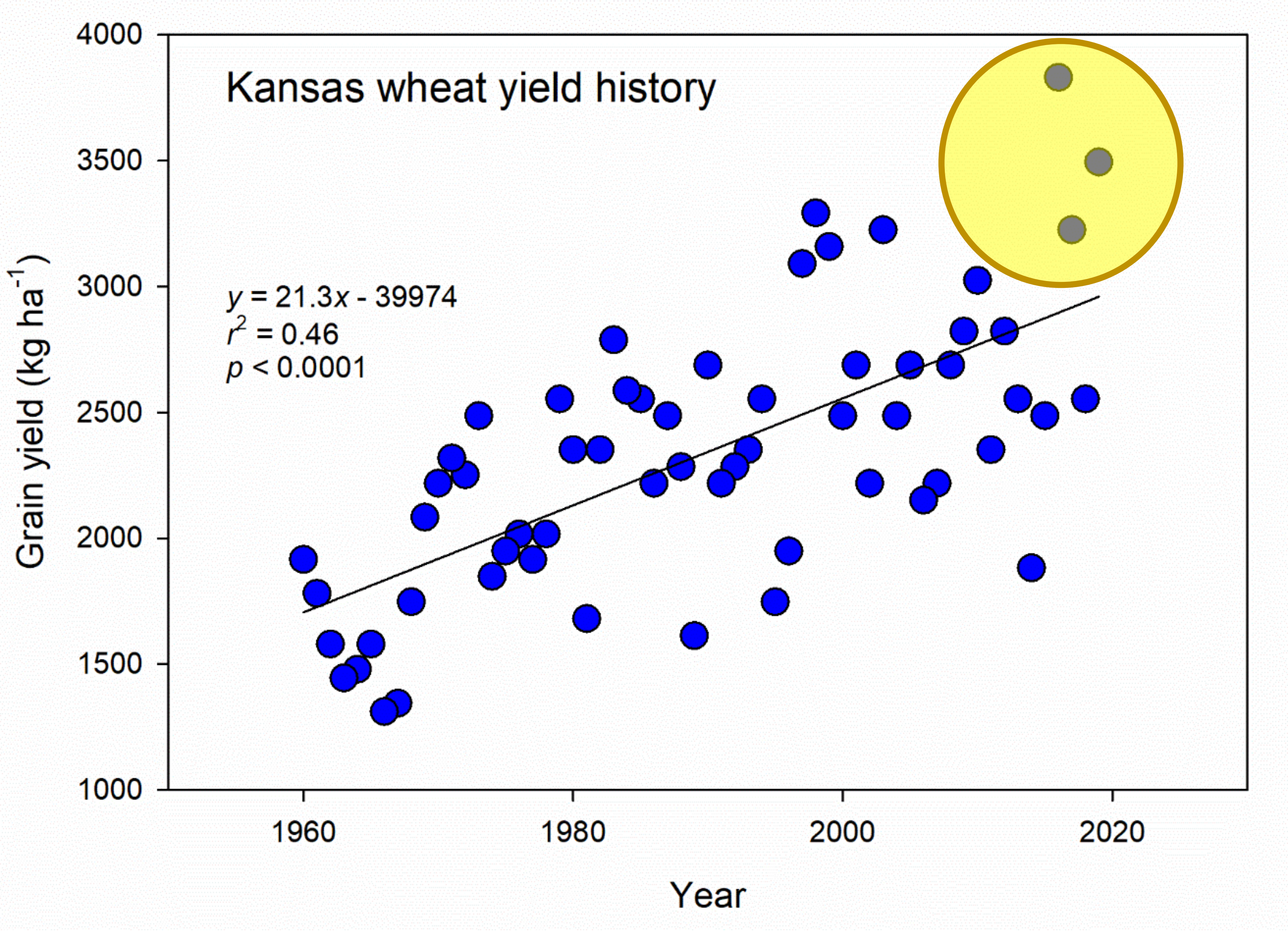
NITROGEN MANAGEMENT

High-Yield and High-Protein Winter Wheat

Dr. Romulo Lollato
Extension Wheat Specialist
KANSAS STATE UNIVERSITY

BACKGROUND


Kansas wheat yield history
y = 21.3x - 39974
r2 = 0.46
p < 0.0001
Grain yield (kg ha-1)
Year
4000
3500
3000
2500
2000
1500
1000
1960
1980
2000
2020

OBJECTIVES

To evaluate N rate by N timing interactions on two winter wheat varieties with contrasting protein concentration:

- Grain yield
- Grain protein concentration
- Biomass and N accumulation patterns
- Several N indices (NUE, NUtE, NRE, etc.)
- Understand the physiological basis for variety-specific protein accumulation

