Current Impact of Changes in Corn Plant Density

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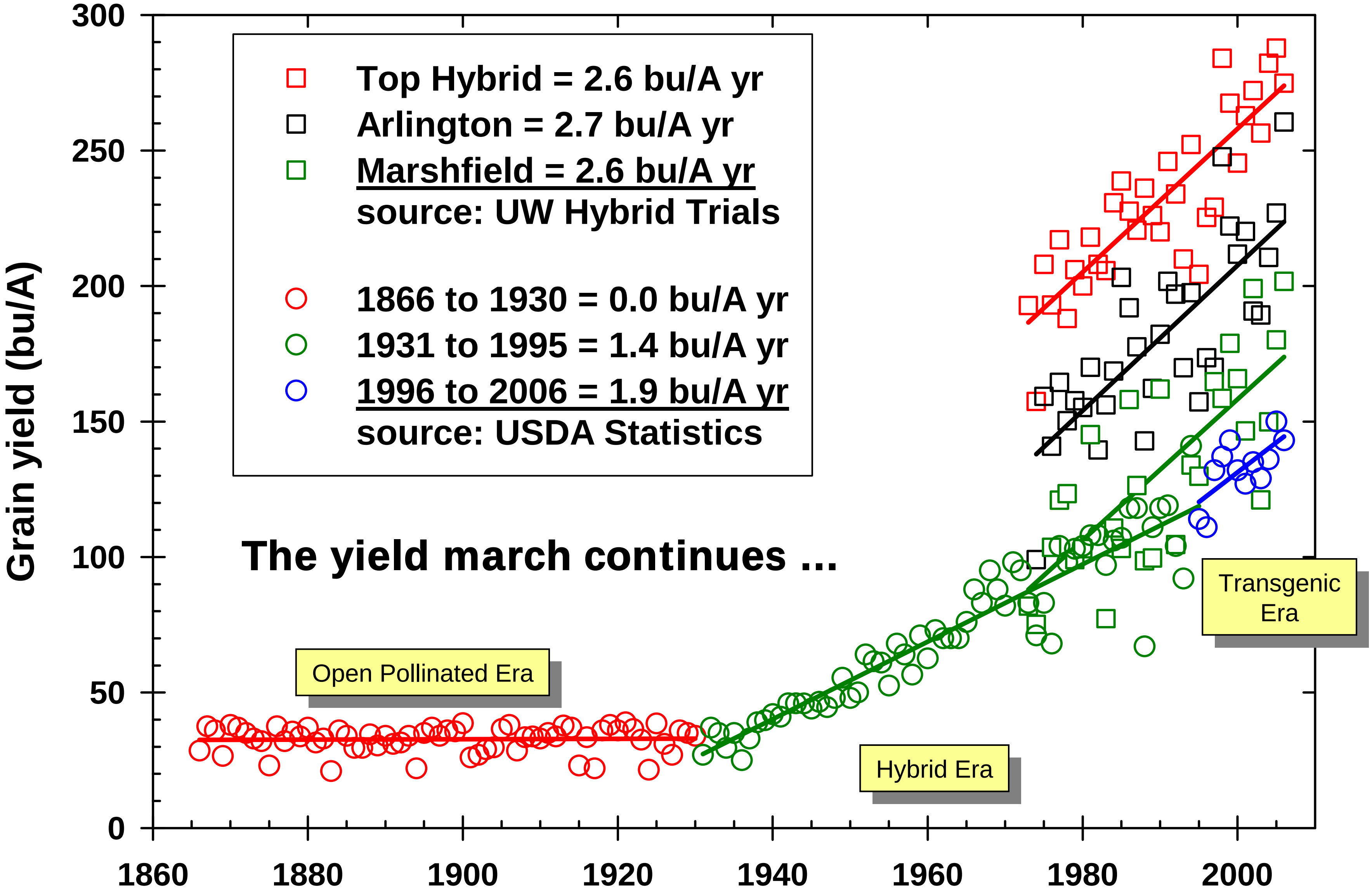
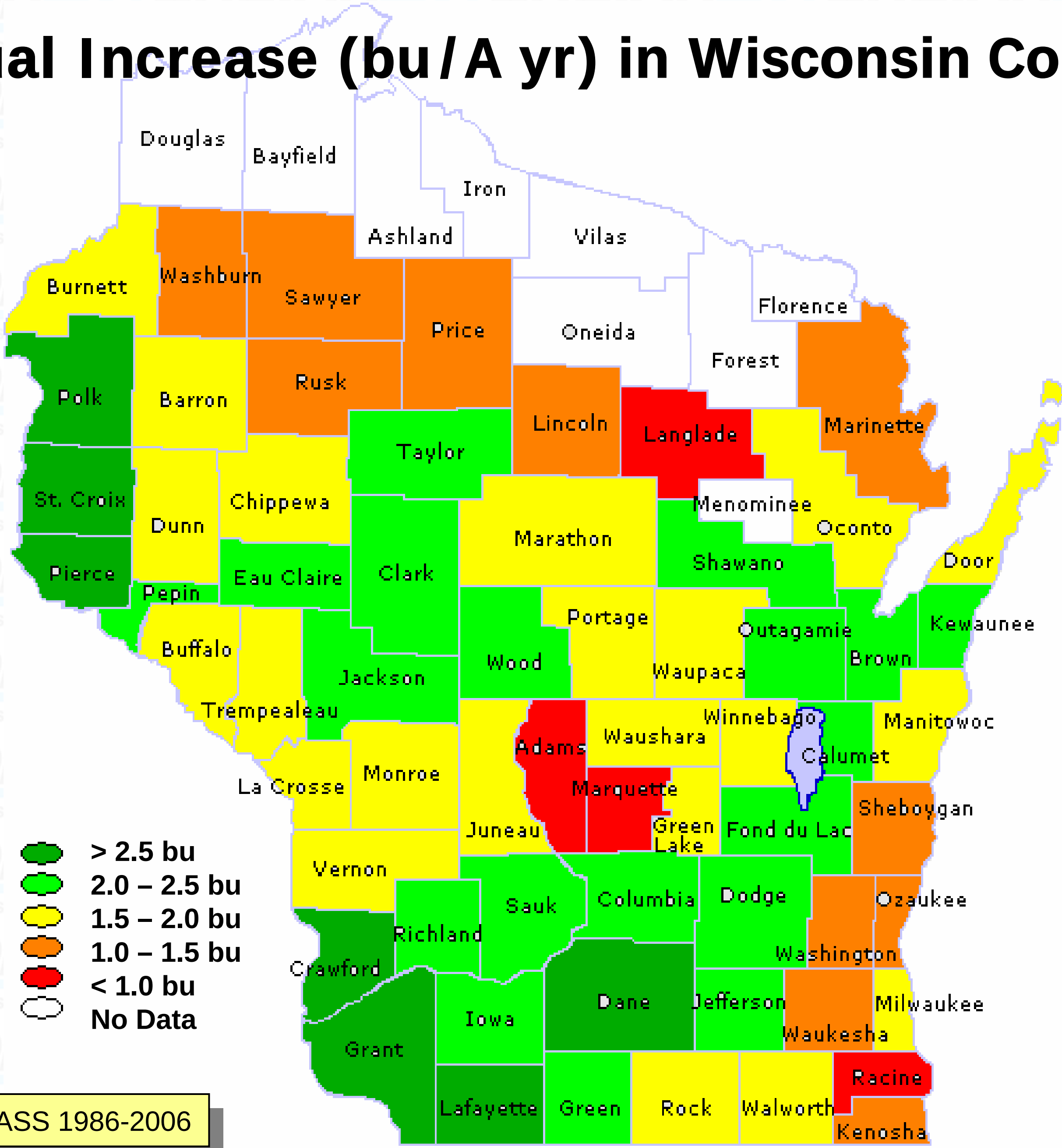
Corn yield in Wisconsin since 1866

