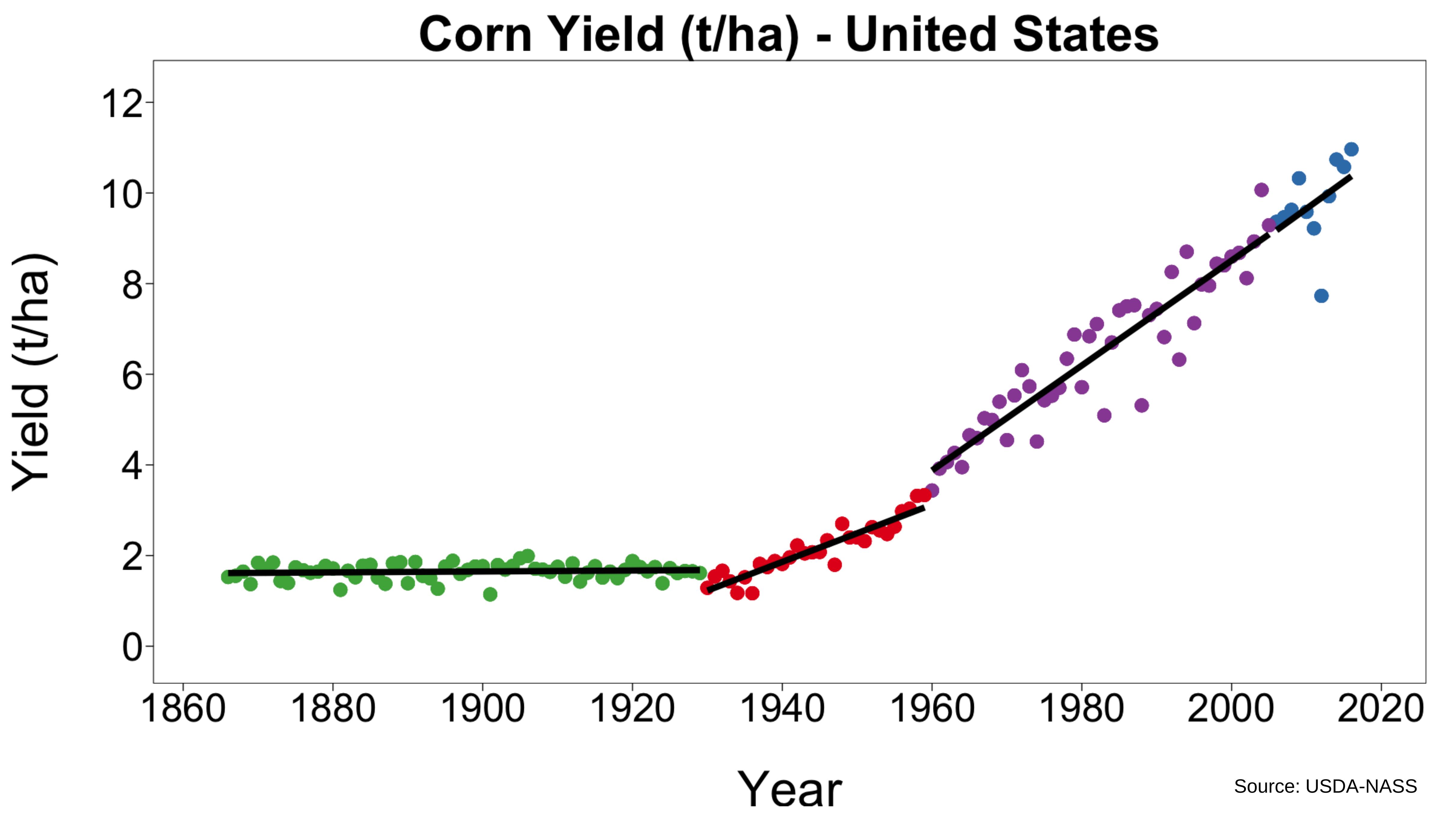
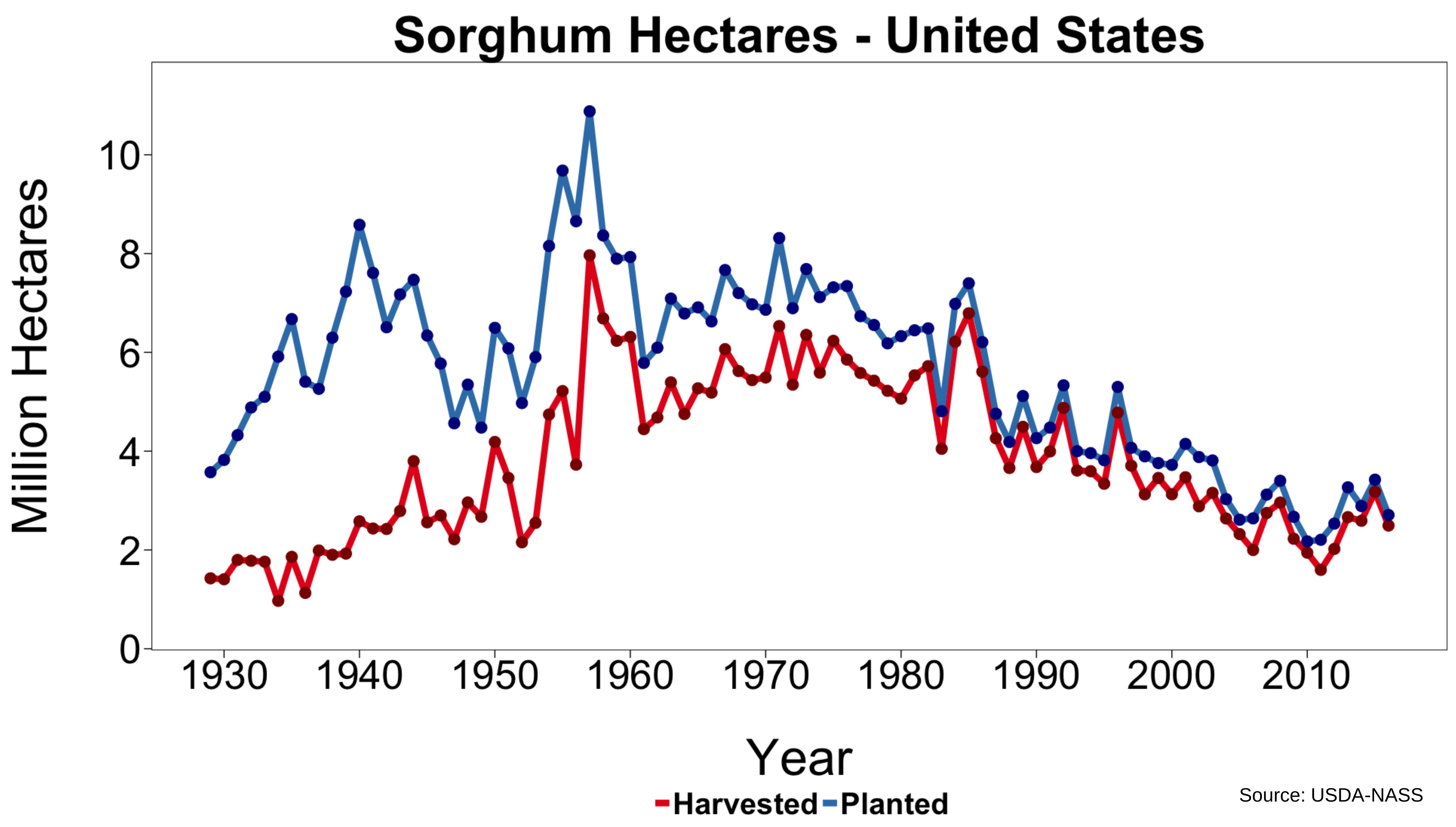
Genetic Contributions to Yield Gains in Sorghum

