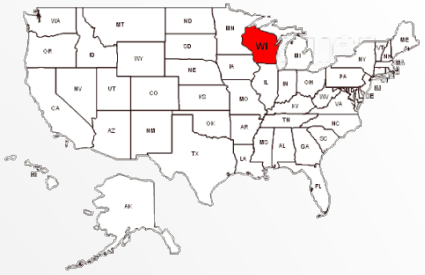


Is the Corn-Soybean Rotation Sustainable? Evidence from Long-Term Cropping System Trials

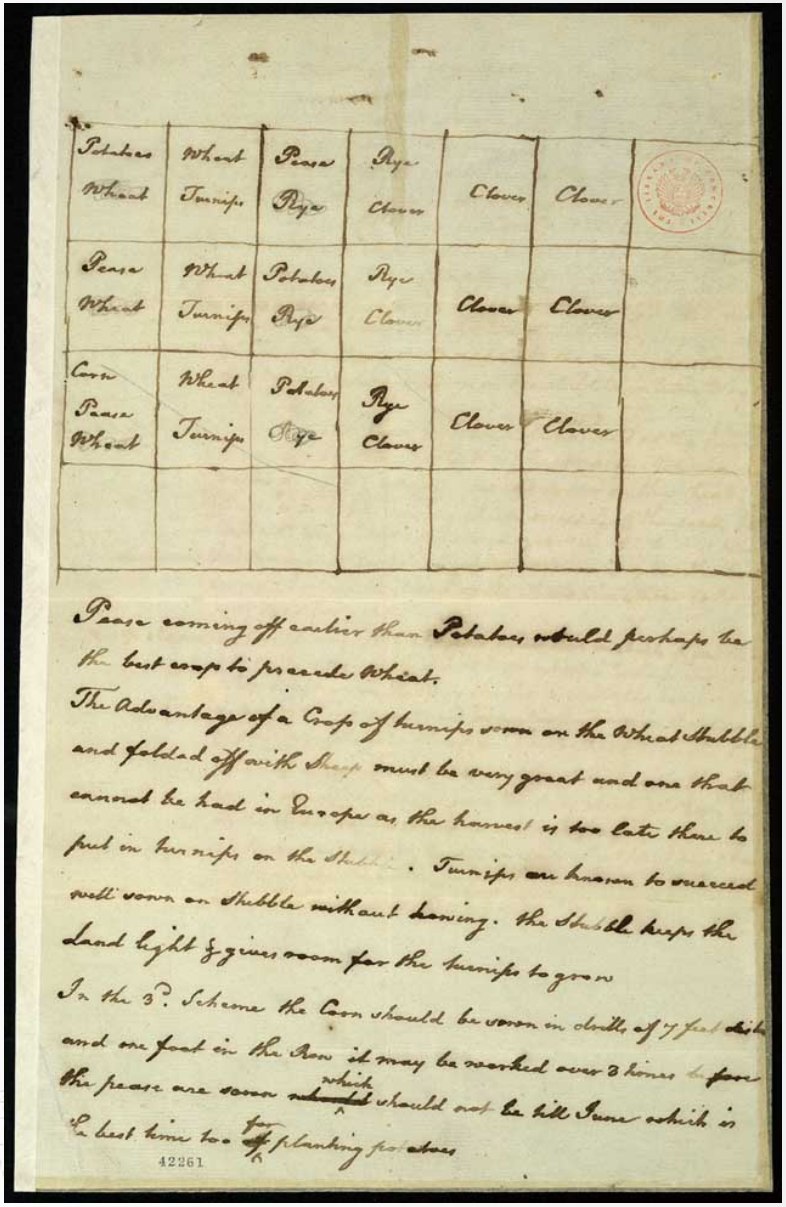
Joe Lauer
University of Wisconsin – Madison

INDIANA CCA CONFERENCE
Indianapolis, IN
December 13, 2017

UW Extension
University of Wisconsin-Extension

http://corn.agronomy.wisc.edu

Crop rotation plan for Monticello



Potatoes Wheat	Wheat Turnips	Peasa Rye	Rye Clover	Clover	Clover	
Peasa Wheat	Wheat Turnips	Potatoes Rye	Rye Clover	Clover	Clover	
Corn Peasa Wheat	Wheat Turnips	Potatoes Rye	Rye Clover	Clover	Clover	

Peasa coming off earlier than Potatoes would perhaps be the best crop to precede Wheat.

The Advantage of a Crop of turnips sown on the Wheat Stubble and fedded off with Sheep must be very great and one that cannot be had in Europe as the harvest is too late there to put in turnips on the Stubble. Turnips are known to succeed well sown on Stubble without hoeing. the Stubble keeps the land light & gives room for the turnips to grow

In the 3d. Scheme the Corn should be sown in drills of 7 feet distant and one foot in the Row it may be worked over 3 times before the peasa are sown which should not be till June which is the best time too for planting potatoes

42261

- Thomas Jefferson used a scientific approach to farming
  - ✓ Carefully considered a workable method of crop rotation for Monticello
  - ✓ An innovative practice at the time
- The corn-soybean system of the U.S. Corn Belt is a relatively young cropping system.
  - ✓ Currently challenged by many abiotic and biotic factors
  - ✓ Is it sustainable?

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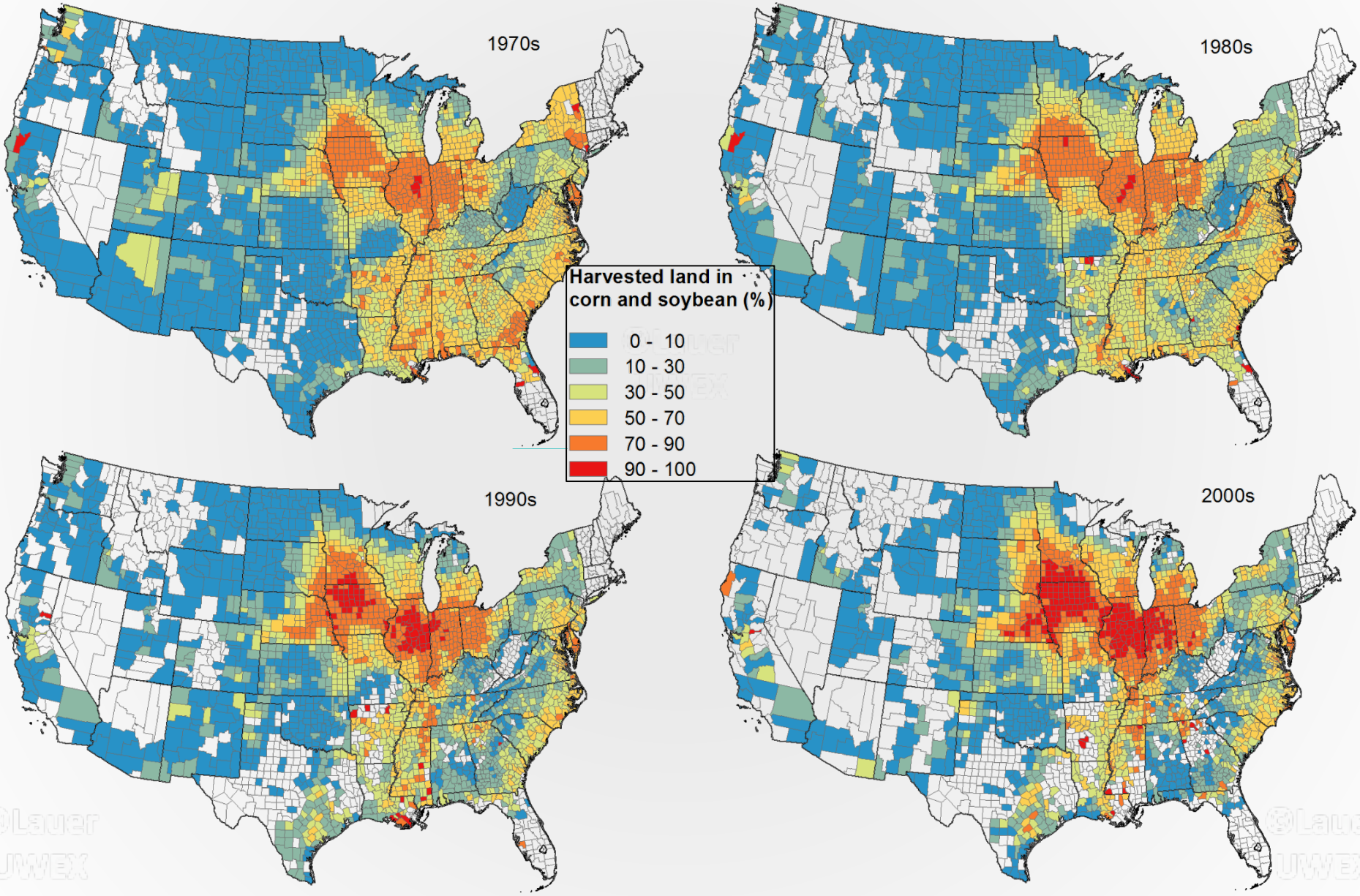
The Rotation Effect – What is it?

- Crop Rotation
  - ✓ Universal management practice
  - ✓ Proven management decision that increases crop yields
  - ✓ Currently, increased economic benefit for monoculture
- Rotation Effect
  - ✓ The effect of all conditions, other than N, supplied by legumes in a rotation (Baldock et al., 1981)
  - ✓ Other non-legume crops can provide benefits as well (Robinson, 1966; Langer and Randall, 1981; Crookston et al., 1988)
  - ✓ Additional benefits of rotating crops
    - ➢ All production inputs can be optimized
    - ➢ Typical problems associated with monoculture are not apparent.
- Mechanism for effect is unknown

