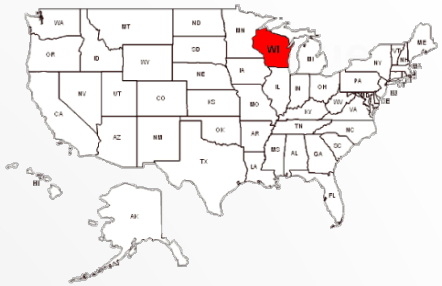


Capitalizing on the rotation effect to increase yield

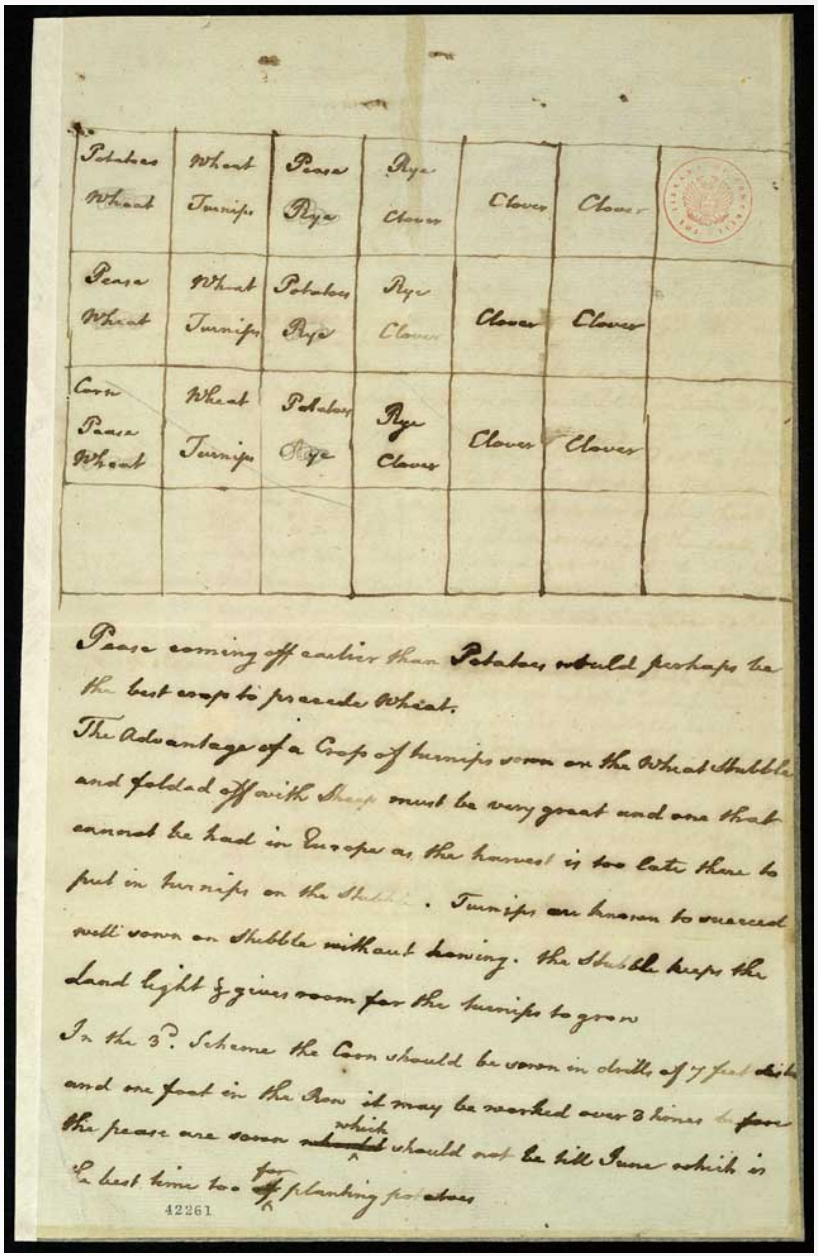
Joe Lauer
University of Wisconsin – Madison

Wisconsin Crop Management Conference
Madison, WI
January 12-14, 2016

UW Extension
University of Wisconsin-Extension

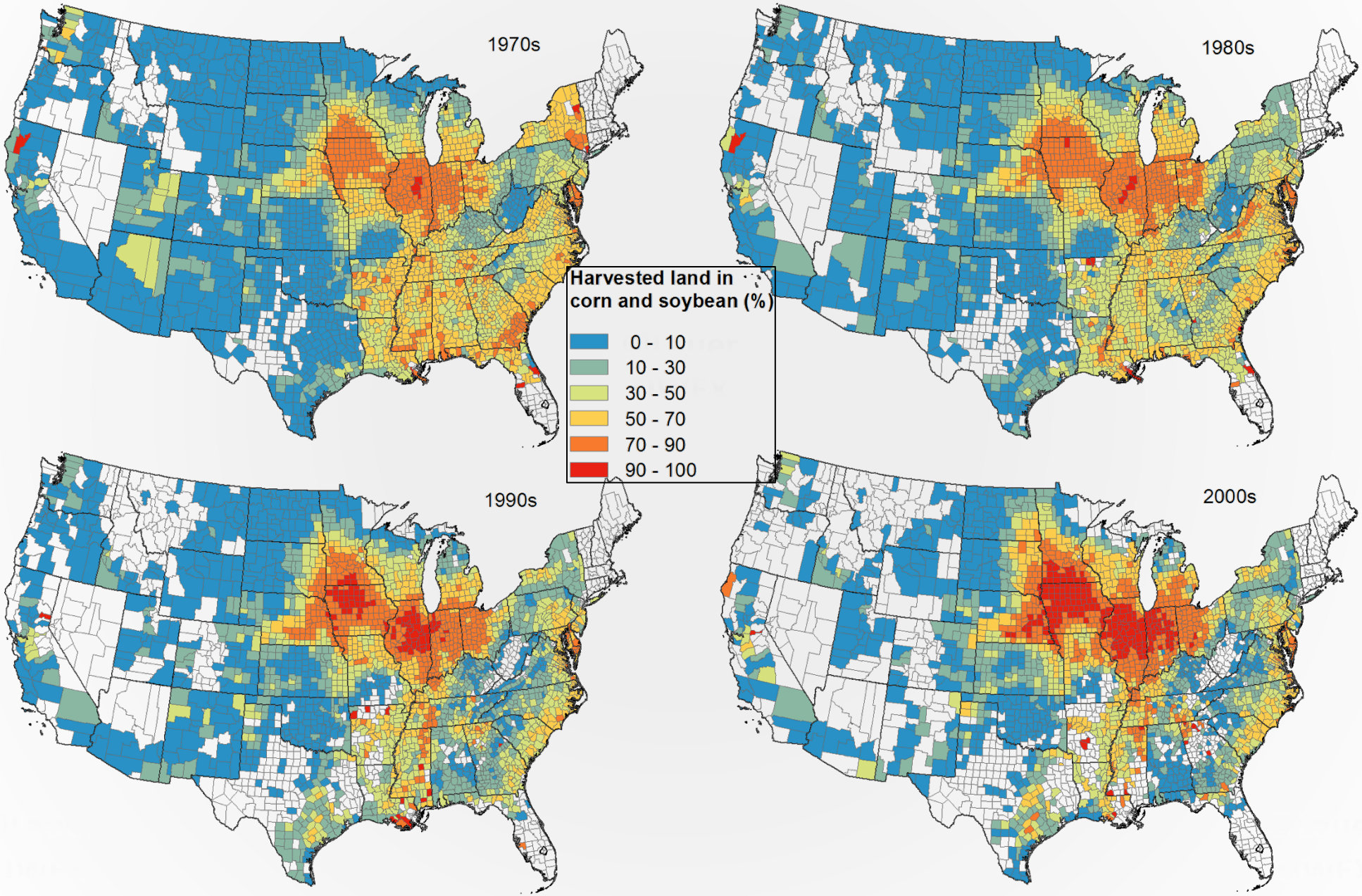
http://corn.agronomy.wisc.edu

Crop rotation plan for Monticello



- 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?

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



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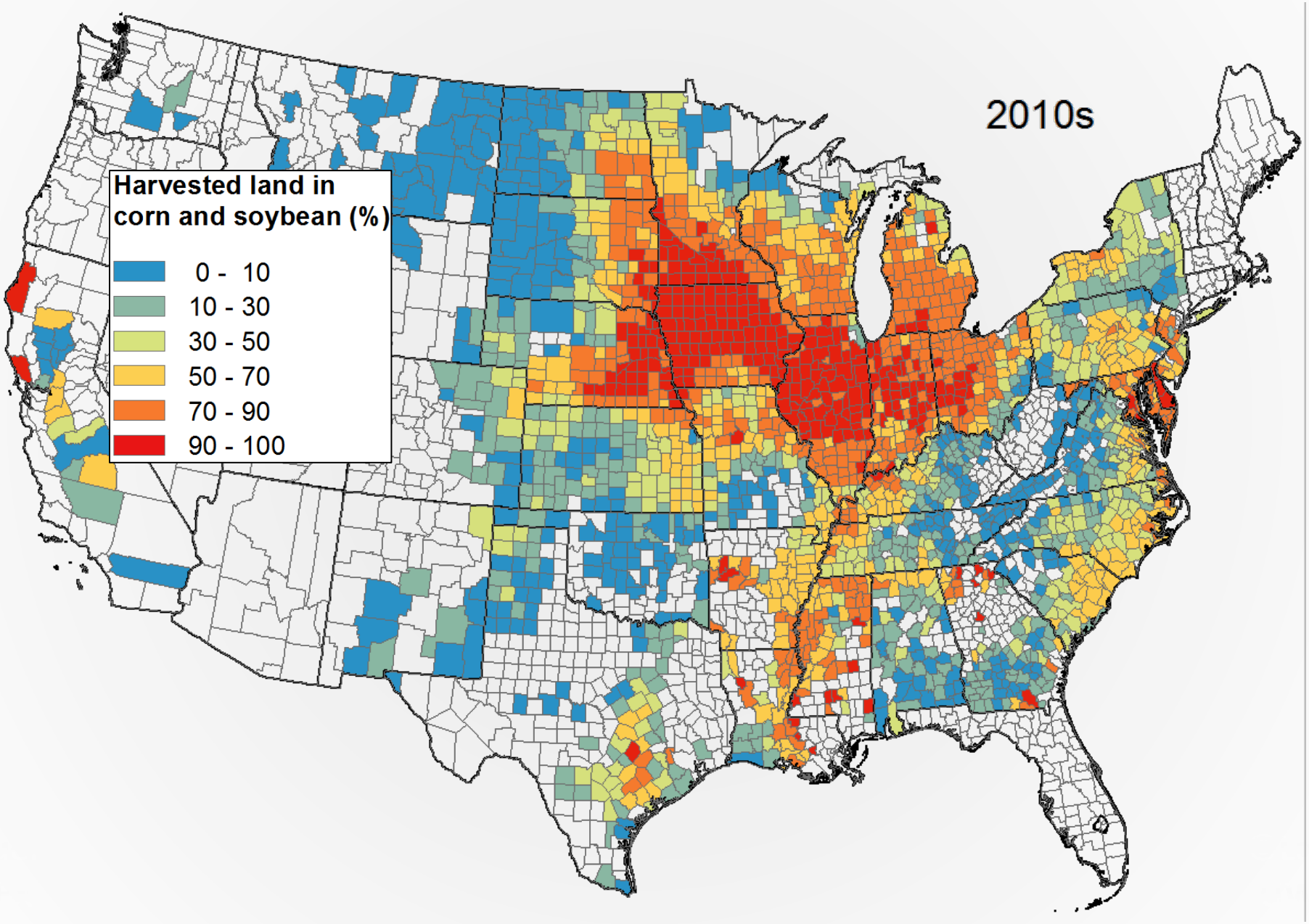
Lauer, 2015 (Data source: USDA-NASS)

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



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Lauer, 2015 (Data source: USDA-NASS 2010-2014)

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)