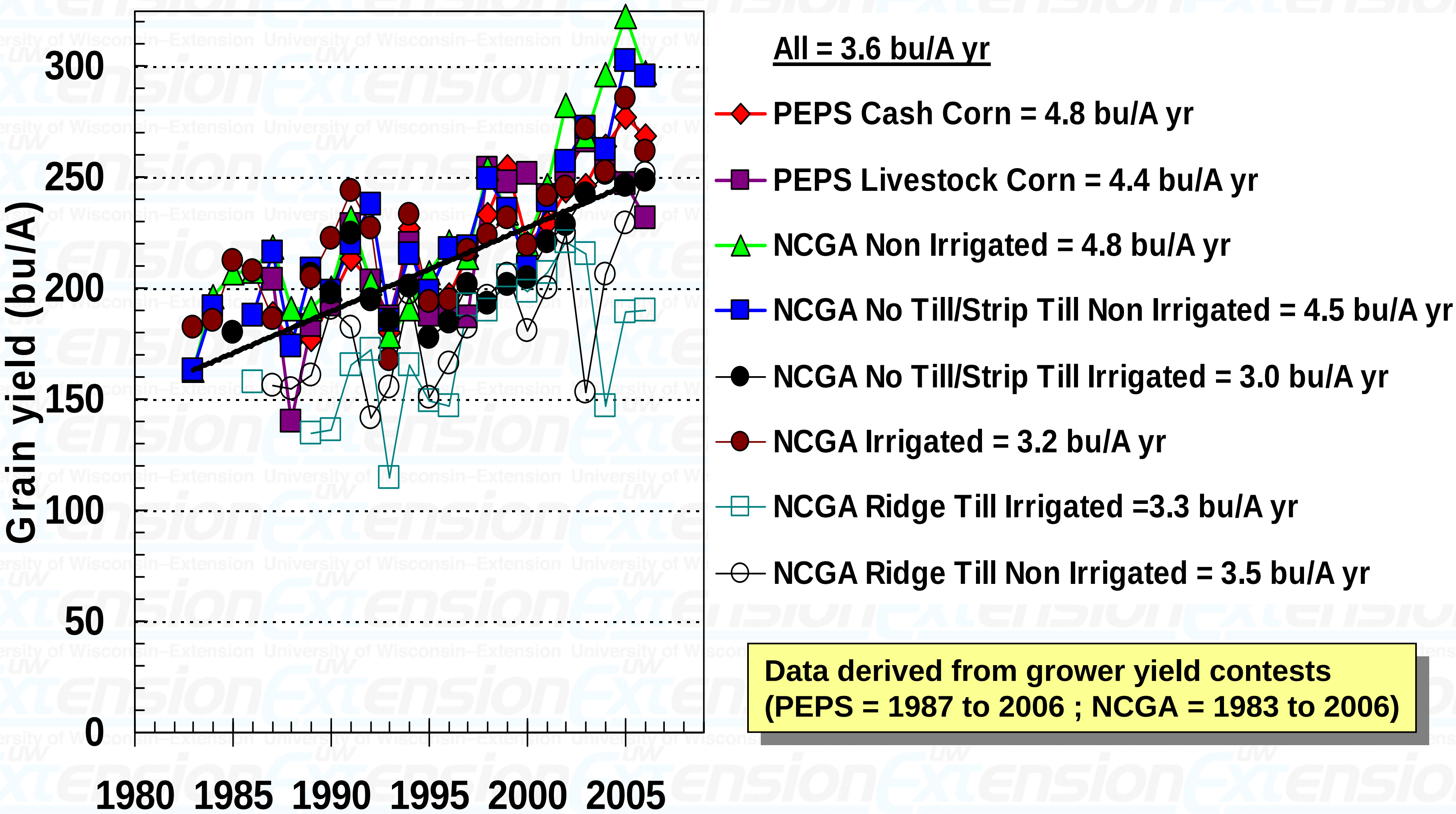


Annual Increase (bu/A yr) in Wisconsin Counties



Source: Mitchell, NASS 1986-2006

Corn Yield Progress in Wisconsin
Top Producer in Category (1983-2006)



Data derived from grower yield contests (PEPS = 1987 to 2006 ; NCGA = 1983 to 2006)

Yield Contest Winners – Plant at High Populations

Herman Warsaw, Saybrook, IL

- 1985: 370 bu/A
- 36,000 plants/A

Ken Beaver, Sterling, NE

- 2001: 319 bu/A
- 39,000 plants/A

Francis Childs, Manchester, IA

- 2002 World Record = 442 bu/A
- 30+ years continuous corn
- 45,000 plants/A

Summary of estimates of grain yield gain and genetic gain of corn hybrids.

Author	Year	Yield gain	Genetic gain
		bu A^{-1} yr^{-1}	%
Frey	1971	---	56
Darrah	1973	1.6	33
Russell – plot	1974	1.2	79
Russell – state	1974	1.2	63
Duvick	1977	1.4	57
Duvick	1977	1.4	60
Tapper – plot	1983	---	42
Tapper – machine	1983	---	67
Castleberry et al.	1984	1.8	75
Duvick	1984	1.6	89
Duvick	1984	1.6	71
Russell	1984	1.4	79
Russell	1984	1.4	56

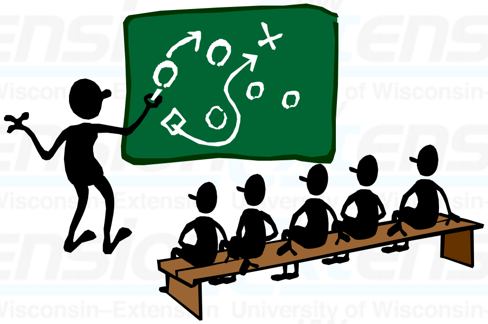
Factors Contributing to Continued Corn Yield Gain

- **Resistance to root and stalk lodging**
  - ✓ Necessary for machine harvesting at higher plant densities
- **Resistance to diseases - little data to support**
- **Resistance to insects**
- **Improvement of stay-green**
  - ✓ Continuous improvement of 2nd ECB resistance (Duvick, 1984)
- **Use of single-cross hybrids**
- **Resistance to barrenness**
- **Better pollen production**
- **Production under higher population**
- **Earlier planting date**
  - ✓ Better seed quality
  - ✓ Improved cold tolerance, better germination and emergence
- **Use of commercial fertilizers**
- **Pest control techniques**

Source: Duvik, 1987

Rationale and Situation

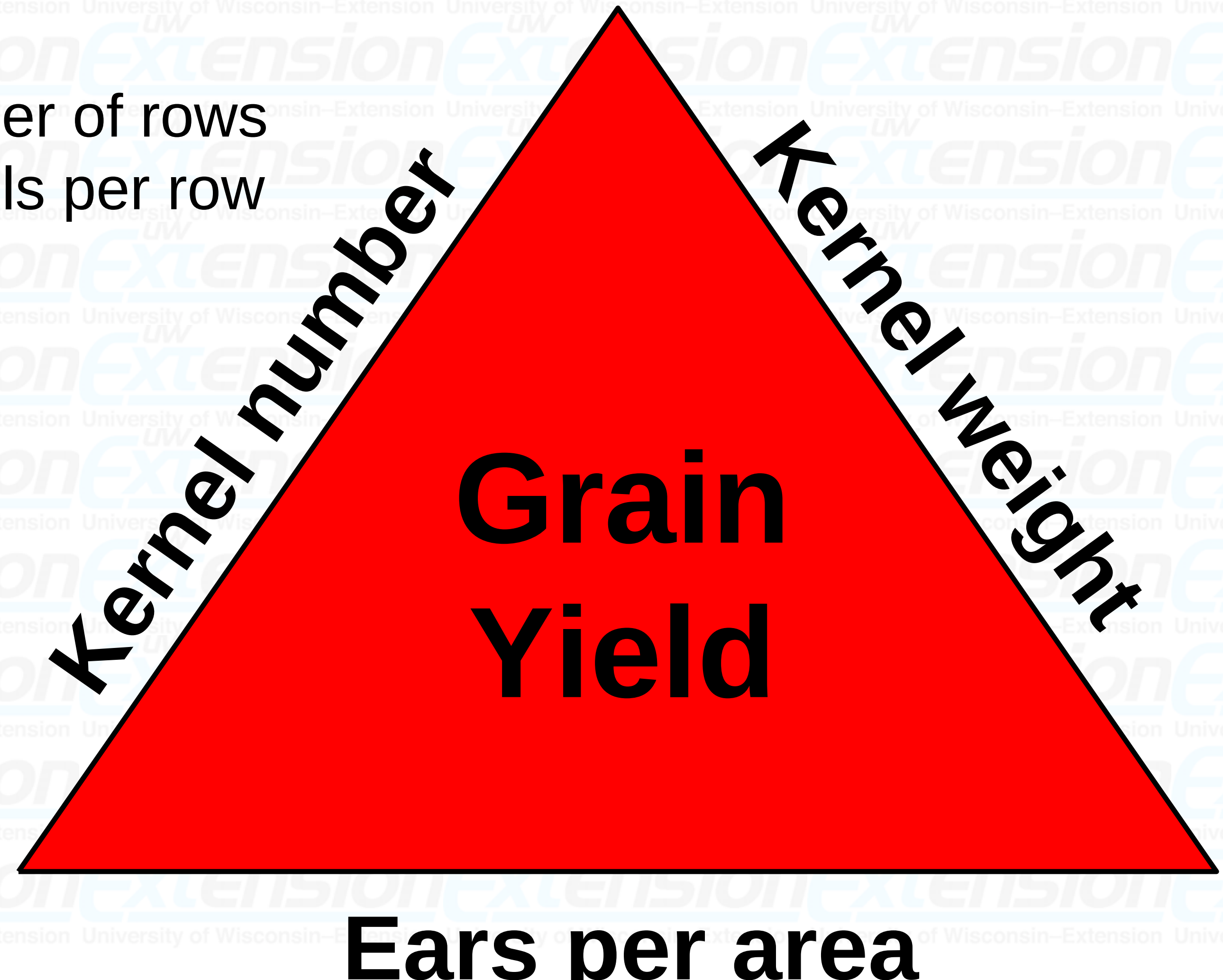
- **Optimum plant densities in corn have been steadily increasing. Wisconsin recommendations:**
  - ✓ 1930s: check-row planting 40 inches - 12,000 plants/A
  - ✓ 1940s: 18,000 plants/A
  - ✓ 1960s: 22,000 plants/A
  - ✓ 1980s: 26,000 plants/A
  - ✓ Current: 30,000 plants/A



- **Many reasons given for observed increase. Many workers.**
  - ✓ Due to stress tolerance? (Tollenaar, 1989)
  - ✓ Due to breeding? Duvick (1977)
  - ✓ Due to better management? (Cardwell, 1982)
- **Transgenic technologies have directly addressed the major constraint of plant lodging.**