Percent of Harvested Field Crop and Vegetable Land in Corn and Soybean



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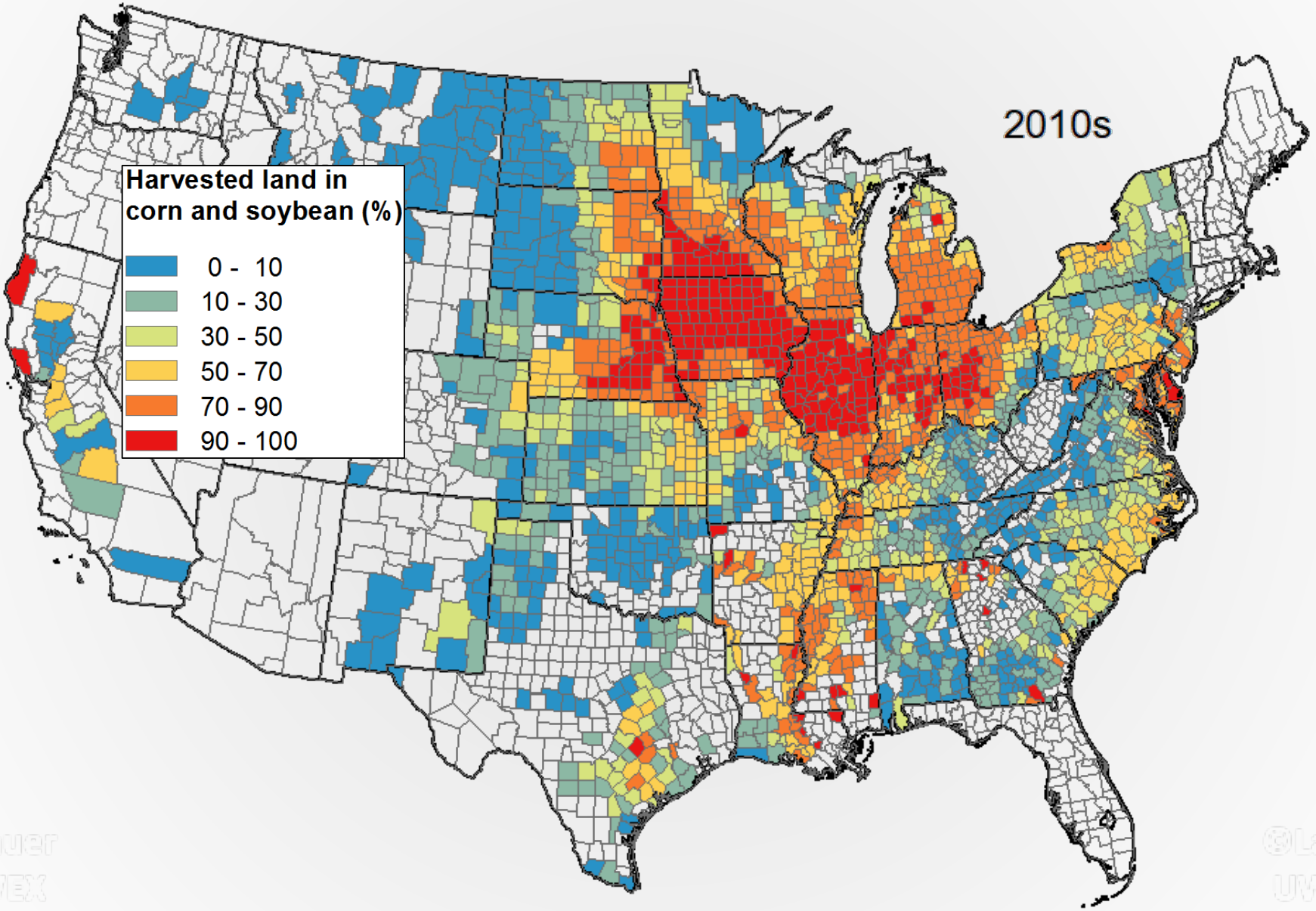
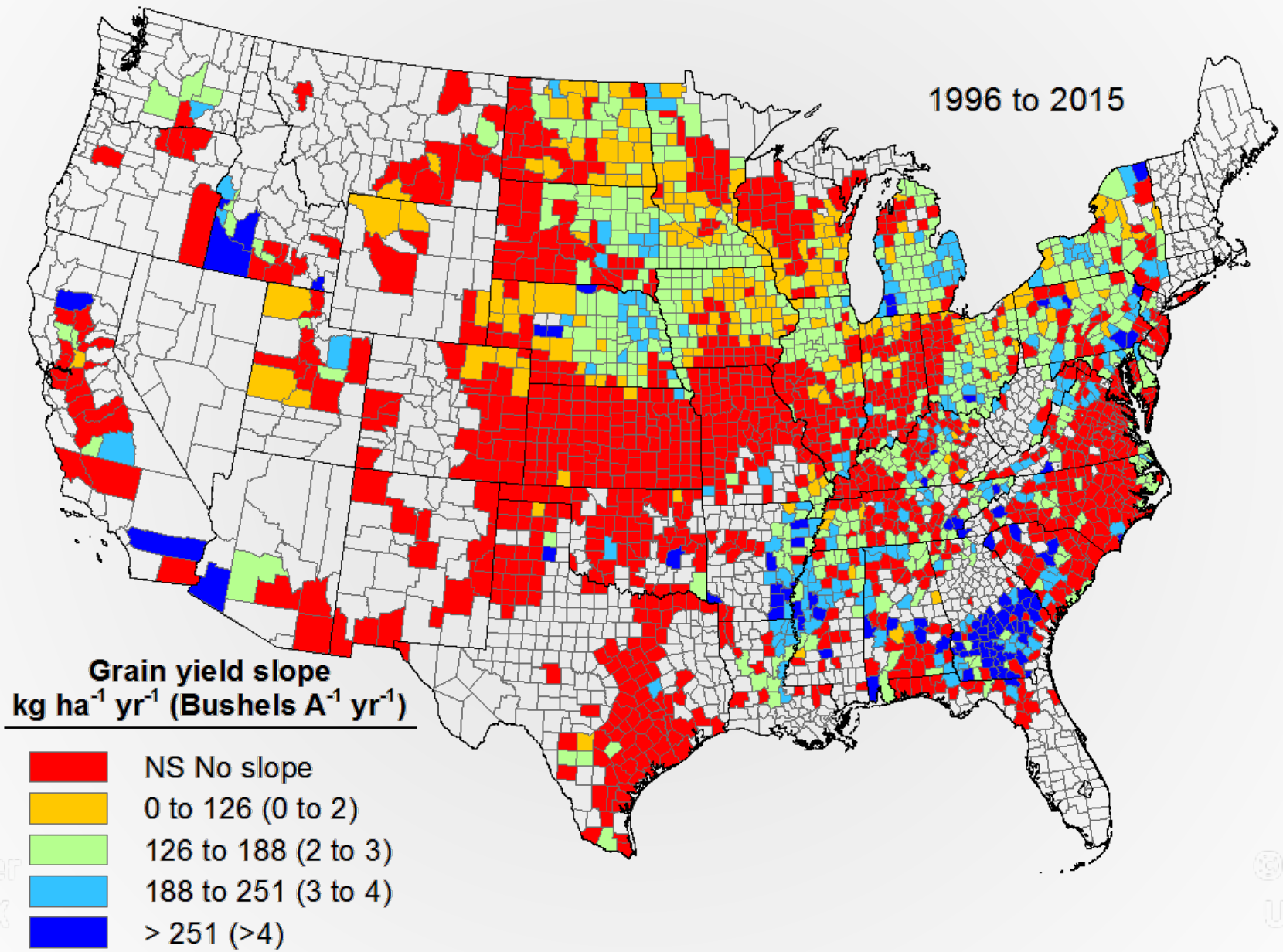
Lauer, 2015 (Data source: USDA-NASS)

Percent of Harvested Field Crop and Vegetable Land in Corn and Soybean



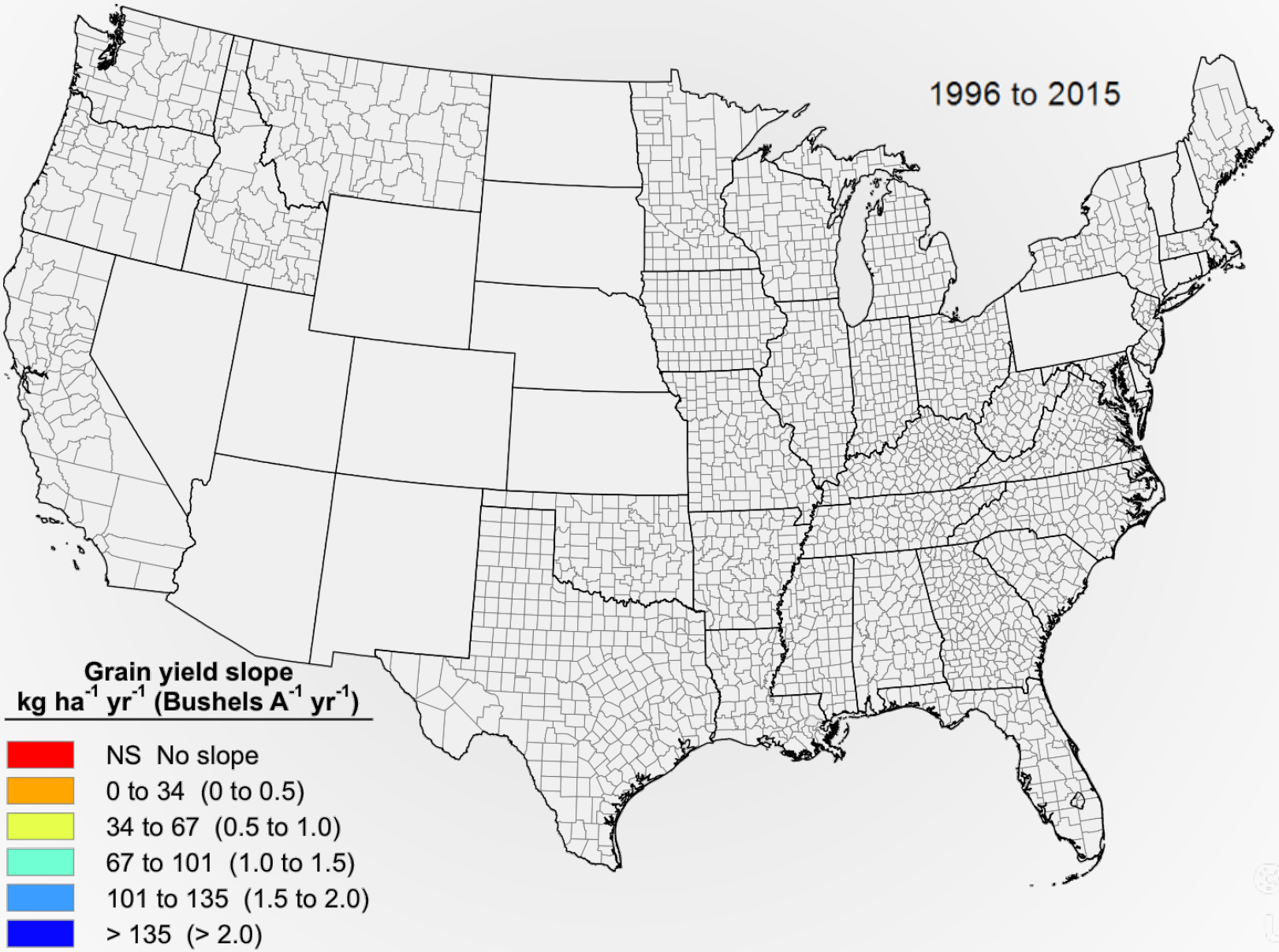
Lauer, 2017 (Data source: USDA-NASS 2010-2016)

Annual Increase of County Average Corn Yield



Lauer, 2016 (Data source: USDA-NASS)

Annual Increase of County Average Soybean Yield



Lauer, 2016 (Data source: USDA-NASS)

Overview

- The “rotation effect”
- A significant interaction
- Extending crop rotations
- What are we looking for?
  - ✓ Economics
  - ✓ Mechanism
- Future implications

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The Wisconsin Rotation Trials

Corn-Soybean-Oat-Alfalfa-Wheat
Lancaster since 1966
CC
CSCOA
CCCOA
CCOAA
COAAA:*1966-1976*
CCAA:*1977-1986*
AA:*1977-2004*
CS:*1987-*
CA:*1987-2004*
CSW:*2005-*

Corn N rate
1966-76: 0, 75, 150, 300
1977- : 0, 50, 100, 200

Corn-Soybean
since 1983
CC
SS
CS
CCCCCSSSSS

Tillage=2
N rate
Cultivar
Population
Row spacing
Seed insecticide
N timing
N source

Tillage
since 2001
CC
CS

Tillage=6
Starter
Planting date

BioChar
since 2009
CC
CS

Tillage=2
BioChar

Corn-Soybean-Wheat
1984 to 2000
CC
SS
CS
CSW:*1984-1994*
CCS:*1995-2000*
CCCS:*1995-2000*