Overview

- Crop Rotation = ↑ yield
  - ✓ The Corn-Soybean rotation
  - ✓ Extending the CS rotation = ↑ yield
  - ✓ The Rotation X Tillage Interaction = ↑ $$$
- What are we looking for?
  - ✓ How can we tell if change is occurring?
  - ✓ What is the experimental unit?
- Sustainability
  - ✓ The necessity of N in a CS rotation
  - ✓ GHG Emissions
  - ✓ C sequestration

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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

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

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

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

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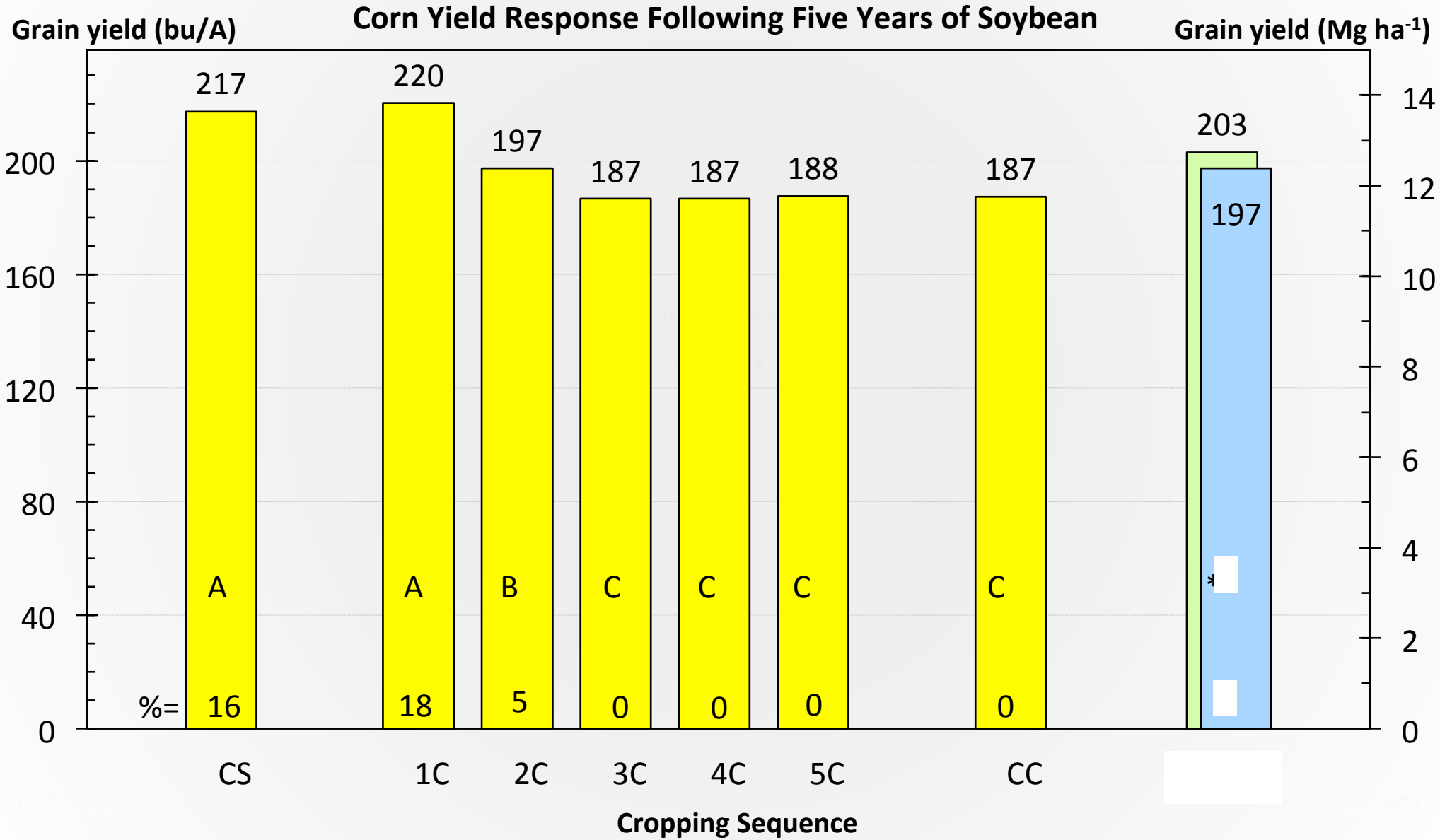
The rotation effect lasts two years increasing corn grain yield 16 to 18% for CS/1C and 5% for 2C …



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

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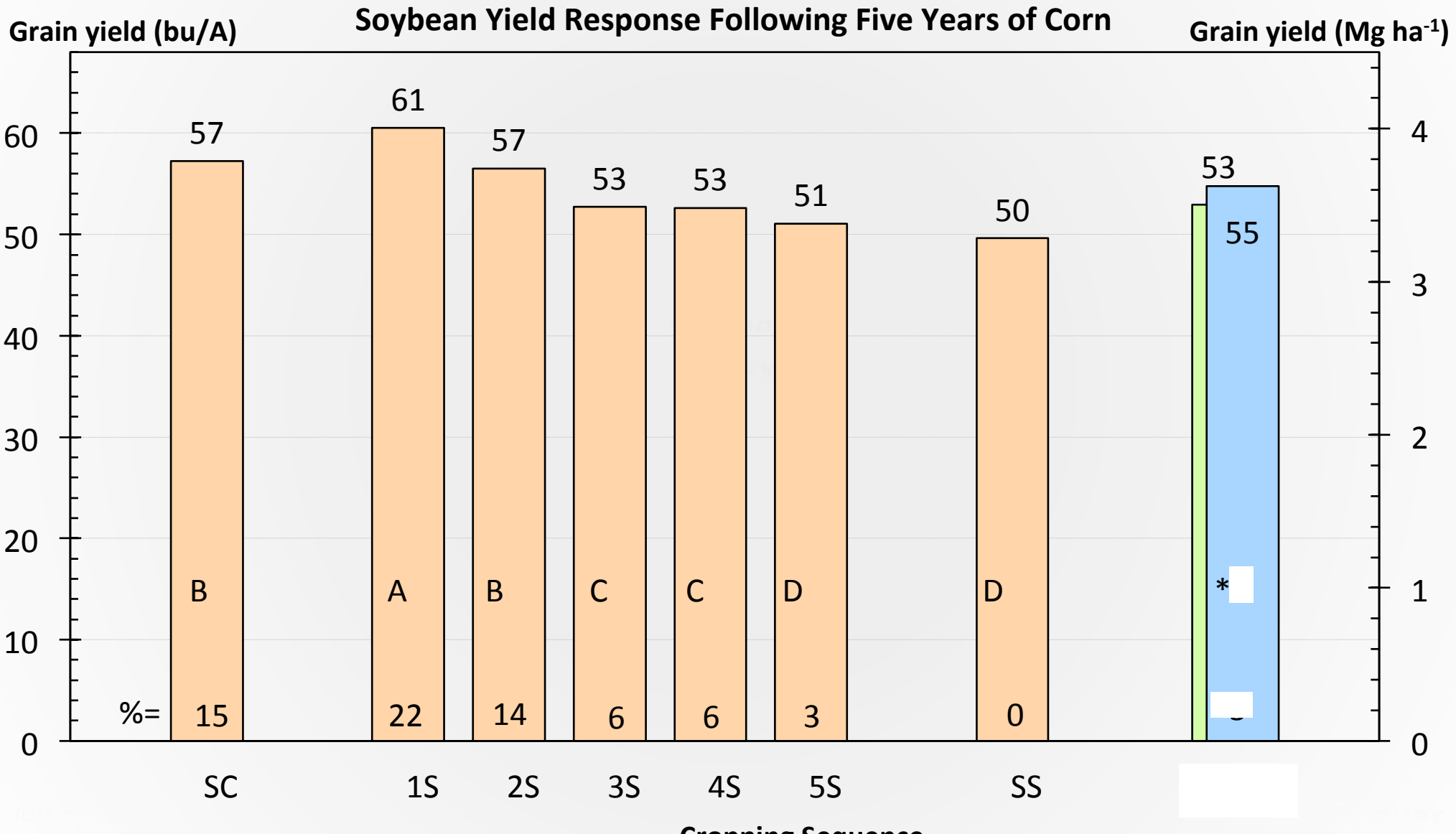
Lauer, 1996-2015 (Arlington, Control treatments)

The story for soybean is different. The rotation effect is greater for 1S than SC. Yield decreases 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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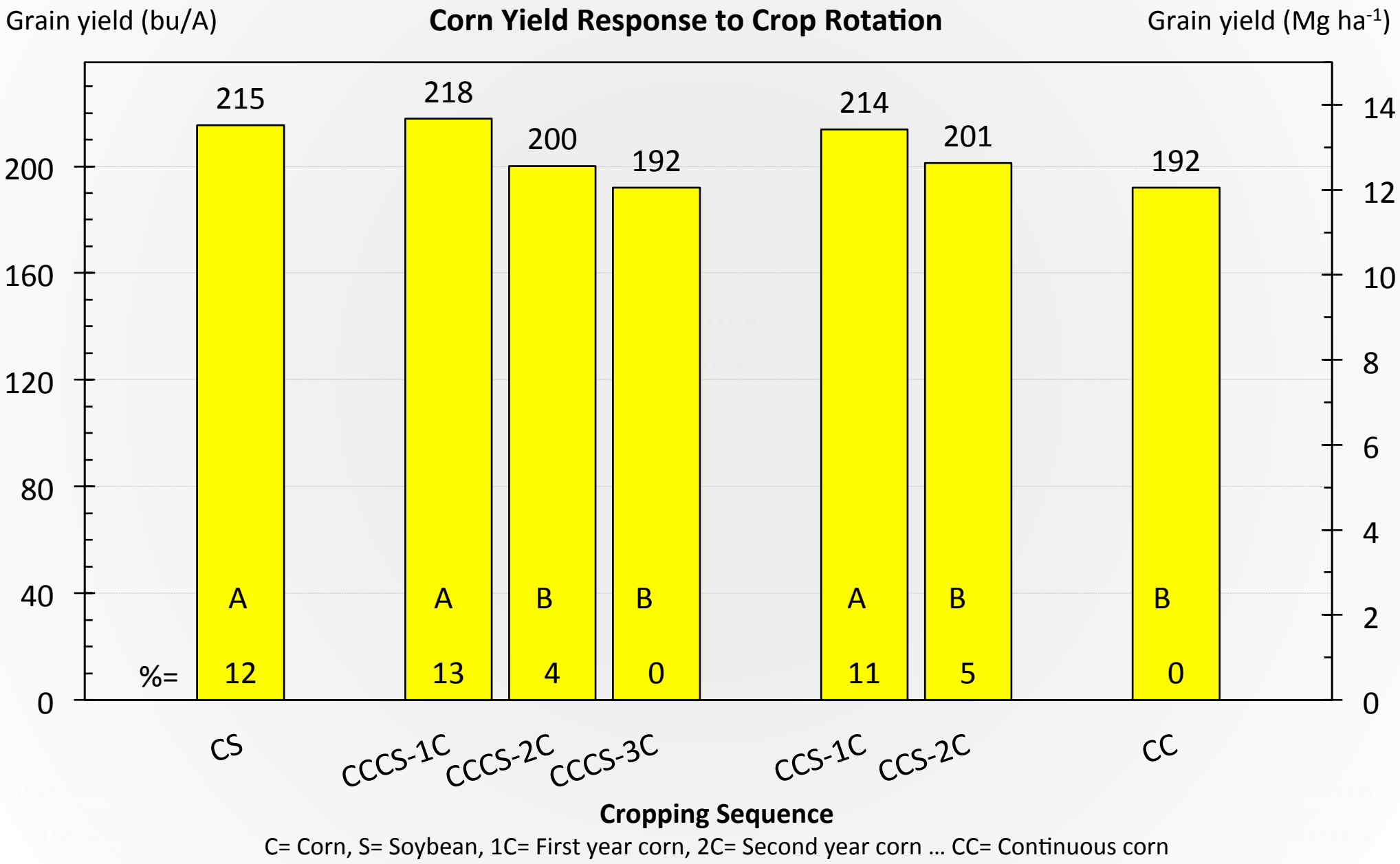
Lauer, 1996-2015 (Arlington, Control treatments)