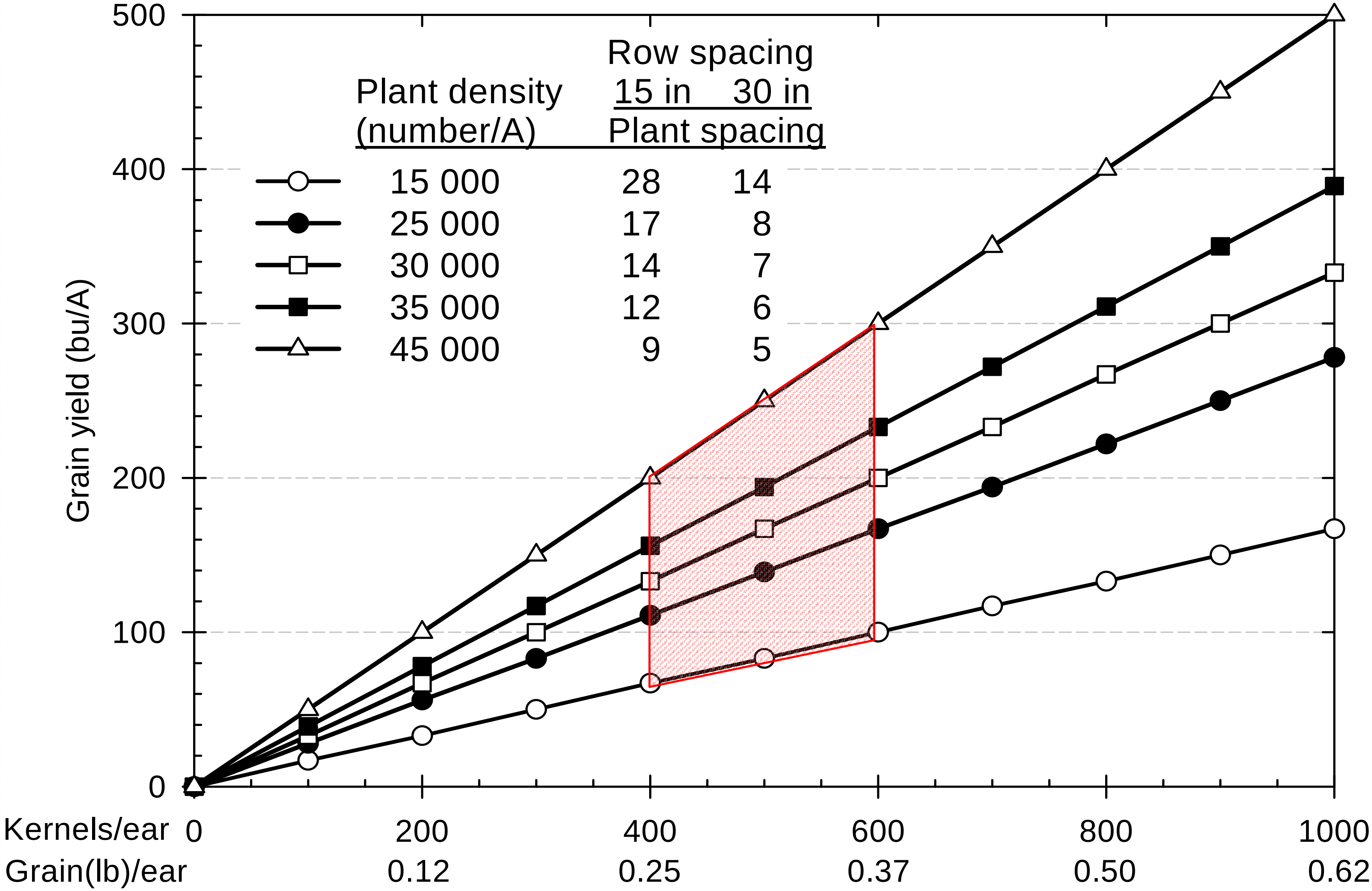
Yield Components of Corn

Number of rows
Kernels per row



Potential Grain Yield Using Calculated Components

Assume 90,000 kernels/bu and 56 lb/bu; kernel mass = 282 mg



http://corn.agronomy.wisc.edu

Objectives

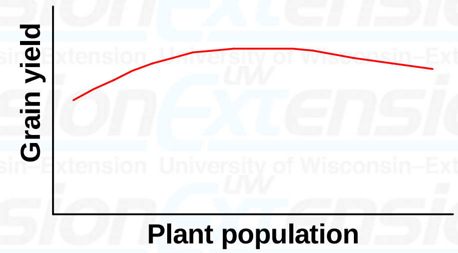
- **To determine the optimum plant population for corn.**
  - ✓ Range: populations at 95% of optimum grain yield
  - ✓ Model form
  - ✓ Influence of time

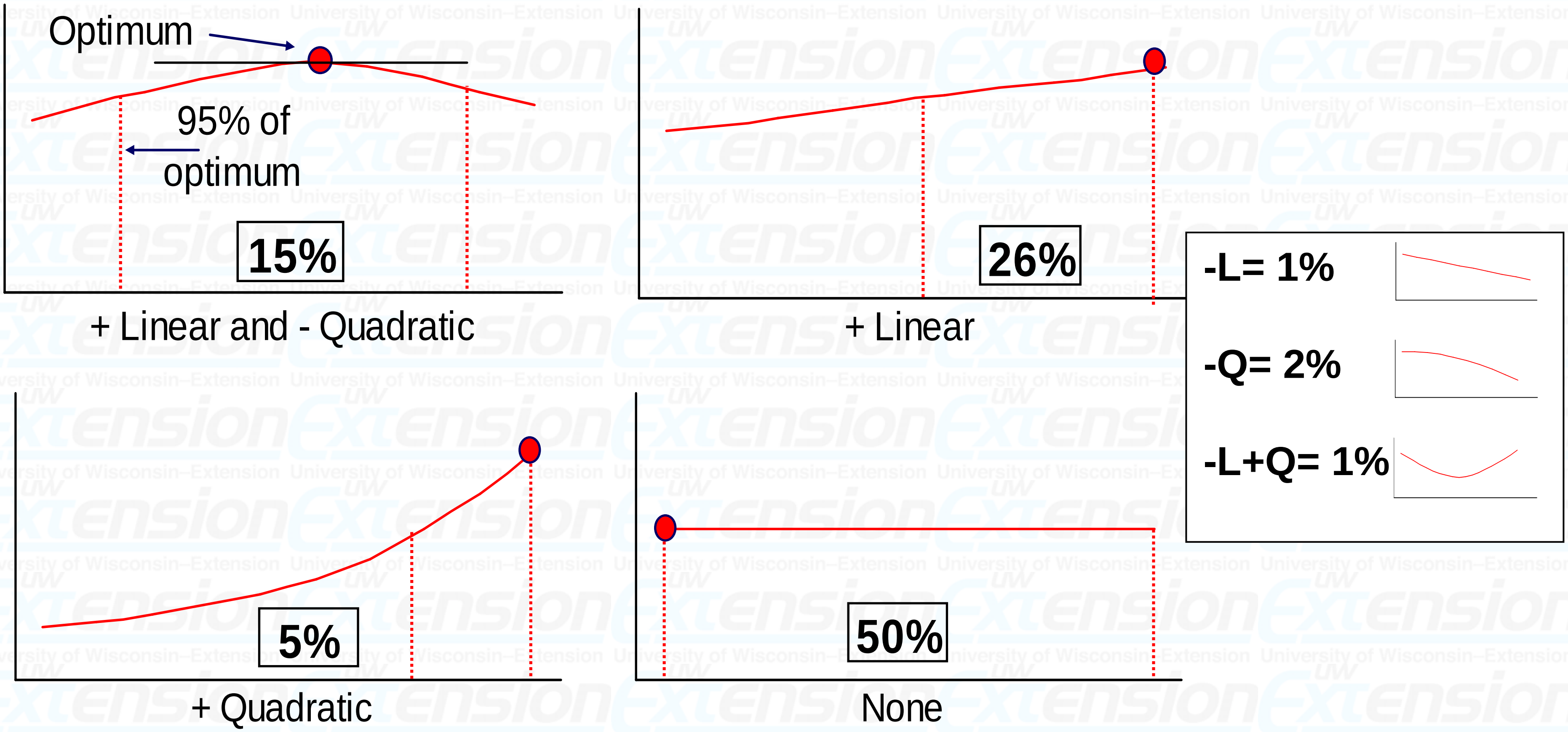
Thanks to Pioneer Hi-Bred for use of data.