Corn-Soybean-Wheat
ARL & MAR since 2002
CC
SS
WW
CS
CSW
CWS
CWS biomass

Seed fungicide
Foliar fungicide
Fusarium management

Systems Trials
Soils *1958-*
Weeds *1987-*
WICST *1990-*
GLBRC *2009-*

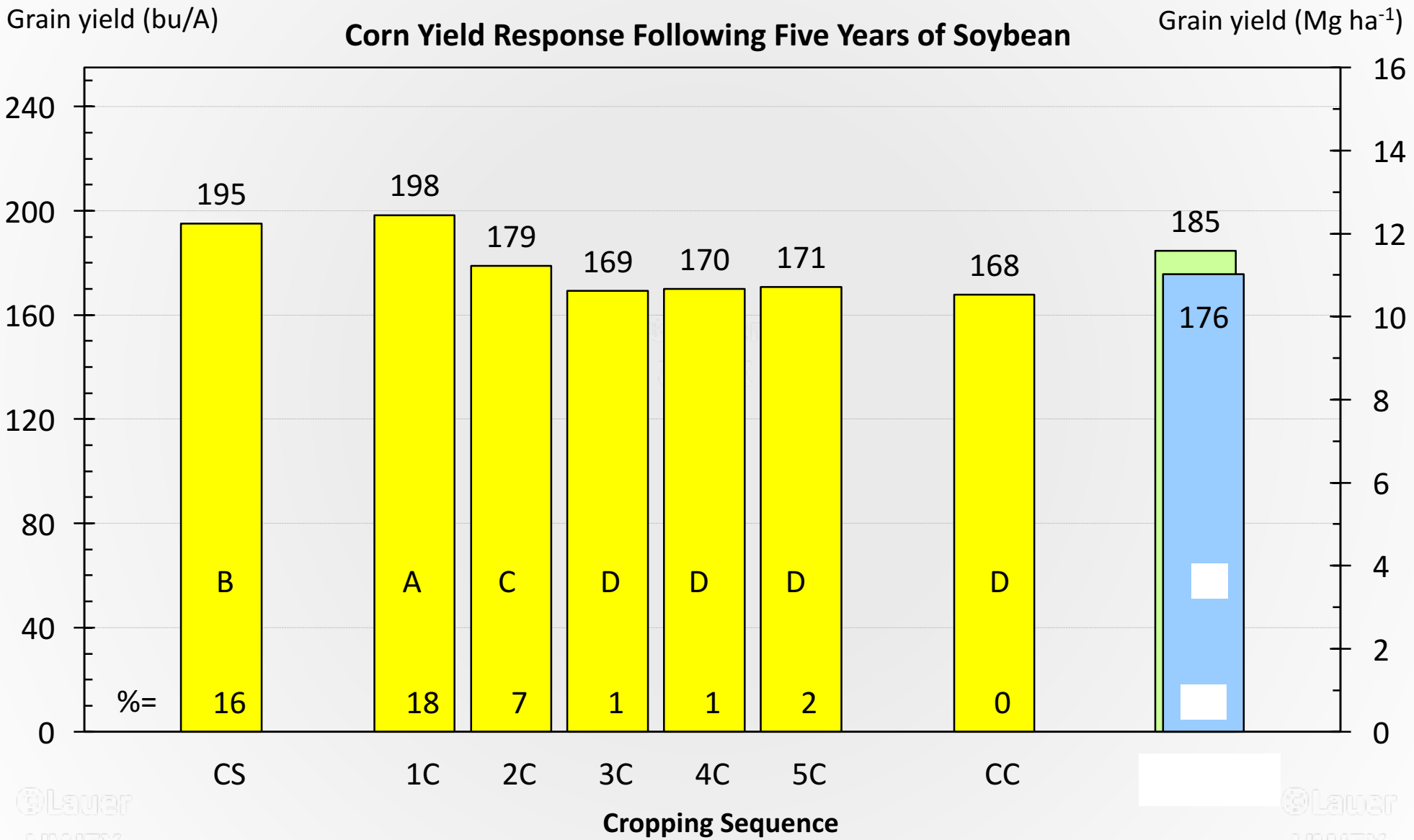
Corn-Alfalfa
ARL and MAR since 2010
CC
CCAAA
CCAA
CCAA biomass

Photo by Justin Hopf

Crop Sequence for 2-Crop Rotation Experiment at Arlington, WI (C= Corn, S= Soybean)

Rotation Sequence	Year									
	1	2	3	4	5	6	7	8	9	10
1	C	C	C	C	C	C	C	C	C	C
2	S	S	S	S	S	S	S	S	S	S
3	C	S	C	S	C	S	C	S	C	S
4	S	C	S	C	S	C	S	C	S	C
5	C	C	C	C	C	S	S	S	S	S
6	C	C	C	C	S	S	S	S	S	C
7	C	C	C	S	S	S	S	S	C	C
8	C	C	S	S	S	S	S	C	C	C
9	C	S	S	S	S	S	C	C	C	C
10	S	S	S	S	S	C	C	C	C	C
11	S	S	S	S	C	C	C	C	C	S
12	S	S	S	C	C	C	C	C	S	S
13	S	S	C	C	C	C	C	S	S	S
14	S	C	C	C	C	C	S	S	S	S

The rotation effect lasts two years increasing corn grain yield 16 to 18% for CS/1C and 7% for 2C …



C= Corn, S= Soybean, 1C= First year corn, 2C= Second year corn … CC= Continuous corn

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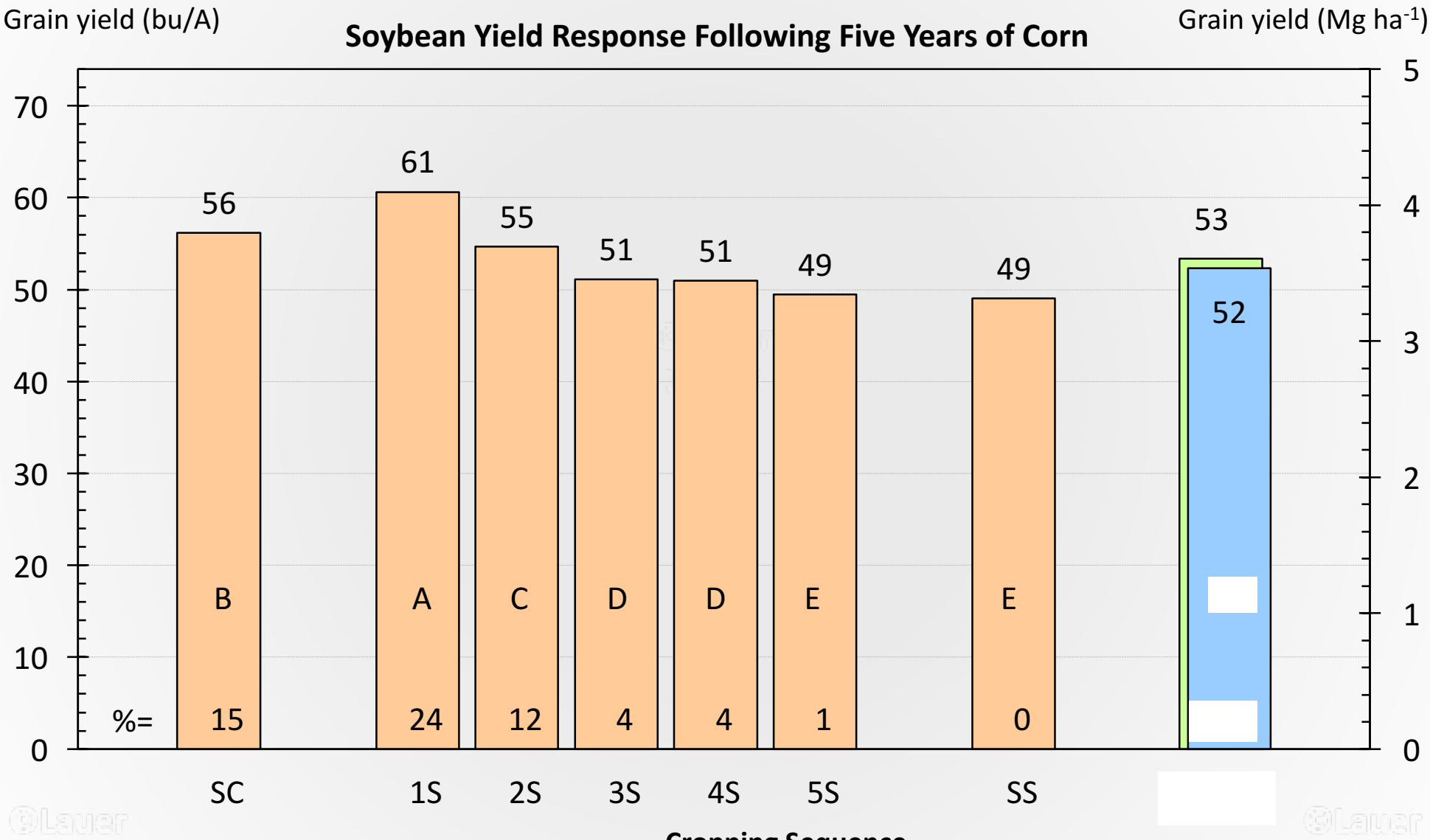
Lauer, 1987-2016 (Arlington, Control treatments)

The story for soybean is different. The rotation effect is greater for 1S than SC. Yield decreases 12% in 2S and still further in 3S …



C= Corn, S= Soybean, 1S= First year soybean, 2S= Second year soybean… SS= Continuous soybean

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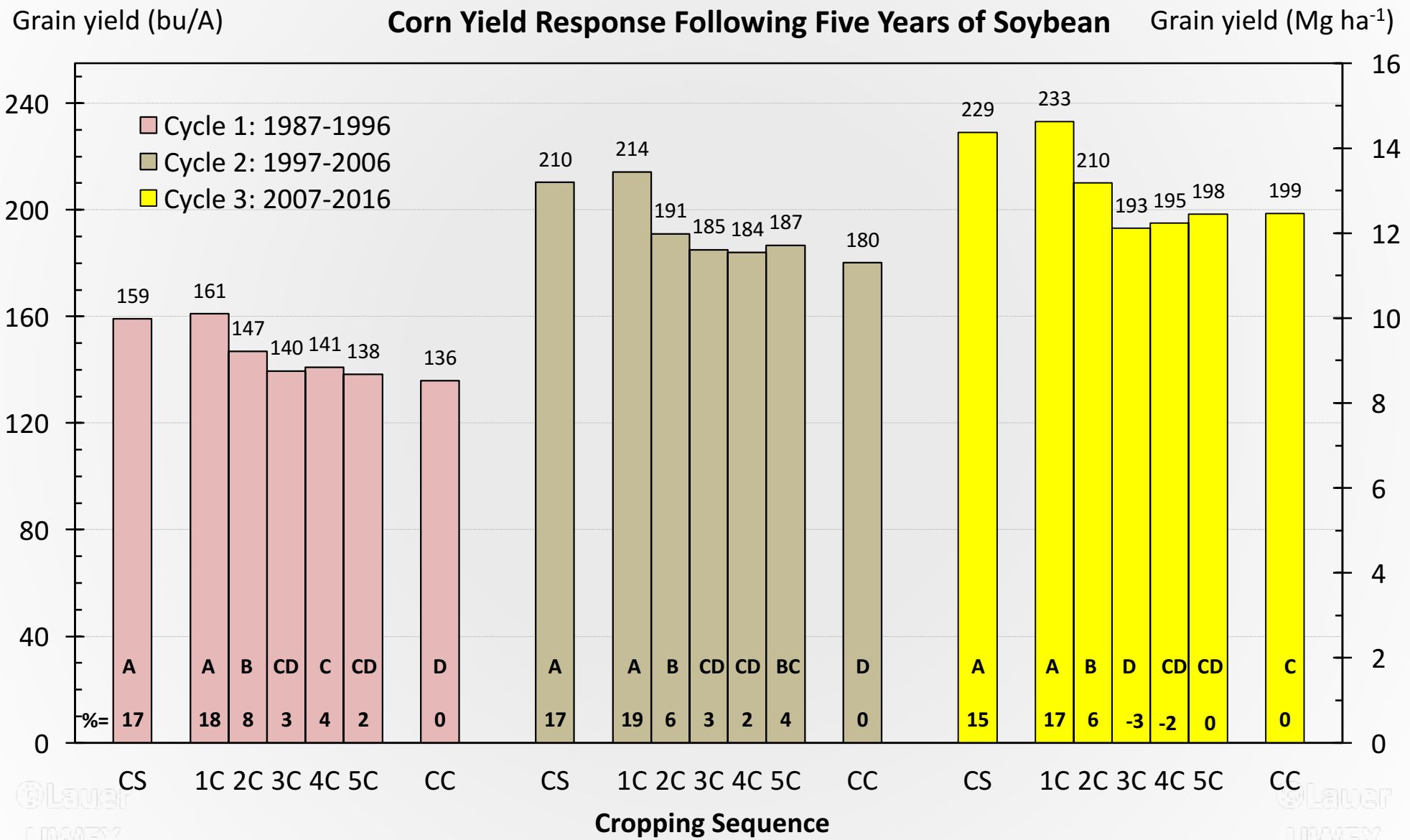
Lauer, 1987-2016 (Arlington, Control treatments)

The rotation effect lasts two years increasing corn grain yield 15-19% for 1C and 6-8% for 2C.