Extending the Crop Rotation = ↑ yield

Photo by Justin Hopf

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



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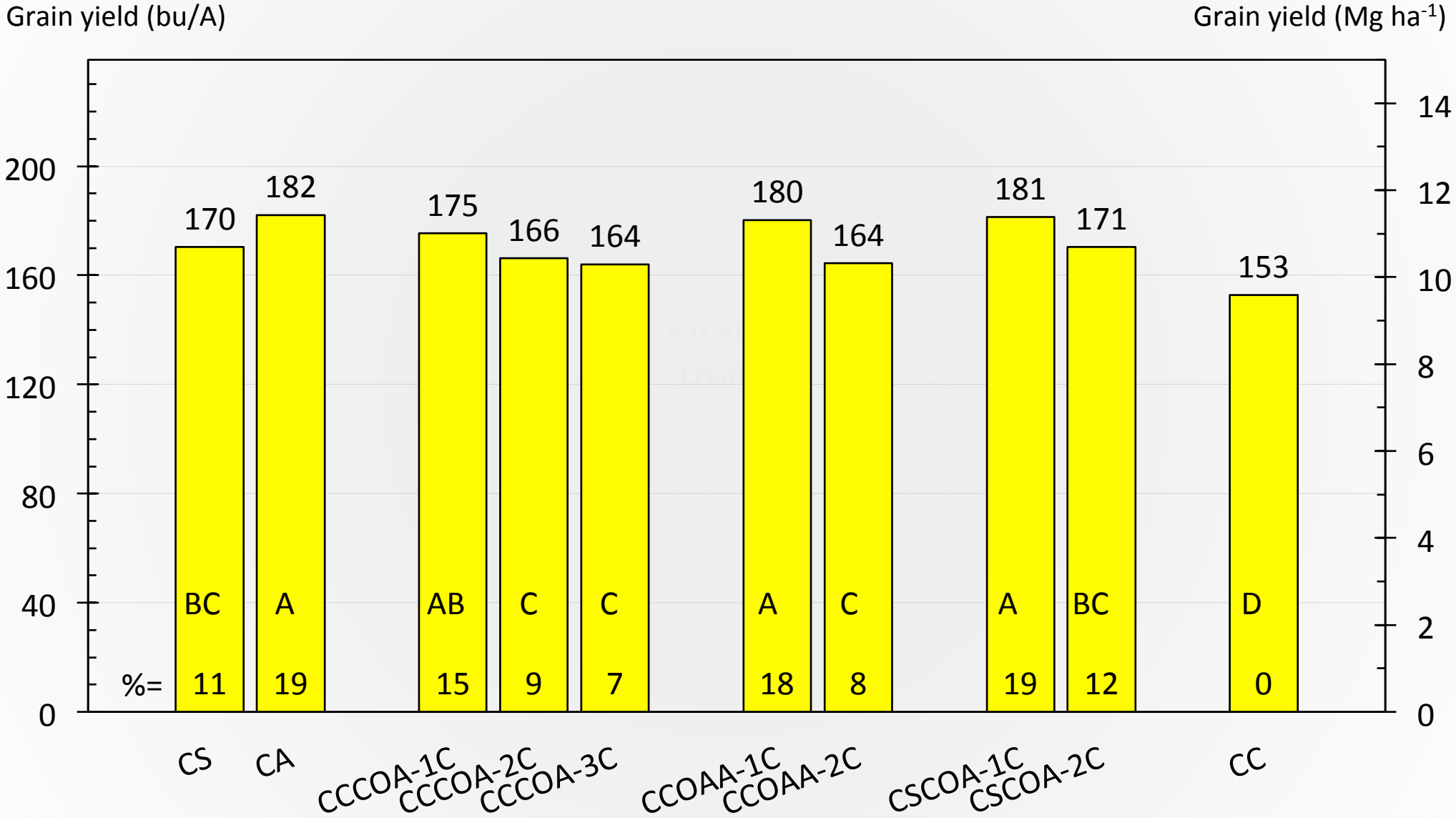
Lauer, 1998-2000 Control treatments

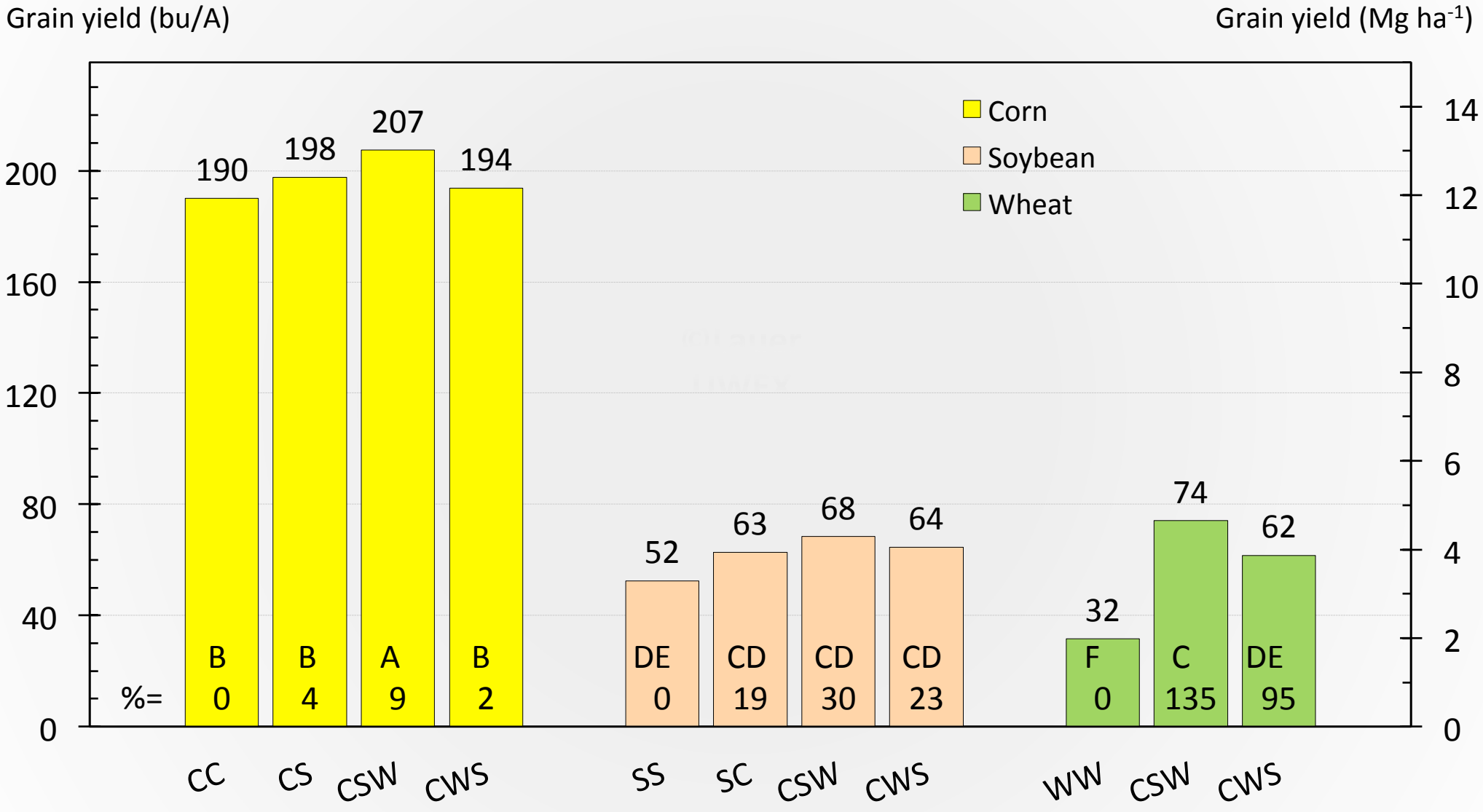
At least two break years are needed to measure a response in the second corn phase (compared to CC) …



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

Lauer, 1990-2009 (Lancaster, Control treatments)

Extending crop rotation improves grain yield of all crops



Cropping Sequence

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

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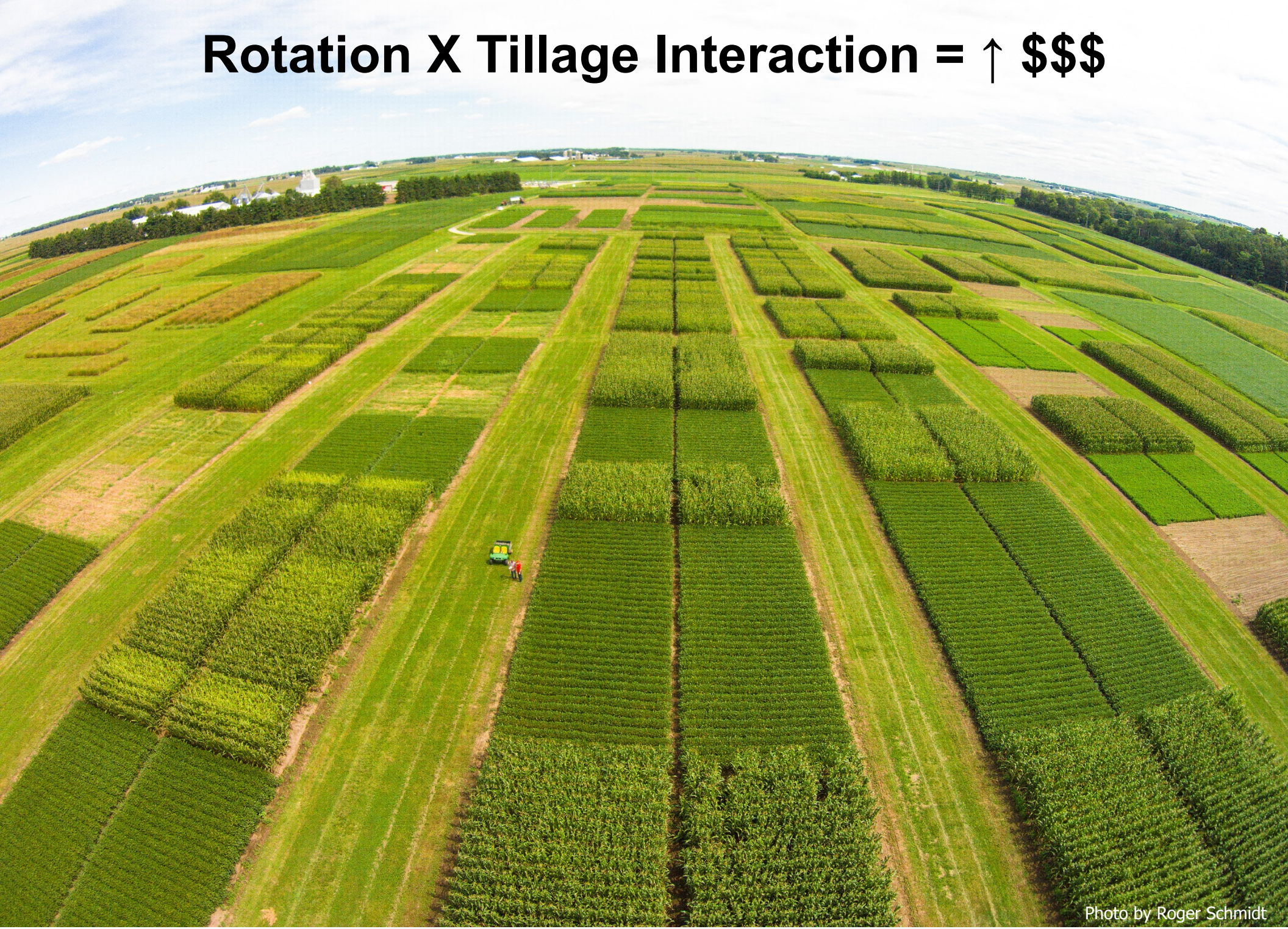
Lauer, 2004-2012 (Arlington, Control treatments)