Materials and Methods

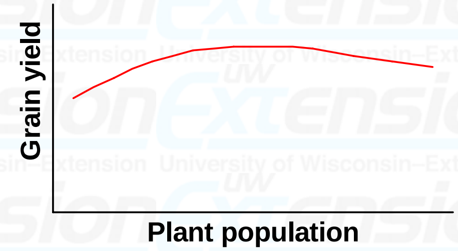
- **Total data set = 80,822 plots from 123 locations (631 hybrids)**
  - ✓ Wisconsin = 10,155 plots from 18 locations (275 hybrids)
  - ✓ Pioneer = 70,667 plots from 105 locations (350 hybrids)
  - ✓ GxE cases = 5571
- **Data cut conditions**
  - ✓ Trial had to have 4 or more plant density treatment levels
  - ✓ Plant density treatment range <= 28,000 and >= 34,000 plants/A
- **Traditional regression analysis**
  - ✓ Plots averaged across plant density treatment.
  - ✓ Means used for regression.
  - ✓ Max/Min kept within the treatment range.
  - ✓ What do you do about non significant cases?
    - ❑ Discard: too much variance, wrong model, or no relationship
    - ❑ Include
- **Proc Mixed analysis**
  - ✓ All data is included.
  - ✓ Year, Rep and Hybrid = random effects.
  - ✓ Fixed effects = Location, State, Maturity Belt or Hybrid Maturity

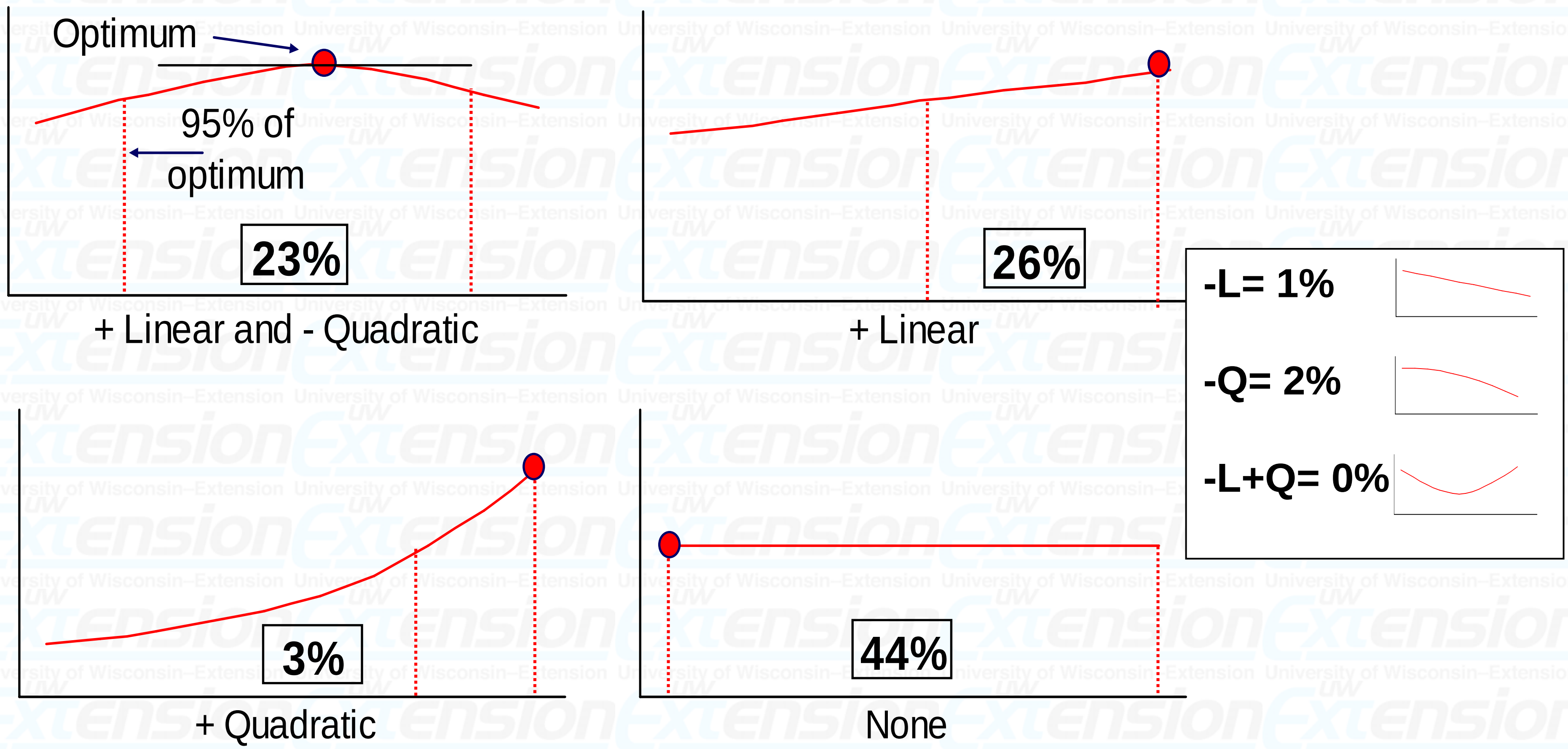
What Does the Relationship Between Grain Yield And Plant Density Look Like?
Total forms = 8; GxE n= 5571 cases
Trials with min PD≤ 28,000 and max PD≥ 34,000





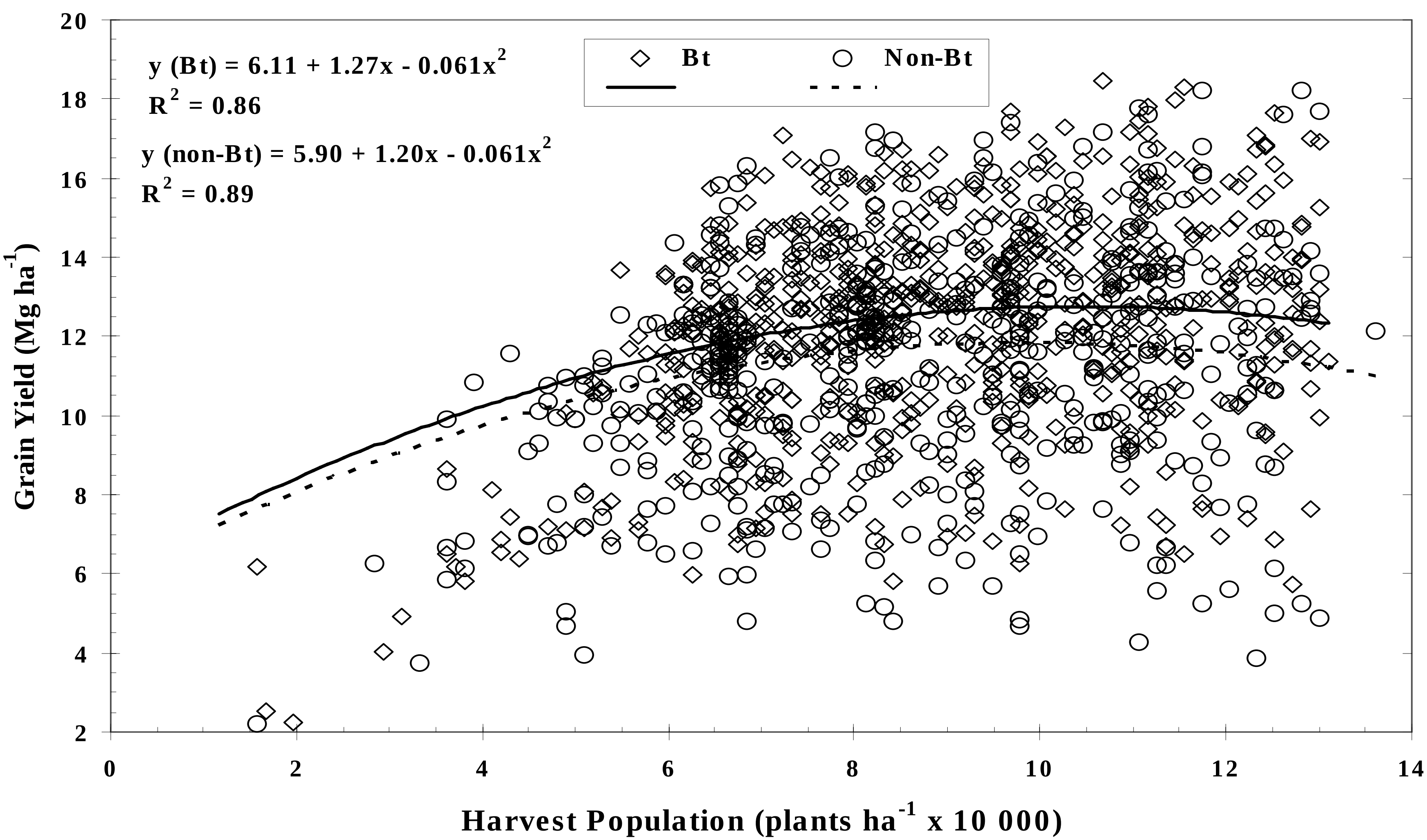
What Does the Relationship Between Grain Yield And Plant Density Look Like?
Total forms = 8; GxE n= 2373 cases
Trials with min PD≤ 24,000 and max PD≥ 40,000





http://corn.agronomy.wisc.edu

The relationship between plant population and grain yield for Bt and non-Bt hybrids in Wisconsin during 2002-2004. Points represent individual plots.