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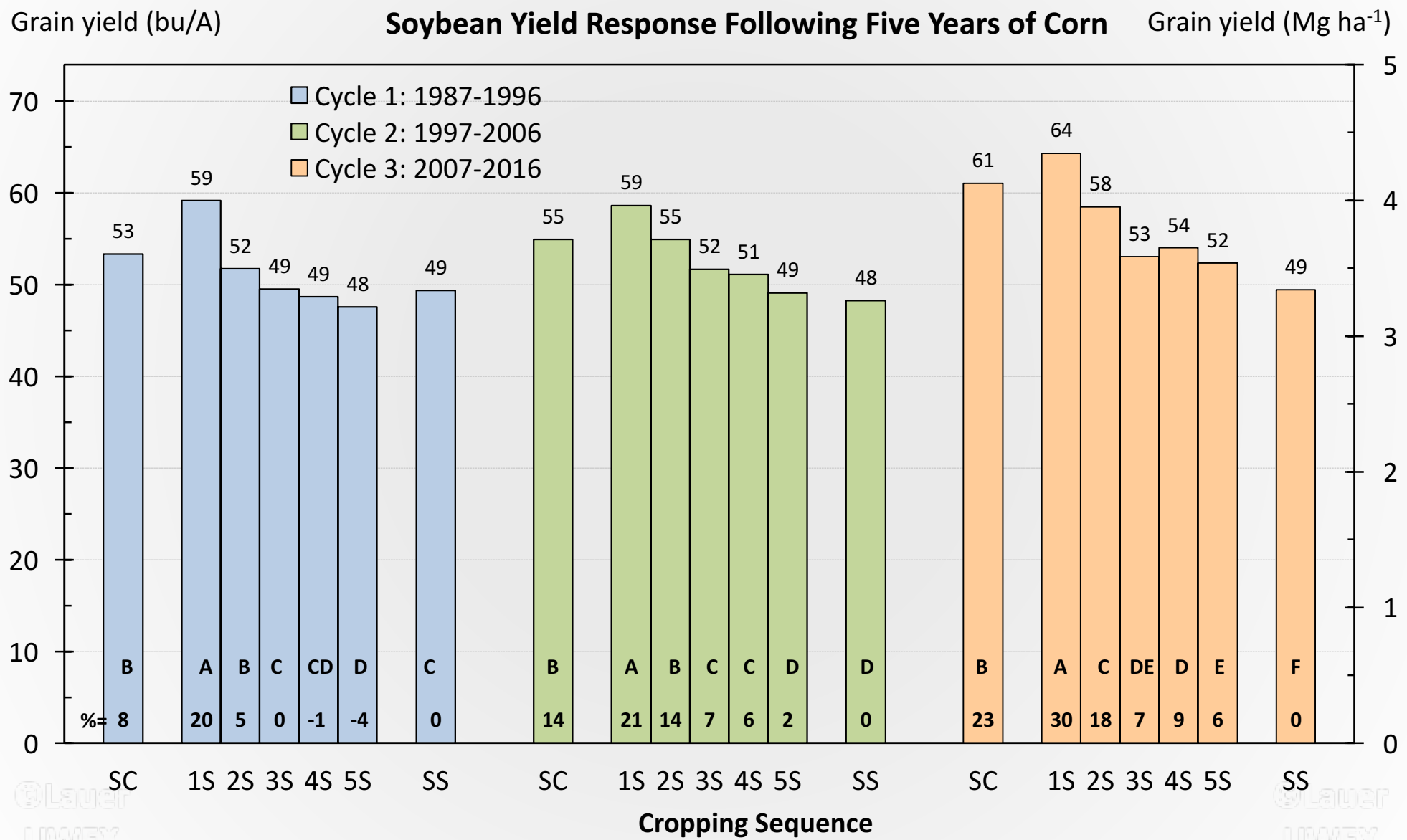
Lauer, 2017 – Arlington, WI
Control treatments, Transgenic hybrids used since 1998

The rotation effect lasts two years increasing soybean grain yield 8-30% for 1S and 5-18% for 2S.



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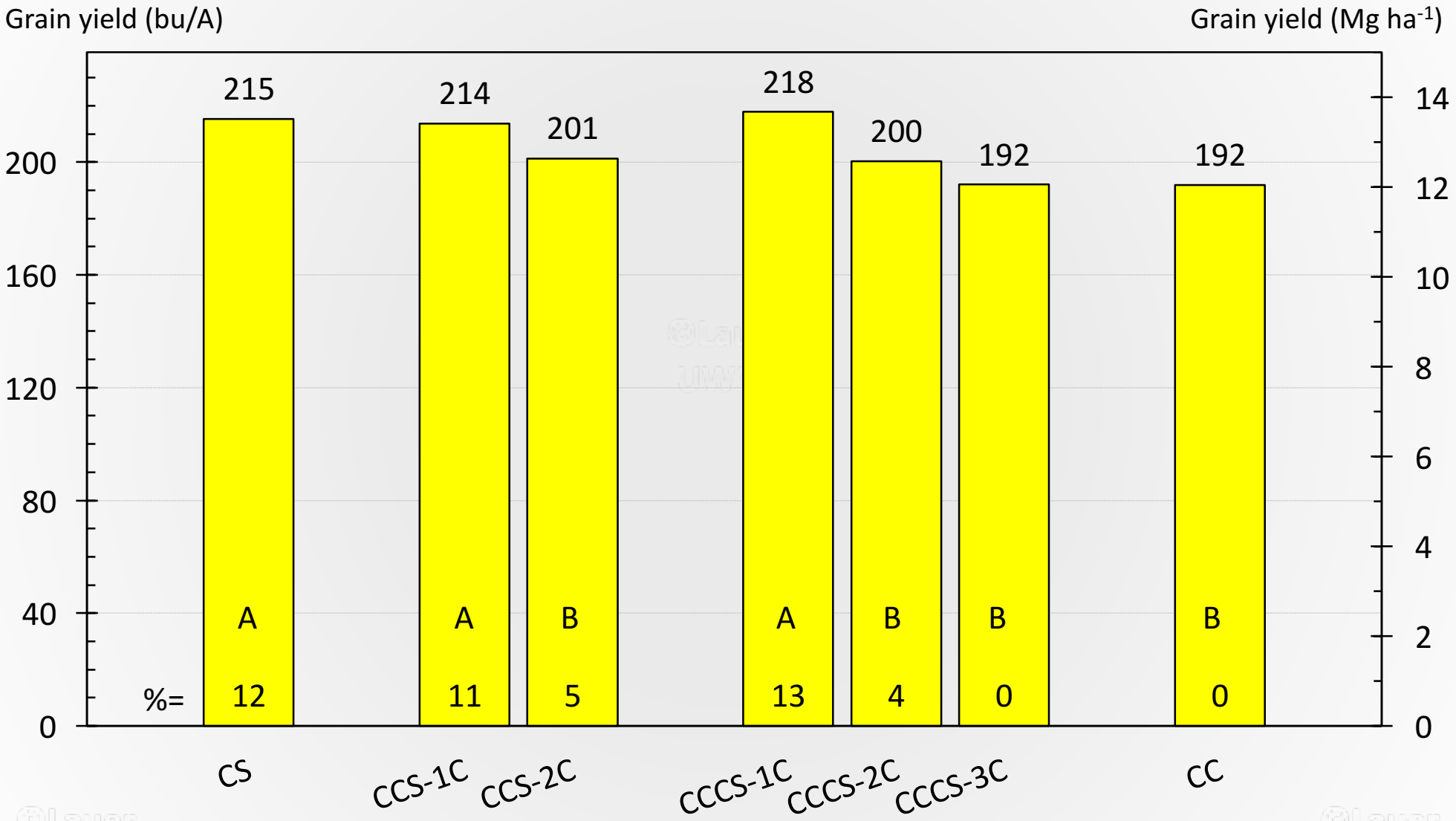
Lauer, 2017 – Arlington, WI
Control treatments, Transgenic varieties used since 1998

If there is only a one year break in the rotation, then the second corn phase is equivalent to continuous corn …



C= Corn, S= Soybean, 1C= First year corn, 2C= Second year corn … CC= Continuous corn

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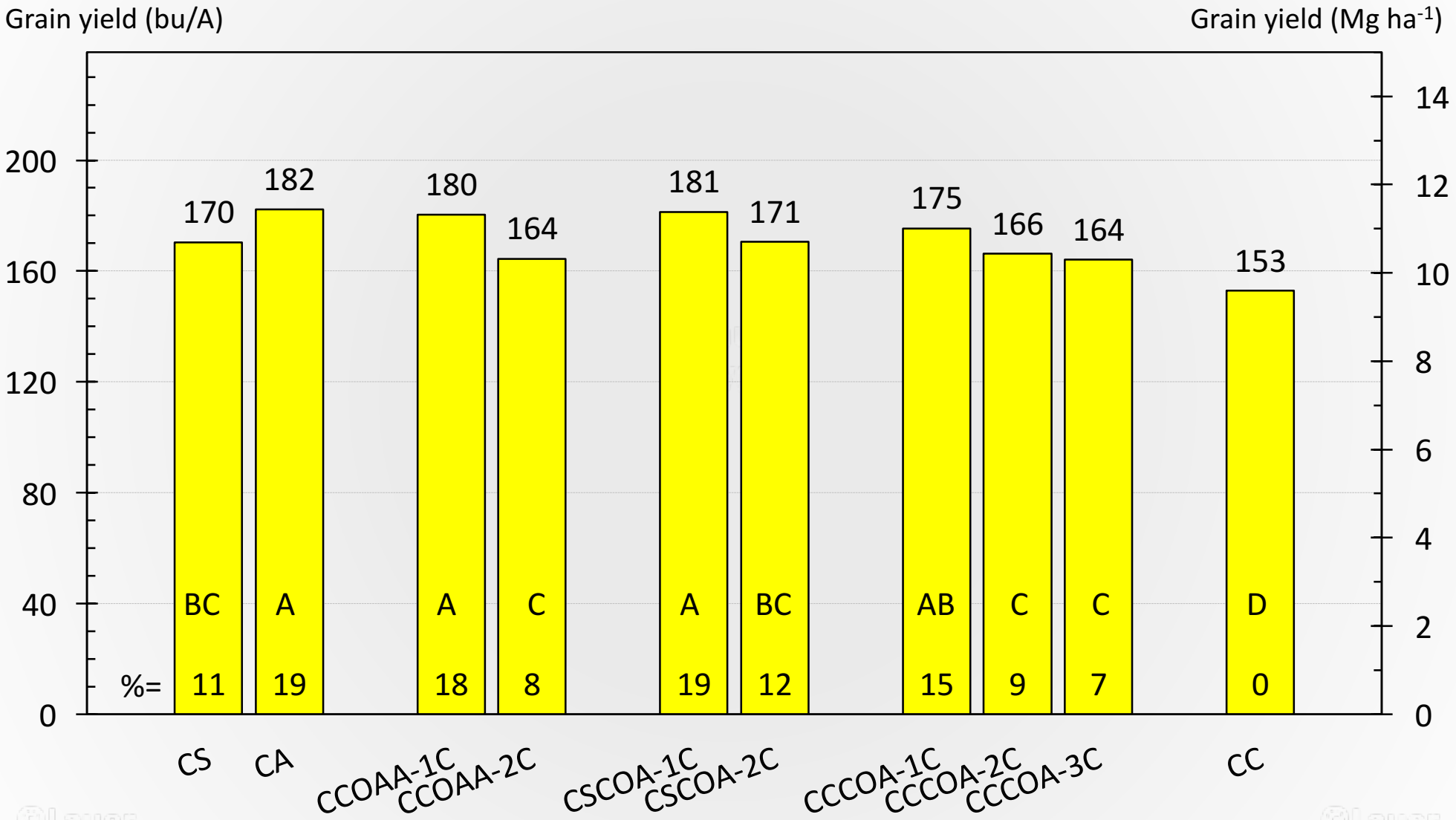
Lauer, 1998-2000 Control treatments