Rotation X Tillage Interaction = ↑ $$$



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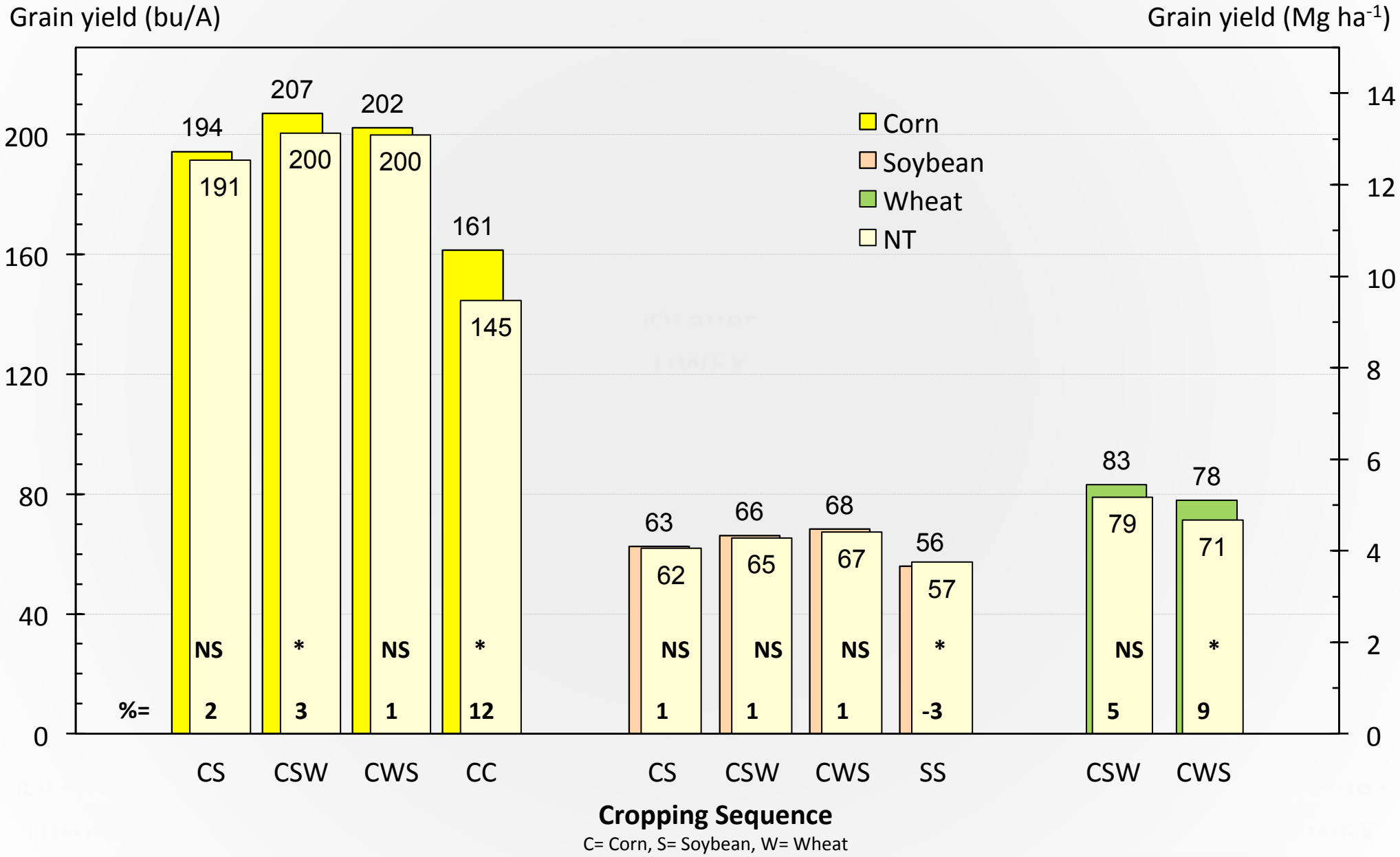
Tillage increases grain yield in CC and CSW, but there is a significant interaction when corn is rotated with soybean



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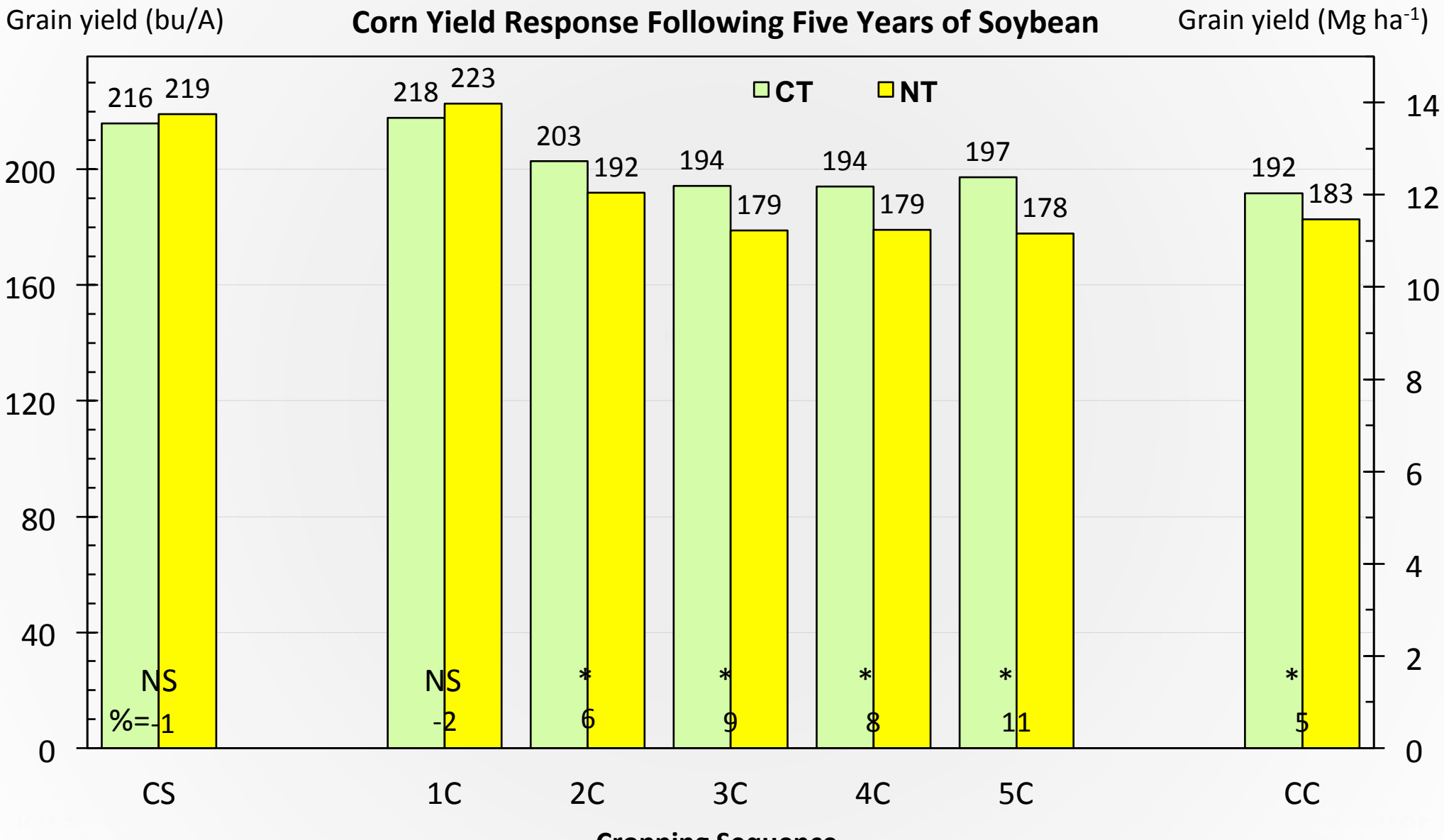
Nafziger, 1998-2012 – Monmouth, IL

Tillage does not affect corn yield in CS/1C, but improves yield in 2C to 5C and CC.



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

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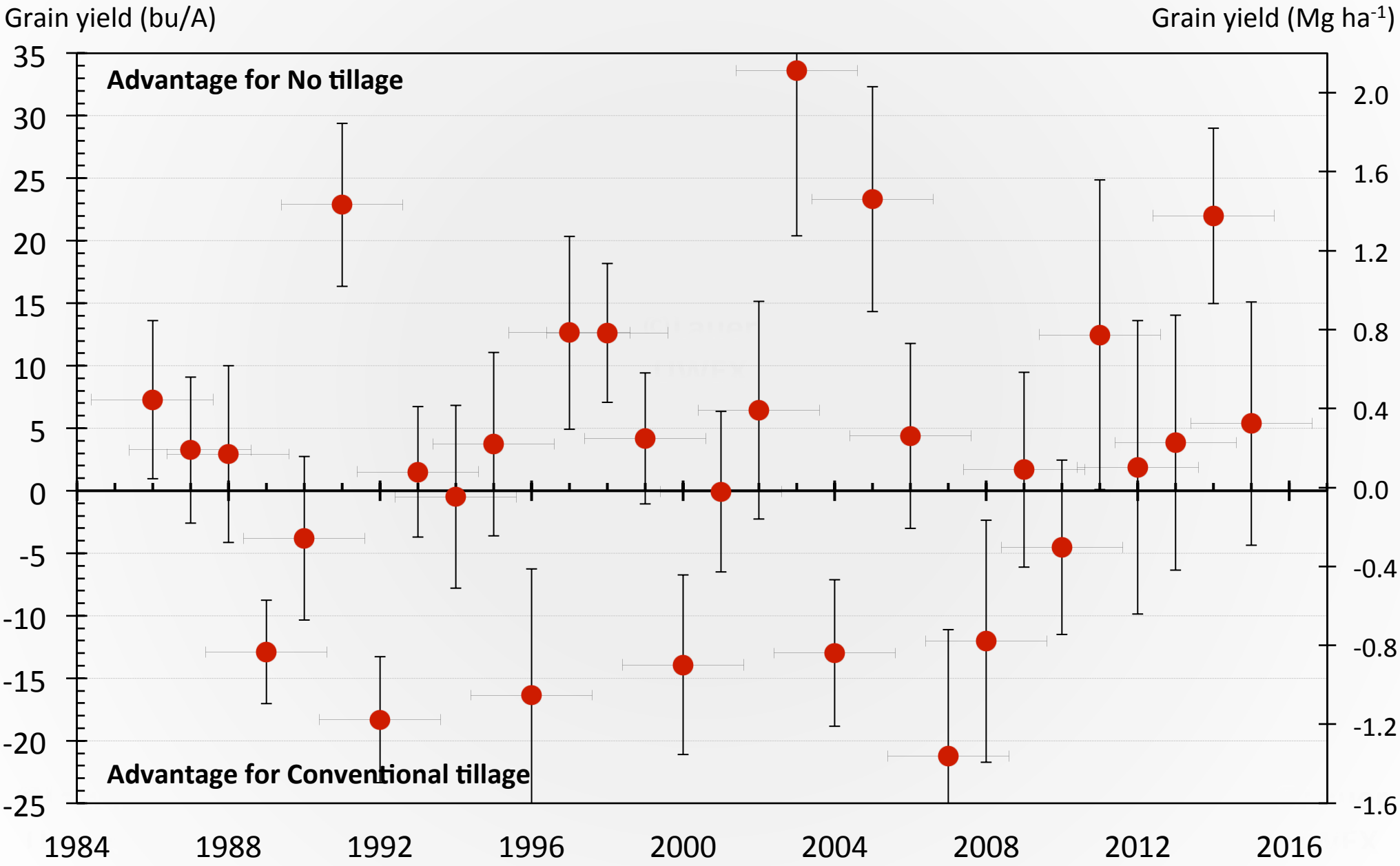
Lauer, 1996-2015 (Arlington, Control treatments)