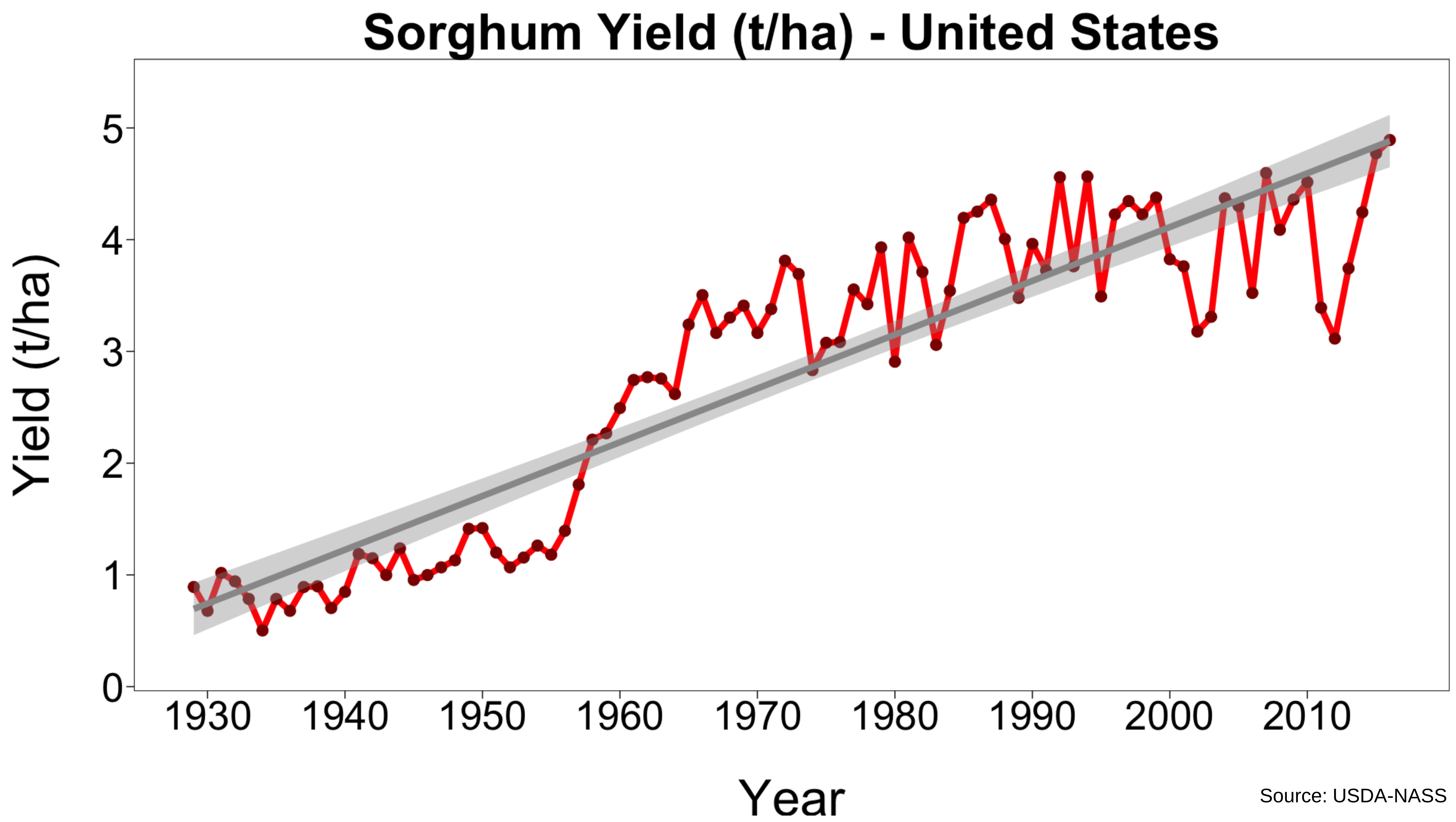
Brian K. Pfeiffer



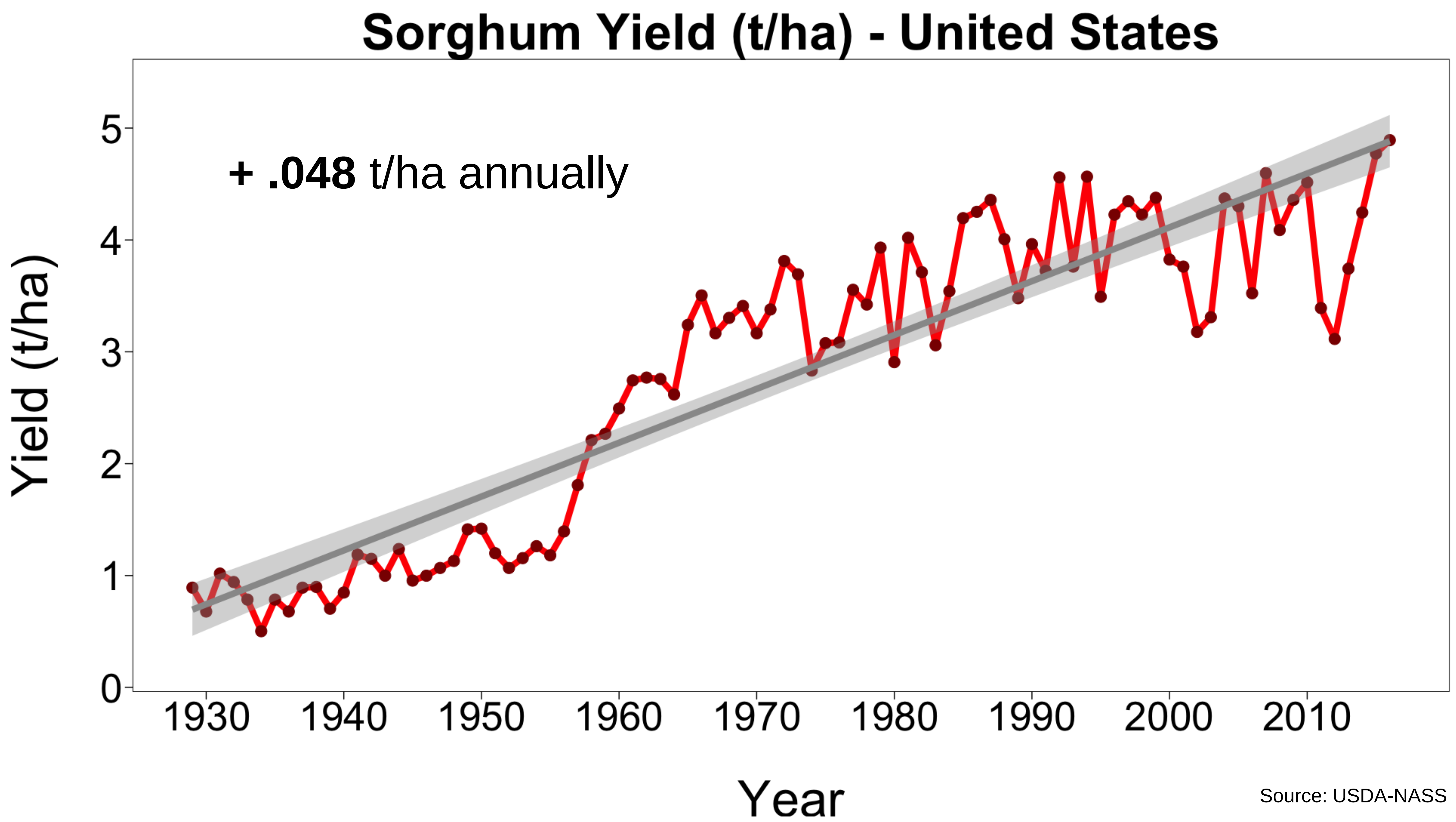
Corn Yield (t/ha) - United States
Yield (t/ha)
0
2
4
6
8
10
12
Year
1860
1880
1900
1920
1940
1960
1980
2000
2020
Source: USDA-NASS



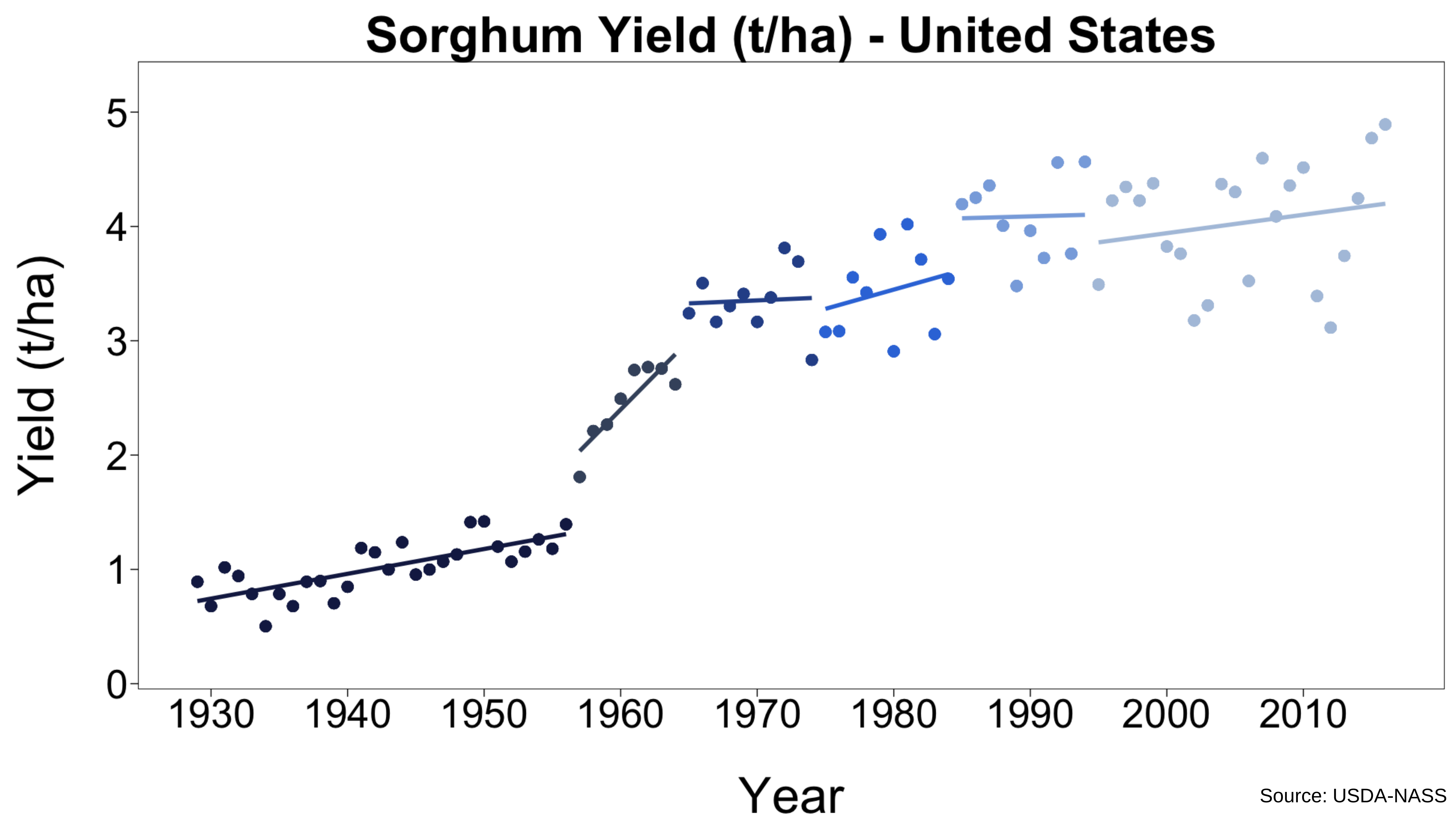
Sorghum Hectares - United States
Million Hectares
0
2
4
6
8
10
1930
1940
1950
1960
1970
1980
1990
2000
2010
Year
Harvested
Planted
Source: USDA-NASS

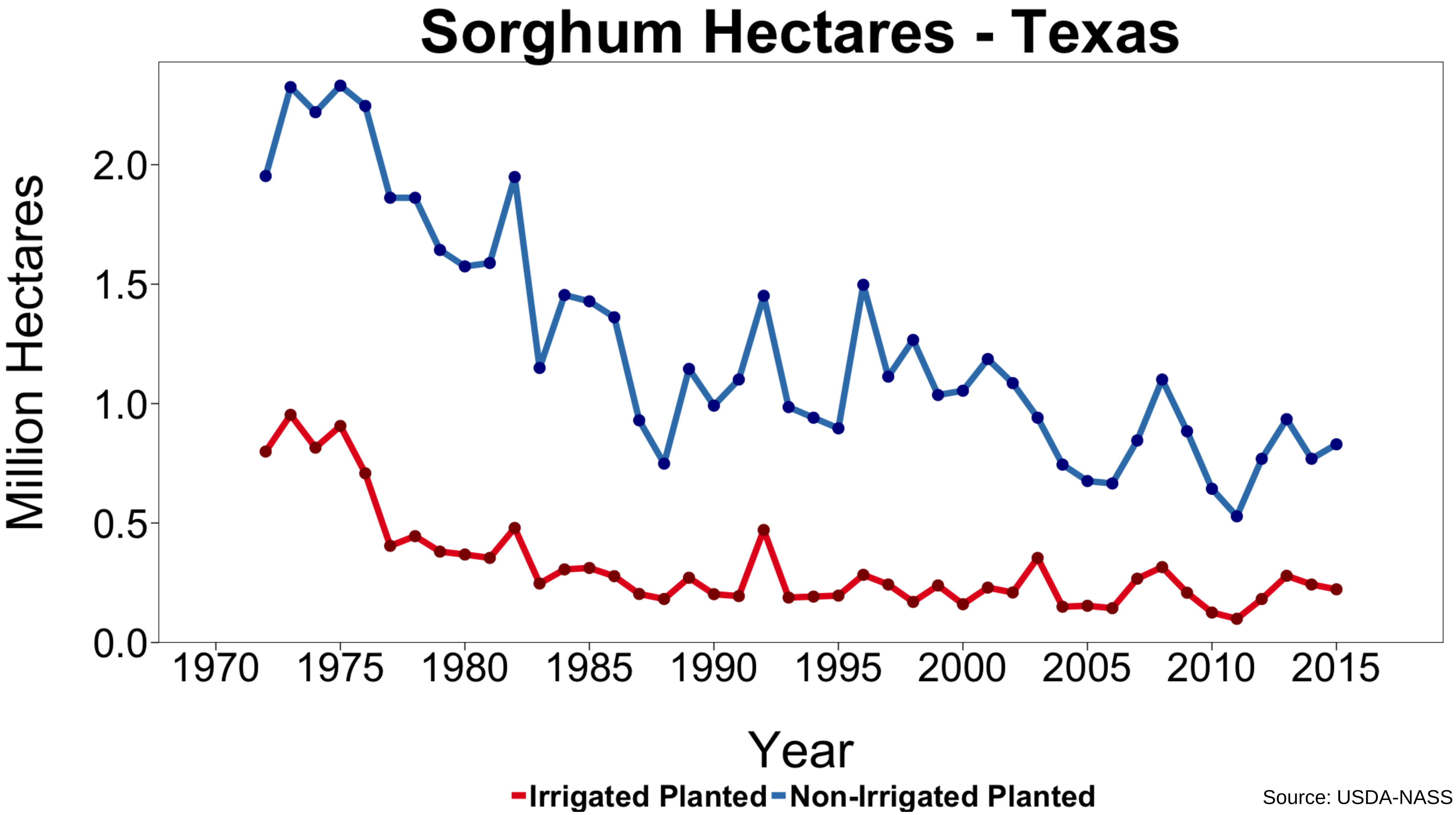


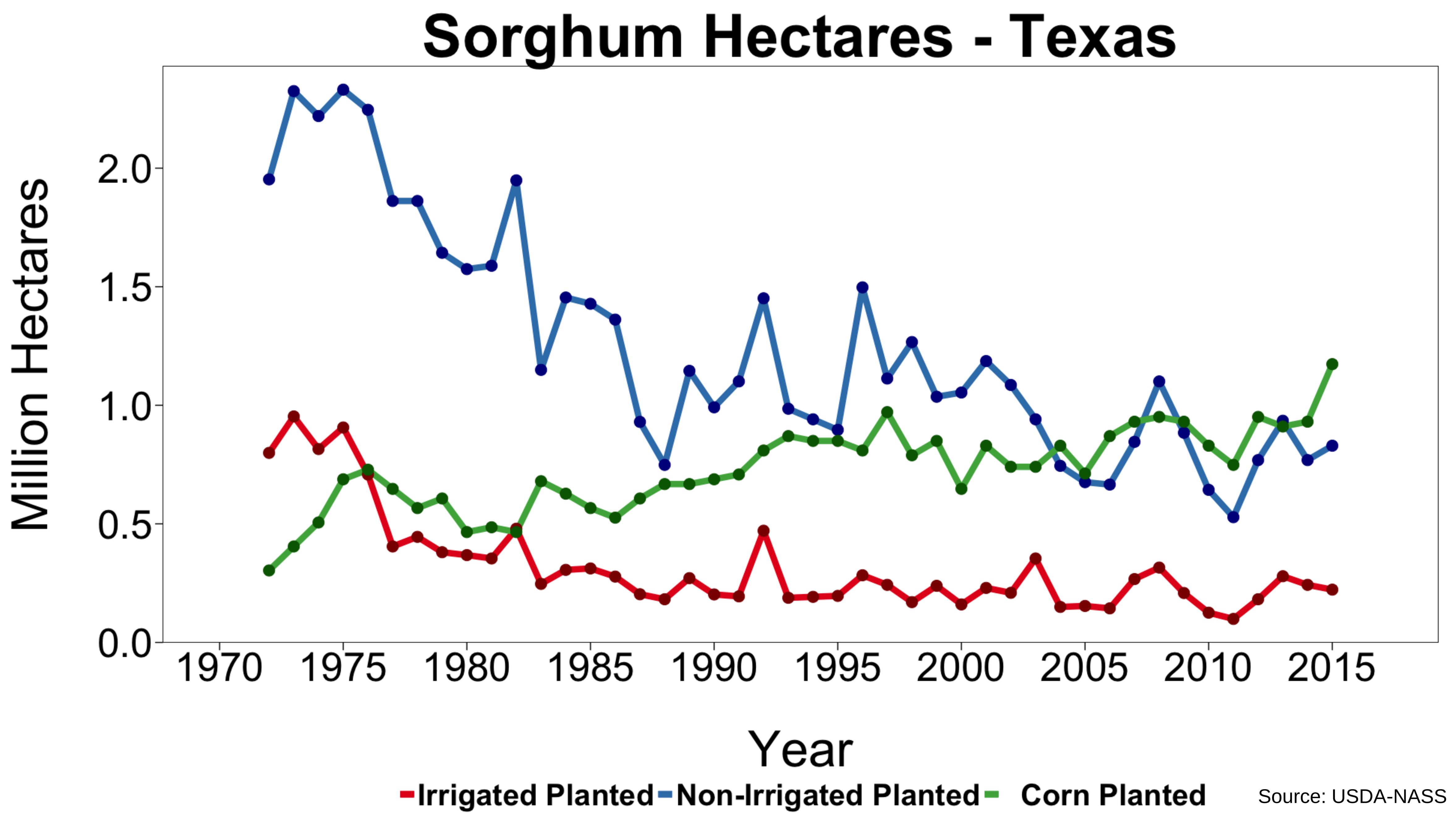
Sorghum Yield (t/ha) - United States
Yield (t/ha)
0
1
2
3
4
5
1930
1940
1950
1960
1970
1980
1990
2000
2010
Year
Source: USDA-NASS