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FIELD METHODOLOGY

Three locations Hutchinson, Belleville, and Manhattan

Two growing seasons 2017-18 and 2018-19

Treatment structure 3-way complete factorial + control

Split-split plot design 4 blocks

Tillage and Previous crop No till, soybeans

Plots size 5 x 40 ft

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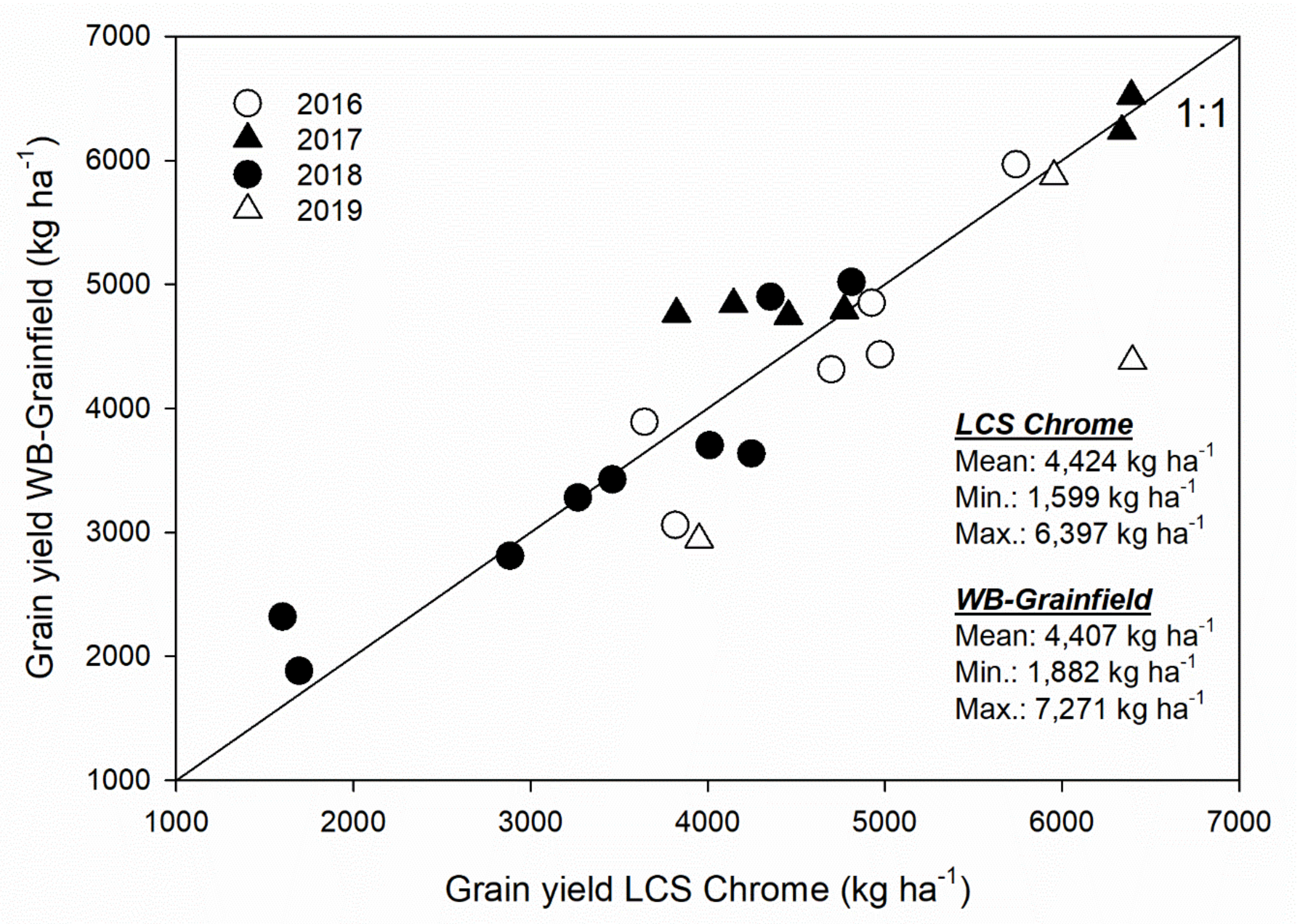
2 Varieties

- Whole plot
- Similar yield performance
- Contrasting grain protein concentration
    - LCS Chrome (high protein)
    - WB-Grainfield (low protein)

YIELD HISTORY IN CENTRAL KANSAS



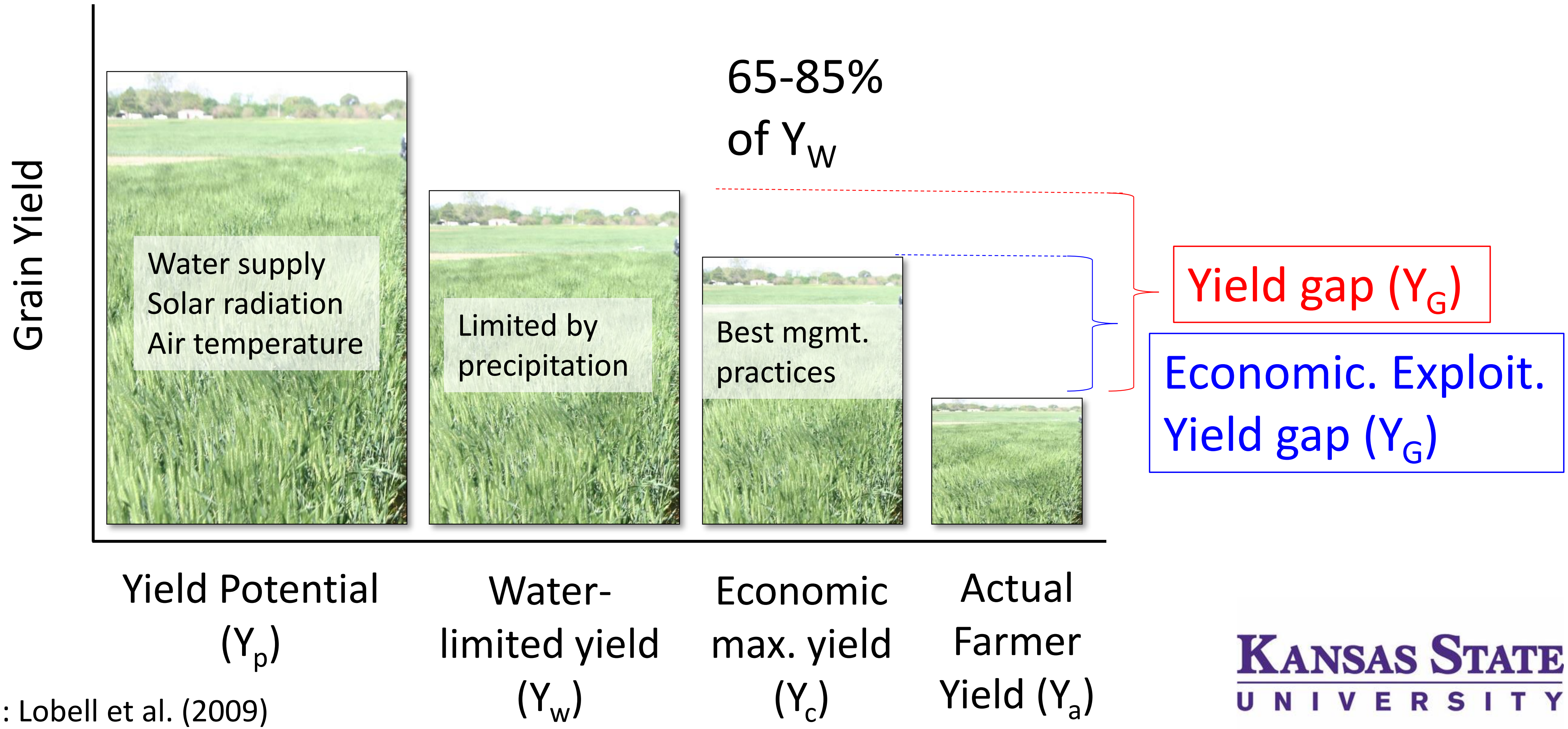
Four N rates

Subplot

Four N rates

- 0 control
- 65% of water-limited yield (Yw)
- 75% of Yw
- 85% of Yw

Yield definitions



Adapted from: Lobell et al. (2009)