For corn in a CS rotation, NT increases yield in 8 of 30 years; CT increases yield in 7 of 30 years; and 15 of 30 years = NS



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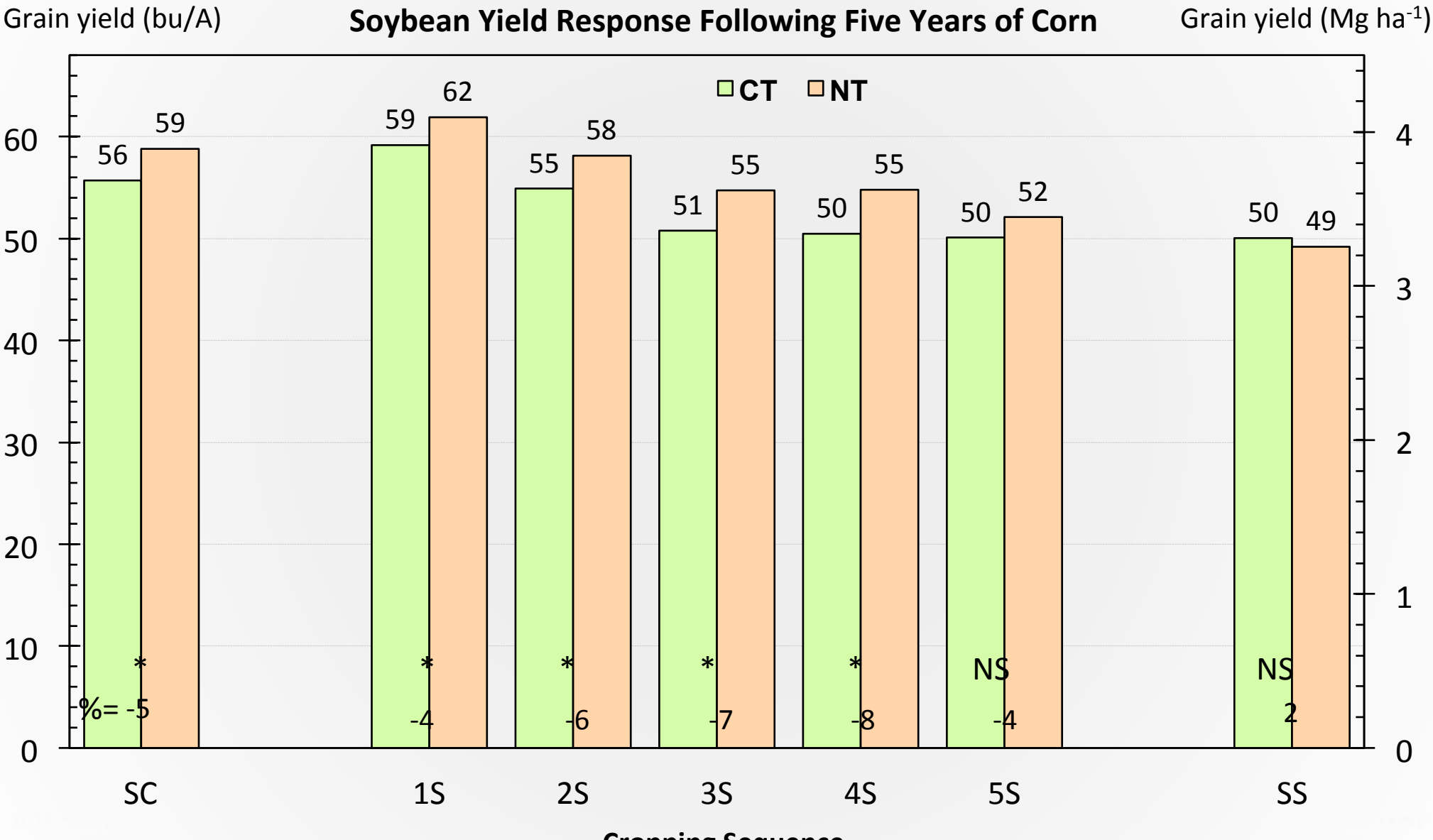
Lauer, 1986-2015 (Arlington, Control treatments)

No-till increases soybean yield in CS and 1S to 4S.



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

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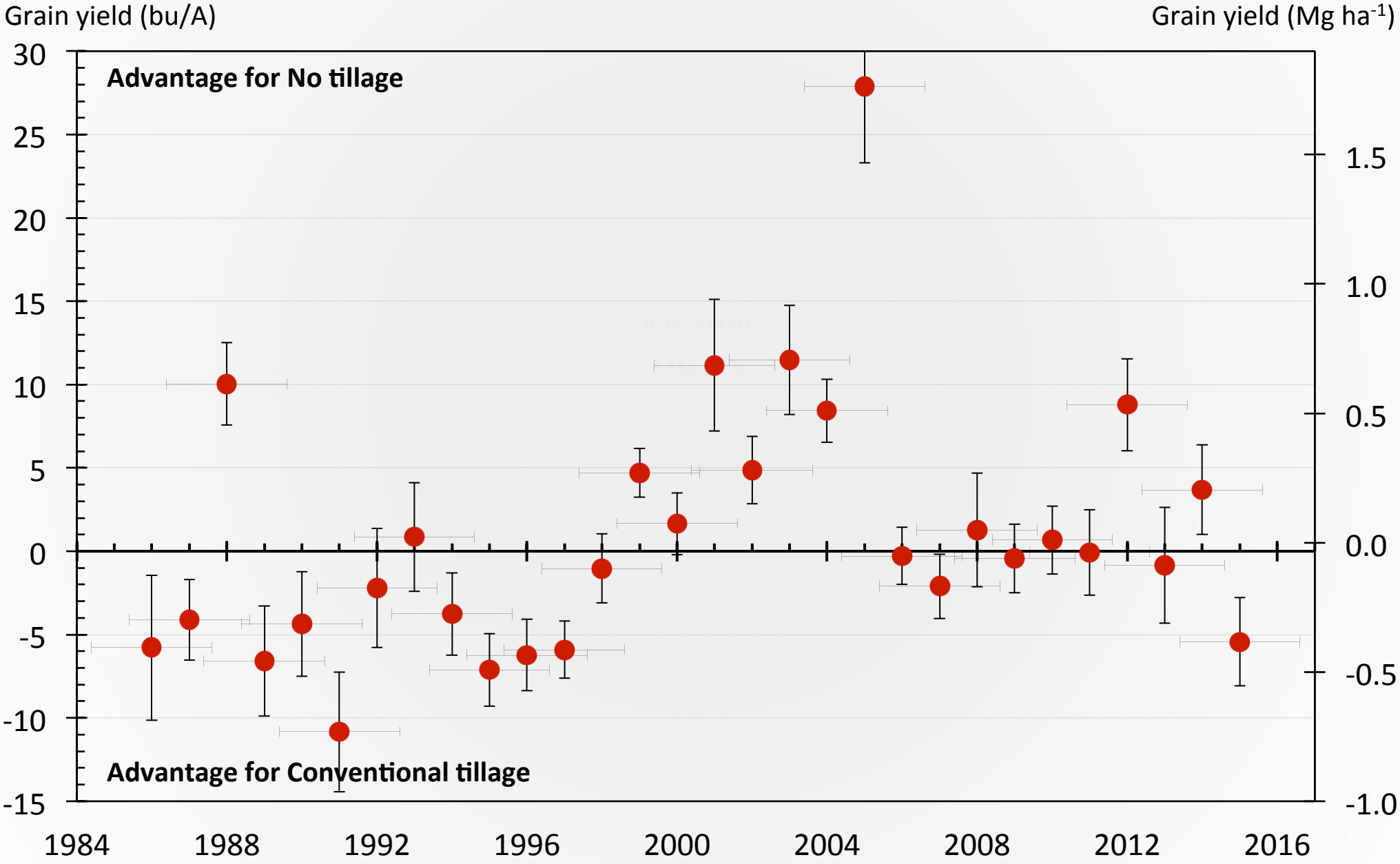
Lauer, 1996-2015 (Arlington, Control treatments)

For soybean in a CS rotation, NT increases yield in 9 of 30 years; CT increases yield in 10 of 30 years; and 11 of 30 years = NS



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Lauer, 1986-2015 (Arlington, Control treatments)

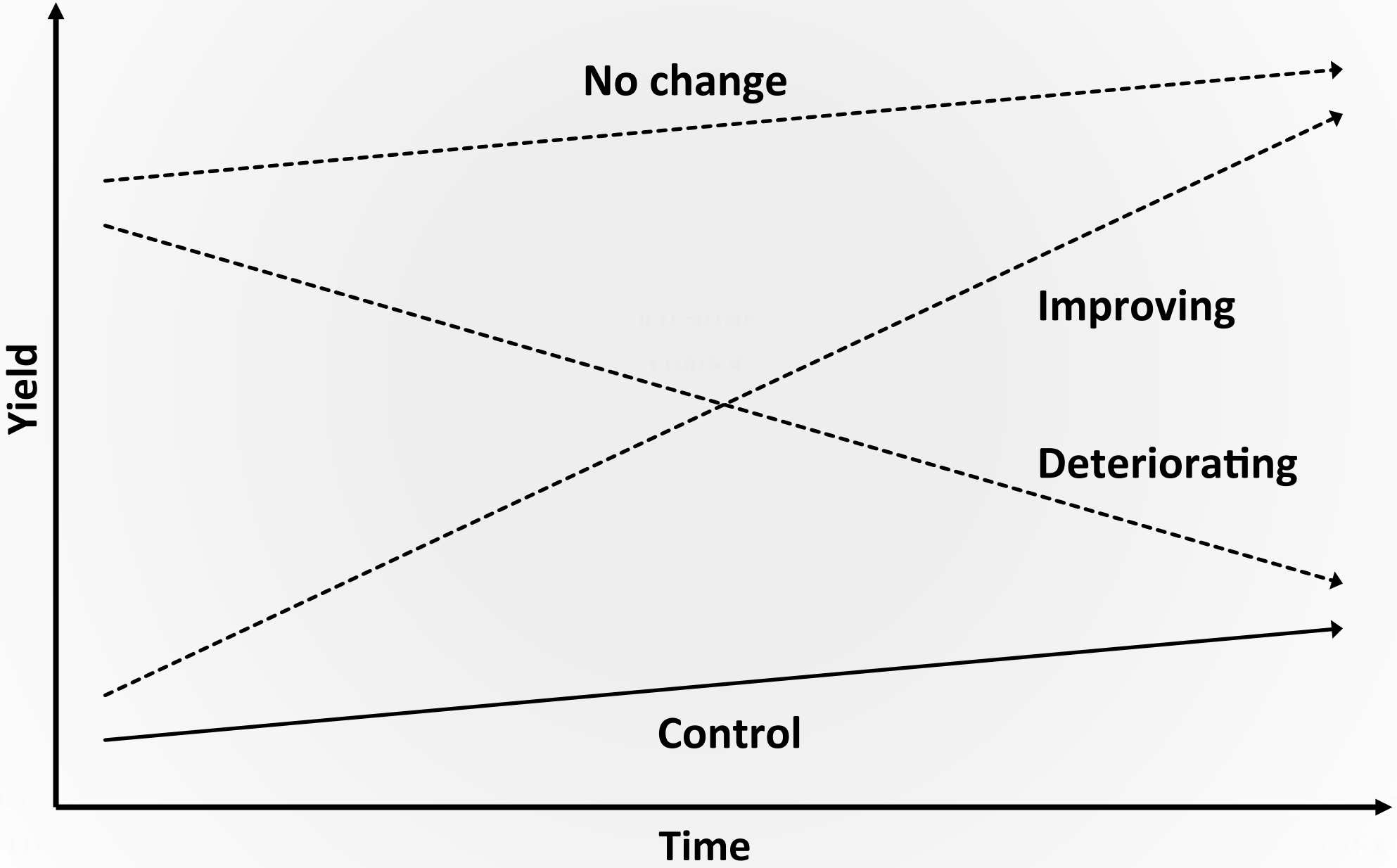
Soil organic carbon changes in Conventional- and No-Tillage Systems

Funded by:
WISCONSIN CORN PROMOTION BOARD, INC.