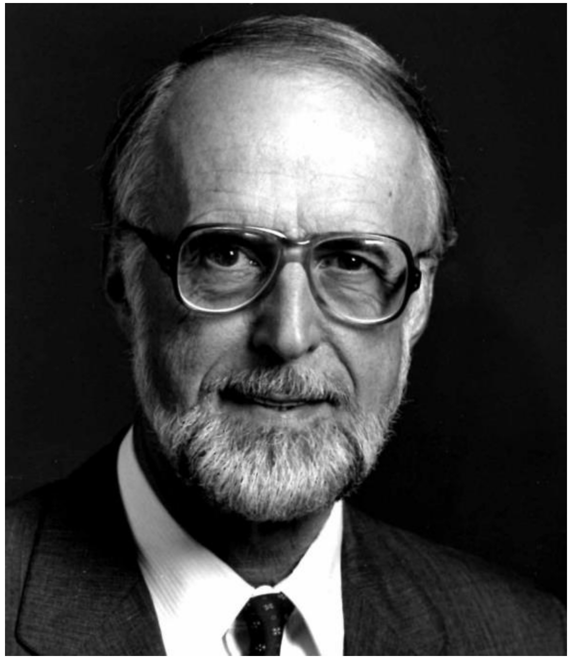
Sorghum Yield (t/ha) - United States
+ .048 t/ha annually
Yield (t/ha)
0
1
2
3
4
5
1930
1940
1950
1960
1970
1980
1990
2000
2010
Year
Source: USDA-NASS

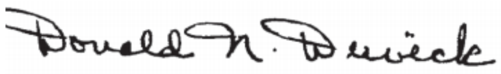

Sorghum Yield (t/ha) - United States
Yield (t/ha)
0
1
2
3
4
5
1930
1940
1950
1960
1970
1980
1990
2000
2010
Year
Source: USDA-NASS


Sorghum Hectares - Texas
Million Hectares
0.0
0.5
1.0
1.5
2.0
1970
1975
1980
1985
1990
1995
2000
2005
2010
2015
Year
Irrigated Planted
Non-Irrigated Planted
Source: USDA-NASS


Sorghum Hectares - Texas
Million Hectares
0.0
0.5
1.0
1.5
2.0
1970
1975
1980
1985
1990
1995
2000
2005
2010
2015
Year
Irrigated Planted
Non-Irrigated Planted
Corn Planted
Source: USDA-NASS

Donald N. Duvick





NATIONAL ACADEMY OF SCIENCES

Post–Green Revolution Trends in Yield Potential of Temperate Maize in the North-Central United States

D. N. Duvick and K. G. Cassman*

ABSTRAC

This paper addresses the question o
increase in yield potential of maize (Ze
in the north-central United States sinc
Revolution" that began in the late 19
published data about hybrid growth rate
traits when grown at yield potential leve
issue indirectly by evaluation of maize
plant traits of commercial hybrids, and
average yield trends and yield trends in
the basis of these sources of informati
potential as the yield that can be achi
when grown without obvious stress of a
is conflicting evidence to support the
potential has increased. We recommend
quantify and investigate the determinan
the north-central United States and for
greater yield potential.

ALTHOUGH THERE IS CONSIDE
predictions of global requ
feed grains during the next 30 y
total requirements will increase
sion of cereal production on la
cultivation is limited by the nee
natural ecosystems and by losses
industrial, and recreational dev
are expected to continue as popu
these constraints on the availabi
yield potential will be a primar
nature of agricultural systems i
issue is the degree of intensifica
systems that will be possible, w
mine the amount of land and na
be spared for other uses (Wagg
One global food supply–dema
global demand for maize will inc
to 784 000 000 t from 1993 to
increased demand coming from
(Rosegrant et al., 1999). Assumi
production area, an annual grow
of ≈1.5% will be needed to meet

Long-term Selection in a Commercial Hybrid Maize Breeding Program

D. N. Duvick
Department of Agronomy
Iowa State University
Ames, Iowa 50011-1010

*J. S. C. Smith and M. Cooper**
Pioneer Hi-Bred International, A DuPont Co
Johnston, Iowa 50131

I. INTRODUCTION
 A. Utility of Studying Long-term Commercial Bre
 B. A Long-term Selection Program in the Private S
  1. Intended Breeding Goals
  2. Starting Materials
  3. Breeding Methods, Breeders
II. RESULTS
 A. Performance Trials
  1. Commercial Hybrids
  2. Heterosis: Single-crosses vs. Parental Inbre
 B. Pedigree Examination
  1. Founder Sources
  2. Proportionate Contribution of Founders
  3. Variability in Proportionate Contribution
 C. Molecular Marker Changes
  1. Number of Alleles
  2. "New" Alleles
  3. Formation of Stiff Stalk and Non Stiff Stalk

*We thank the many Pioneer scientists who have contri
and interpretation of data from the Era hybrid studies. We
ers and professional plant breeders that created this gern

Plant Breeding Reviews, Volume 24, Part 2. Edited by J

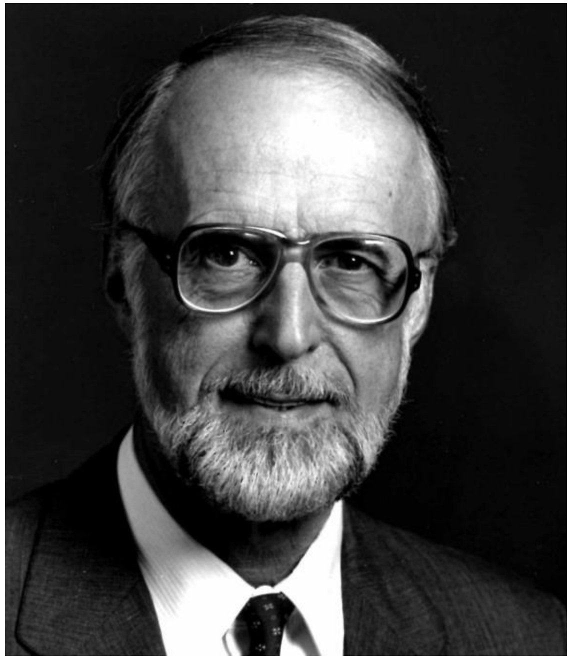
THE CONTRIBUTION OF BREEDING TO YIELD ADVANCES IN MAIZE (*ZEA MAYS* L.)

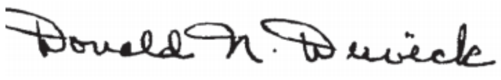
Donald N. Duvick

Iowa State University
Ames, Iowa 50011

I. Introduction
 A. Maize Yield Trends During the Past Century
 B. Factors Responsible for Upward Yield Trends
II. Genetic Gains in Grain Yield of Hybrids
 A. Previously Reported Genetic Yield Gains
 B. Recent Estimates of Genetic Yield Gains
 C. Estimates of the Contribution of Breeding to Total Yield Gains
 D. Changes that Have Accompanied Genetic Yield Gains in Hybrids
III. Genetic Gains from Population Improvement
 A. Comparisons with Genetic Gains in Hybrids
 B. Relative Contributions of Population Improvement and Pedigree Breeding
IV. Analysis and Conclusions
 A. Possible Reasons for Genetic Yield Gains
 B. Potential Helps or Hindrances to Future Gains in Yield
 C. Predictions
References

Donald N. Duvick





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Improvement – Intentional

- Grain yield
- Smaller tassel
- Resistant to root lodging
- Stay green

No Change – Intentional

- Plant Height
- Ear Height
- Flowering

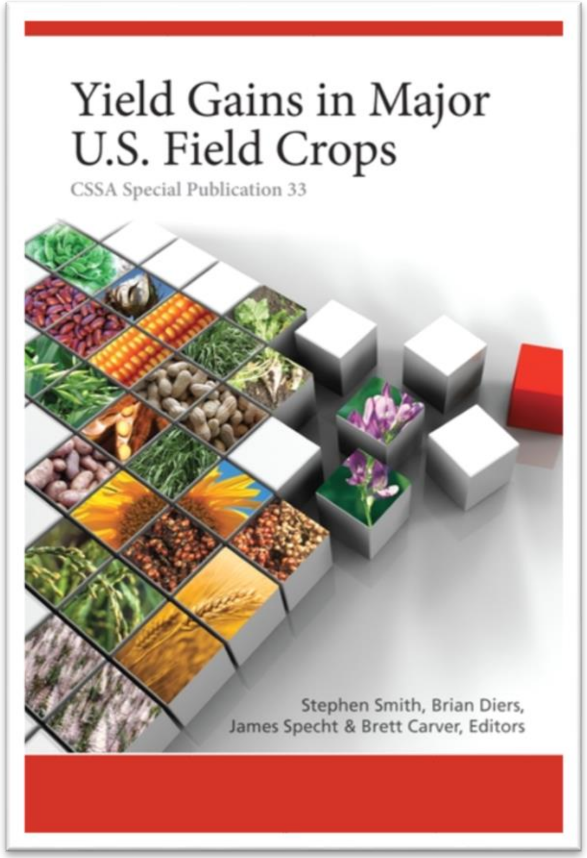
Improvement – Indirect

- Less protein
- Higher starch
- Leaf angle

No Change – Despite Effort

- Leaf number
- LAI
- Number of ears per plant
- Yield potential per plant
- Heterosis

Sorghum Genetic Gain



GENETICS	AGRONOMY
50%	50%

Traits with Genetic Gain

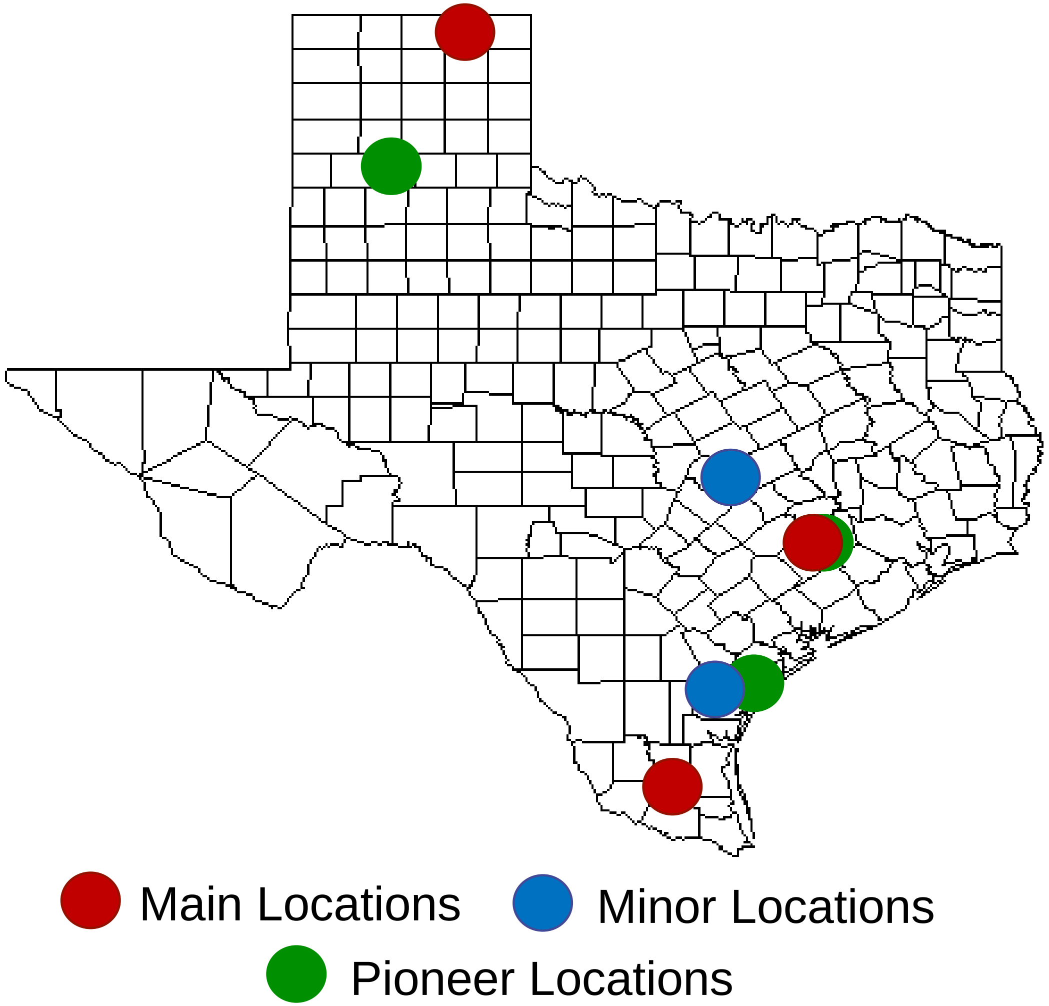
- Number of kernels/panicle
- Total plant weight
- Height
- Leaf area
- Staygreen