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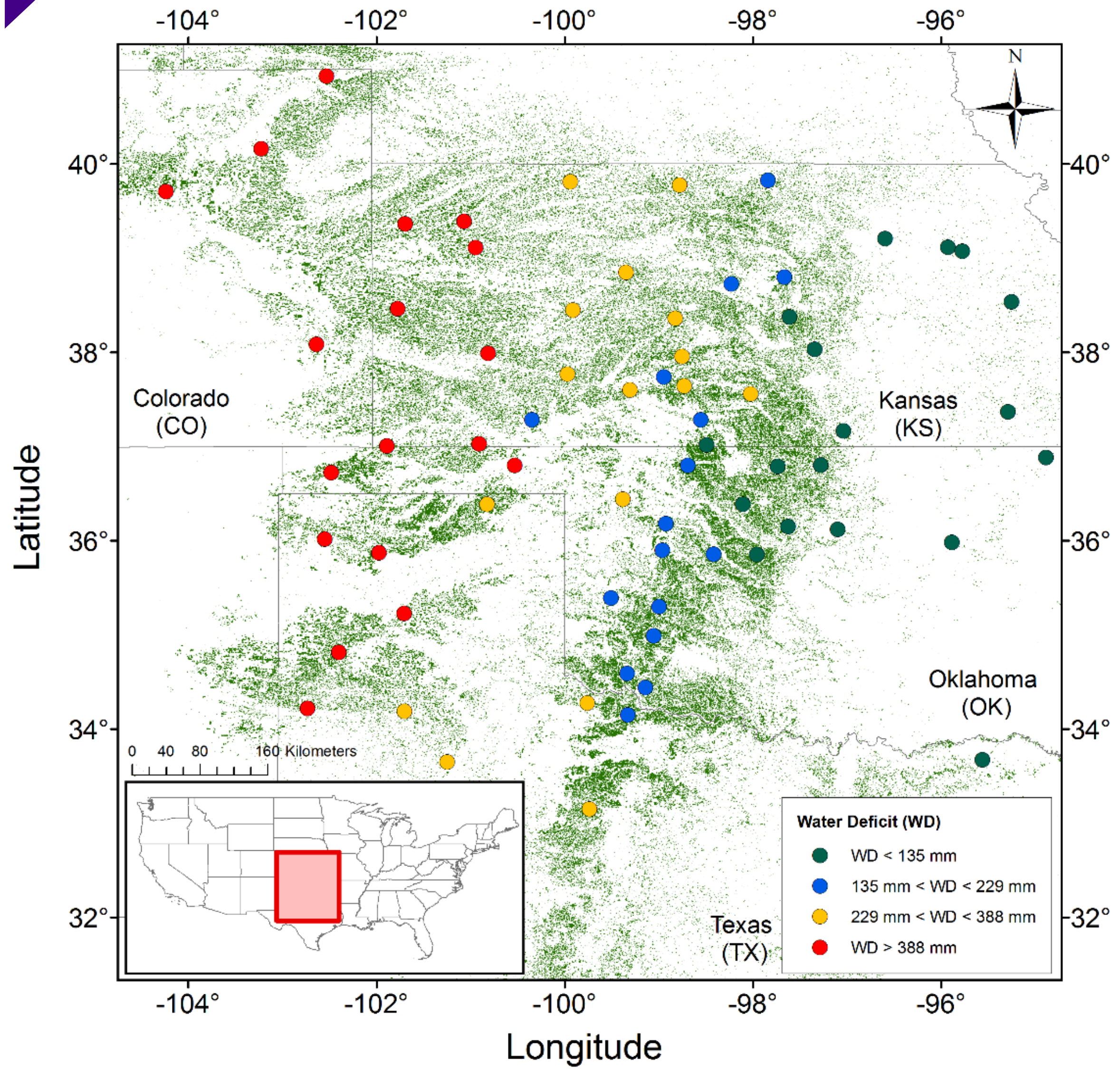
Wheat Yw in the US southern GP



Area-weighted Y = 5.2 Mg ha^{-1}

212-226.

Nr

Le

5.2 x 0.85 = 4.4 Mg ha^{-1} (~160 lbs N/a)

5.2 x 0.75 = 3.9 Mg ha^{-1} (~140 lbs N/a)

5.2 x 0.65 = 3.4 Mg ha^{-1} (~120 lbs N/a)

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Four timings

Four N timings
- 100% Fall
- 100% Spring
- 40% Fall and 60% Spring
- 40% Fall, 50% Spring and 10% Anthesis

N sources UAN or Gradual-N (anthesis)

26 treatments

- Two varieties
  - LCS Chrome (high protein)
  - WB Grainfield (low protein)
- Four N rates
  - (0-N control)
  - 65% of Yw
  - 75% of Yw
  - 85% of Yw
- Four N timings
  - Fall
  - Spring
  - Split
  - Anthesis
- N sources
  - UAN or Gradual-N (anthesis)

BIOMASS SAMPLING

- Four timings
  - Jointing
  - Anthesis
  - Soft dough
  - Maturity
- Partitioning
  - Leaves
  - Stem
  - Head
- Treatments
  - 0 N control
  - 85% Yw (Timing 40:60)
  - 85% Yw (Timing 40:50:10)
  - Both varieties

NITROGEN INDICES – ALL TREATMENTS

Grain N removal = Grain yield x Grain N concentration

NUE = Grain yield / N available

N recovery efficiency (NRE) = $\frac{(\text{Grain } N_{N1} - \text{Grain } N_{N0})}{\text{N fertilizer}_{N1}}$

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NITROGEN INDICES – 6 TRT. BIOMASS

Proportion of N uptake by anthesis

Spike N gain between Anthesis and Maturity

Stover N remobilization (leaf+stem N at maturity – Anthesis)

N utilization efficiency (NUtE) = $\dfrac{\text{Grain yield}}{\text{Shoot N uptake (maturity)}}$

STATISTICAL ANALYSES

Variables measured on entire experiment

Zero-N control precluded 3-way ANOVA on raw data

Difference from control calculated per replication for each variable

3-way ANOVA performed on the difference from control

By site-year and combined (experiments as random)