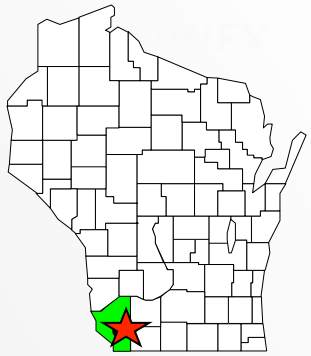
Rotation	Soil depth (inches)	Conventional tillage (%)	No-Tillage (%)
CC	0 to 6	1.8	1.8
	6 to 12	0.9	1.4
	12 to 24	0.6	1.0
CS	0 to 6	2.1	2.3
	6 to 12	1.3	1.9
	12 to 24	1.1	1.3

Significant Tillage, Rotation and Depth differences. No interactions.

How can you tell if a cropping system is changing?



The Lancaster Rotation Experiment
A Long-Term Cropping System Study



- A multiple crop rotation experiment established in 1966
- Objective: To compare the benefits of growing corn continuously and in rotation using commercial nitrogen fertilizer.
- RCB in a split-plot arrangement with two replications.
  - ✓ Main-plots= 21 rotations (all phases in all years)
  - ✓ Split-plots= four N levels in corn production year
- Assumption: Corn grain yield is the agronomic integrator, but economics is the decision maker.

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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

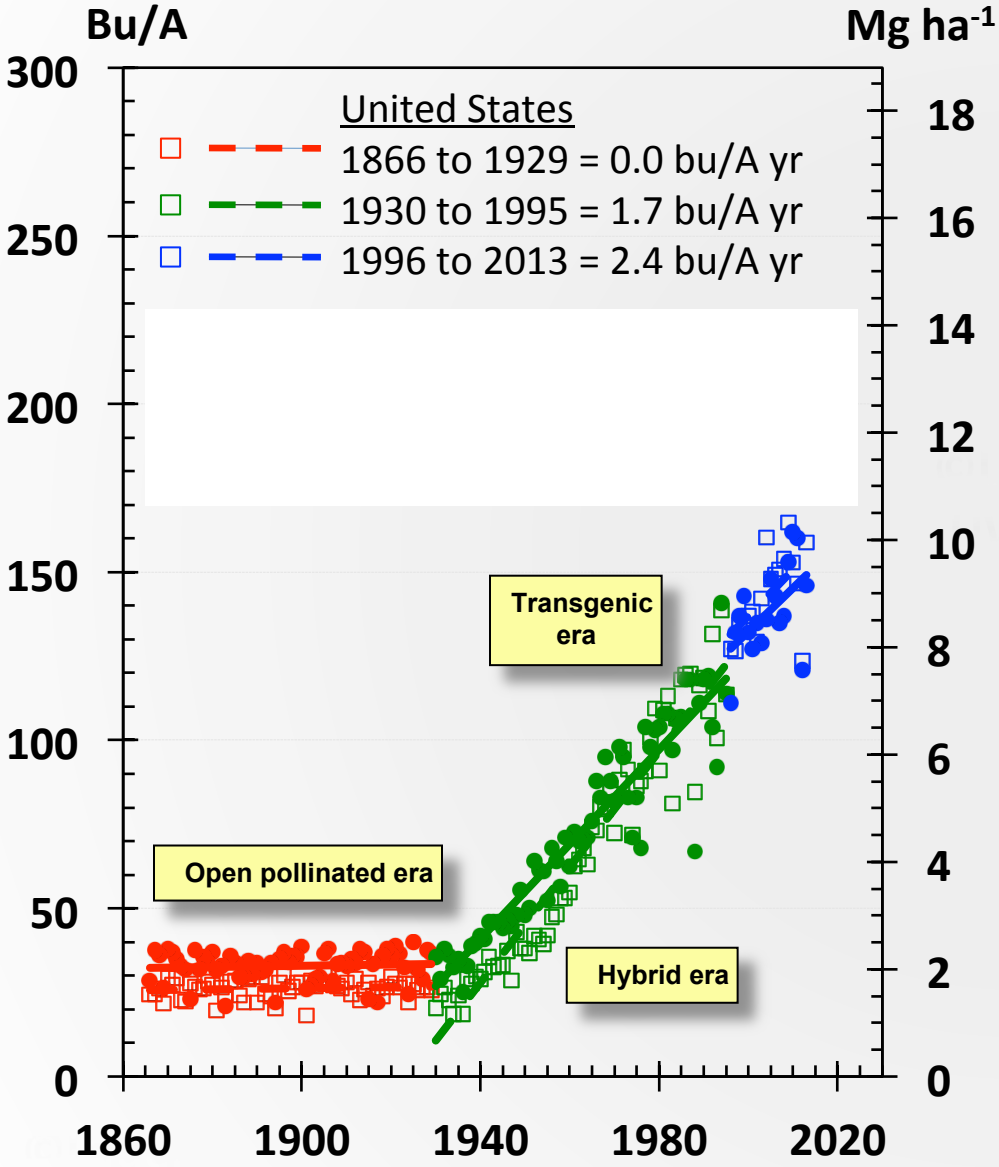
- C, Corn; S, Soybean; Oa, Oat with alfalfa seeding; A, Alfalfa; W, Wheat
- C, first phase; C, second phase; C, third phase

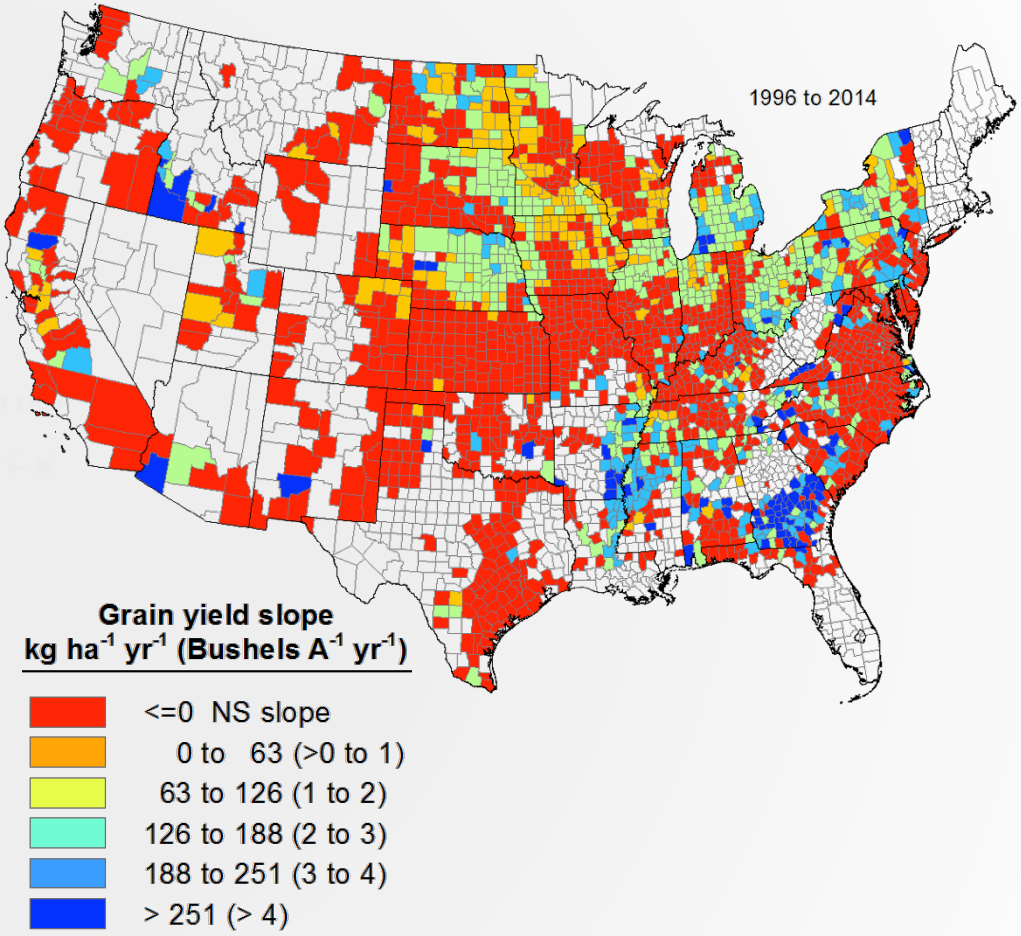
What is the experimental unit?
Analysis over Time and Space (2-yr and 5-yr Cycles)

Cycle	CC	Cycle	CS		Cycle	CSCOaA				
1	C	1	C	S	1	C	S	C	A	Oa
2	C	1	S	C	1	Oa	C	S	C	A
3	C	2	C	S	1	A	Oa	C	S	C
4	C	2	S	C	1	C	A	Oa	C	S
5	C	3	C	S	1	S	C	A	Oa	C

Stanger and Lauer, 2008

U.S. Corn Yield
The yield march continues …





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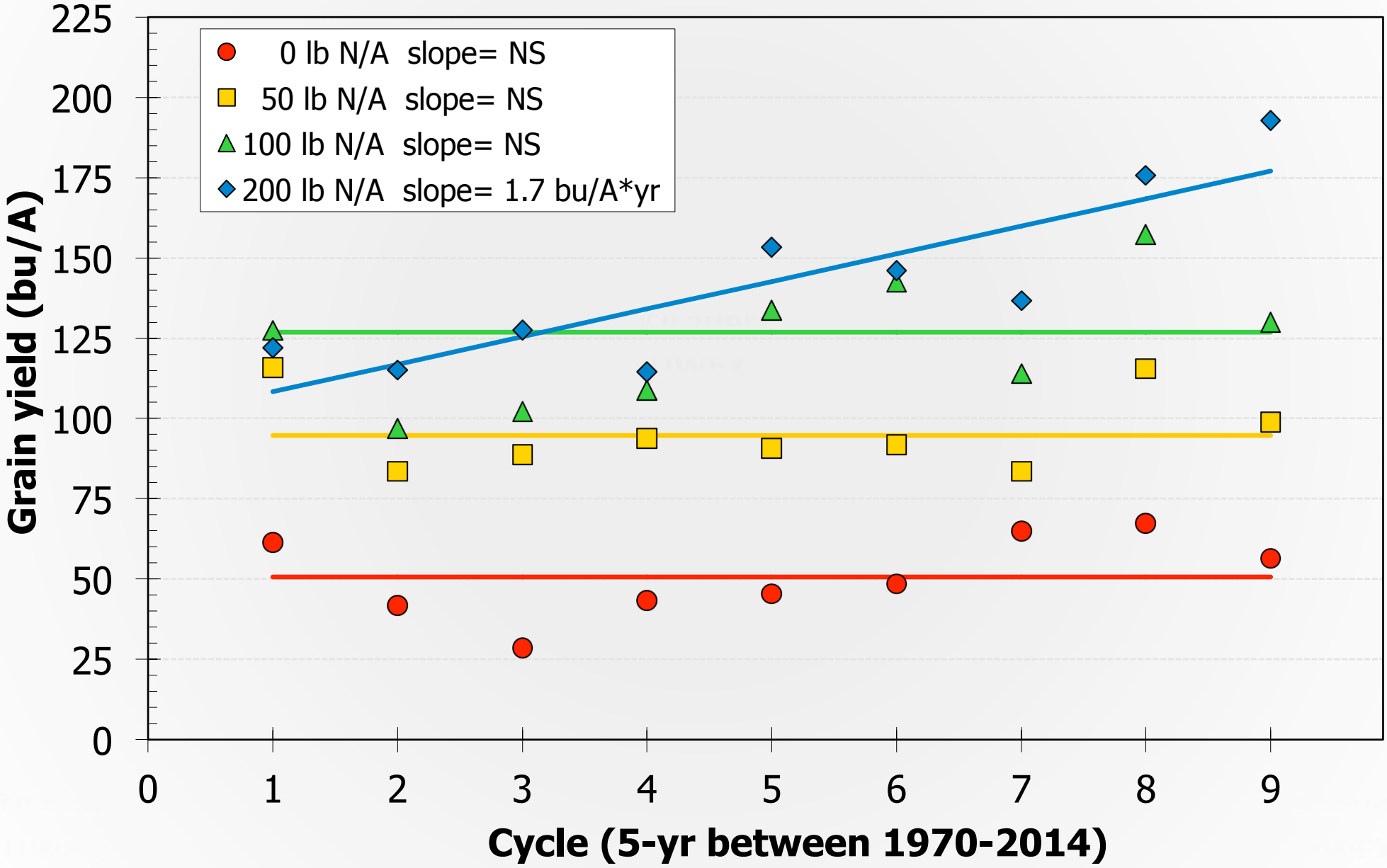
Lauer, 2015 (Data source: USDA-NASS)