48%
Yield Increase
1950-1980

1-2%
Annual
Yield Increase

Miller and Kebede, 1980   Monk et al., 2014

My Genetic Gain Study



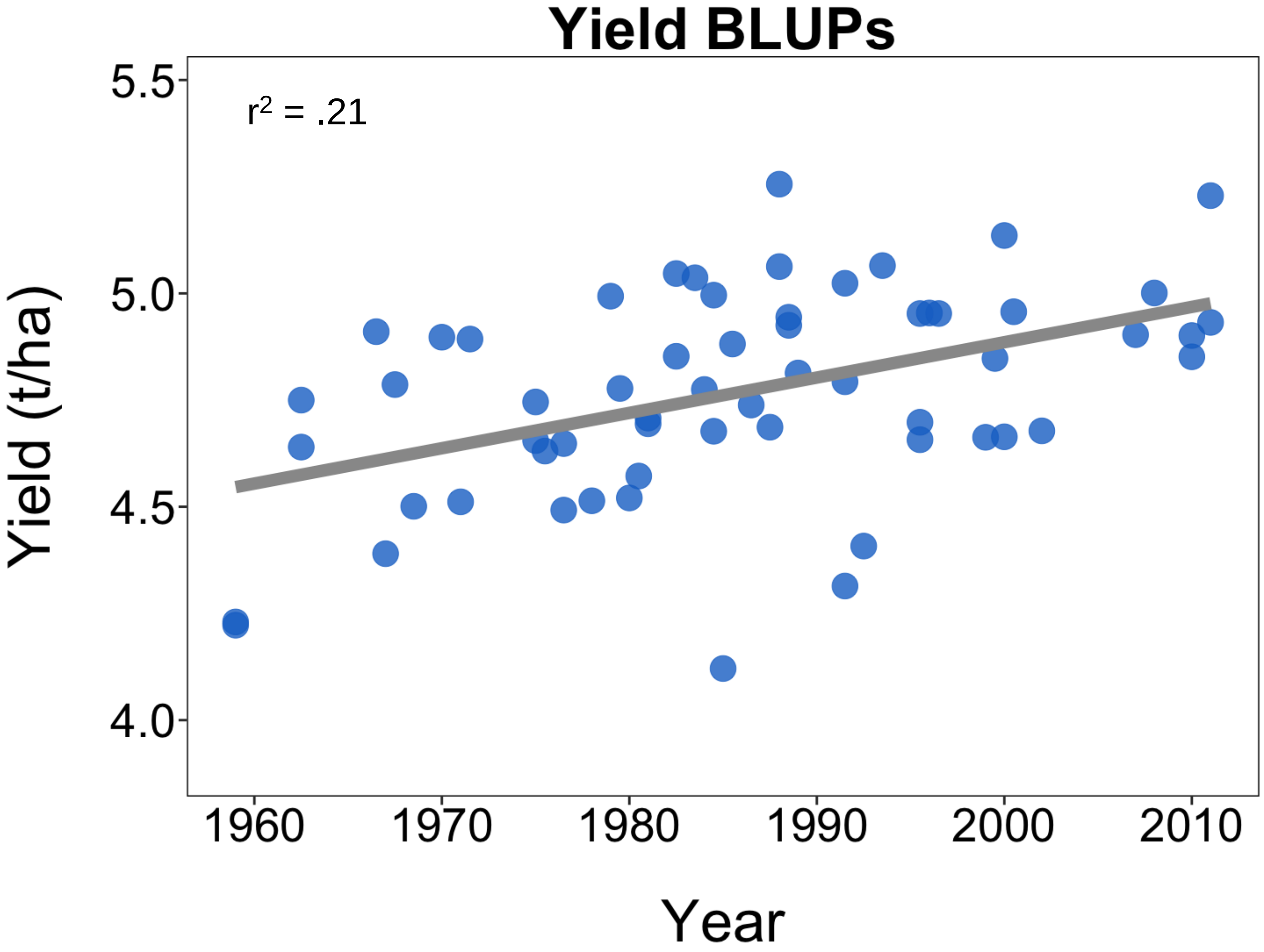
Plant Material

- 60 hybrids
- 20 parental lines
- 14 Pioneer hybrids

Environments

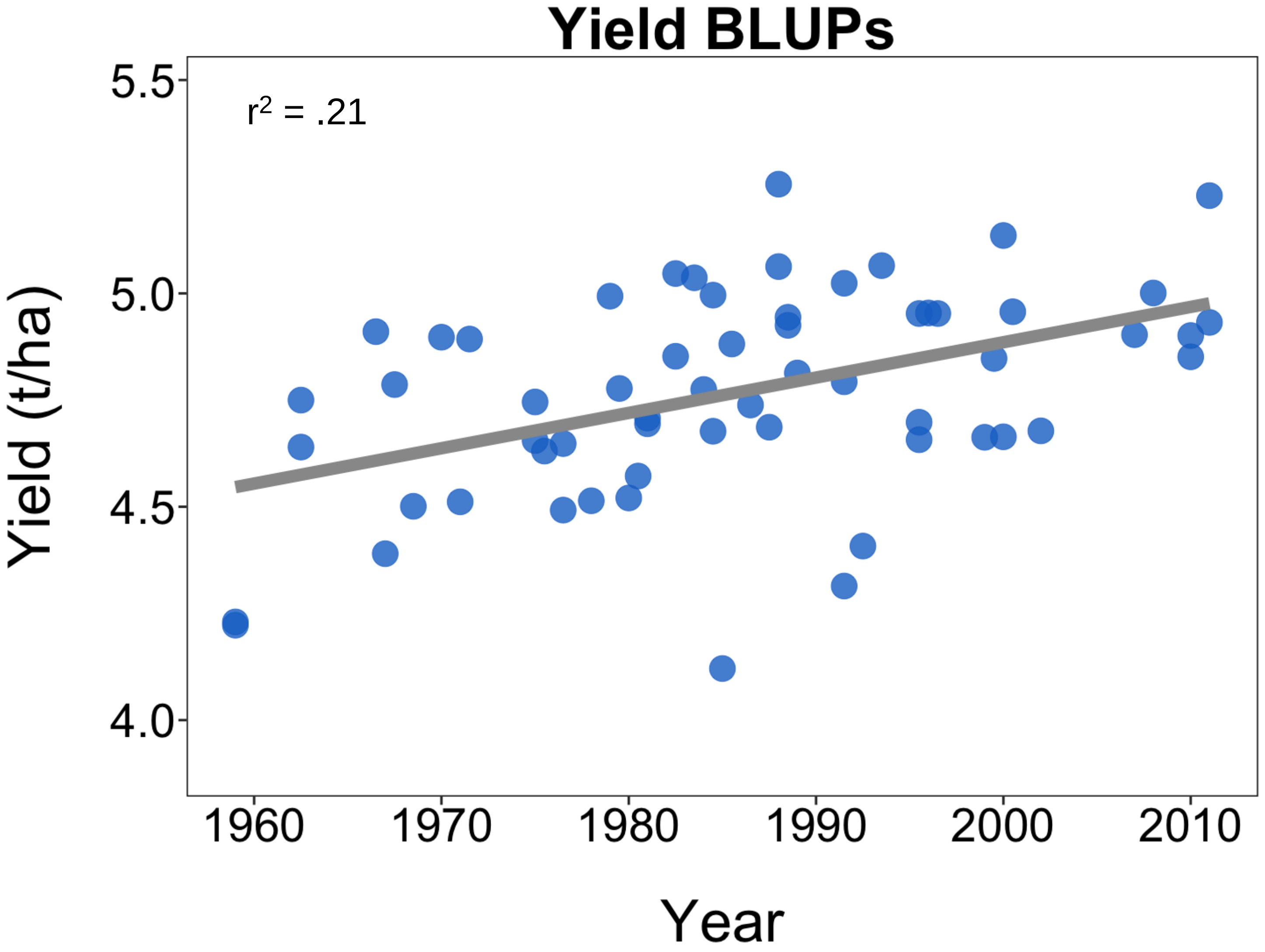
- 3 full hybrid set
- 2 limited hybrid set
- 3 Pioneer hybrid

Yield



Source	Variance	Percent
Environment	4.36	81.27
Genotype	0.12	2.21
G x E	0.18	3.39
Rep(Env.)	0.00	0.04
Residual	0.70	13.09
TOTAL	5.36	100.00

Yield



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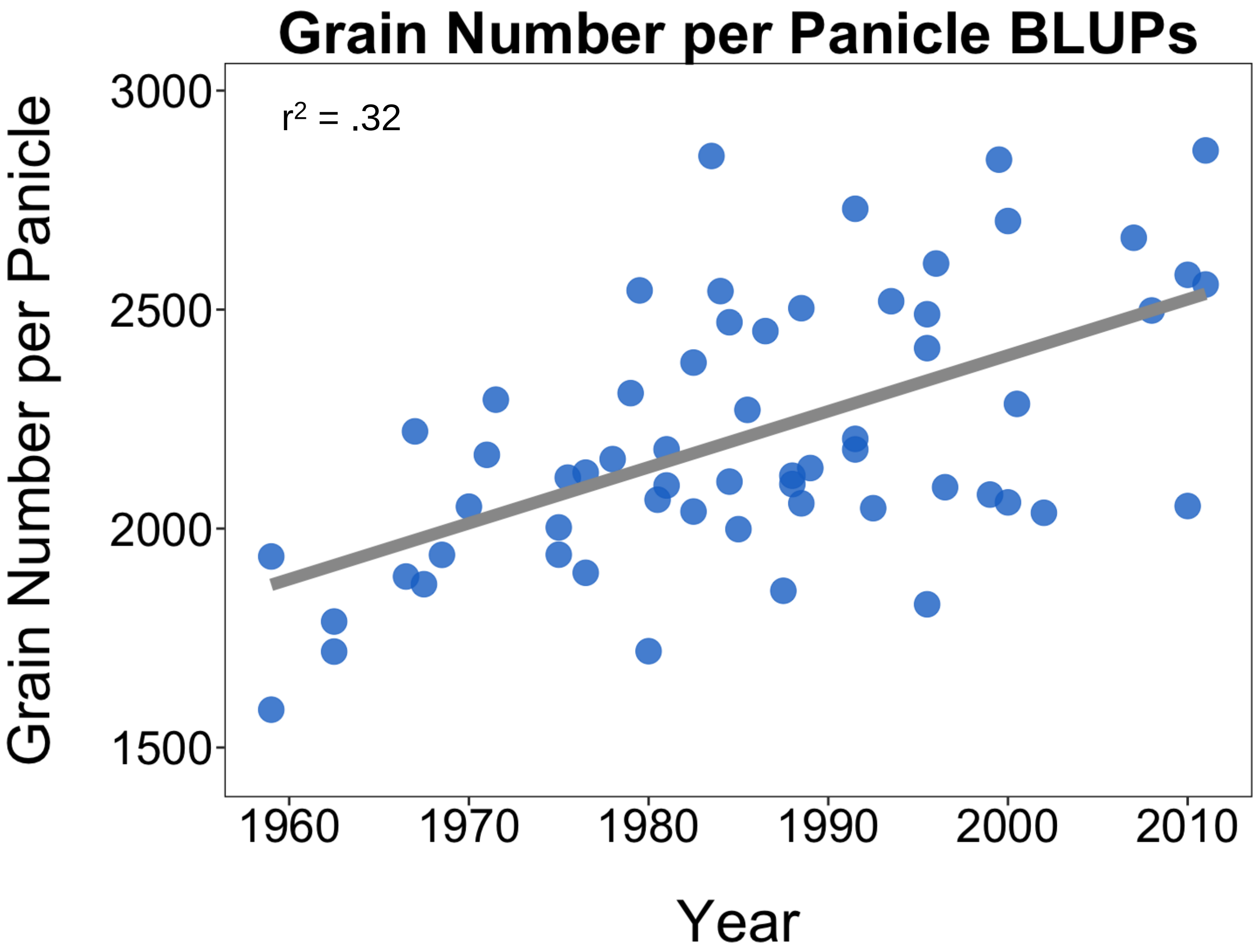
Rep(Env.)	0.00	0.04
Residual	0.70	13.09
TOTAL	5.36	100.00

