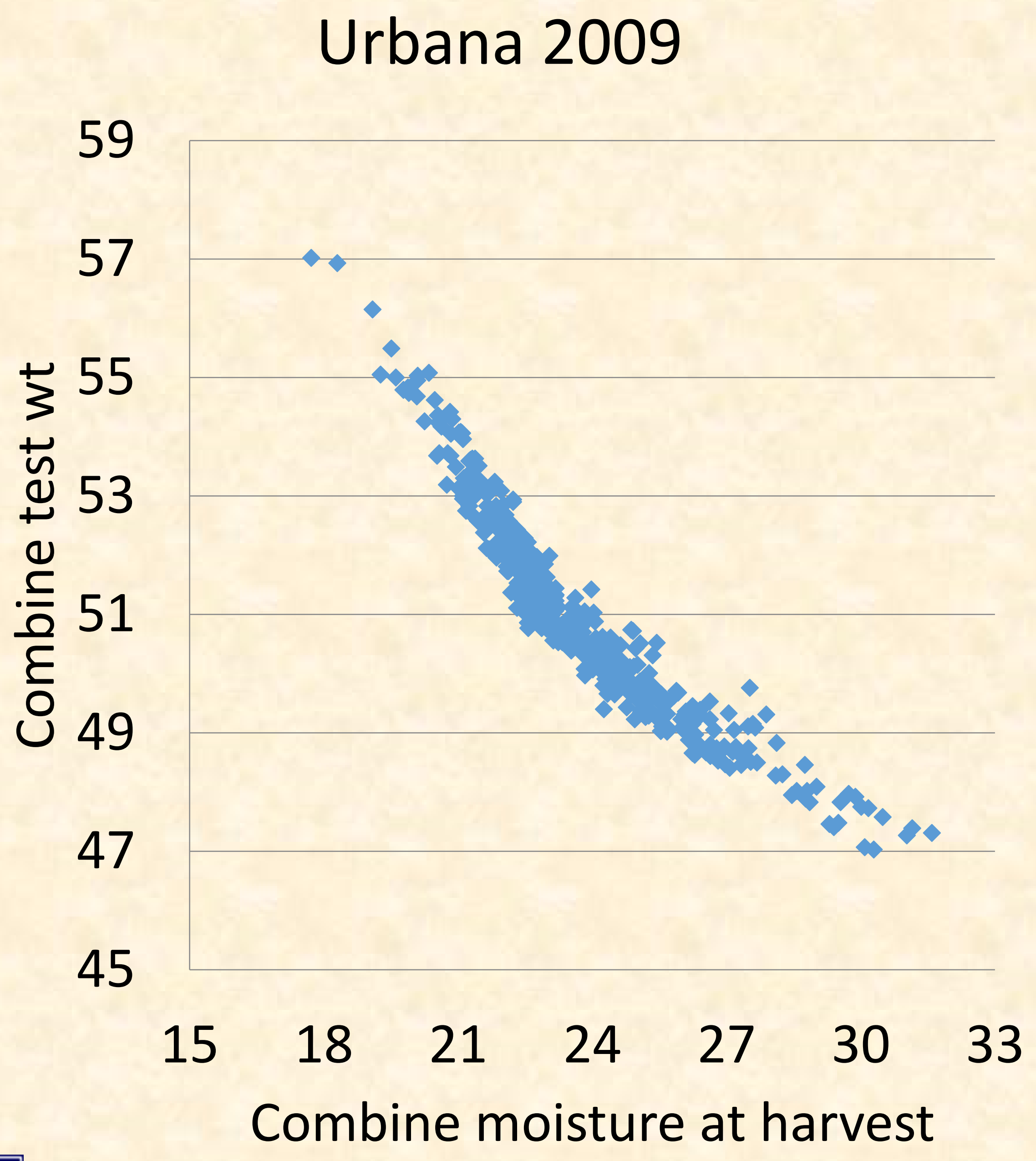
¼ ML to BL: 22 d

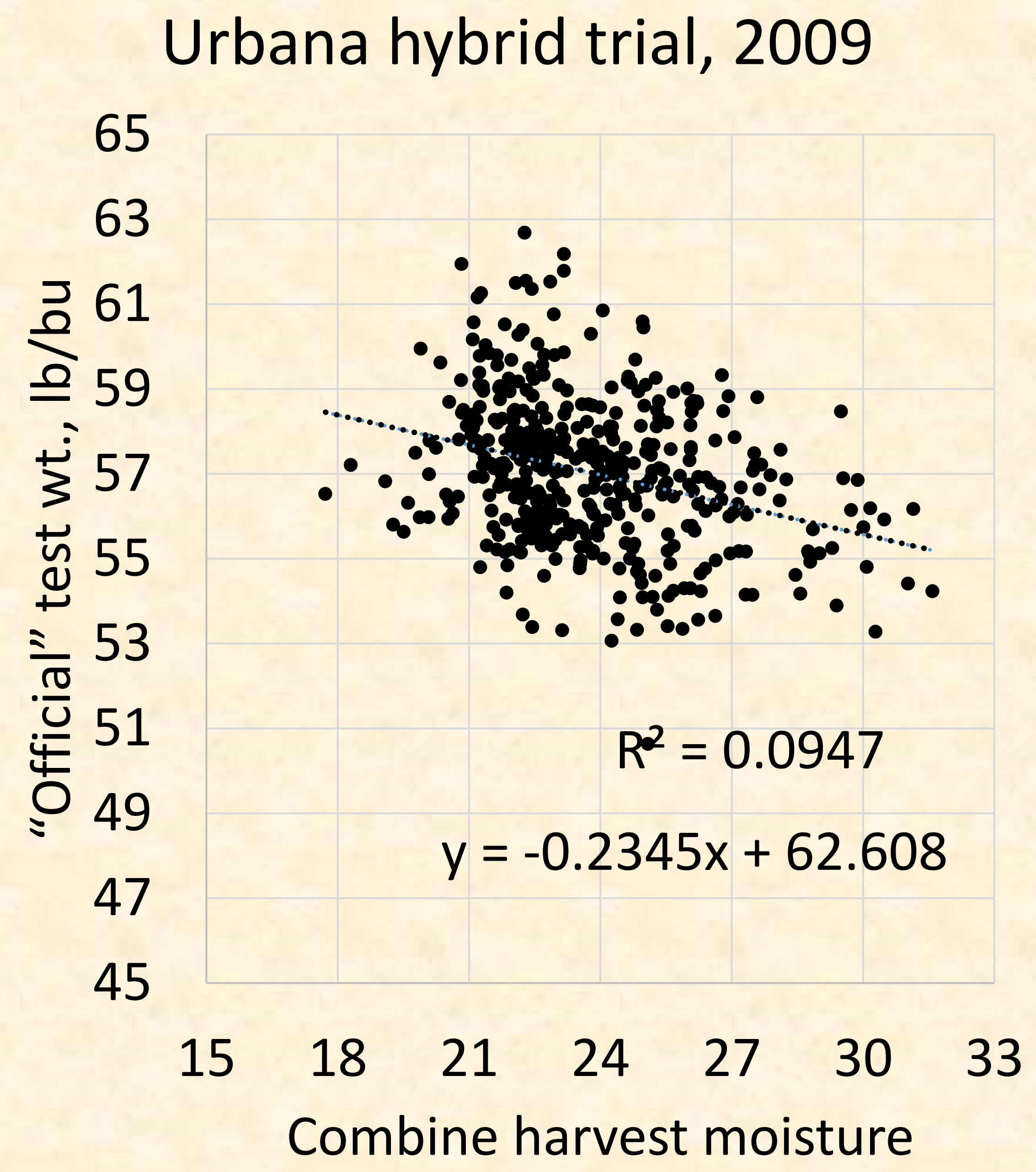
½ ML to BL: 15 d

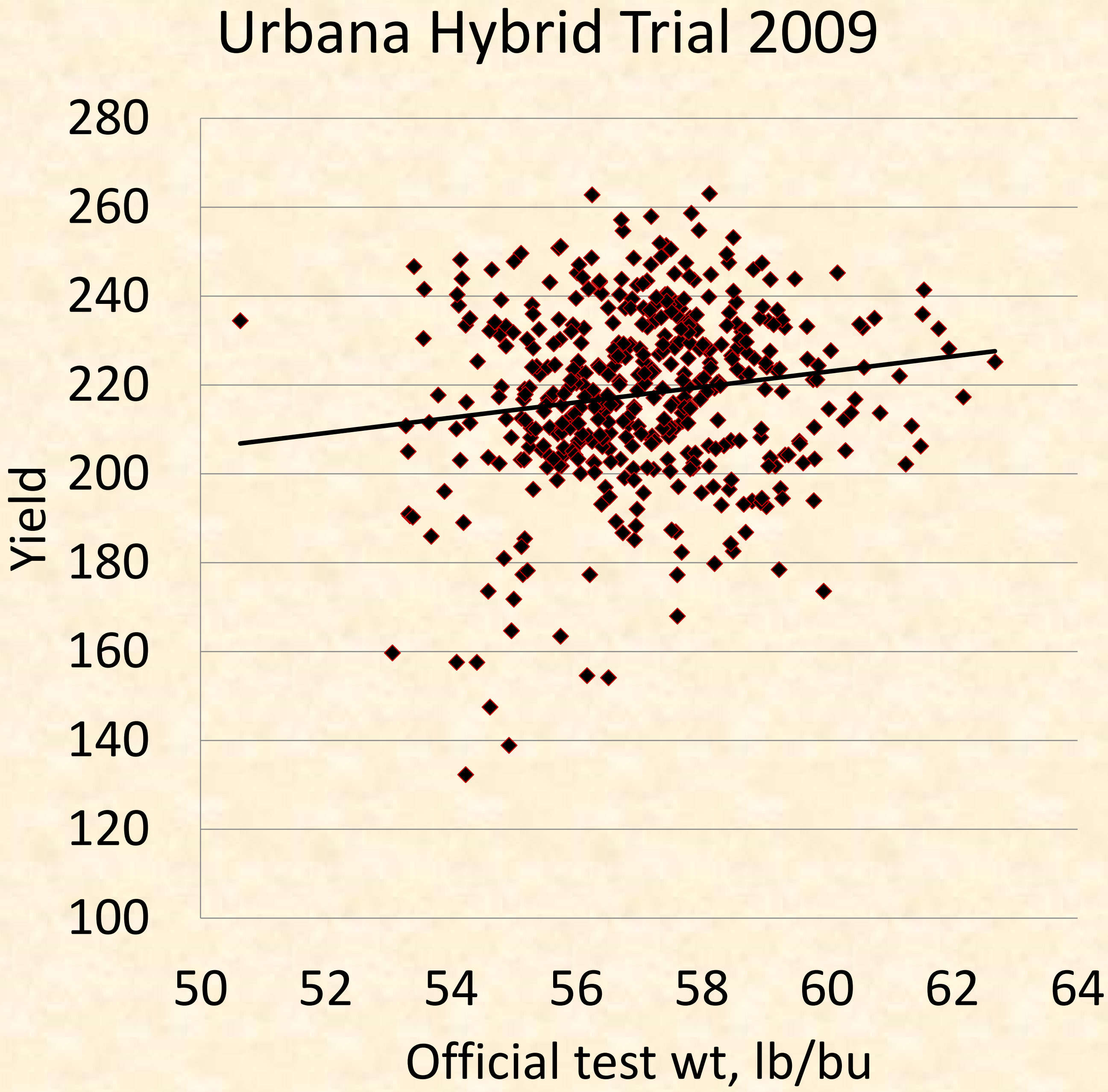
¾ ML to BL: 7 d

Test weight is often a "victim" of late maturity

- Weight in lb of a bushel (1.244 ft^3) volume of grain(= bulk density)
- Has an official measurement procedure, using funnel apparatus and manual strikeoff; some combines measure it but that's not "official"
- Part of U.S Grain Standards for wheat (60), corn (56), grain sorghum (56), oats (32), but no longer for soybean
- Widely used in the seed corn industry as an advertised trait: many hybrids are said to have "high" TW
- Widely viewed as an indicator of how well a hybrid reached its yield potential
- But TW is a complex measure, including kernel density, size and shape, moisture, and seedcoat slipperiness
  - Example: TW can sometimes be increased by running grain through an auger