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



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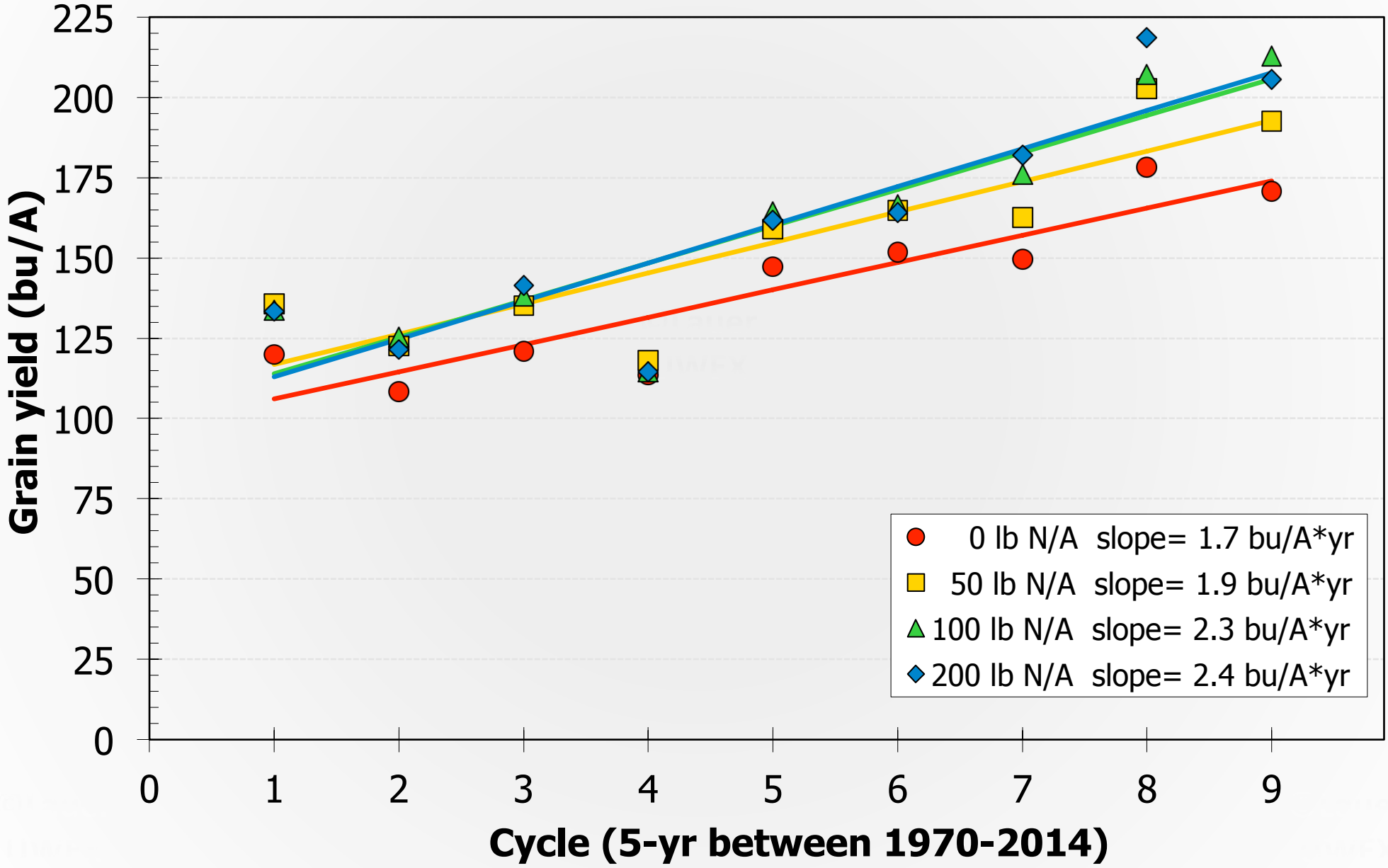
Stanger and Lauer, 2008
Updated by Lauer 2016

First phase corn grain yield response to N rate in a CSCOaA rotation at Lancaster, WI.



Stanger and Lauer, 2008
Updated by Lauer 2013

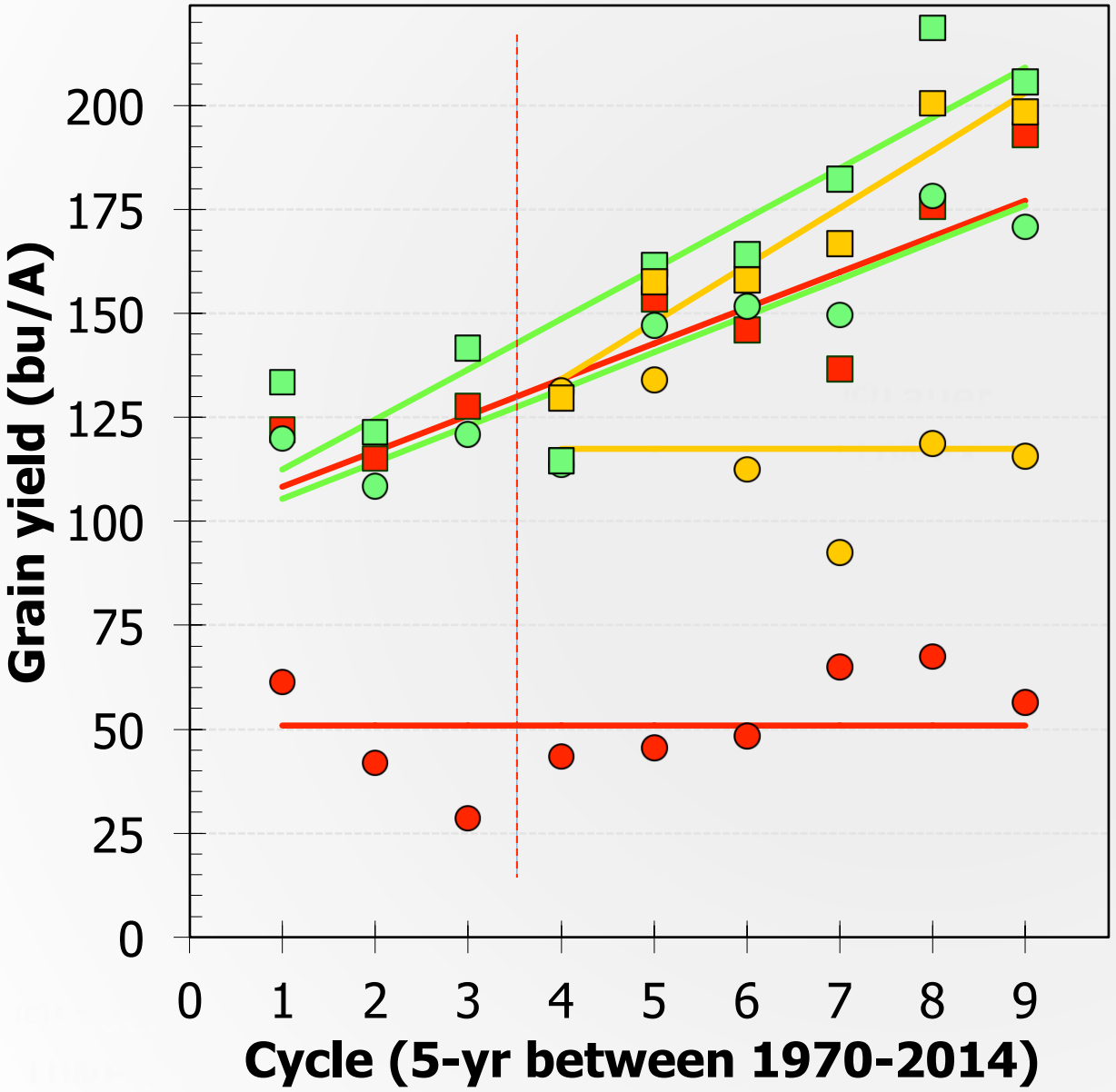
Is Corn Grain Yield Changing? (Is there a slope?)
First Corn Phase (5-yr Cycles; 1970-2014; 9 Cycles)

	N rate (lb N A^{-1})			
Rotation	0	50	100	200
	bu A^{-1} yr^{-1}			
CC	NS	NS	NS	1.7**
CCCAA	2.4**	2.6**	2.8**	3.2**
CCOaAA	2.0**	2.3**	2.3**	2.3**
CSCOaA	1.7**	1.9**	2.3**	2.4**

†, *, **, *** Significant at the 0.10, 0.05, 0.01, and 0.001 levels

Stanger and Lauer, 2008
Updated by Lauer 2016

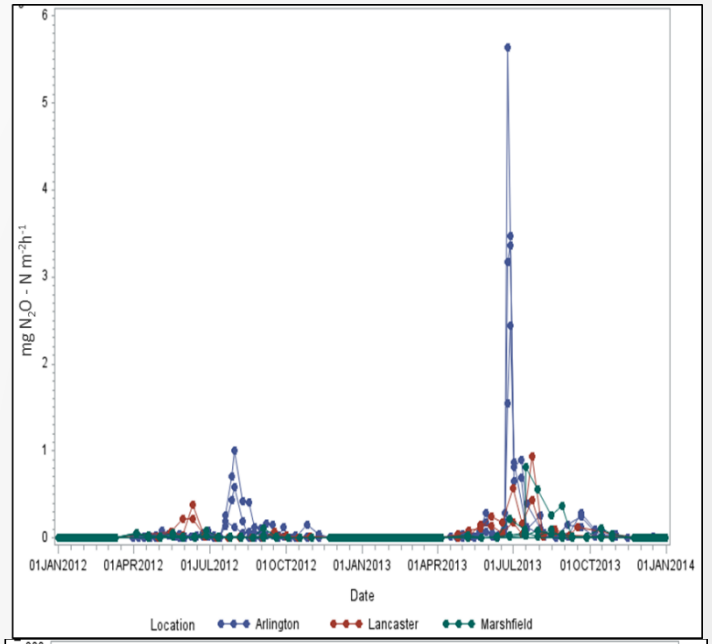
Are CC, CSCOaA and CS rotations improving (+) or deteriorating (-) for grain yield? …