Variables measured on six biomass treatments

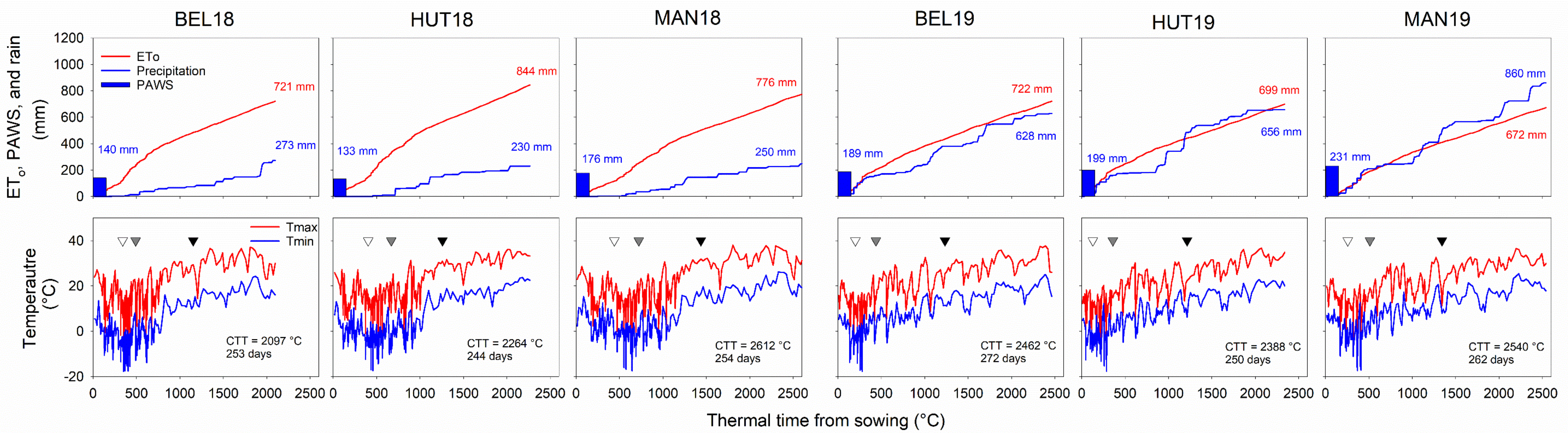
2-way ANOVA (N management x variety)

By site-year and combined (experiments as random)