At least two break years are needed to measure a response in the second corn phase (compared to CC) …



A= Alfalfa, C= Corn, O= Oat, S= Soybean, 1C= First year corn, 2C= Second year corn … CC= Continuous corn

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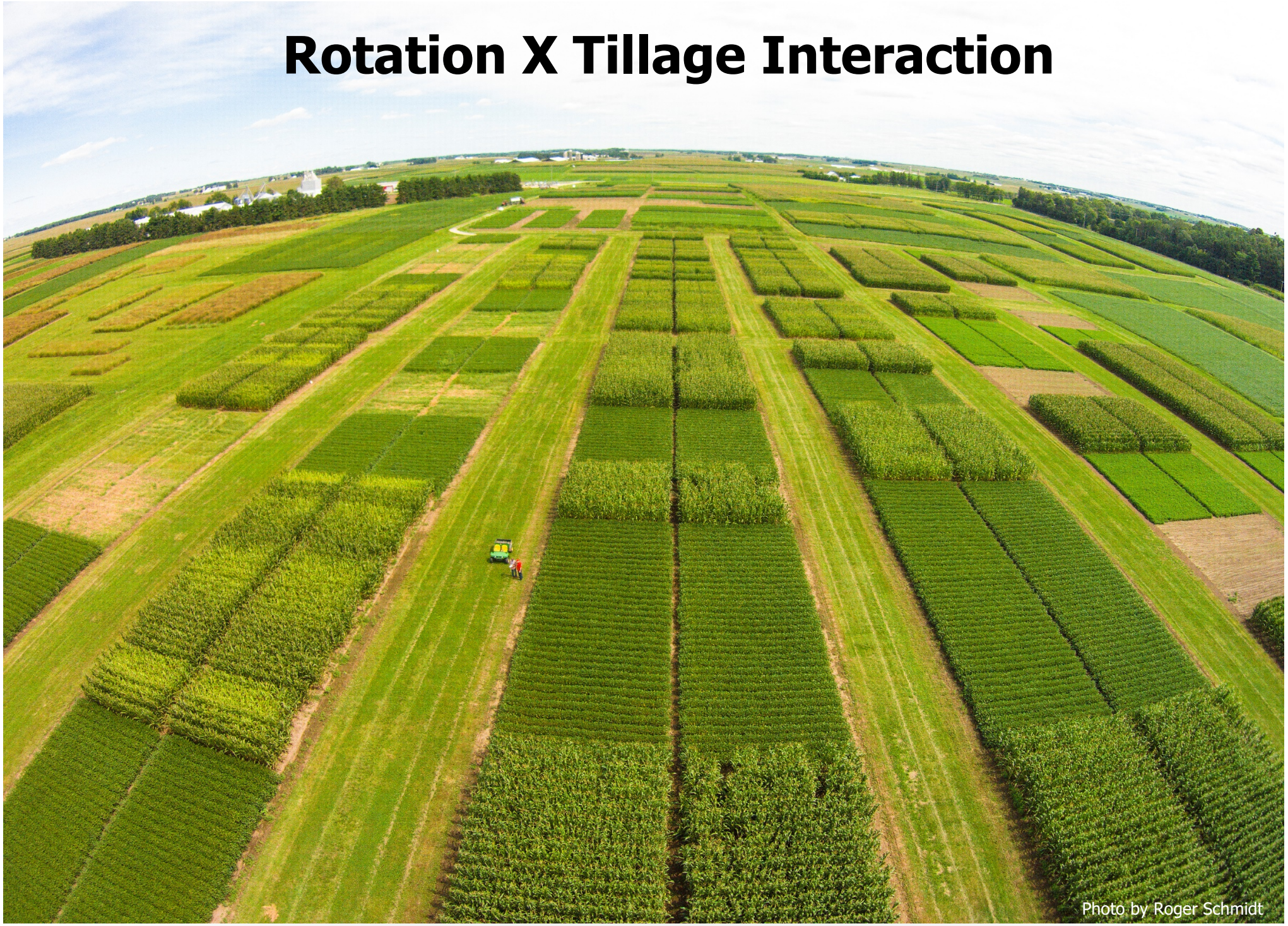
Lauer, 1990-2009 (Lancaster, Control treatments)

Rotation X Tillage Interaction



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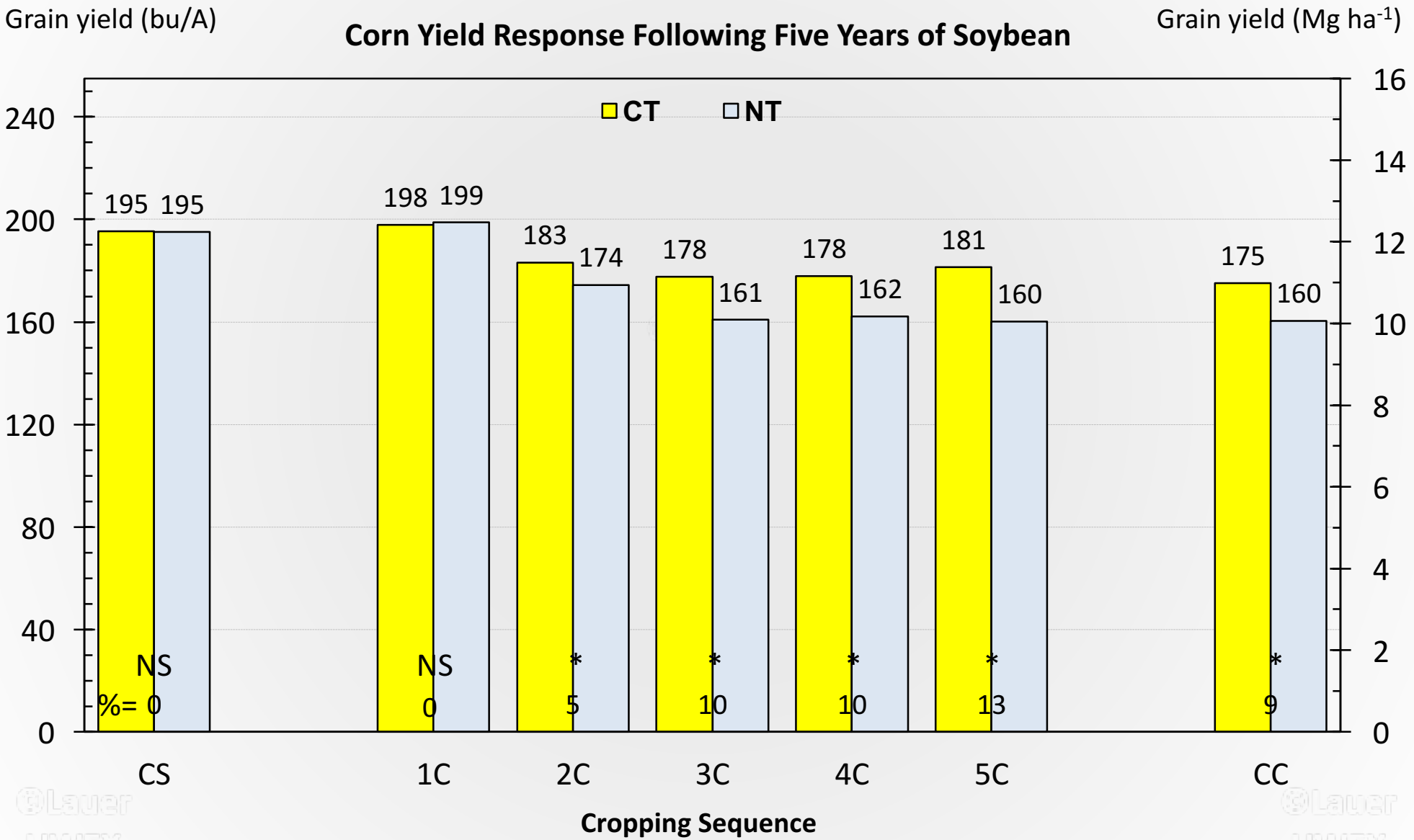
Tillage does not affect corn yield in CS/1C, but improves yield 5% in 2C, and 10% in 3C …



C= Corn, S= Soybean, 1C= First year corn, 2C= Second year corn … CC= Continuous corn

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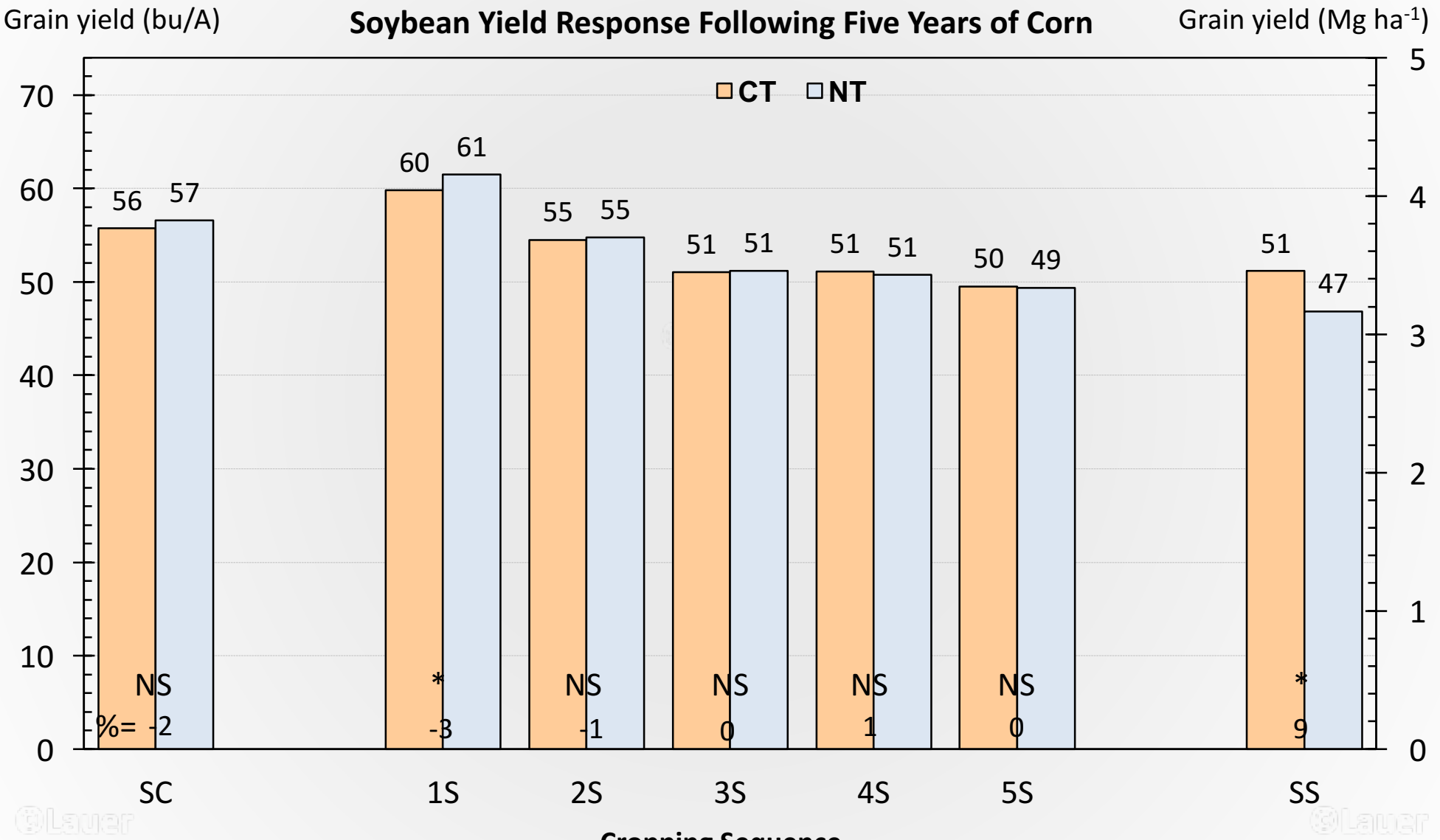
Lauer, 1987-2016 (Arlington, Control treatments)

Tillage either decreases soybean grain yield 3% in 1S or has no effect on soybean yield, except for SS.