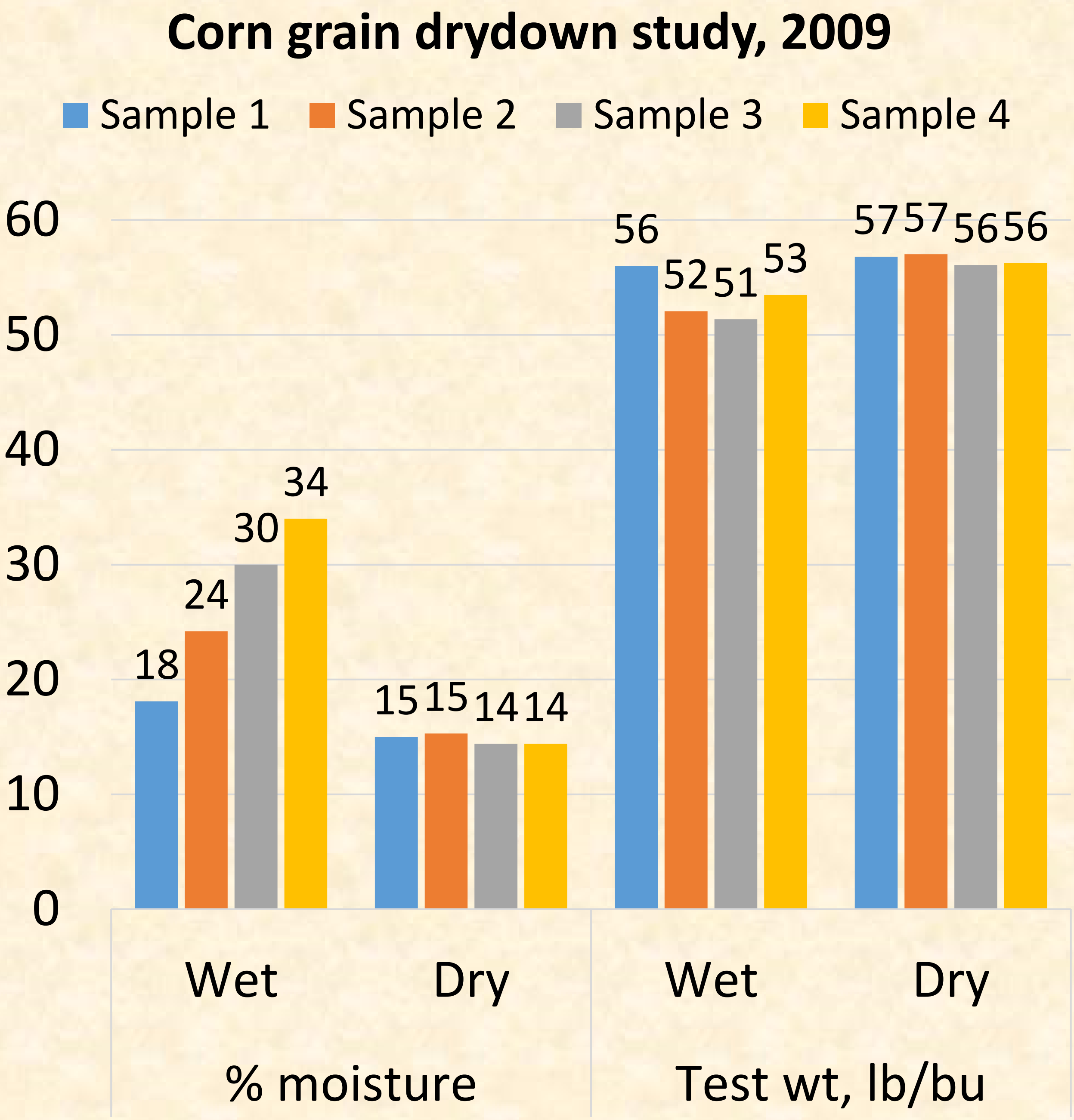

Urbana 2009
59
57
55
53
51
49
47
45
Combine test wt
15
18
21
24
27
30
33
Combine moisture at harvest