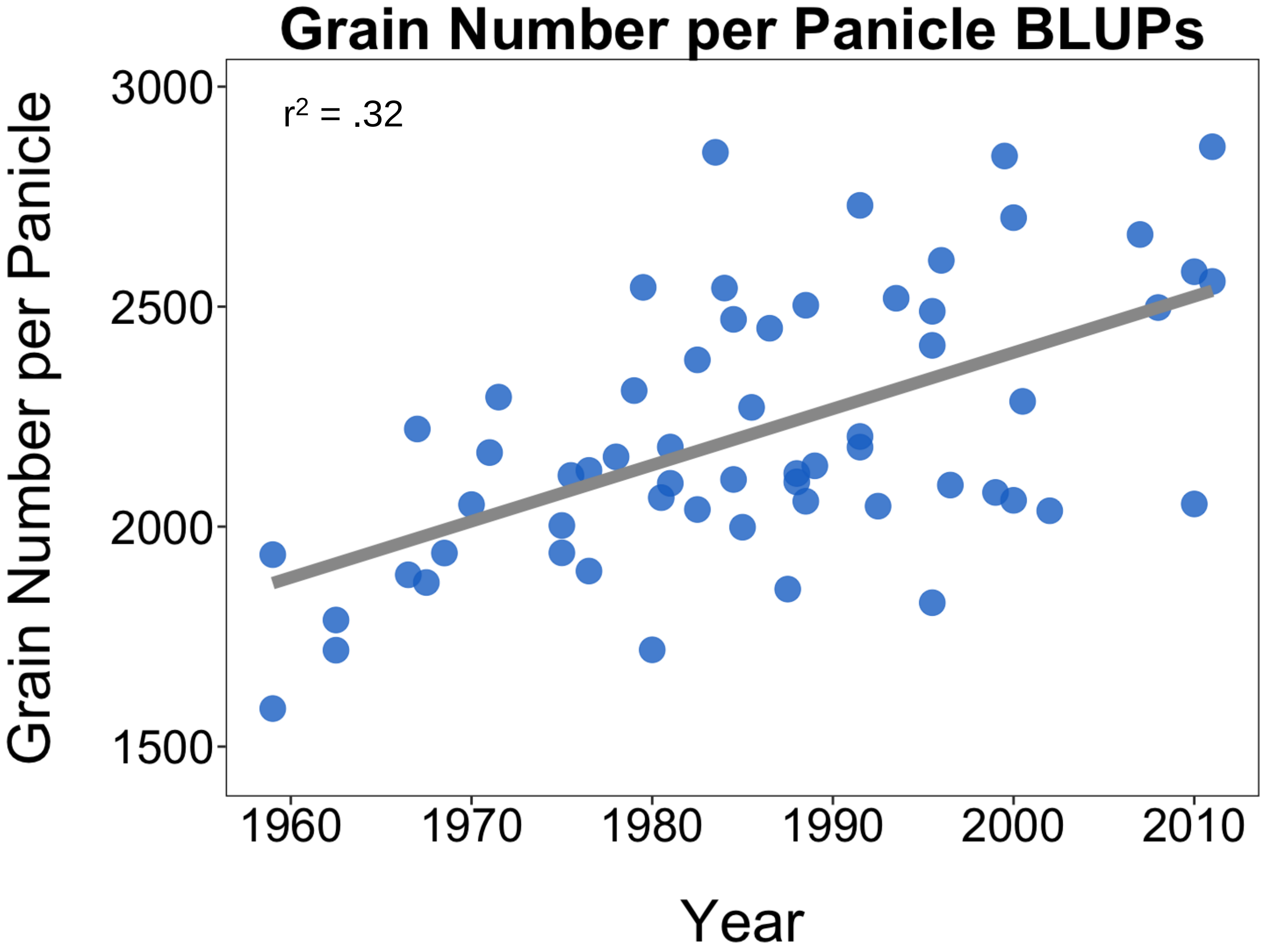
+ .008 t/ha annually

Grain Number per Panicle



Source	Variance	Percent
Environment	181312.90	28.72
Genotype	124215.34	19.68
G x E	66745.62	10.57
Rep(Env.)	14914.99	2.36
Residual	244060.12	38.66
TOTAL	631248.97	100.00

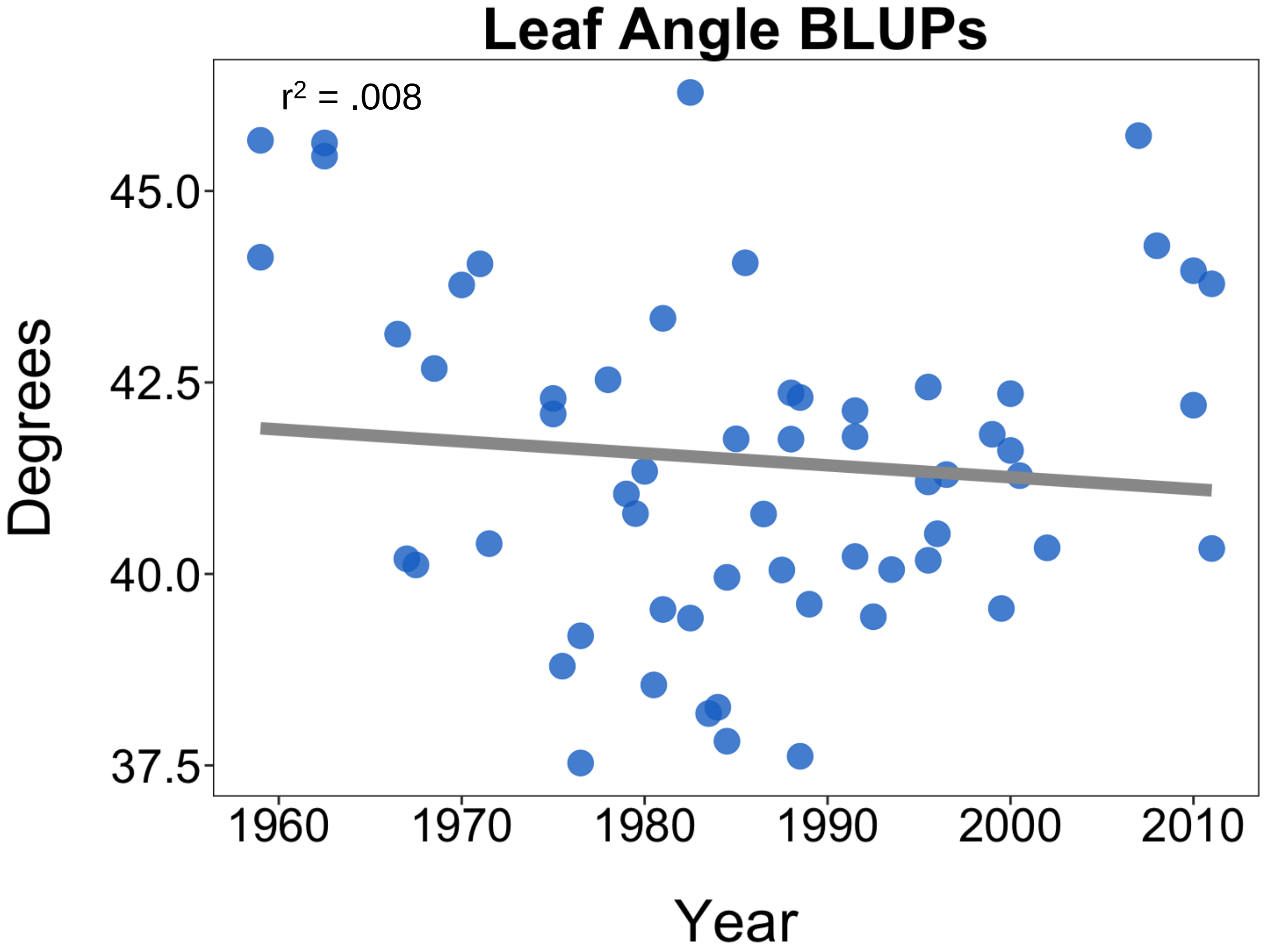
Grain Number per Panicle



Source	Variance	Percent
Environment	181312.90	28.72
Genotype	124215.34	19.68
G x E	66745.62	10.57
Rep(Env.)	14914.99	2.36
Residual	244060.12	38.66
TOTAL	631248.97	100.00

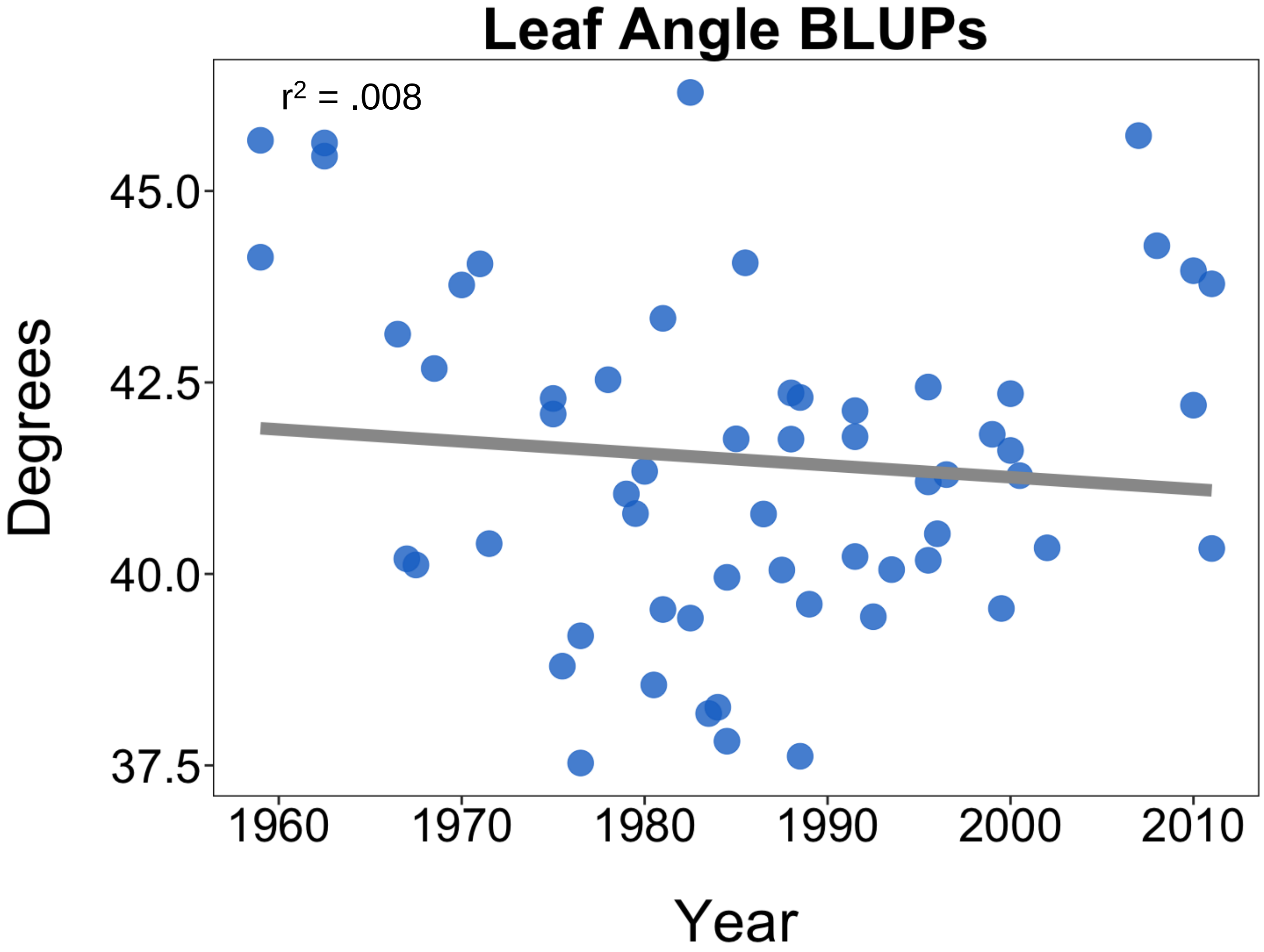
+ 13 grains annually

Leaf Angle



Source	Variance	Percent
Environment	41.18	52.16
Genotype	6.43	8.14
G x E	0.73	0.92
Rep(Env.)	7.56	9.58
Residual	23.05	29.20
TOTAL	78.95	100.00