C= Corn, S= Soybean, 1S= First year soybean, 2S= Second year soybean … SS= Continuous soybean

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Lauer, 1987-2016 (Arlington, Control treatments)

What about extending the rotation by adding a third crop?

Photo by Justin Hopf

Crop Sequence for 3-Crop Rotation Experiment at Arlington and Marshfield, WI (C= Corn, S= Soybean, W= Wheat)

Rotation Sequence	Year		
	1	2	3
1	C	C	C
2	S	S	S
3	W	W	W
4	C	S	C
5	S	C	S
6	C	S	W
7	W	C	S
8	S	W	C
9	C	W	S
10	S	C	W
11	W	S	C
12 (Biomass removed)	C	W	S
13 (Biomass removed)	S	C	W
14 (Biomass removed)	W	S	C

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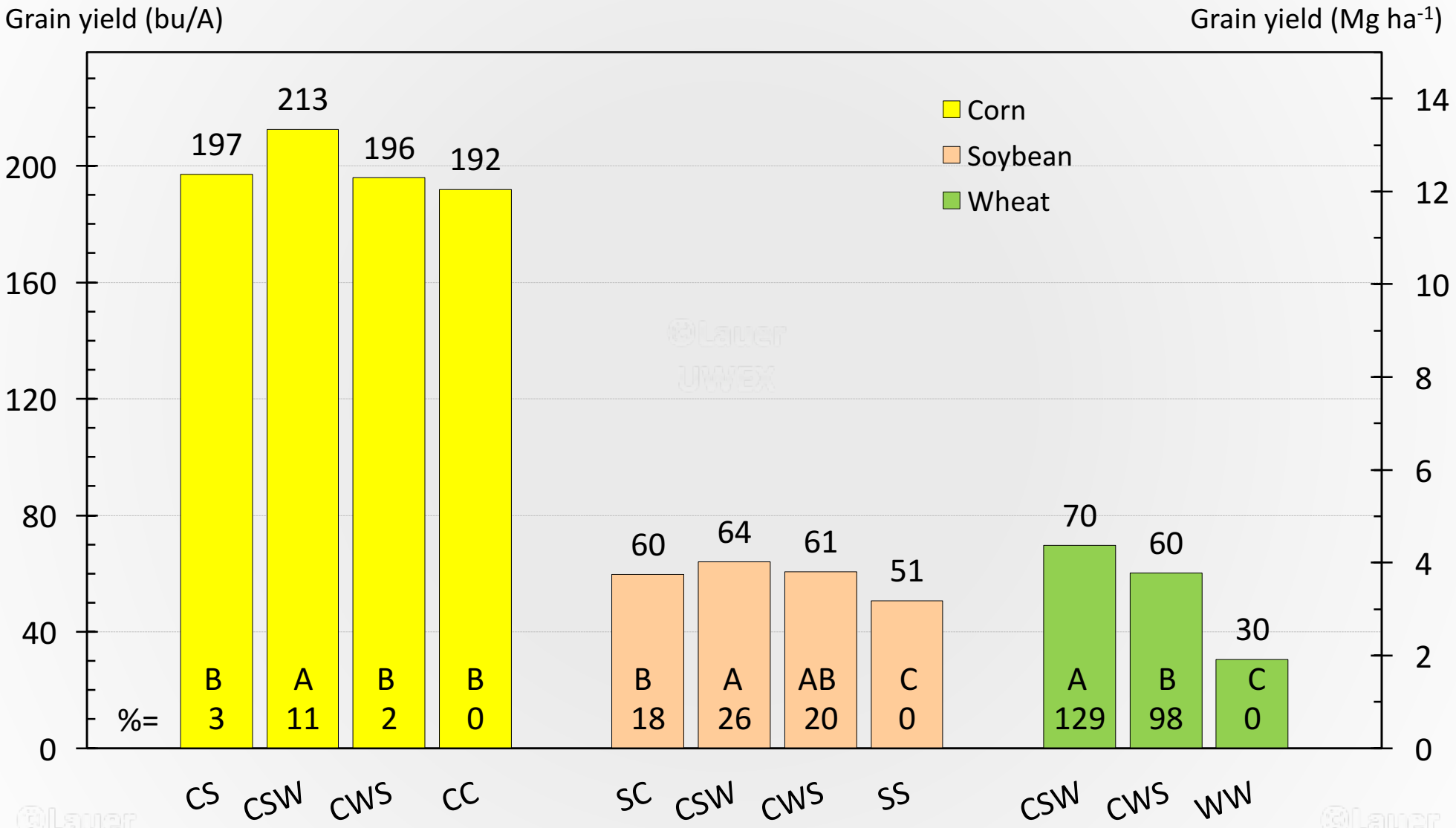
Extending crop rotation improves grain yield of all crops, but sequence is important



C= Corn, S= Soybean, Wheat= W, CC, SS, or WW= Continuous corn, soybean or wheat

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Lauer, 2005-2016 (Arlington, Control treatments)

Is the Corn-Soybean Rotation Sustainable? What are we looking for?

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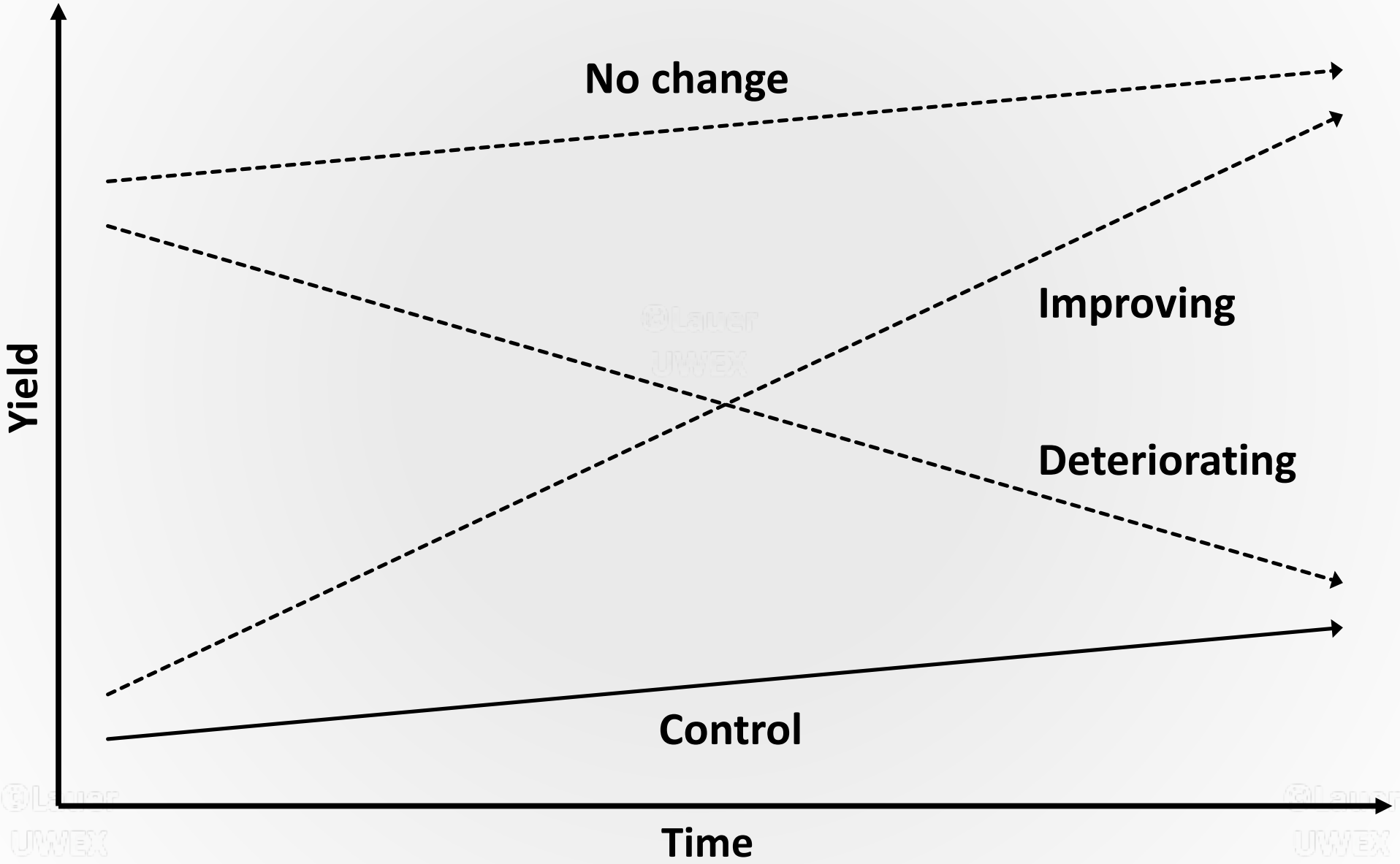
How can you tell if a cropping system is changing?