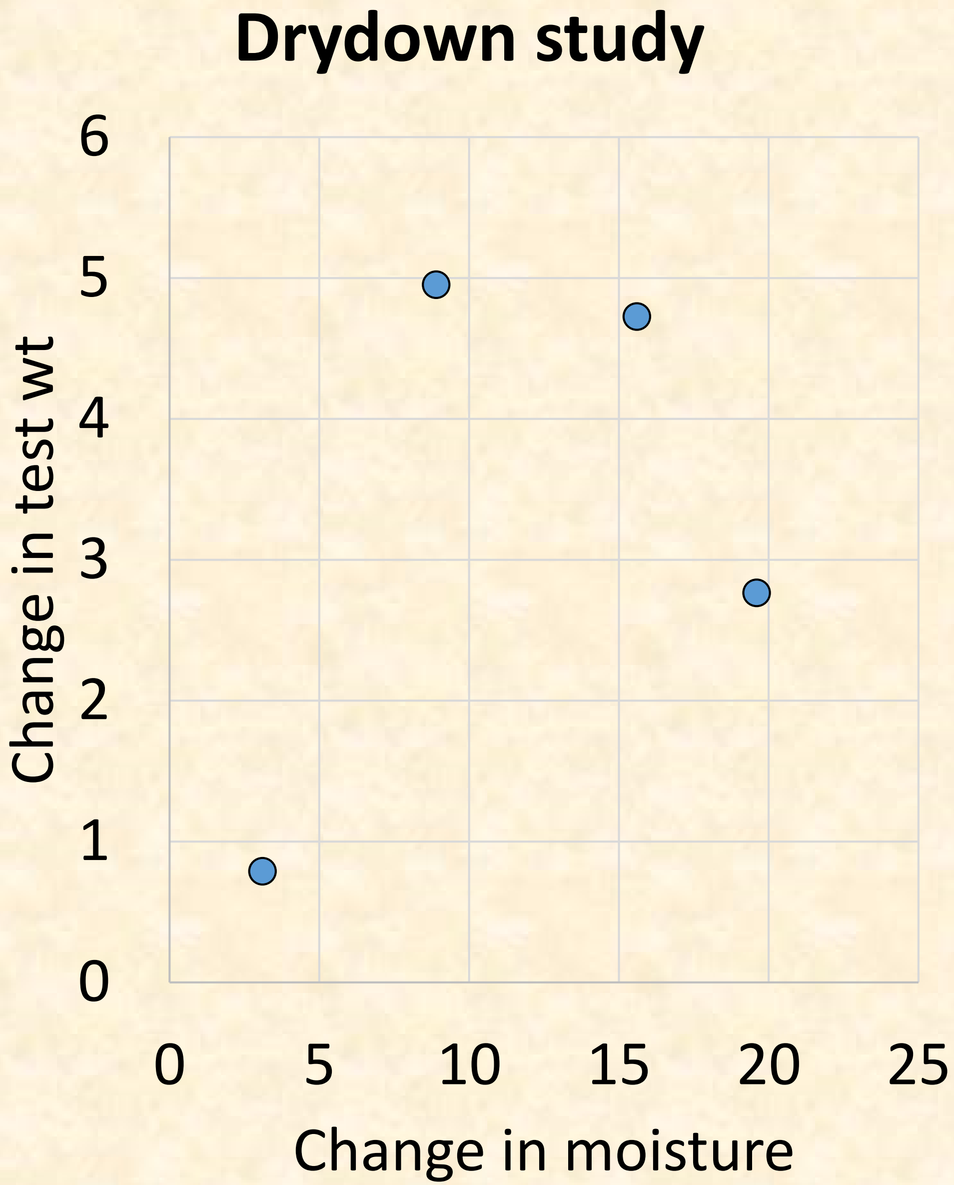

Urbana hybrid trial, 2009
65
63
61
59
57
55
53
51
49
47
45
"Official" test wt., lb/bu
R² = 0.0947
y = -0.2345x + 62.608
15
18
21
24
27
30
33
Combine harvest moisture