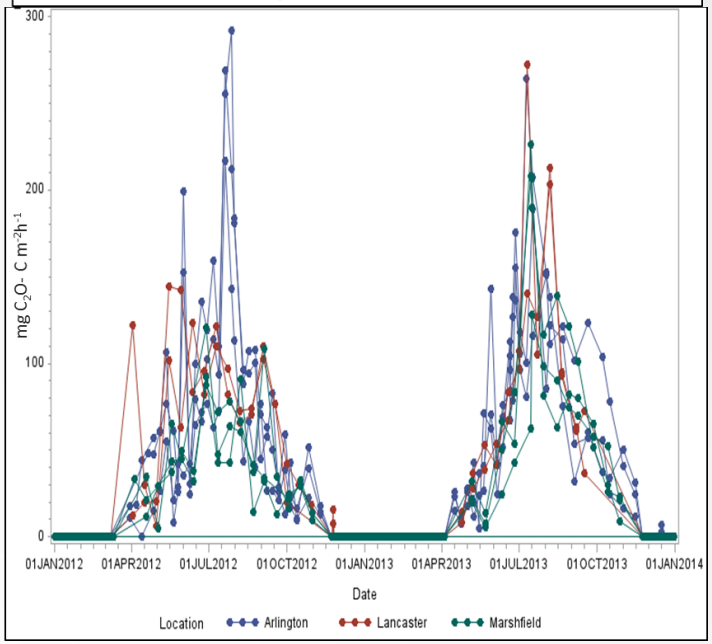


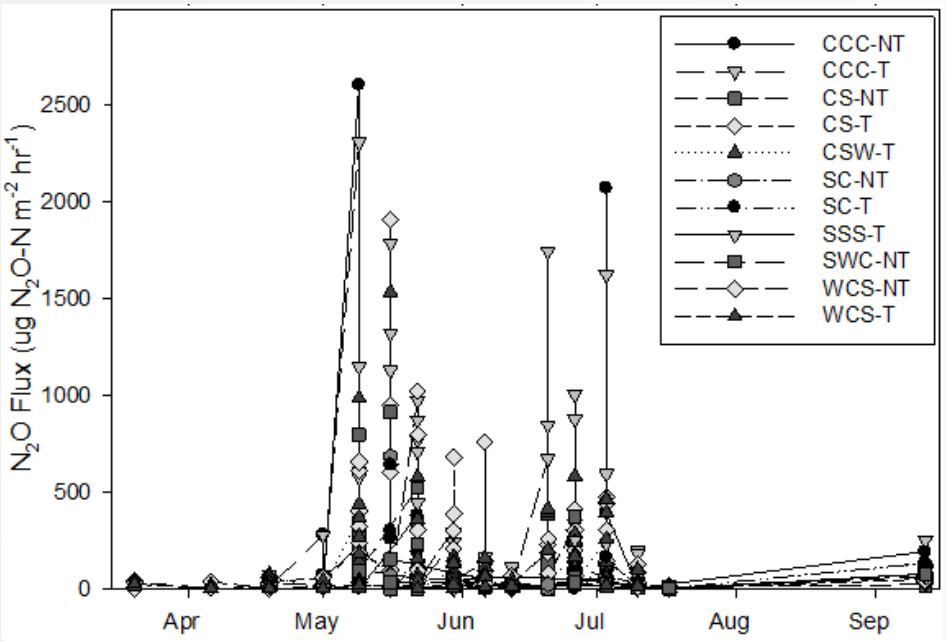
- CC 0 lb N/A slope= NS
- CC 200 lb N/A slope= 1.7 bu/A*yr
- CSCOaA 0 lb N/A slope= 1.8 bu/A*yr
- CSCOaA 200 lb N/A slope= 2.4 bu/A*yr
- CS 0 lb N/A slope= NS
- CS 200 lb N/A slope= 2.8 bu/A*yr

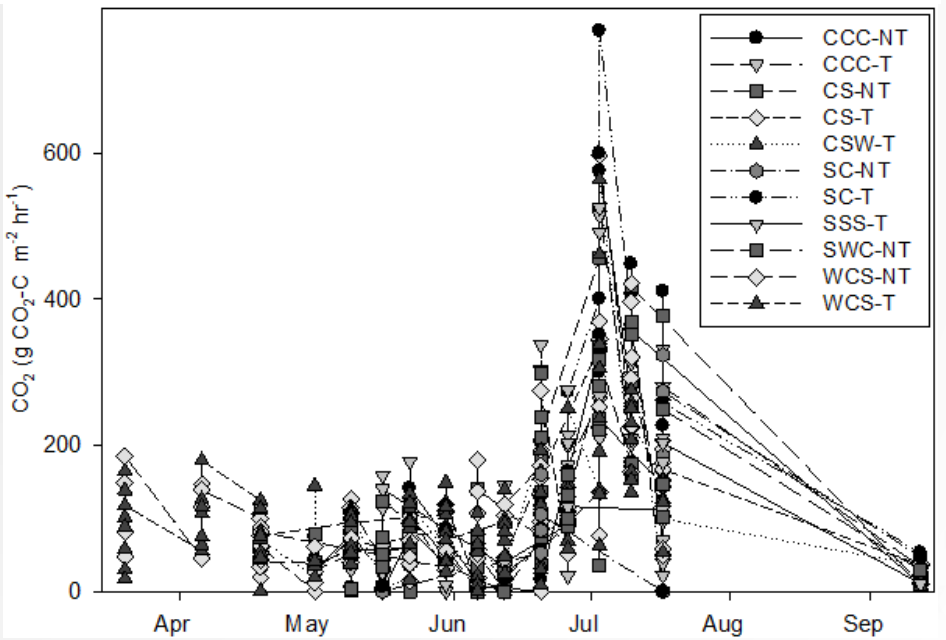
Stanger and Lauer, 2008
Updated by Lauer 2016

Seasonal Distribution N_2O and CO_2 emissions at Monmouth, IL and three locations in WI





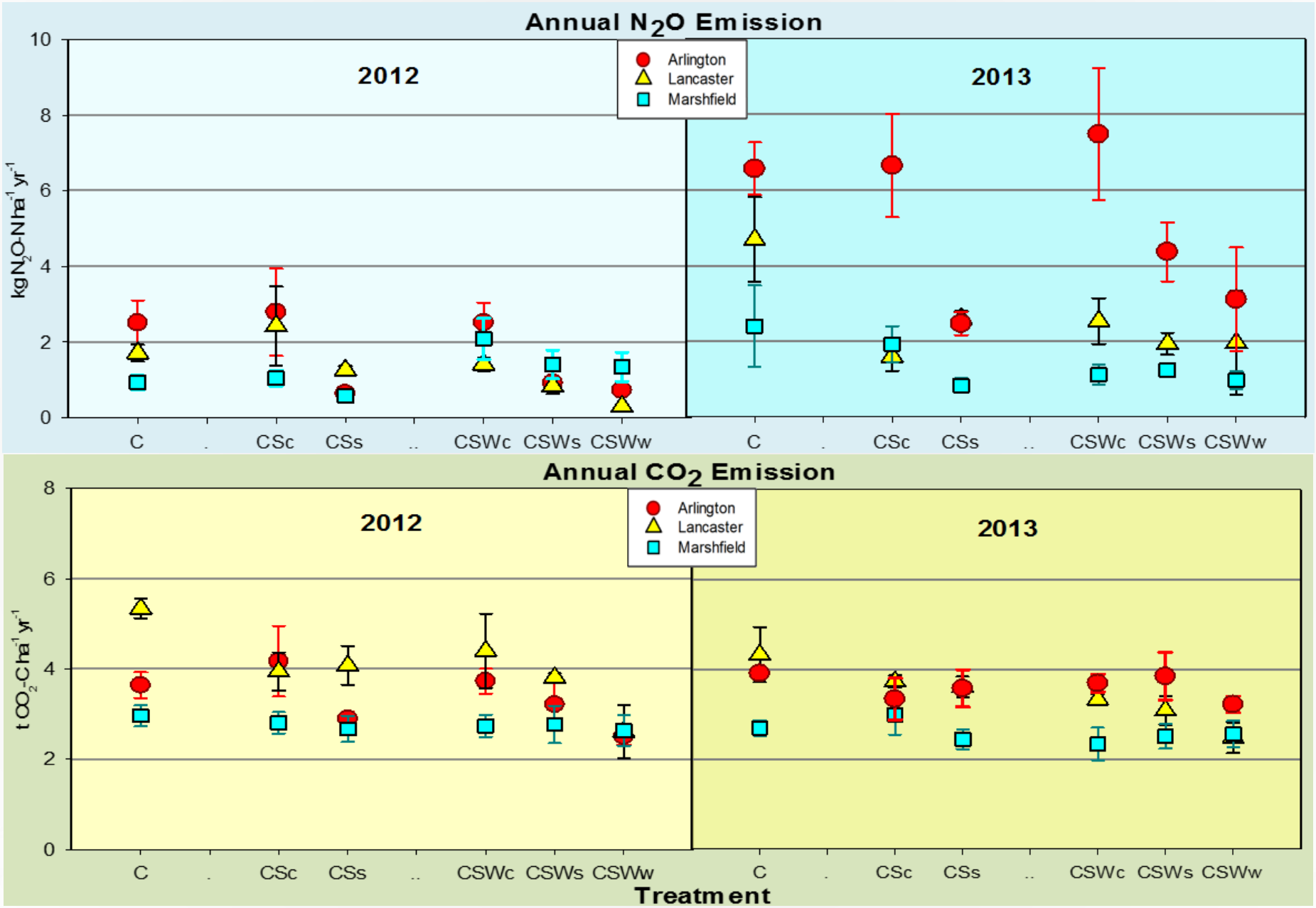




Kazula, 2012-2013

Nafziger, 2012 (Monmouth, IL)

Cumulative N_2O and CO_2 emissions at three locations in Wisconsin



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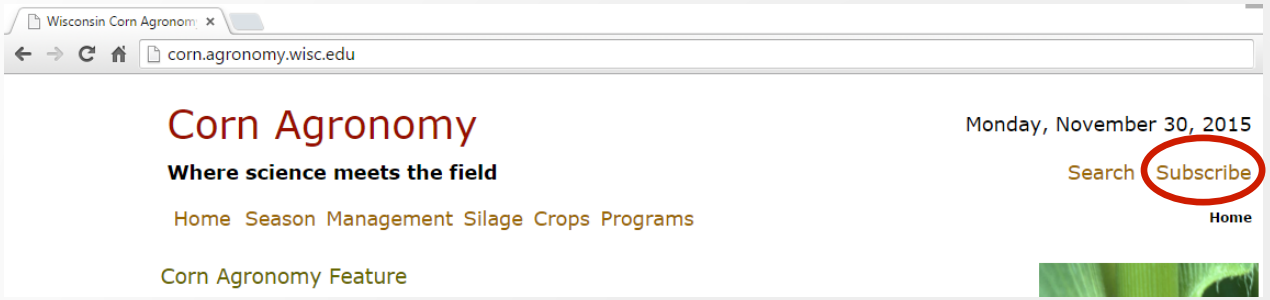
Kazula, 2012-2013

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 grain yield 10 to 19% for 1C and 0 to 7% for 2C.
- 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 9% in the third year.
- The addition of other crops to the rotation can improve grain yield of all crops.
  - ✓ Prudent thing to do
- Greenhouse gas emissions can be mitigated by extended crop rotations.
- The “rotation effect” is probably unique from field to field.
- Long-term rotation experiments are giving us a preview of crop rotation responses in the future.
  - ✓ Allows faster development and formulation of producer recommendations

Thanks for your attention! Questions?



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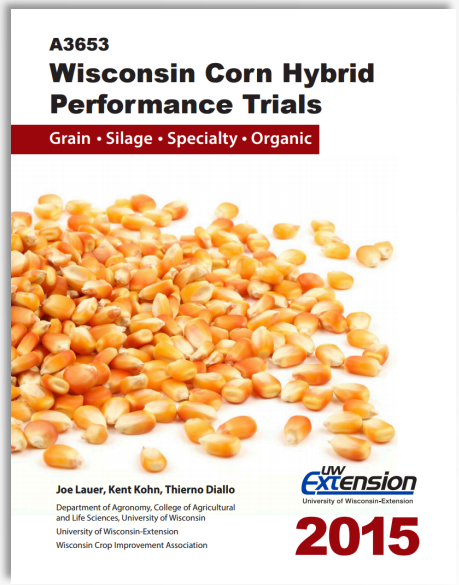

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