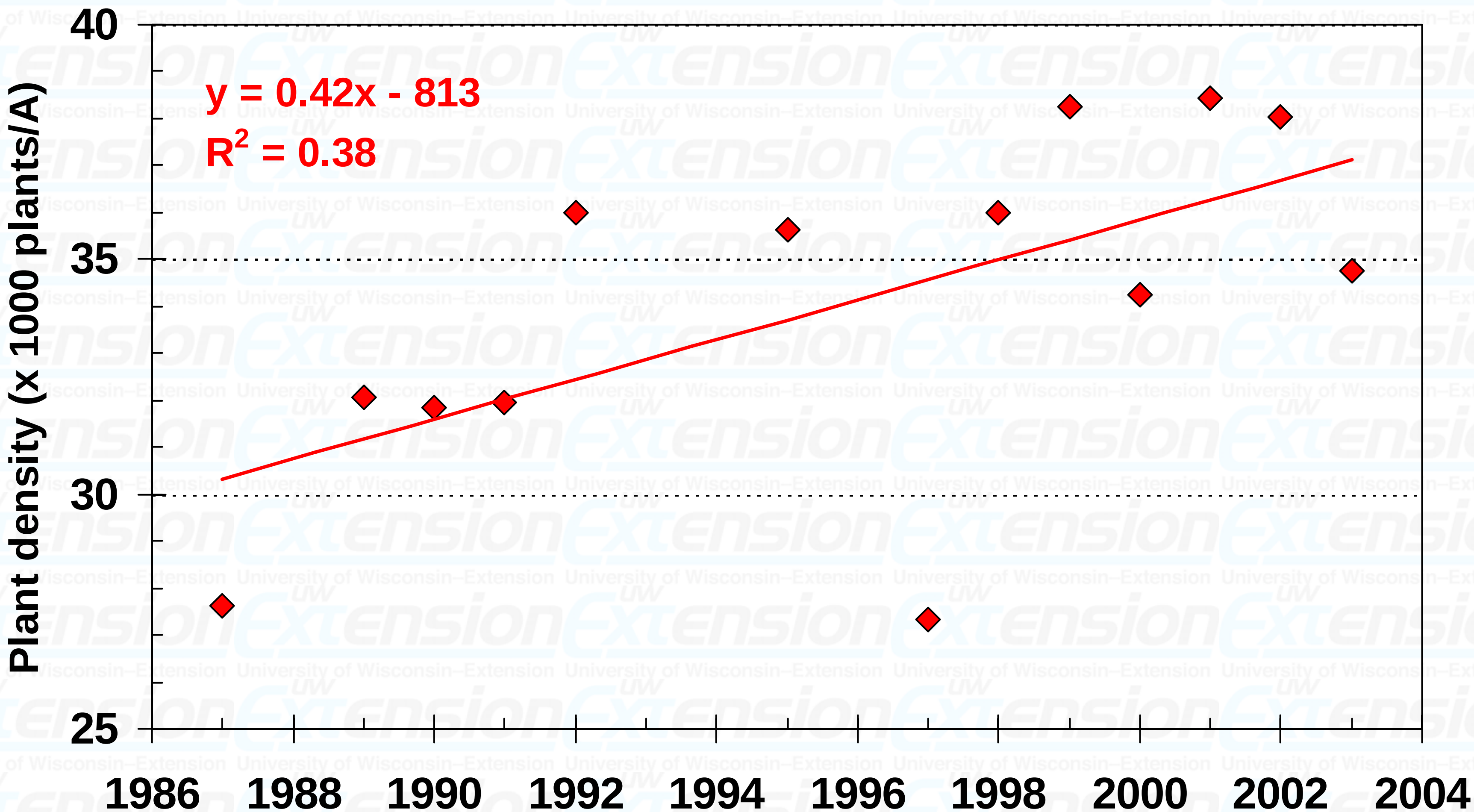


Source: Stanger and Lauer, 2006

Is Maximum Yield Plant Density Changing with Time?

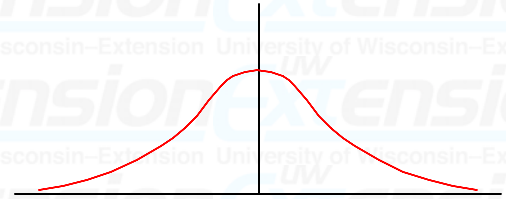
(02 PD - Arlington, WI 1987 to 2003)

Annual grain yield increase at optimum plant density = 2.8 bu/A

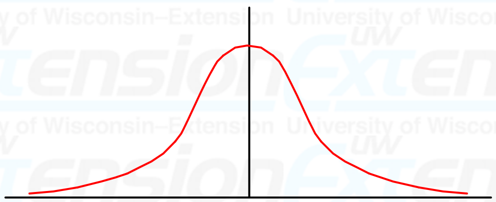



This ain’t good!

Risk Distributions

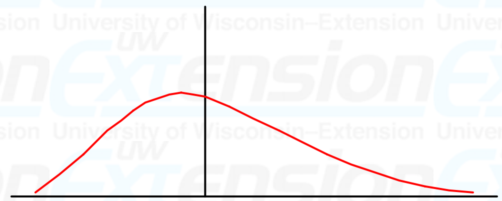


\- Normal +



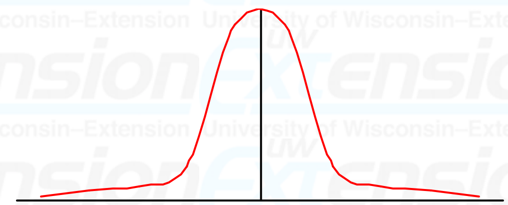
\- Low Standard Deviation +

Low risk



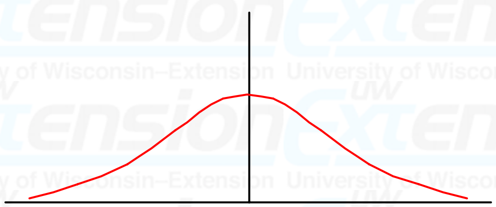
\- Positive Skew +

High “upside” risk



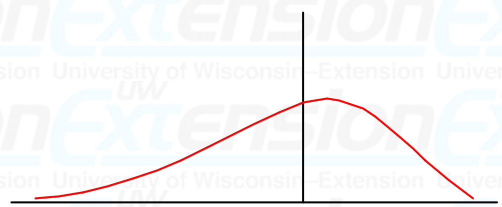
\- Positive Kurtosis +

Infrequent extremes



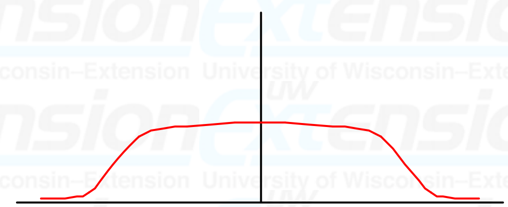
\- High Standard Deviation +

High risk



\- Negative Skew +

High “downside” risk

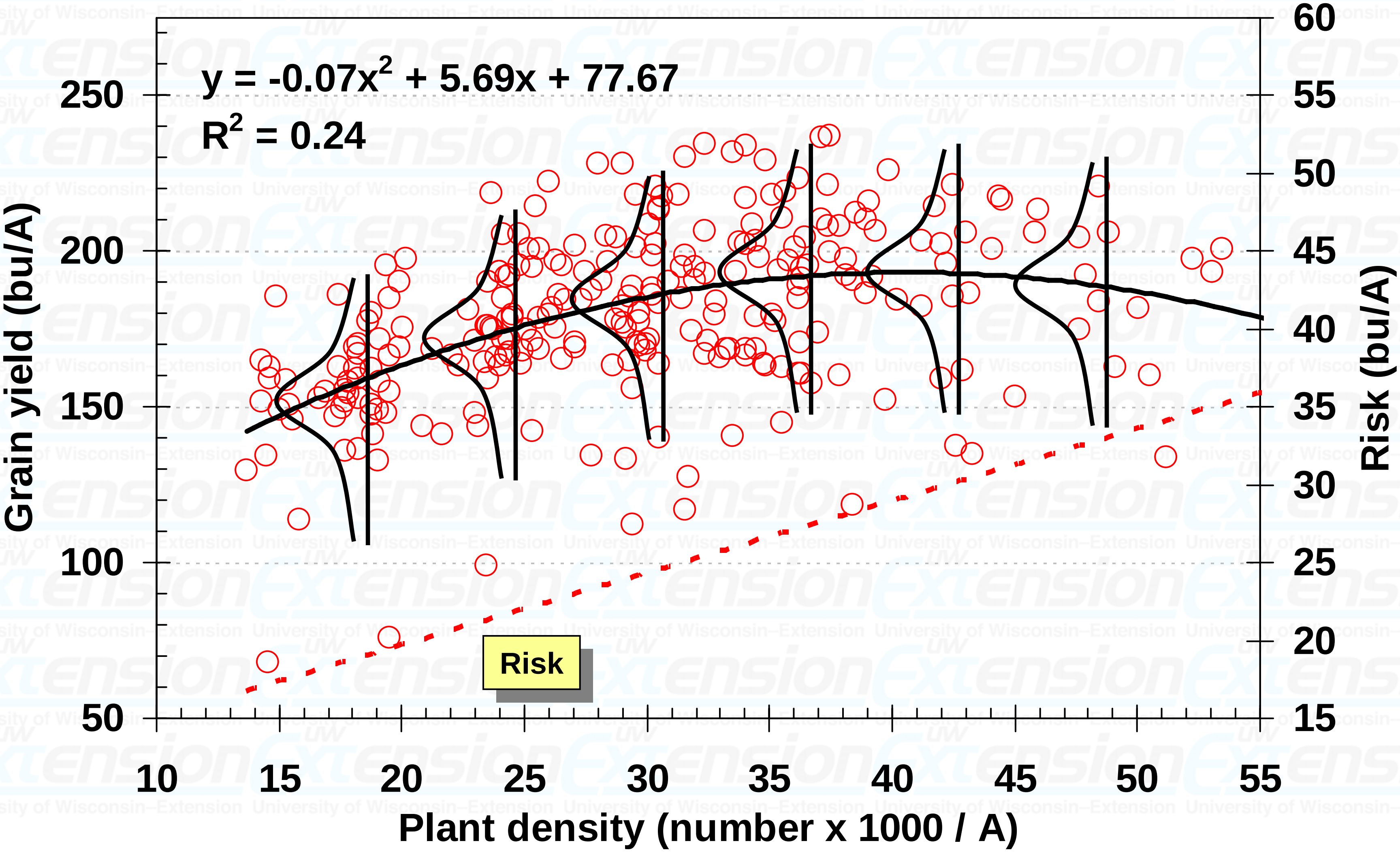


\- Negative Kurtosis +

Frequent extremes

Analyzing risk with increasing plant density

(1987 to 2005 at Arlington, WI, n= 867 plots)