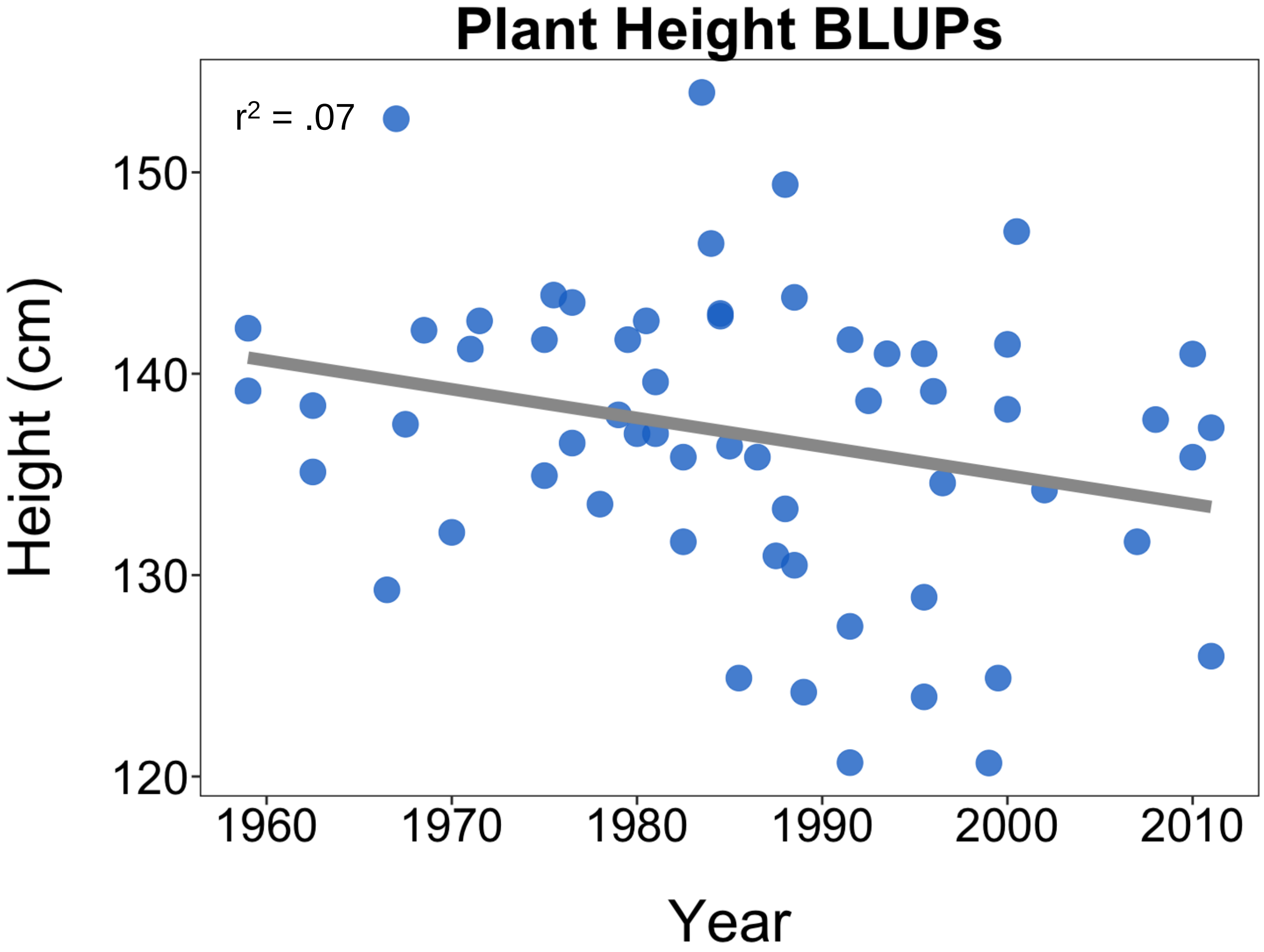
Leaf Angle



Source	Variance	Percent
Environment	41.18	52.16
Genotype	6.43	8.14
G x E	0.73	0.92
Rep(Env.)	7.56	9.58
Residual	23.05	29.20
TOTAL	78.95	100.00

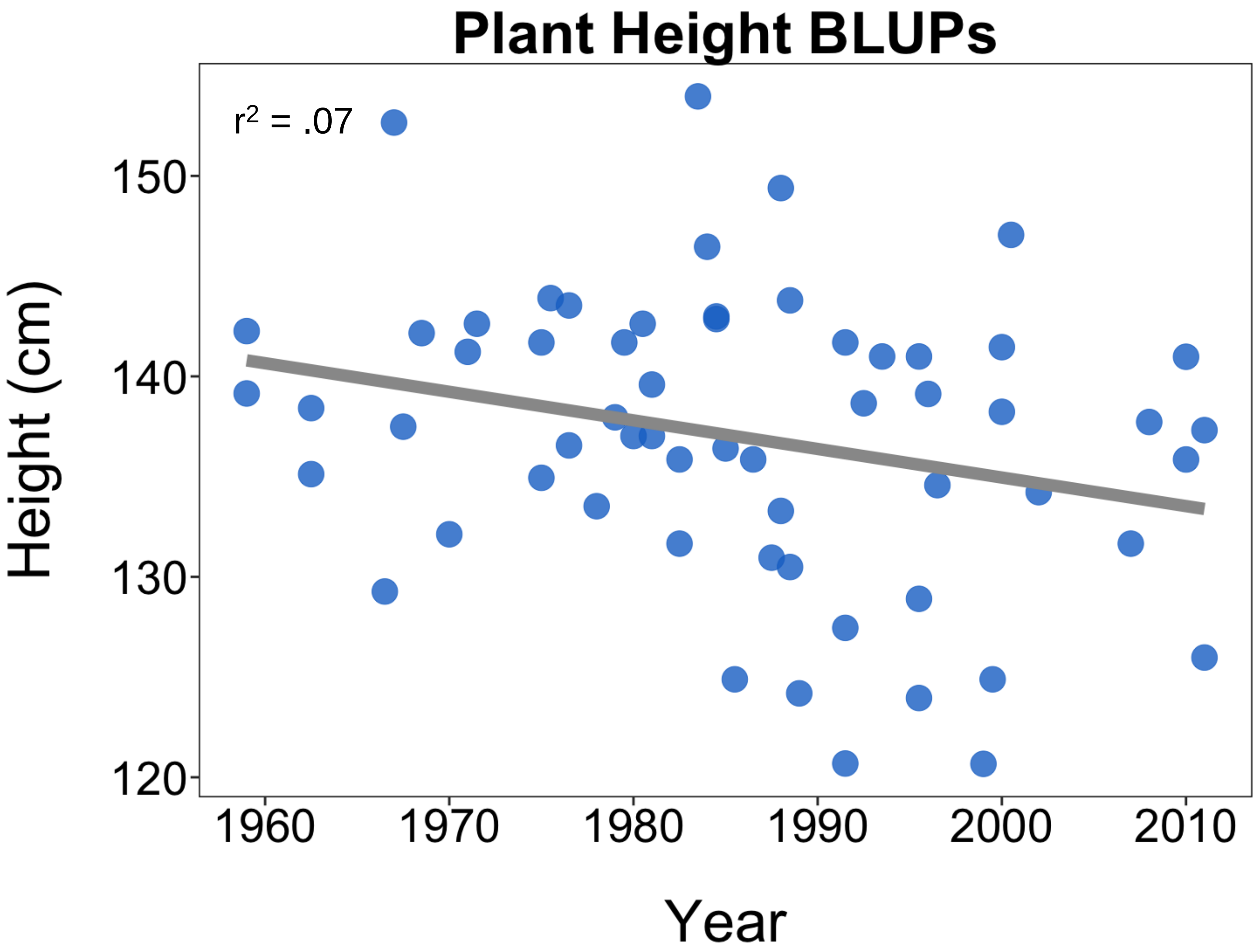
- .02 degrees annually

Plant Height



Source	Variance	Percent
Environment	19.88	12.84
Genotype	62.36	40.28
G x E	24.29	15.68
Rep(Env.)	3.73	2.41
Residual	44.59	28.80
TOTAL	154.85	100.00

Plant Height



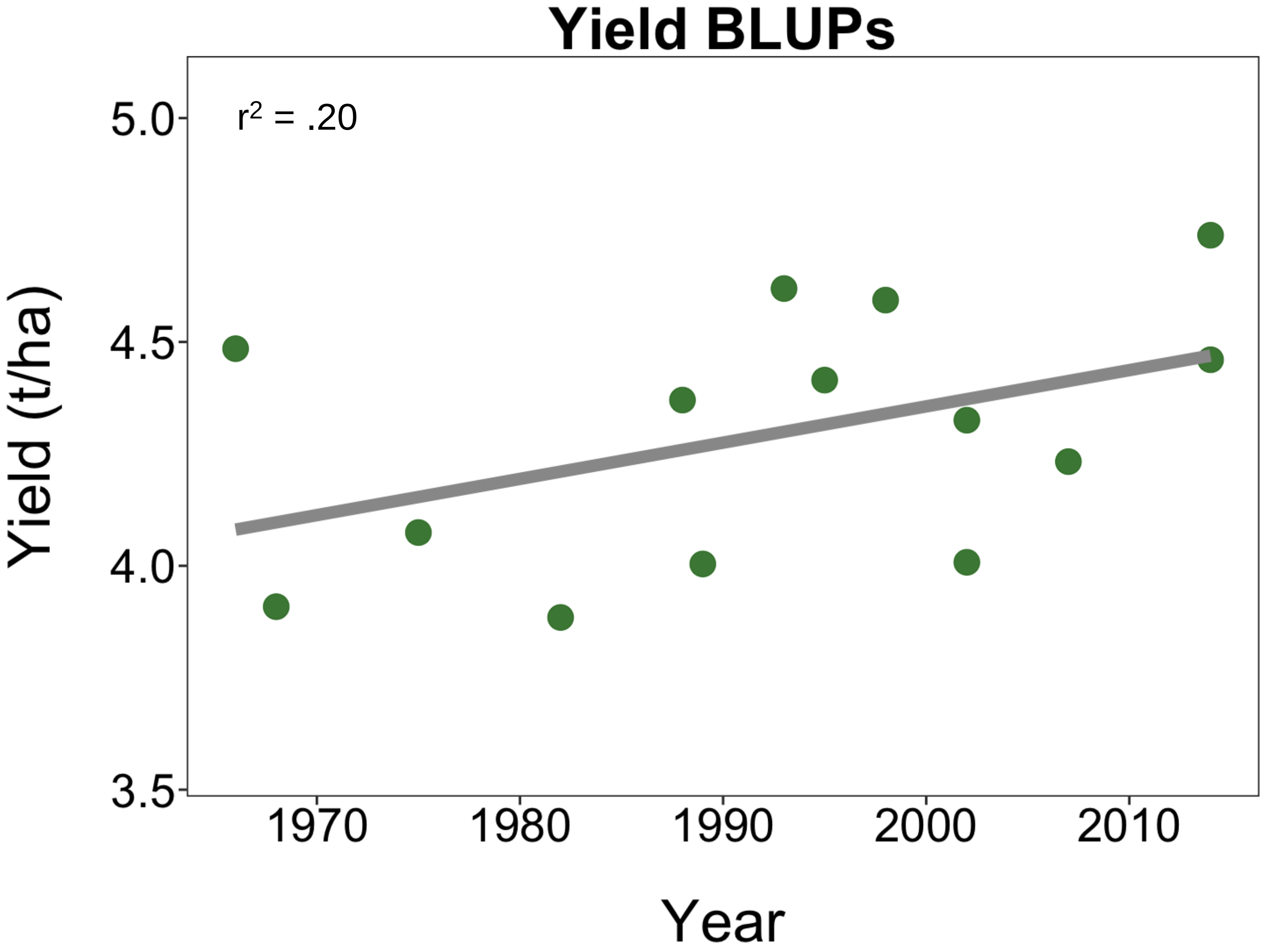
Source	Variance	Percent
Environment	19.88	12.84
Genotype	62.36	40.28
G x E	24.29	15.68
Rep(Env.)	3.73	2.41
Residual	44.59	28.80
TOTAL	154.85	100.00

- .14 cm annually

Genetic Gain

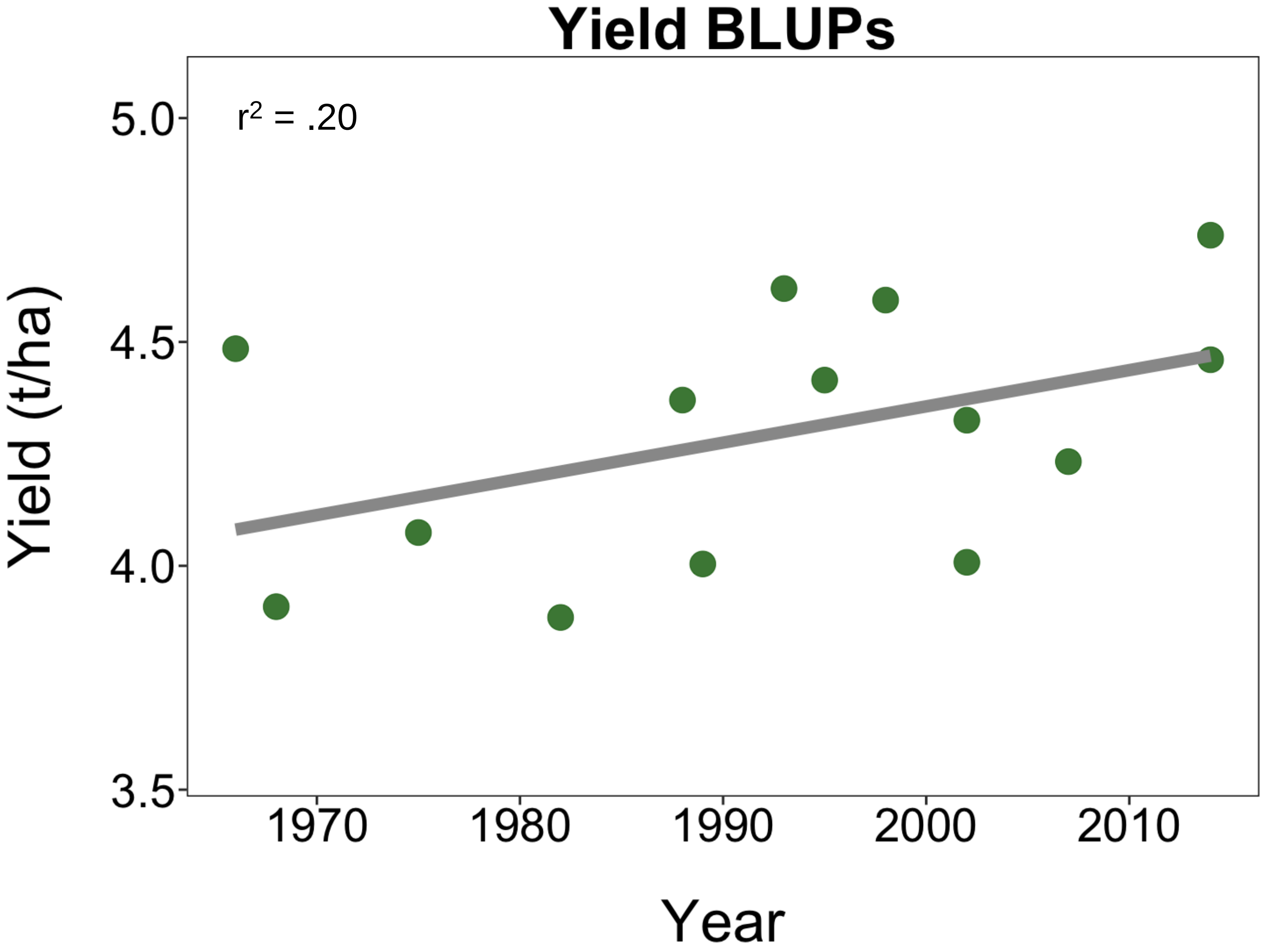
Trait	Slope	r^2
Test weight	**+ 0.28** kg/m^3 annually	.16
Panicle size	**+ .24** cm^2 annually	.13
Number of panicles	**- .015** panicles annually	.00079
Days to flowering	**+ .02** days annually	.08
500 seed weight	**- .04** g annually	.37