RESULTS

Photo: Brian FitzGerald

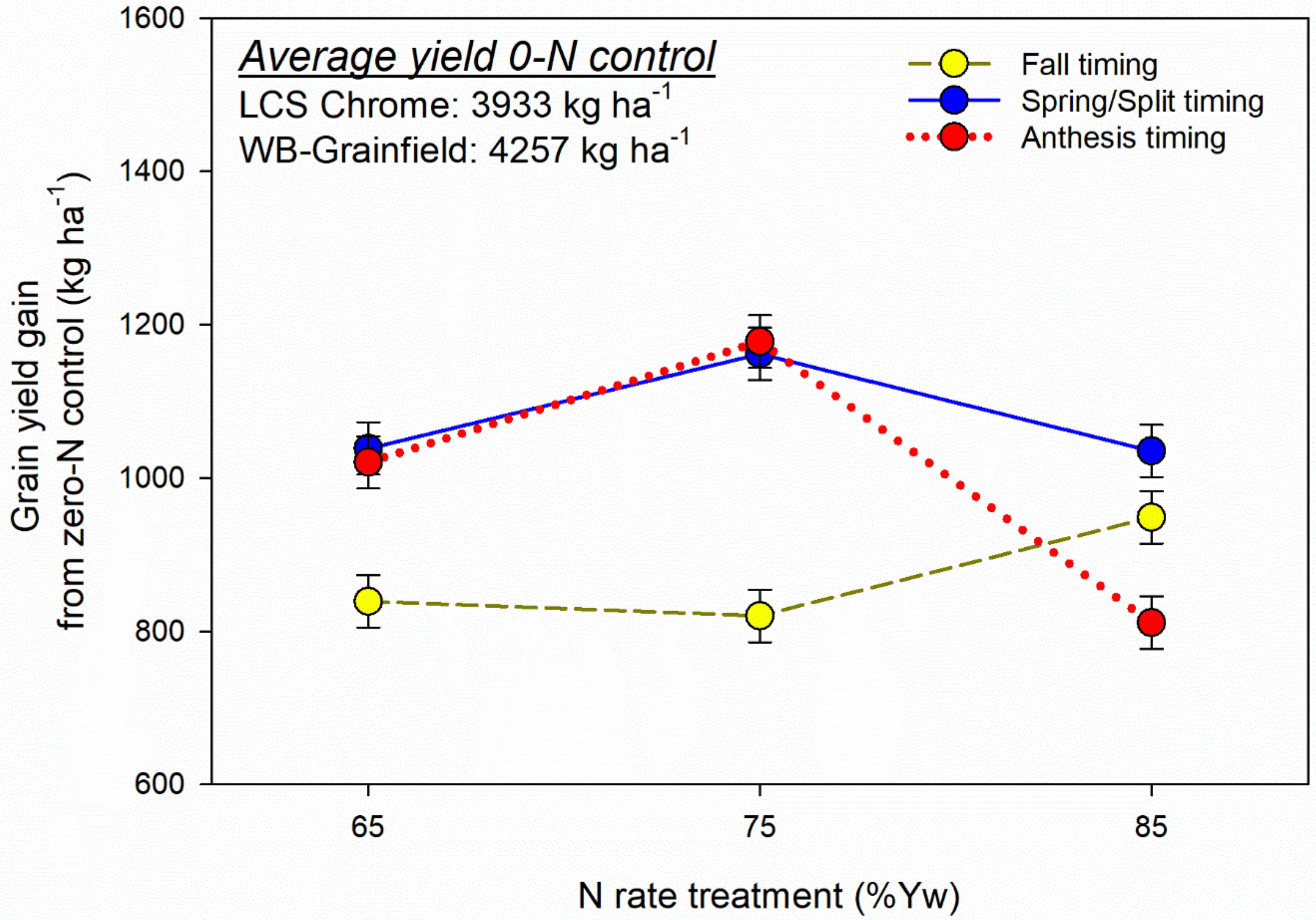
GROWING SEASON WEATHER



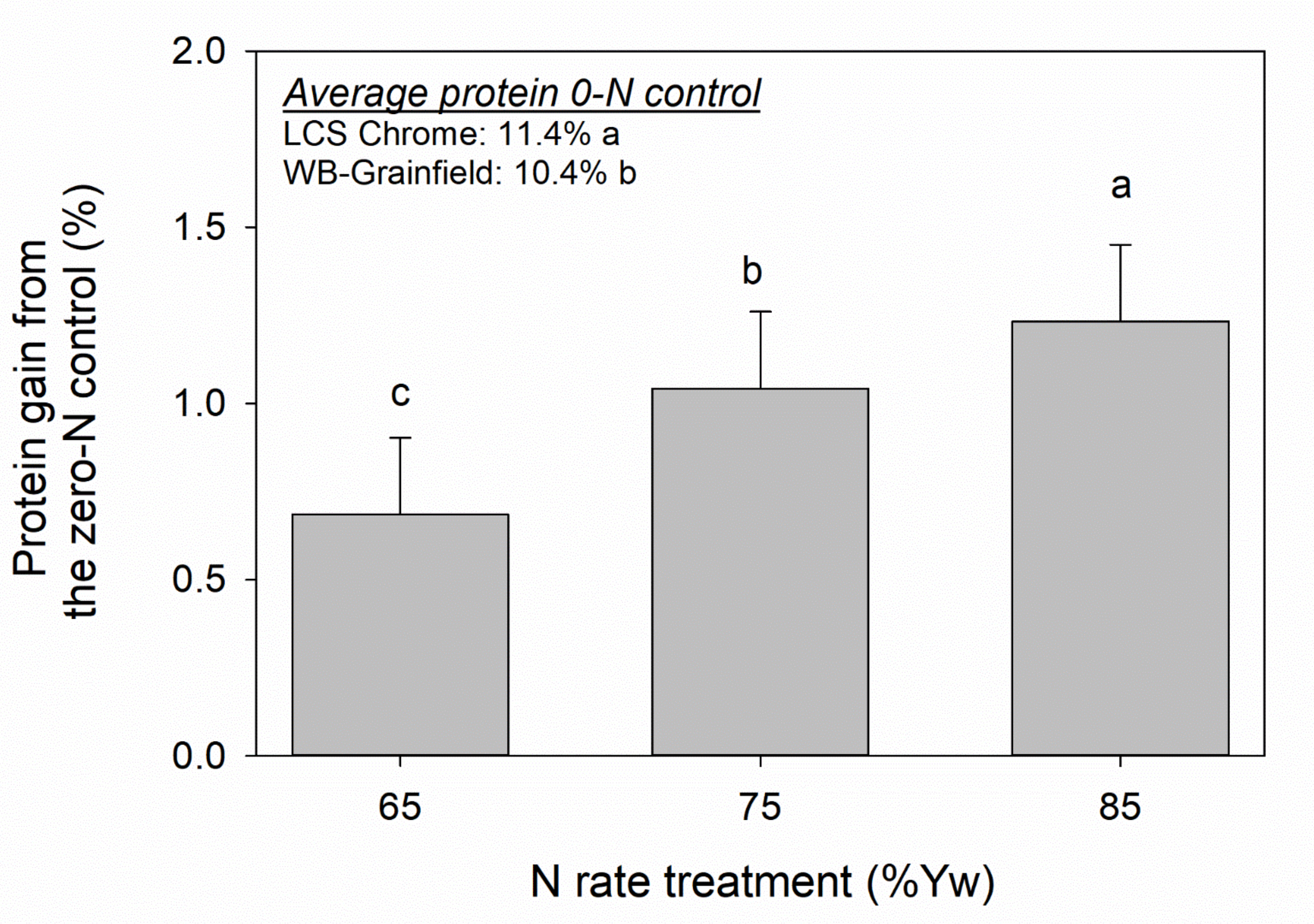
Dry and hot, short growing season (244-254 days)

Cool and moist, long growing season (250-272 days)

YIELD GAIN: RATE x TIME (***)

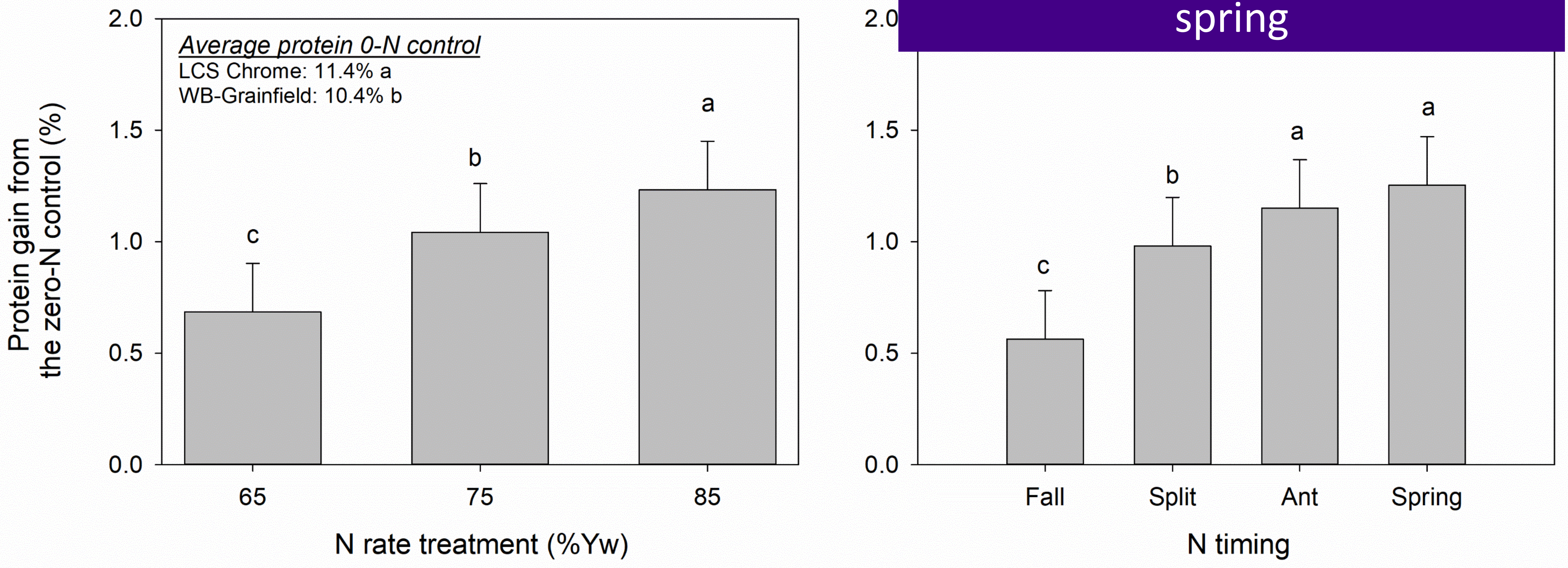


PROTEIN GAIN: RATE and TIME (***)