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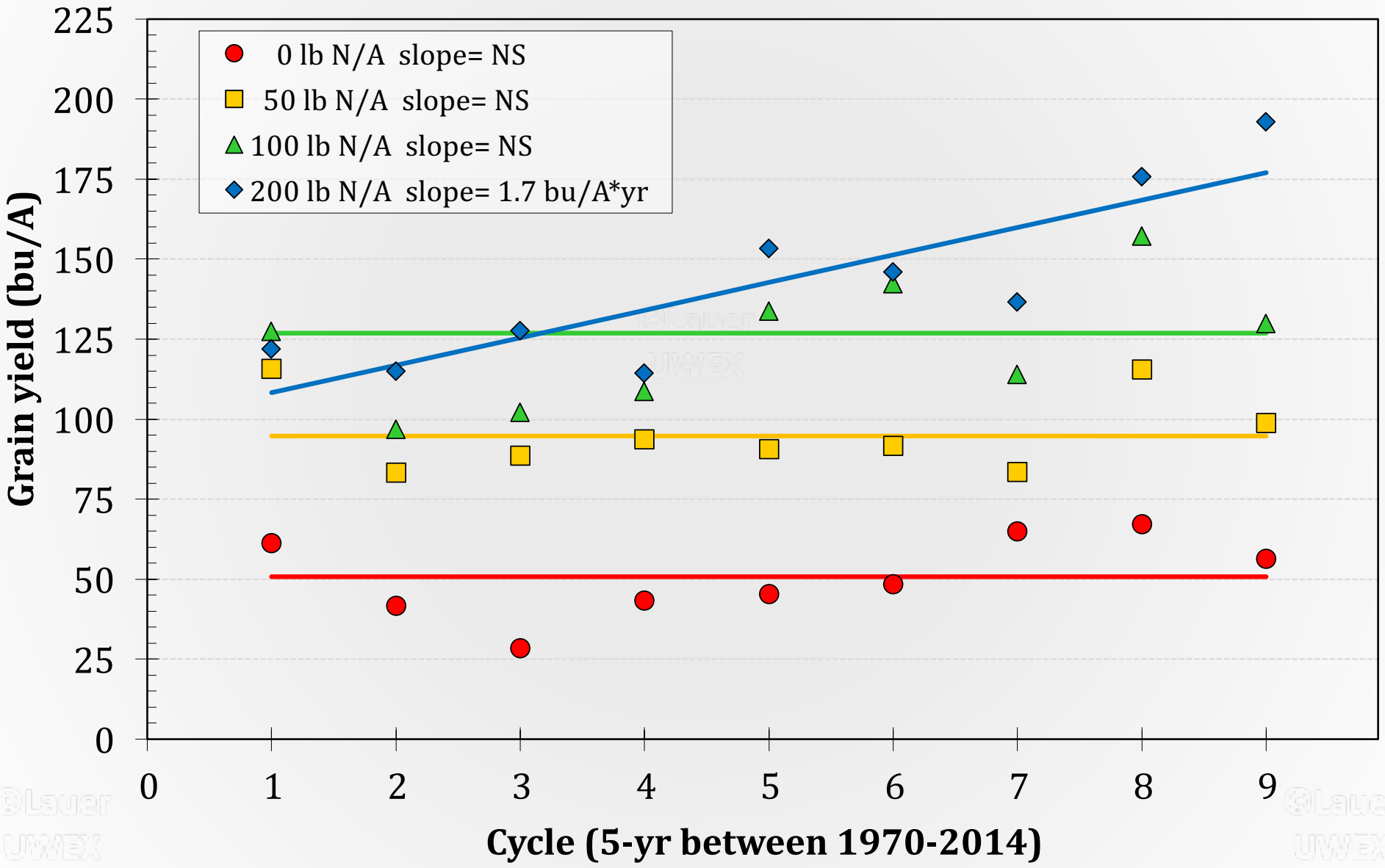
History of the Lancaster Rotation Experiment

Year of change	Rotations							Corn N rates (lbs N A^{-1})
1966	CC	CSCOaA	CCCOaA	CCOaAA	COaAAA			0, 75, 150, & 300
1977	CC	CSCOaA	CCCAA	CCOaAA	CCAA	AA		0, 50, 100, & 200
1987	CC	CSCOaA	CCCAA	CCOaAA	CS	CA	AA	0, 50, 100, & 200
2005	CC	CSCOaA	CCCAA	CCOaAA	CS	CSW		0, 50, 100, & 200

- C, Corn; S, Soybean; Oa, Oat with alfalfa seeding; A, Alfalfa; W, Wheat
- C, first phase; C, second phase; C, third phase

Continuous corn grain yield response to N rate in (over time and space) at Lancaster, WI.



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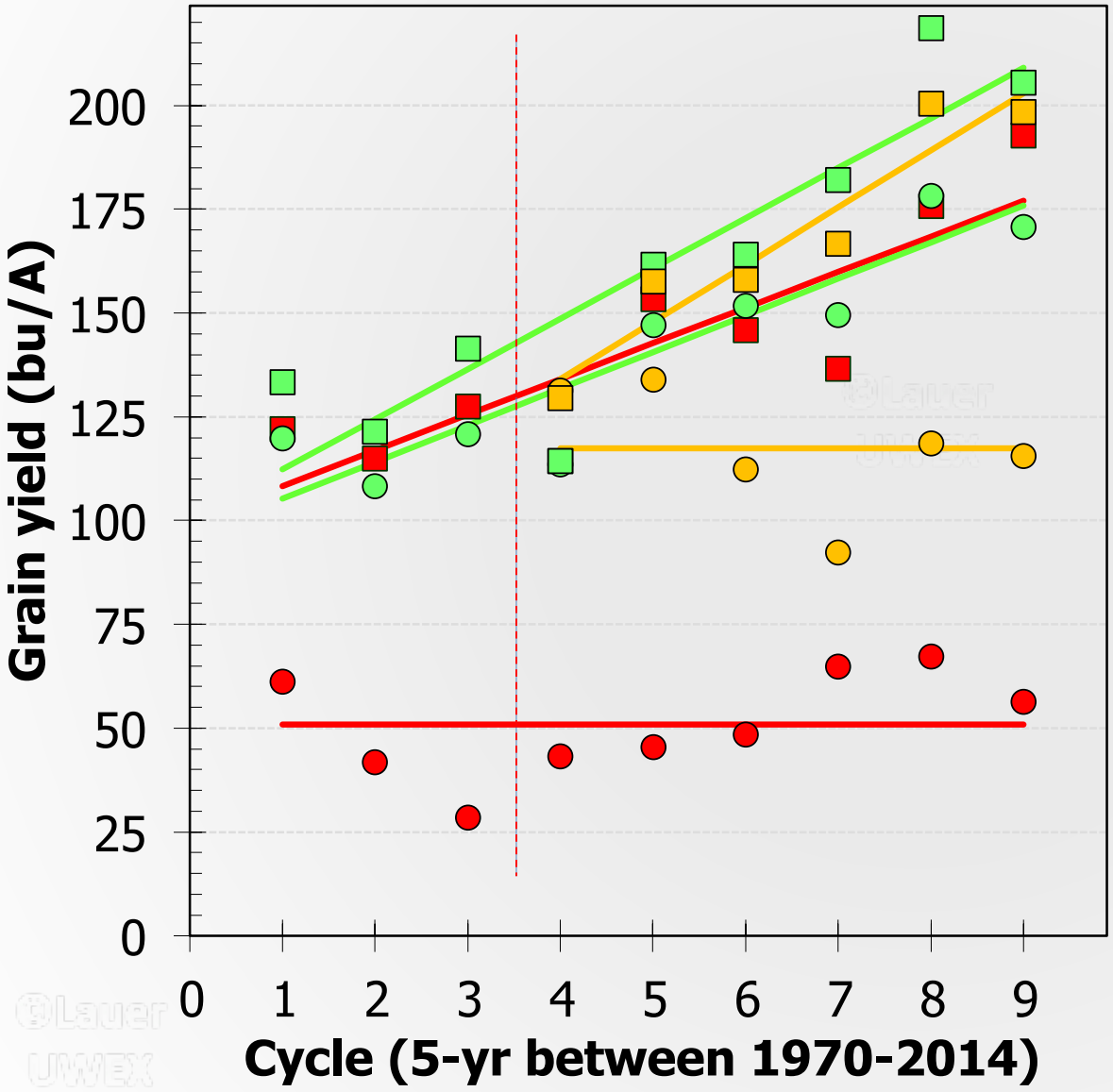
Stanger and Lauer, 2008
Updated by Lauer 2016

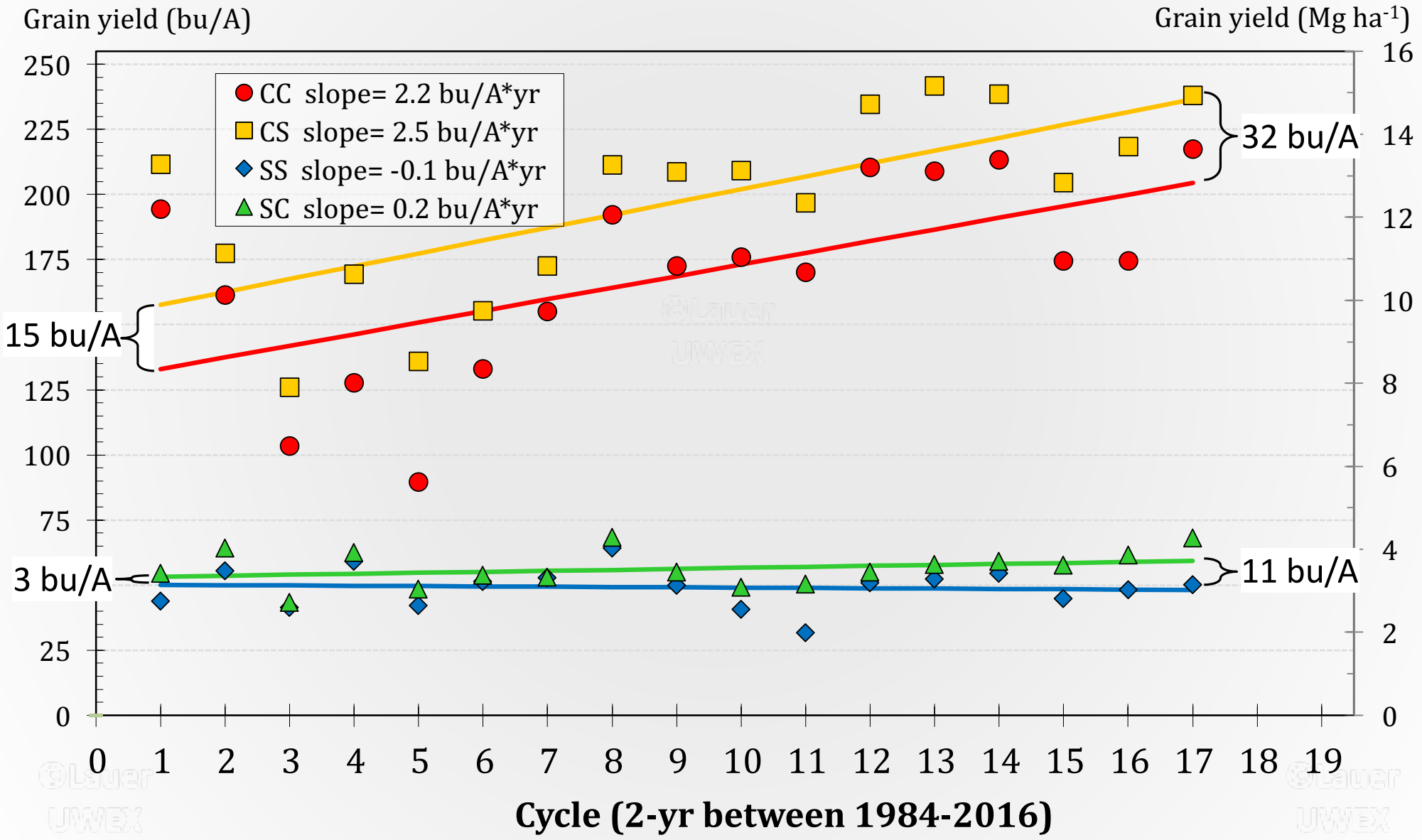
Are CC, CSCOaA and CS rotations improving (+) or deteriorating (-) for grain yield? …



- CC 0 lb N/A slope= NS
- CC 200 lb N/A slope= 1.7 bu/A*yr
- CSCOaA 0 lb N/A slope= 1.8 bu/A*yr
- CSCOaA 200 lb N/A slope= 2.4 bu/A*yr
- CS 0 lb N/A slope= NS
- CS 200 lb N/A slope= 2.8 bu/A*yr

Stanger and Lauer, 2008
Updated by Lauer 2016

Continuous and rotated corn and soybean grain yield response (over space and time) at Arlington, WI.