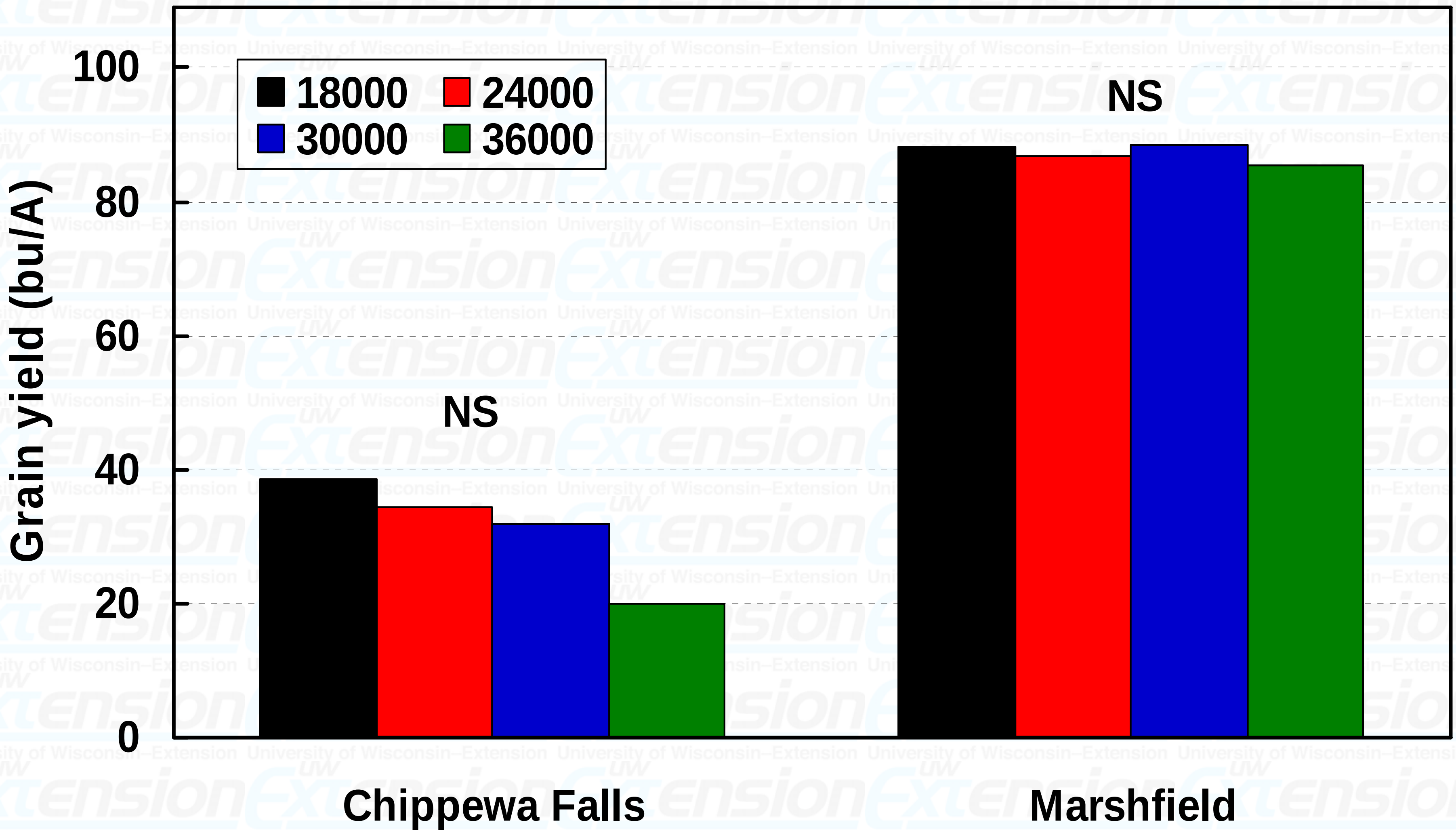


What about drought?