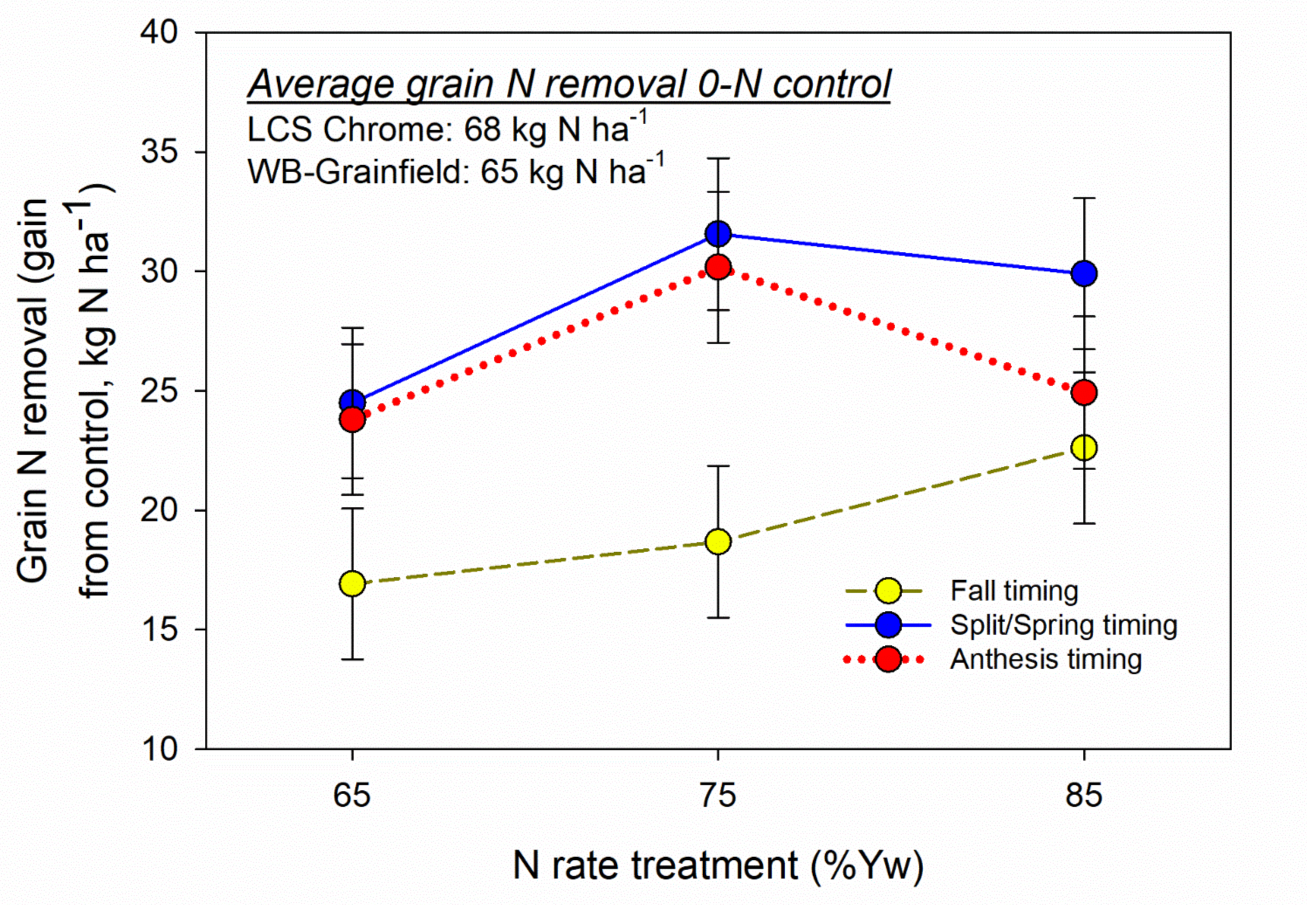


PROTEIN GAIN: RATE and TIME (***)

Anthesis N application increased protein relative to split, but not to spring



N REMOVAL: RATE x TIME (***) and VAR. (*)



Grain N removal

Associated with grain yield

Variation in GNR at the same yield level are brought by [protein].

Linear-linear model with greater slope at grain yield < ~4300 kg ha^{-1}

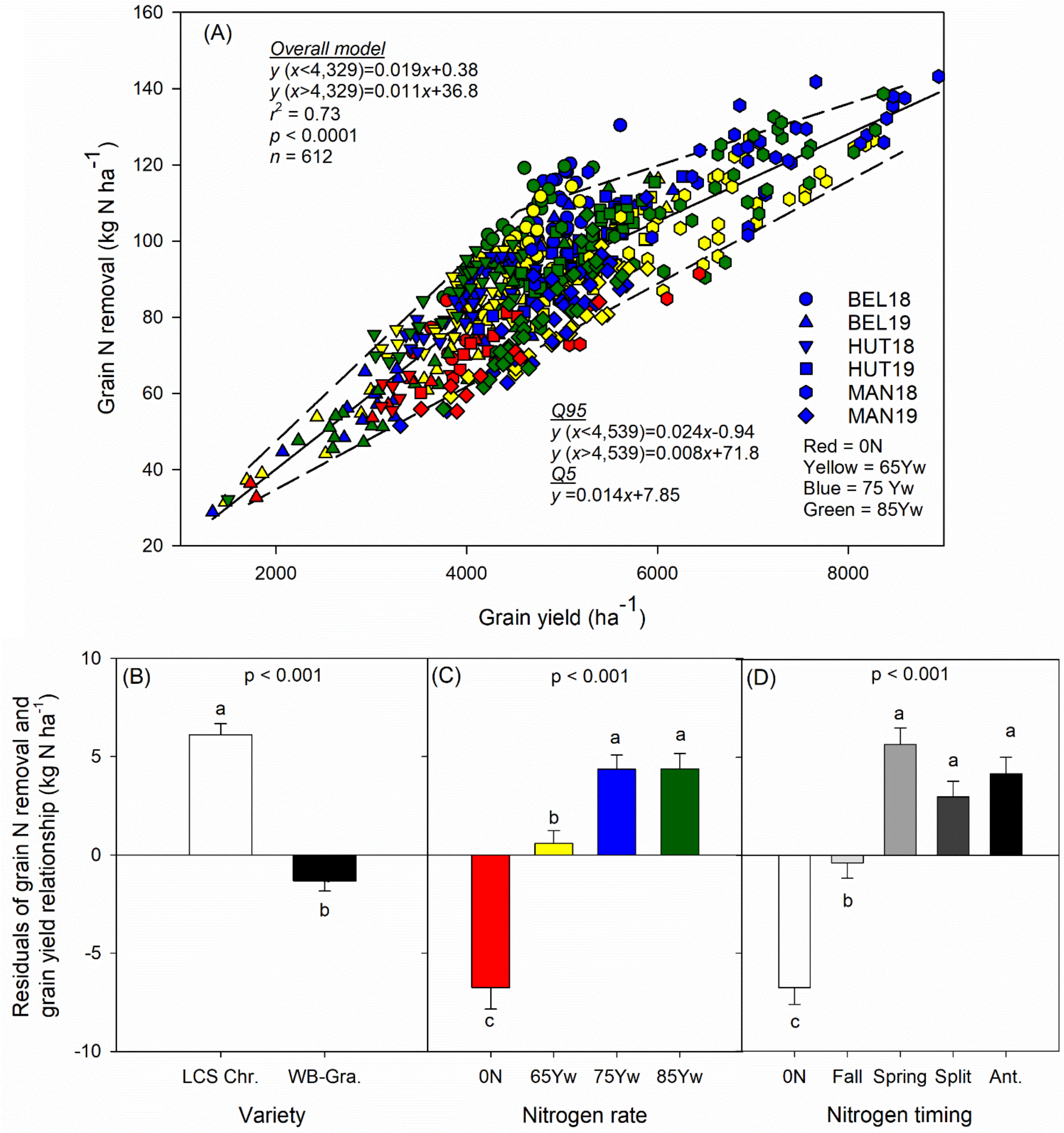
More N required per unit grain yield to sustain high protein levels at high yield levels