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Lauer 2017 (Arlington, Control plots)

Profitability and Risk

Rotation	lb N A^{-1}	\$ A^{-1} Yr^{-1}
CS	100	125[a]
CS	200	111[ab]
CS	50	109[abc]
CSCOaA	100	92[bcd]
CSCOaA	50	90[bcd]
CSCOaA	200	88[b-e]
CS	0	87[b-e]
CCOaAA	50	87[b-e]
CCOaAA	100	85[b-f]
CCOaAA	200	83[c-g]
CSCOaA	0	78[d-h]
CCOaAA	0	73[d-i]
CCCAA	100	67[d-i]
AA	50	62[e-i]
CCCAA	200	62[e-i]
CC	200	59[f-i]

- Most profitable rotations
  - ✓ CS – 50, 100, 200 lbs N/A
  - ✓ CSCOaA – 50, 100, 200 lbs N/A
  - ✓ CC – 200 lbs N/A
- Remaining cropping systems were less profitable and risk inefficient:
  - ✓ CCCAA – 0 & 50 lbs N/A
  - ✓ CA – 0, 50, 100, & 200 lbs N/A
  - ✓ AA – 0, 100, & 200 lbs N/A
  - ✓ CC – 0, 50, & 100 lbs N/A
- FDSD analysis failed
- SDSD efficient

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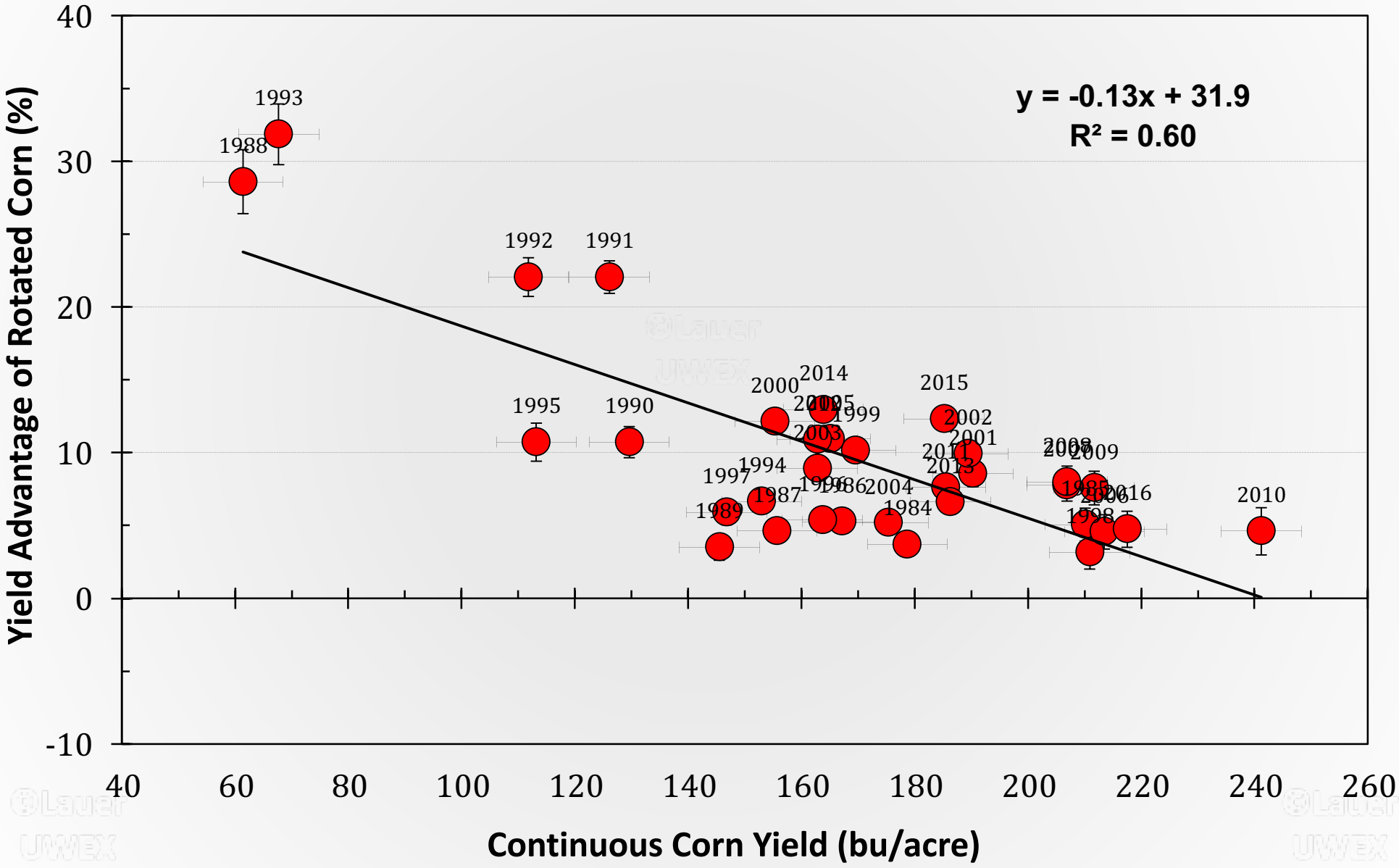
Stanger et al., 2008, AJ 100:105

Mechanism for rotation effect is unknown Hypotheses

- Direct factor – Traditional hypothesis
  - ✓ First proposed by Augustin Pyramus de Candolle (1778 - 1841) Geneva, Switzerland

  - ✓ Alleopathic: "A given crop's own residue has an auto-inhibitory effect when that crop is maintained under monoculture, and/or that residues of alternate crops have a stimulatory effect on one another under rotation."
    - ➢ Pro: Bhowmik and Doll (1982)
    - ➢ Con: Crookston and Kurle (1989)
- Indirect factor
  - ✓ "Effect is not due to some lingering positive effect of the previous crop. Rather, a rotated crop apparently serves to relieve the negative effect of continuous cropping, and does not make any positive, growth-regulatory contribution to the yield of a following crop."
    - ➢ Crookston et al. (1988)
- Many factors – Environment determines
  - ✓ "Due to a combination of factors, including long-recognized benefits of changes in soil nutrient or physical status, levels of pests, etc., any of which may, or may not, be of significance in a given environment or cropping sequence."
    - ➢ Crookston et al. (1991), Porter et al. (1997)

Rotation is more important in stress environments …



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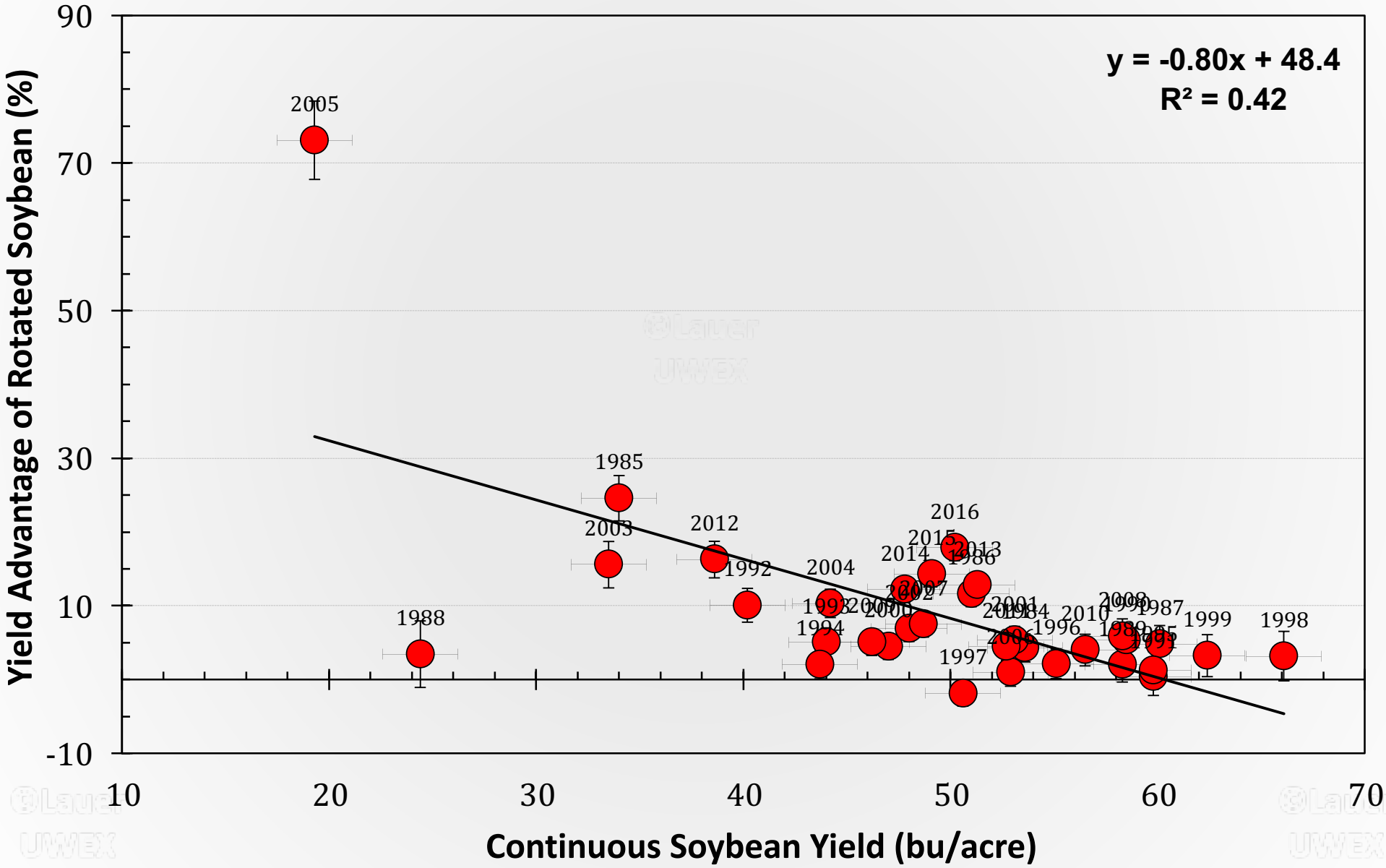
Lauer, 1984-2016 (Arlington, Control treatments)

Rotation is more important in stress environments …



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Lauer, 1984-2016 (Arlington, Control treatments)

NCGA Corn Yield Contest Winners

David Hula, Charles City, VA
2015: 532 bu/A

Randy Dowdy, Valdosta, GA
2016: 521 bu/A

Francis Childs, Manchester, IA
2002: 442 bu/A

Herman Warsaw, Saybrook, IL
1985: 370 bu/A

Summary

- Modern corn hybrids and management practices have the same rotation response as older hybrids and practices.
- The rotation effect lasts at most two years increasing corn grain yield 16 to 18% for 1C and 0 to 7% for 2C. Soybeans = 15 to 24% for 1S and 12% for 2S.
- At least two break years are needed to measure a response in the second continuous cropping year.
  - ✓ A one year break using soybean reduces the rotation effect in the second continuous year.
- Tillage does not affect corn yield the first year following soybean, but improves yield 5% in the second year, and 10% in the third year.
- The addition of other crops to the rotation can improve grain yield of all crops.
  - ✓ Prudent thing to do
- Mechanism for rotation effect is unknown. It is probably unique over space and time.
  - ✓ Hypothesis #1: One factor causes effect (+ or -).
  - ✓ Hypothesis #2: Multiple factors cause effect and risk of expression depends upon the environment.
- Yield comparisons do not provide the appropriate basis for economic decision-making regarding cropping systems.
  - ✓ Ultimate decision for farmer is based upon economics.

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The End For Now – Questions?
Thanks for your attention!

Maciek Kazula
Hayley Bunselmeyer
Justin Hopf
Zhe Yan
Trenton Stanger
Palle Pedersen
Heather Darby
Jorge Cusicanqui
... many undergrads

Kent Kohn
Thierno Diallo
Pat Flannery
John Gaska
Mike Bertram
Keith Hudelson
Tim Wood
Dwight Mueller
Darwin Frye

Shawn Conley
Randy Shaver
Natalia DeLeon
Jim Coors
Johnny Pendleton
Ed Oplinger
Paul Carter
Roger Higgs
Larry Bundy
Greg Roth
Peter Thomison
Roger Elmore
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Chad Lee

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Photo by Justin Hopf