Yield – Pioneer Hybrids



Source	Variance	Percent
Environment	4.36	87.73
Genotype	0.12	2.05
G x E	0.18	4.24
Rep(Env.)	0.00	0.04
Residual	0.70	5.94
TOTAL	5.36	100.00

Yield – Pioneer Hybrids



Source	Variance	Percent
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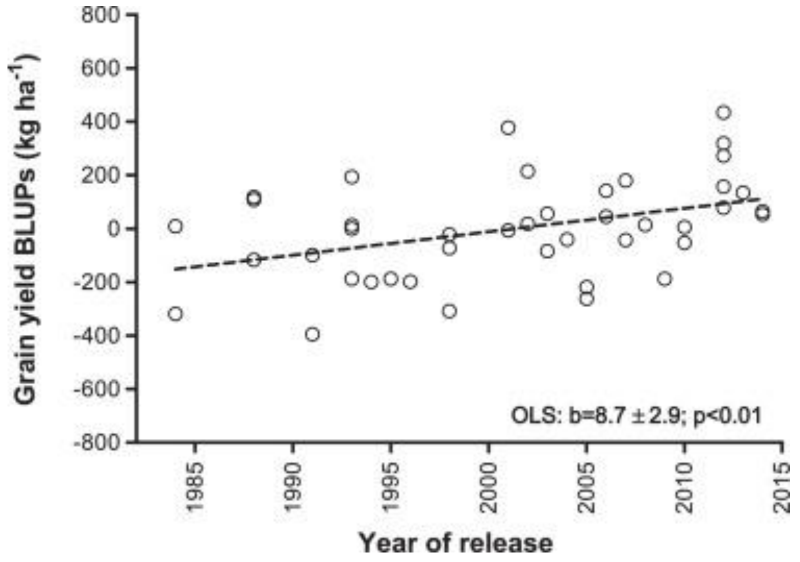
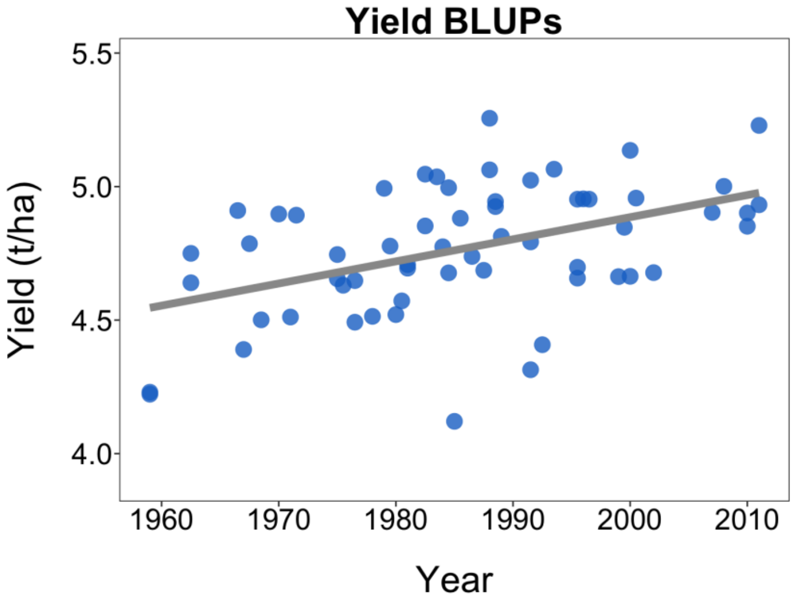
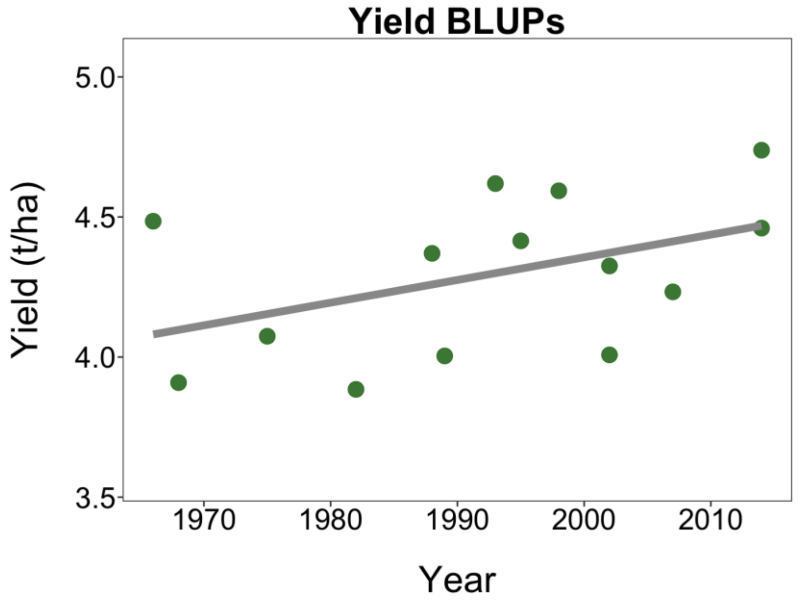
G x E	0.18	4.24
Rep(Env.)	0.00	0.04
Residual	0.70	5.94
TOTAL	5.36	100.00

+ .008 t/ha annually

Genetic Gain Comparison



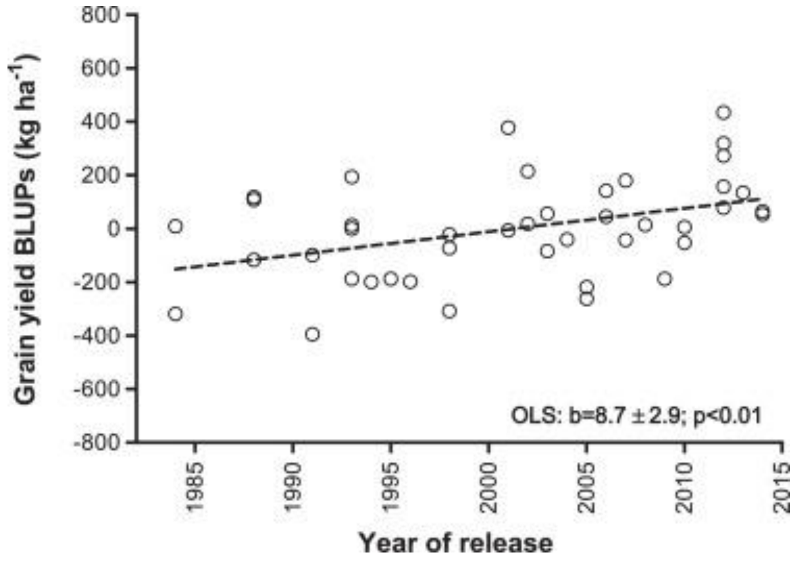




Gizza and Gambin, 2015, *Field Crops Research*

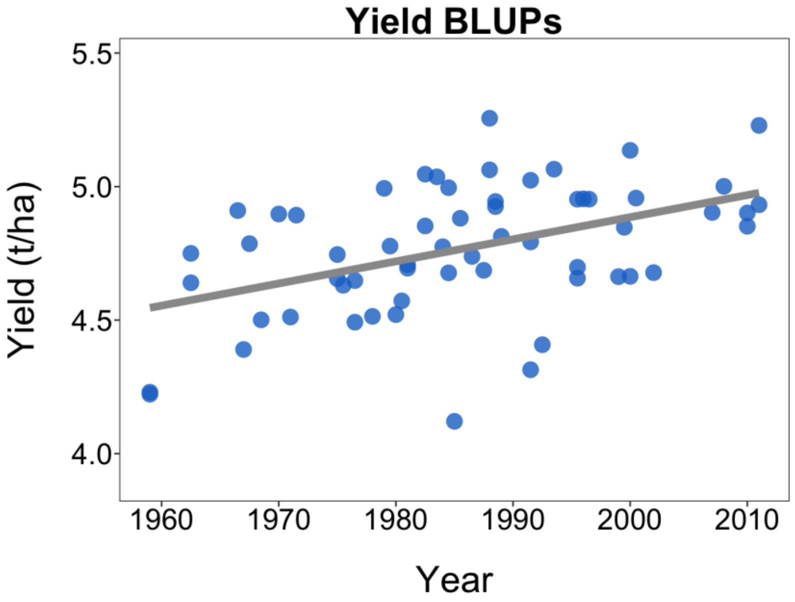
Genetic Gain Comparison

ADVANTA



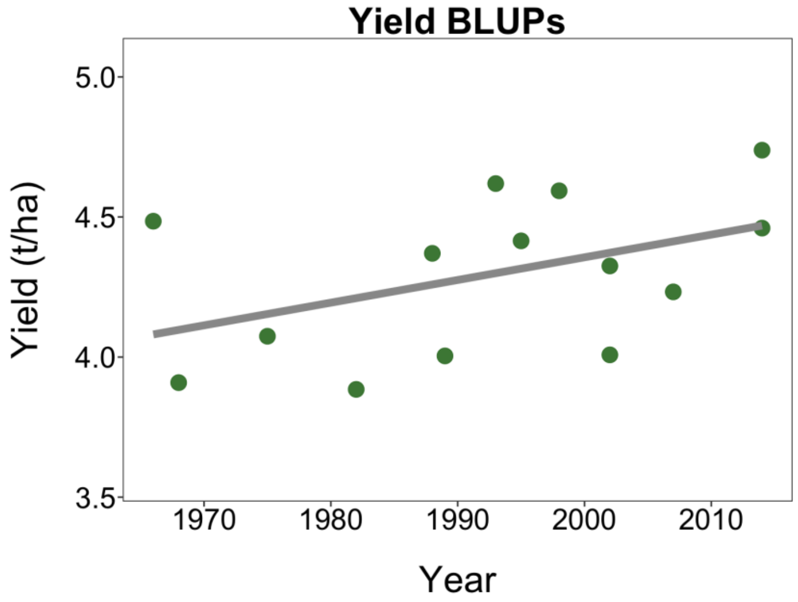
+ .008 t/ha annually

TEXAS A&M AGRILIFE RESEARCH



+ .008 t/ha annually

DUPONT PIONEER



+ .008 t/ha annually

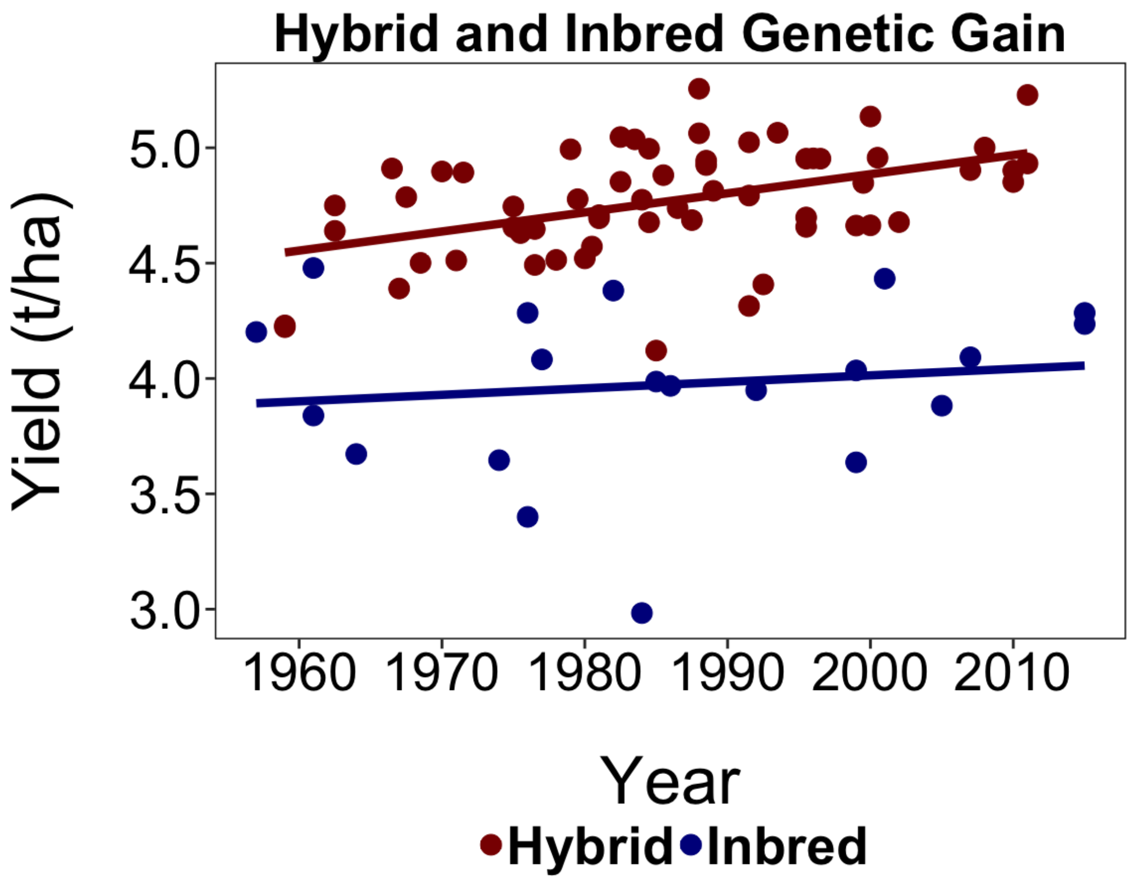
Gizza and Gambin, 2015, *Field Crops Research*