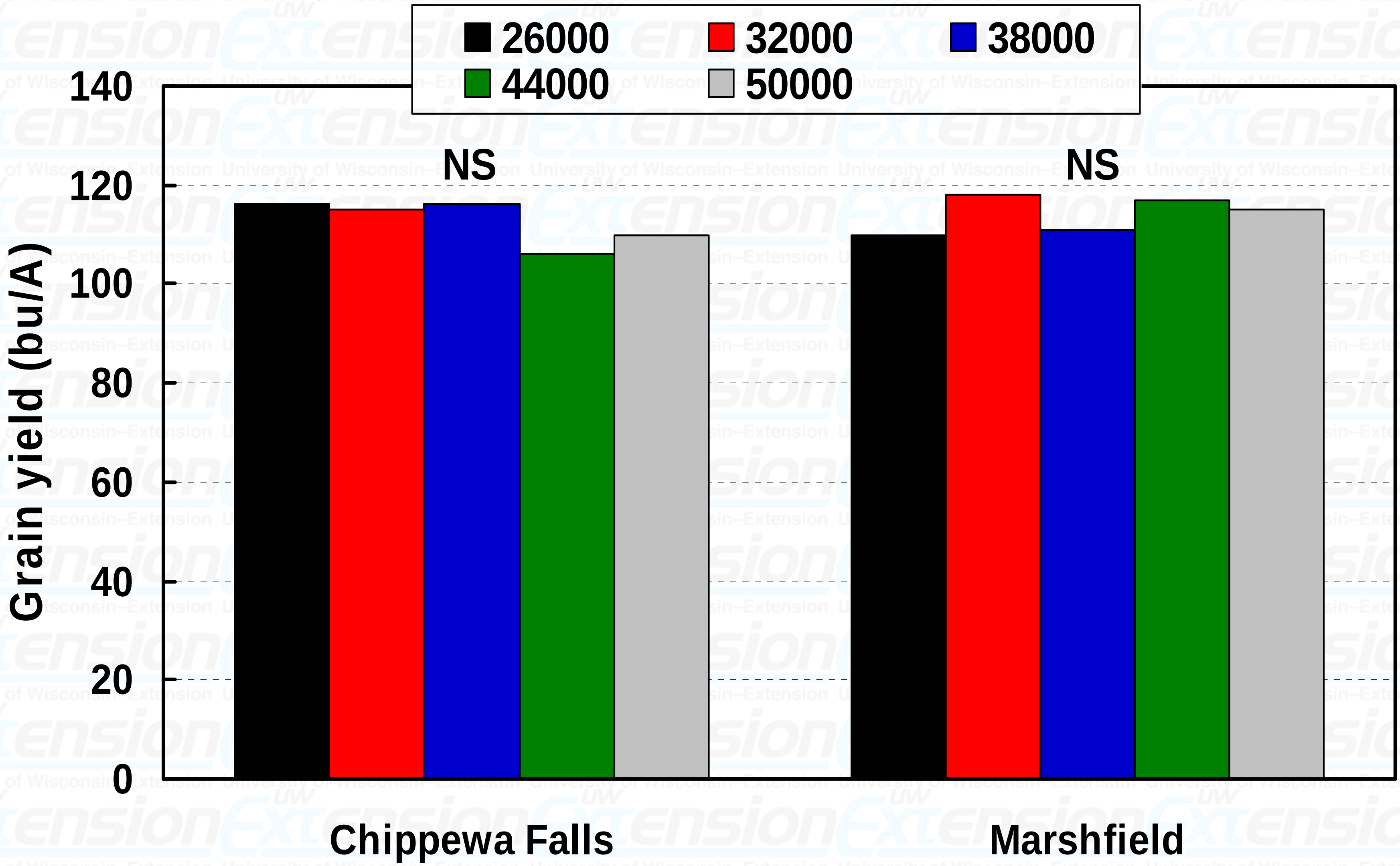
Chippewa Falls
September 19, 2003

Marshfield
October 6, 2003

Response of corn to plant density during 1988



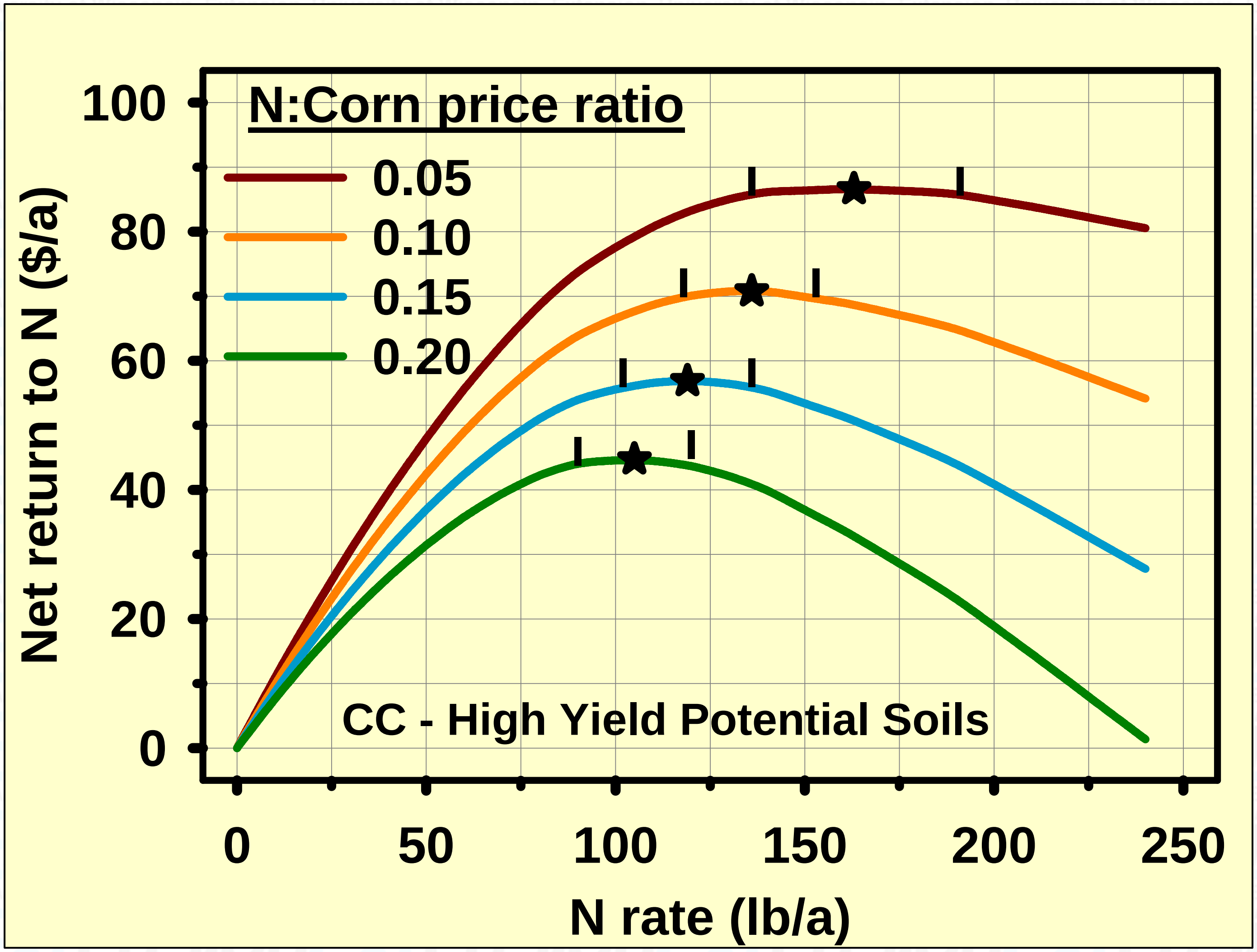
Response of corn to plant density during 2003



Should We Be Concerned About Seed Costs?

- **Seed costs have dramatically increased over the last few years.**
  - ✓ Transgenic hybrids and technology fees has driven the cost of seed
    - ❑ Premium hybrids cost $160-$180 per bag,
    - ❑ Ten years ago, premium seed would run about $80-$100 per bag.
- **When corn prices are low farmers are concerned about the cost of all inputs for corn production**
  - ✓ High energy prices have
    - ❑ Increased fertilizer price
    - ❑ Increased gasoline/diesel/LP for field operations and grain drying after harvest.
  - ✓ Minimizing field operations (especially moving towards no-till), early planting date, and appropriate hybrid maturity selection are management options that reduce energy costs.
- **Yield response of corn to plant density has increased over time.**
- **Ultimately, optimum plant density is affected by both seed cost and corn price.**

Profitable N Rates

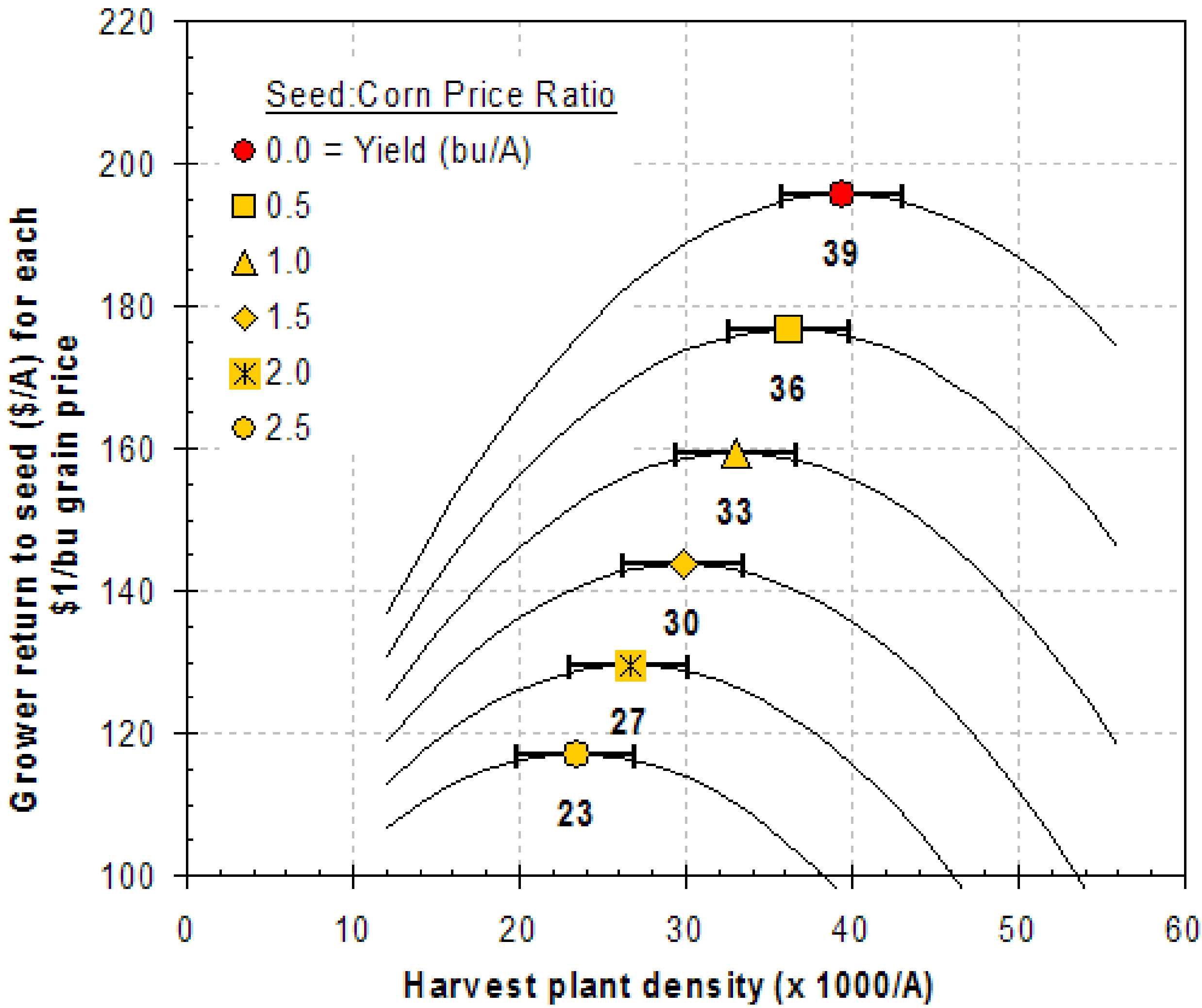


- A range of N rates can produce profitable yields
- Economics clearly drives the profitable N rate

Price Ratio of Seed:Corn
(i.e. $/1000 seeds ÷ $/bu corn)