Analysis of residuals

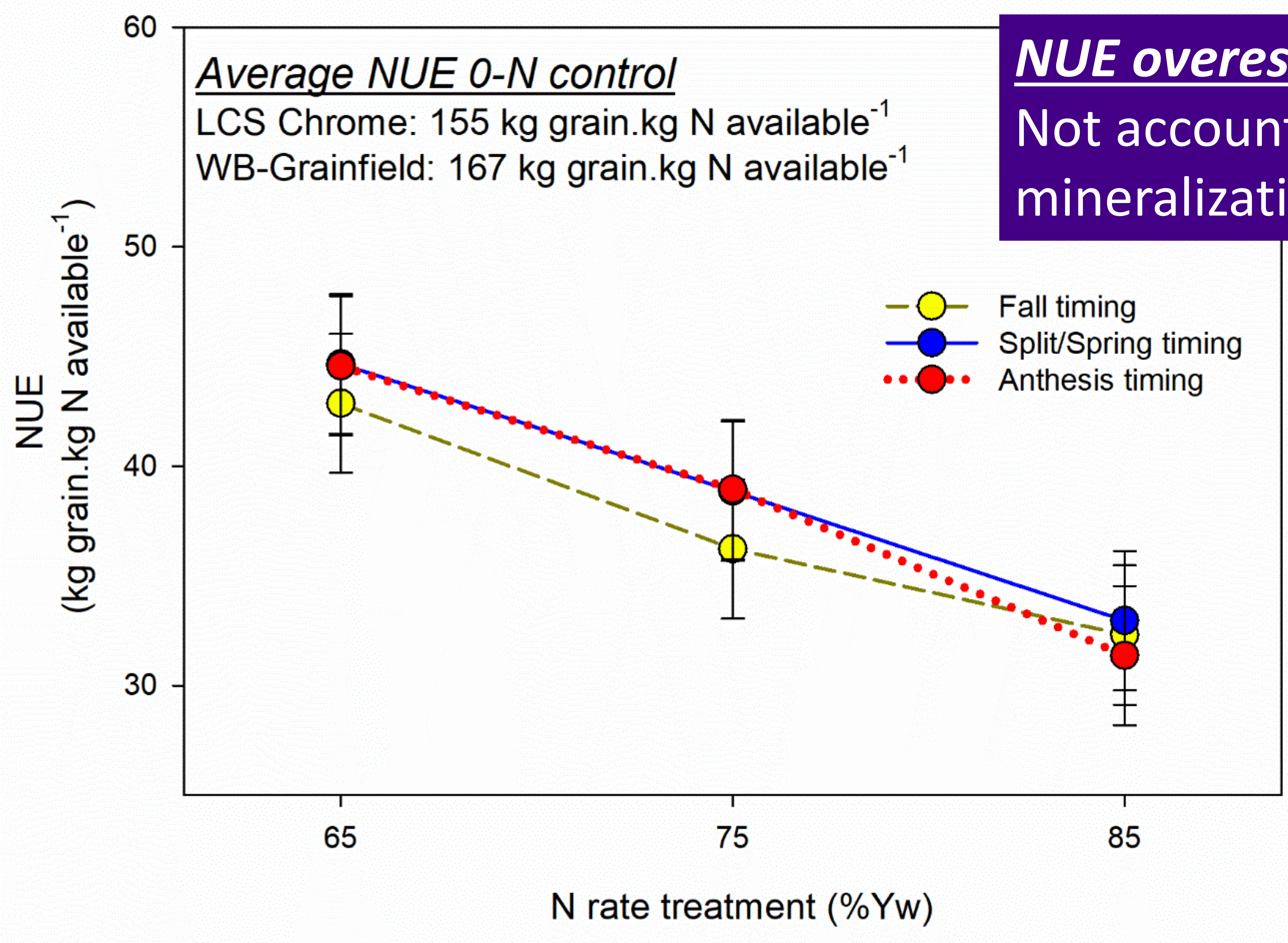
LCS Chrome > WB-Grainfield

Greater N rates, greater N removal

0-control and Fall < Spring treatments