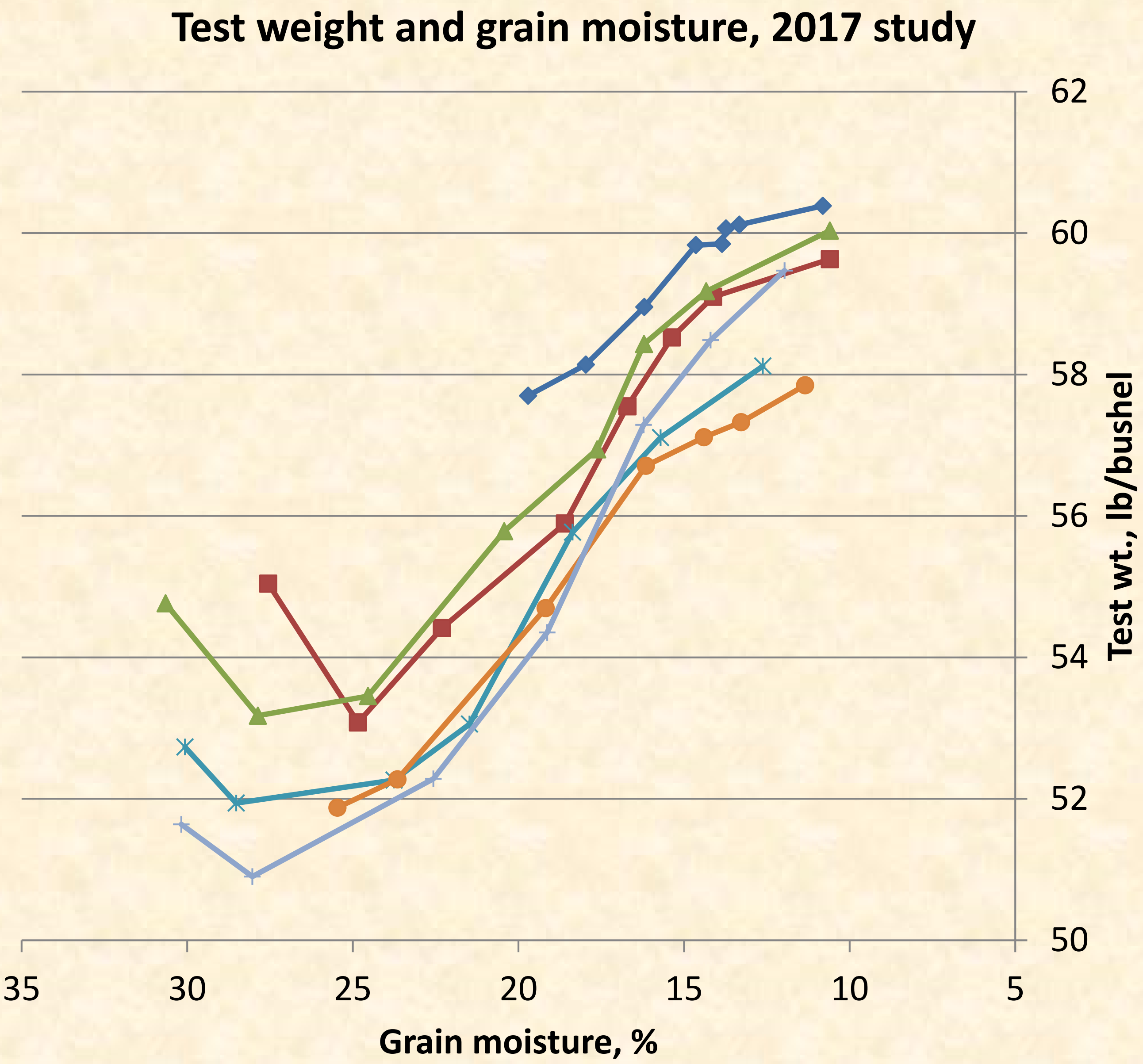


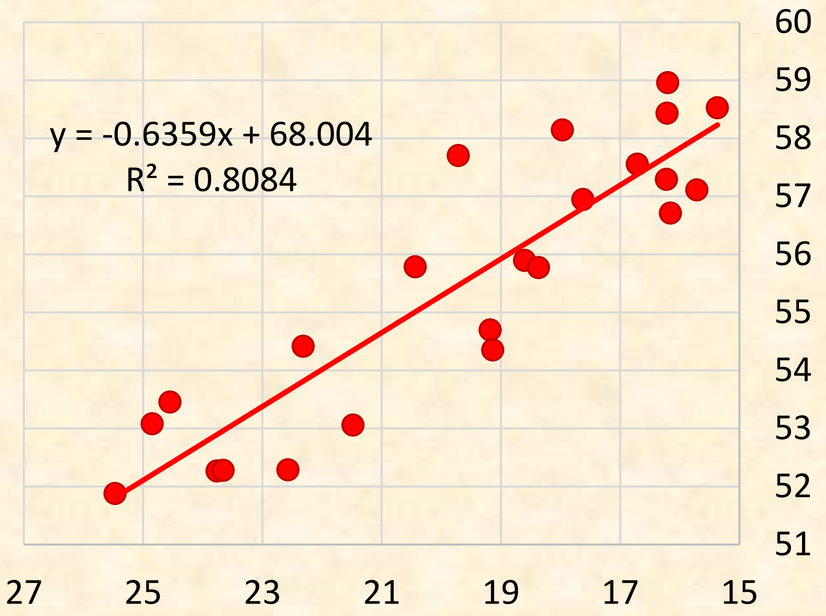
Test weight, moisture, hybrids, and yield: it's complicated:

- 2009 was a cool season, with a wide range of grain moistures and low test weights as measured on the combine
- Official test weight measurements were very different than combine-measured ones
- TW measured both ways showed a negative correlation between grain moisture and TW, but it was much stronger with combine-measured TW
- Yield was higher at higher TW, which means higher with lower moisture: in this season, earlier-maturing hybrids were better able to finish grainfilling


Corn grain drydown study, 2009
Sample 1
Sample 2
Sample 3
Sample 4
60
50
40
30
20
10
0
18
24
30
34
15
15
14
14
56
52
51
53
57
57
56
56
Wet
Dry
Wet
Dry
% moisture
Test wt, lb/bu