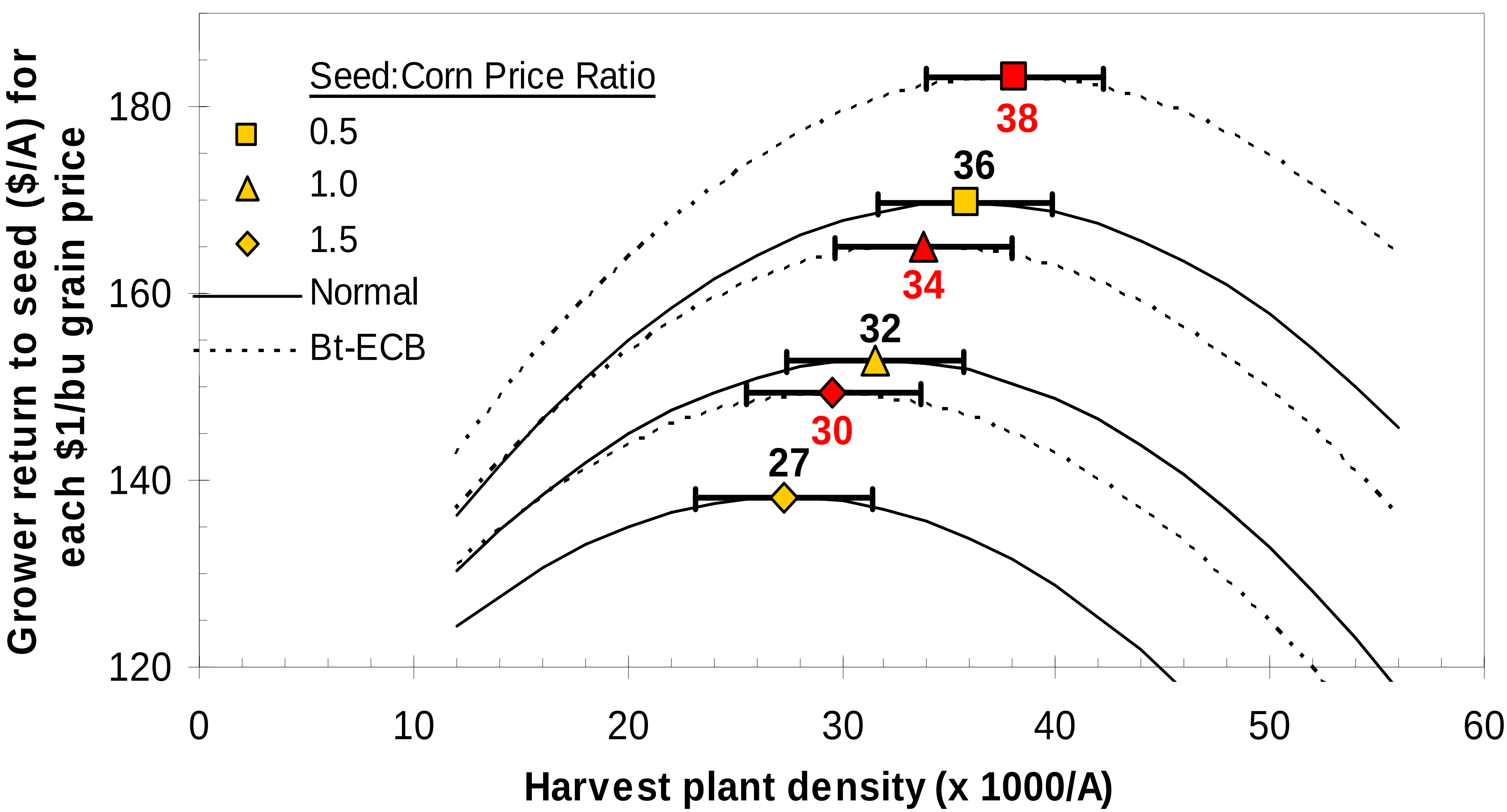
Price of seed		Price of corn ($/bu)					
$/80 K bag	$/1000 seeds	$1.00	$1.50	$2.00	$2.50	$3.00	$3.50
$40	$0.50	0.50	0.33	0.25	0.20	0.17	0.14
$60	$0.75	0.75	0.50	0.38	0.30	0.25	0.21
$80	$1.00	1.00	0.67	0.50	0.40	0.33	0.29
$100	$1.25	1.25	0.83	0.63	0.50	0.42	0.36
$120	$1.50	1.50	1.00	0.75	0.60	0.50	0.43
$140	$1.75	1.75	1.17	0.88	0.70	0.58	0.50
$160	$2.00	2.00	1.33	1.00	0.80	0.67	0.57
$180	$2.25	2.25	1.50	1.13	0.90	0.75	0.64
$200	$2.50	2.50	1.67	1.25	1.00	0.83	0.71
$220	$2.75	2.75	1.83	1.38	1.10	0.92	0.79

As Seed:Corn price ratios increase, economic optimum plant density decreases …



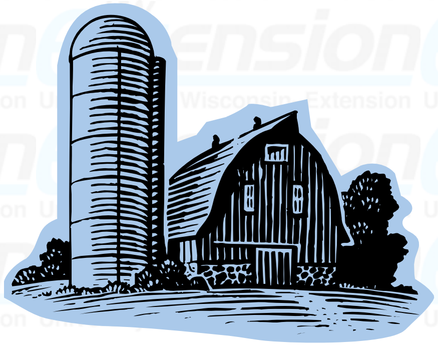
- **Symbols represent the economic optimum return to plant density (EOPD).**
- **Error bars are the low and high ends of the range of profitability (within $1/A of EOPD) at each seed:corn price ratio.**

Bt-CB corn should be grown at higher plant density than conventional corn …



Conclusions

- **Optimum plant populations for grain yield are higher than currently recommended levels.**
  - ✓ At Arlington, optimum plant density has been annually increasing 420 plants/A
  - ✓ Plant density at 95% of optimum has changed little.
- **About half of the environments (46%) do not respond to plant population. But,**
  - ✓ High plant populations rarely reduce grain yield (<4%)
  - ✓ Need to manage for the opportunities in a responsive environment.



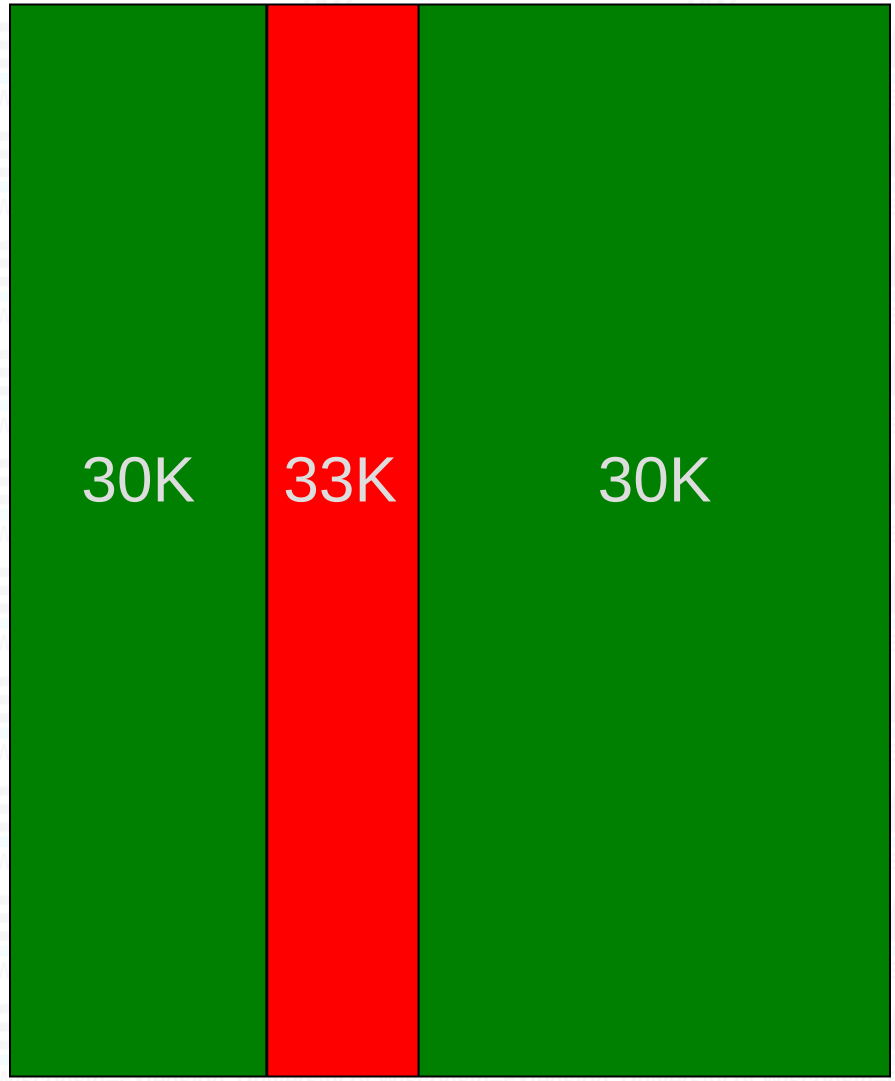
Guidelines for Choosing an Appropriate Plant Density for Corn

- **May have the most potential to move a farmer from current yield levels.**
  - ✓ Might be the place to start for moving off the “yield plateau.”
- **Optimum plant densities seem to be increasing as newer hybrids are commercialized.**
  - ✓ Grain yield increases to plant densities of 39,400 plants/A.
- **The EOPD for seed:corn price ratios between 0.5 and 1.5 is 29,800 to 36,200 plants/A.**
  - ✓ The plant density of 32,700 plants/A is within $1.00 of the EOPD for ratios between 0.5 and 1.5.
- **In general, silage yield increases as plant density increases.**
  - ✓ A trade-off exists where quality decreases with increasing population.
  - ✓ Thus, the EOPD is the same for corn grown for silage or grain.
  - ✓ Corn silage is often more valuable than grain, thus the EOPD follows more closely seed:corn price ratios less than 1.0.

One place to begin is evaluate your plant density for each field …

Reference Strips for On-Farm Testing Plant Density

- **Field specific**
- **At least one strip per field. Total of 3-4 strips per farm.**
- **Increase plant population 10% in one-strip.**
  - ✓ Plant majority of field to normal plant density
  - ✓ Ideally 2-3 strips per field



Future Directions

- **Mixed analysis of models**
  - ✓ Linear
  - ✓ Quadratic
  - ✓ Linear-Linear (Quadratic) segmented
  - ✓ Linear-Plateau segmented
  - ✓ Quadratic-Plateau segmented
  - ✓ Negative exponential
  - ✓ Carmer-Jakobs
- **What is risk of higher plant populations?**
- **Economics of seed costs to grain prices**
- **What causes lodging?**

The End of the Row – Questions?
Thanks for your attention!

University of Wisconsin – Agronomy