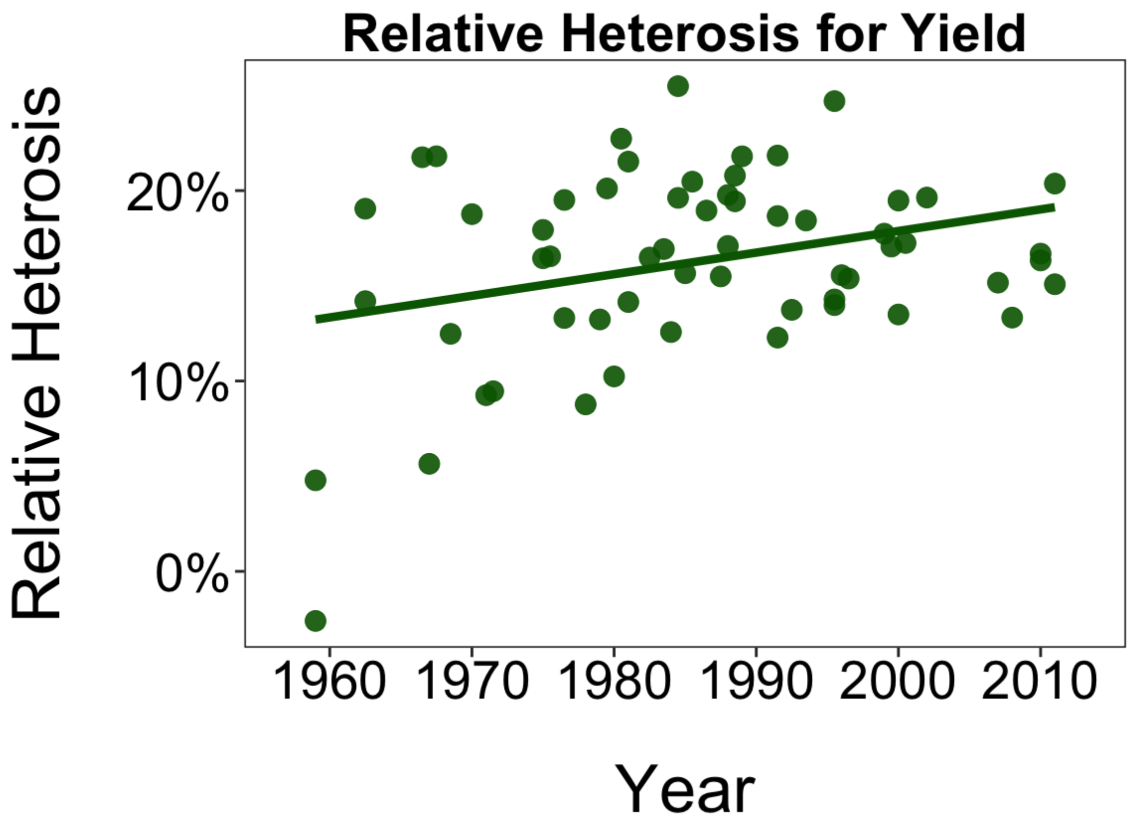
Relative Heterosis

$$\frac{(Yield\ of\ Hybrid\ - Yield\ of\ Midparent)}{Yield\ of\ Hybrid} \times\ 100$$

Schnell, 1974 Duvick, 2005

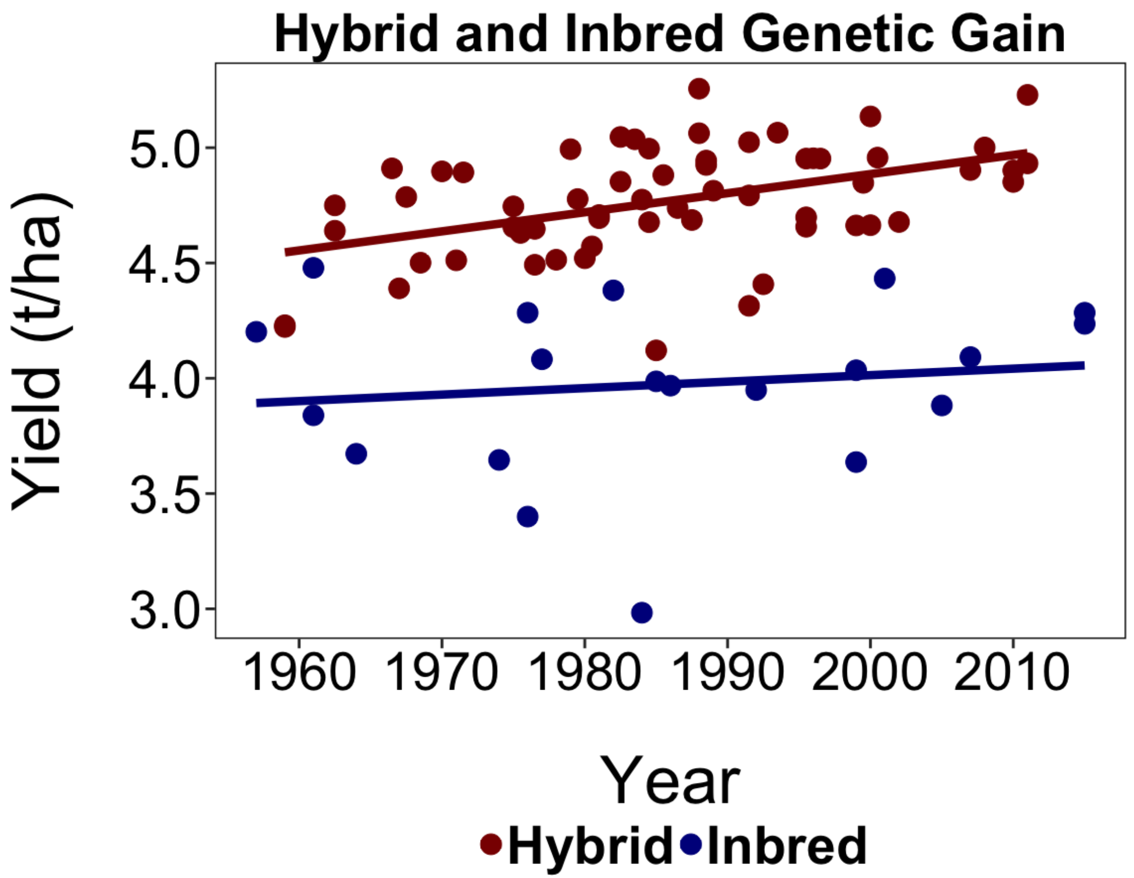
Heterosis

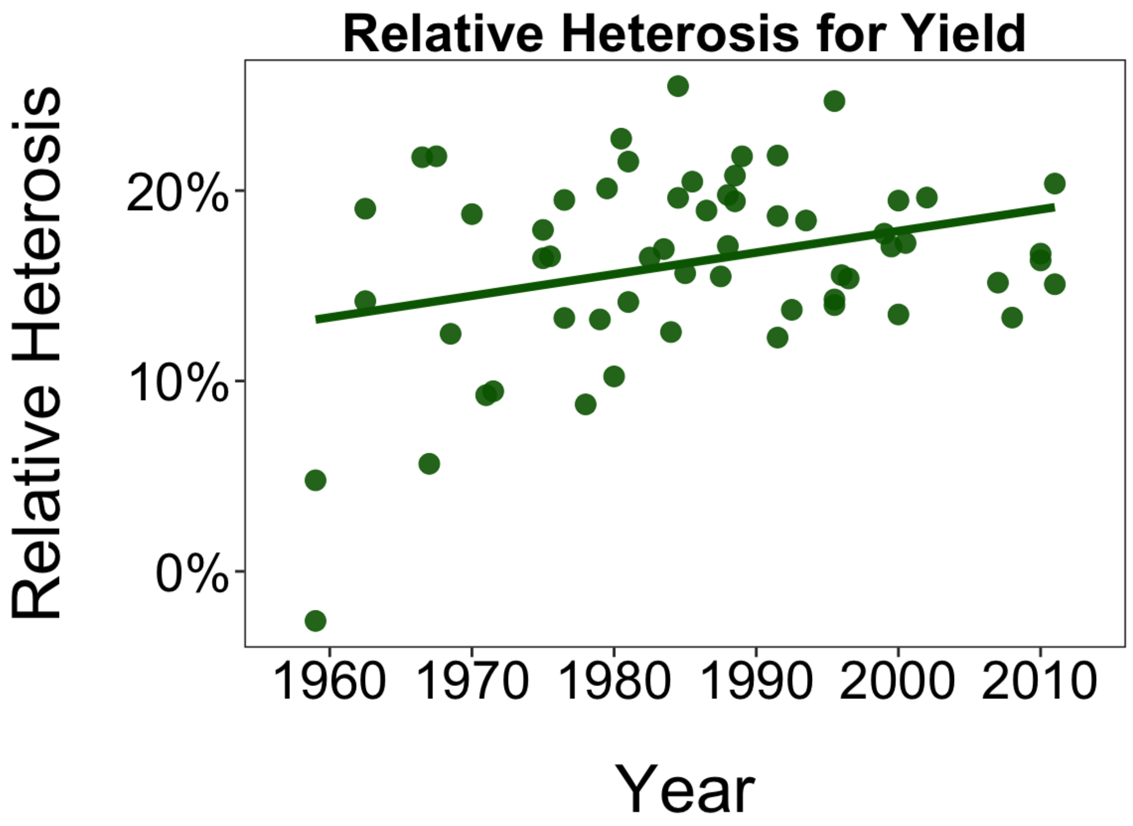




$$\frac{(Yield\ of\ Hybrid\ - Yield\ of\ Midparent)}{Yield\ of\ Hybrid} \times 100$$

Heterosis





+ .008 annually **+ .003** annually

+ 0.11 % annually

Physiological Changes

Physiological Changes

Improvement – Intentional

- Grain yield
- “Yield potential per plant”
- Heterosis

Physiological Changes

Improvement – Intentional

- Grain yield
- “Yield potential per plant”
- Heterosis

No Change – Intentional

- Days until flowering
- Plant height

Physiological Changes

Improvement – Intentional

- Grain yield
- "Yield potential per plant"
- Heterosis

No Change – Intentional

- Days until flowering
- Plant height

Improvement – Indirect

- Test weight
- Panicle size
- Grain number/panicle

Physiological Changes

Improvement – Intentional

- Grain yield
- "Yield potential per plant"
- Heterosis

No Change – Intentional

- Days until flowering
- Plant height

Improvement – Indirect

- Test weight
- Panicle size
- Grain number/panicle

No Change

- Leaf angle
- Number of panicles/area

Conclusions

Conclusions

- Top-end yield potential only valuable if accompanied with strong yield stability

Conclusions

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- Yield increasing at 0.3% per year in private & public breeding programs

Conclusions

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- Yield increasing at 0.3% per year in private & public breeding programs
- Relative heterosis continues to increase

Conclusions

- Top-end yield potential only valuable if accompanied with strong yield stability
- Yield increasing at 0.3% per year in private & public breeding programs
- Relative heterosis continues to increase
- Many physiological traits have accompanied increases in grain yield

Conclusions

- Top-end yield potential only valuable if accompanied with strong yield stability
- Yield increasing at 0.3% per year in private & public breeding programs
- Relative heterosis continues to increase
- Many physiological traits have accompanied increases in grain yield
- Leaf angle shows no trend over time

“I believe the more you know about the past, the better you are prepared for the future.”

— Theodore Roosevelt

Thank You

Texas A&M AgriLife Research

Variety Testing Program

DuPont Pioneer