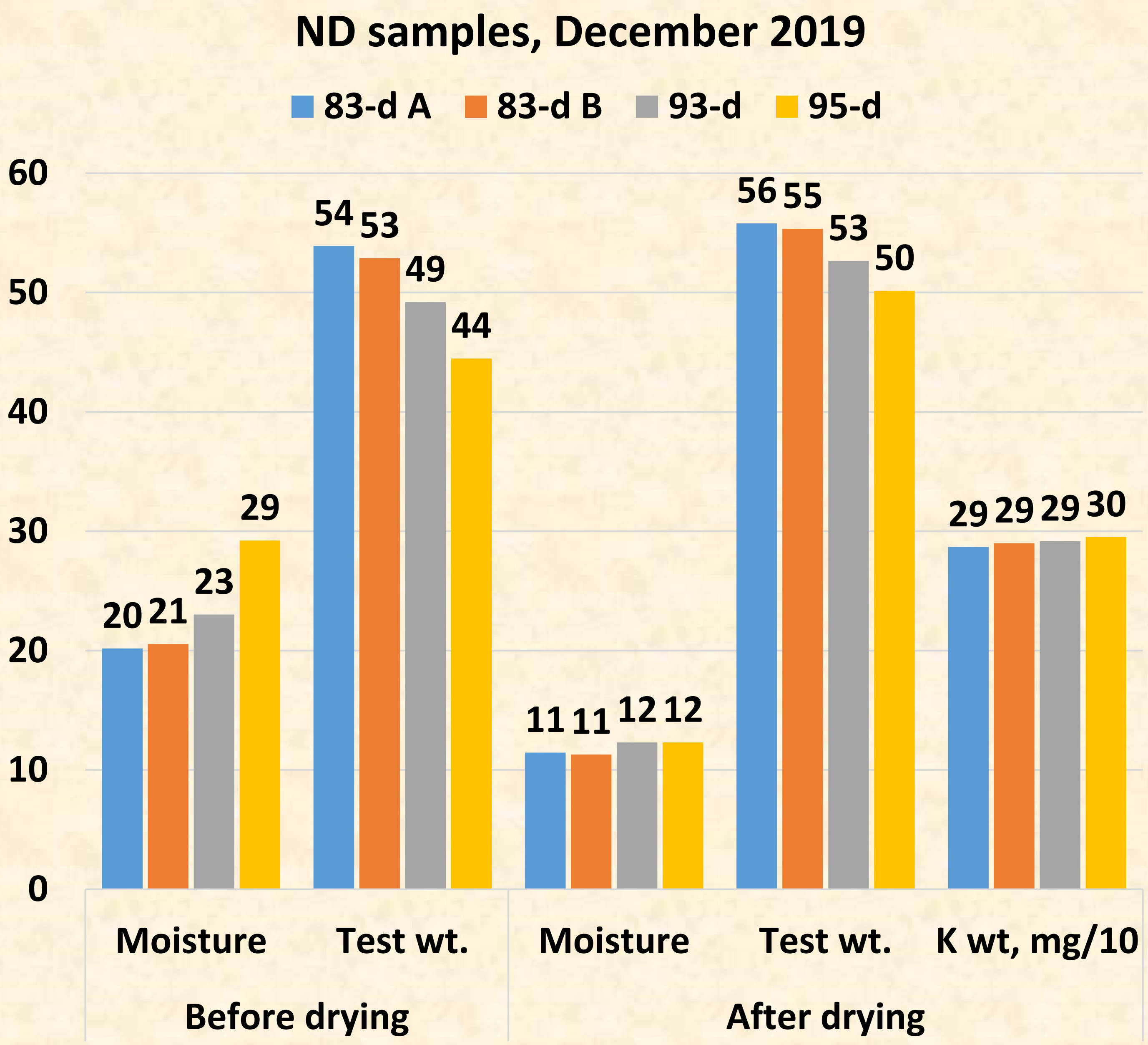

Drydown study
Change in test wt
6
5
4
3
2
1
0
0
5
10
15
20
25
Change in moisture





From 26 to 15% moisture:

- TW increased by 7 lb/bu, or 0.63 lb/point
- This differed some by sample
- From >30% down to 25%, TW decreased some (why?)
- TW increased as grain dried below 15%, but the change rate slowed
- Q: Is air-drying the same as in a dryer?


ND samples, December 2019
83-d A
83-d B
93-d
95-d
60
50
40
30
20
10
0
20
21
23
29
54
53
49
44
11
11
12
12
56
55
53
50
29
29
29
30
Moisture
Test wt.
Moisture
Test wt.
K wt, mg/10
Before drying
After drying


93-d RM
TW 52.7


95-d RM
TW 50.2

What do we learn from test weight?

- Test weight is an (inexact) indicator of how well the grainfilling process has gone, including the sugar supply, kernel diseases, and weather during the process
- If grainfill has been complete or nearly complete, then low test weights measured on wet grain rebound as grain is dried
- Low test weights mean more volume to handle, but dockage due to low test weights are problematic IF test weight once dried is normal
- Test weight is partly used in marketing as a proxy for “low-quality” (low starch density, unfilled kernels) grain
- But TW is not a reliable indicator of the value of the grain as feed: crude protein can be higher in unfilled kernels