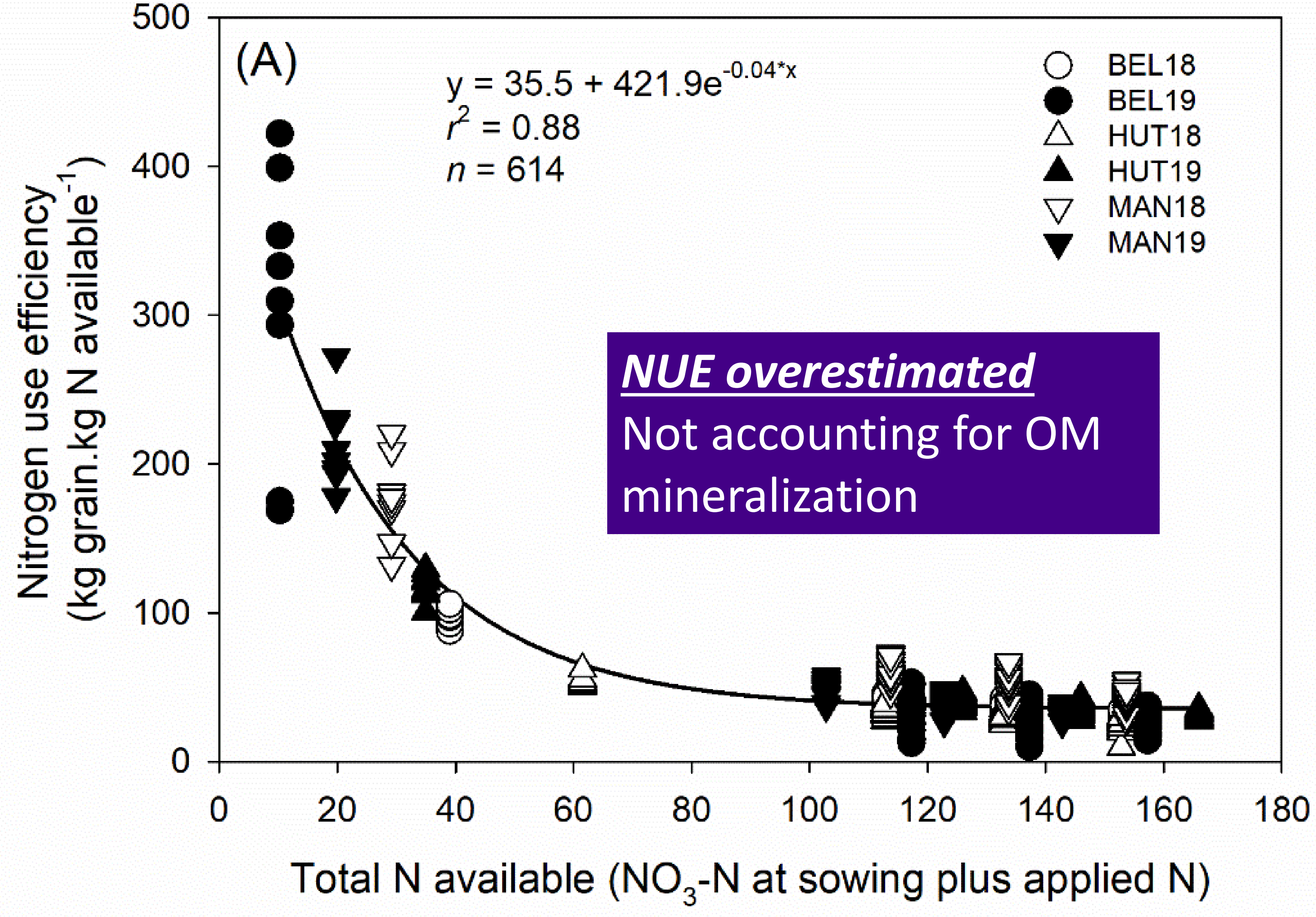


NUE: RATE x TIME (***)

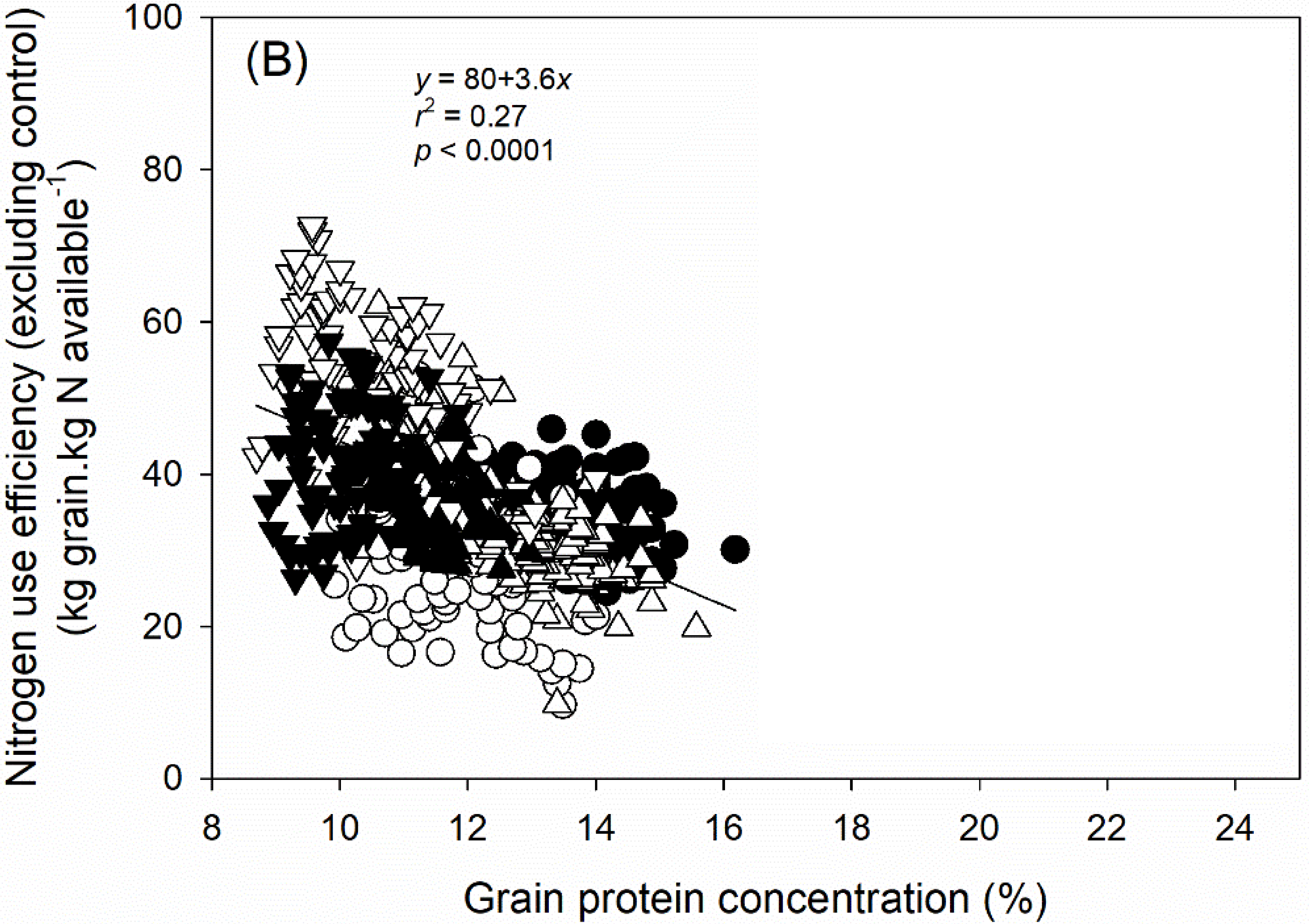


NUE overestimated

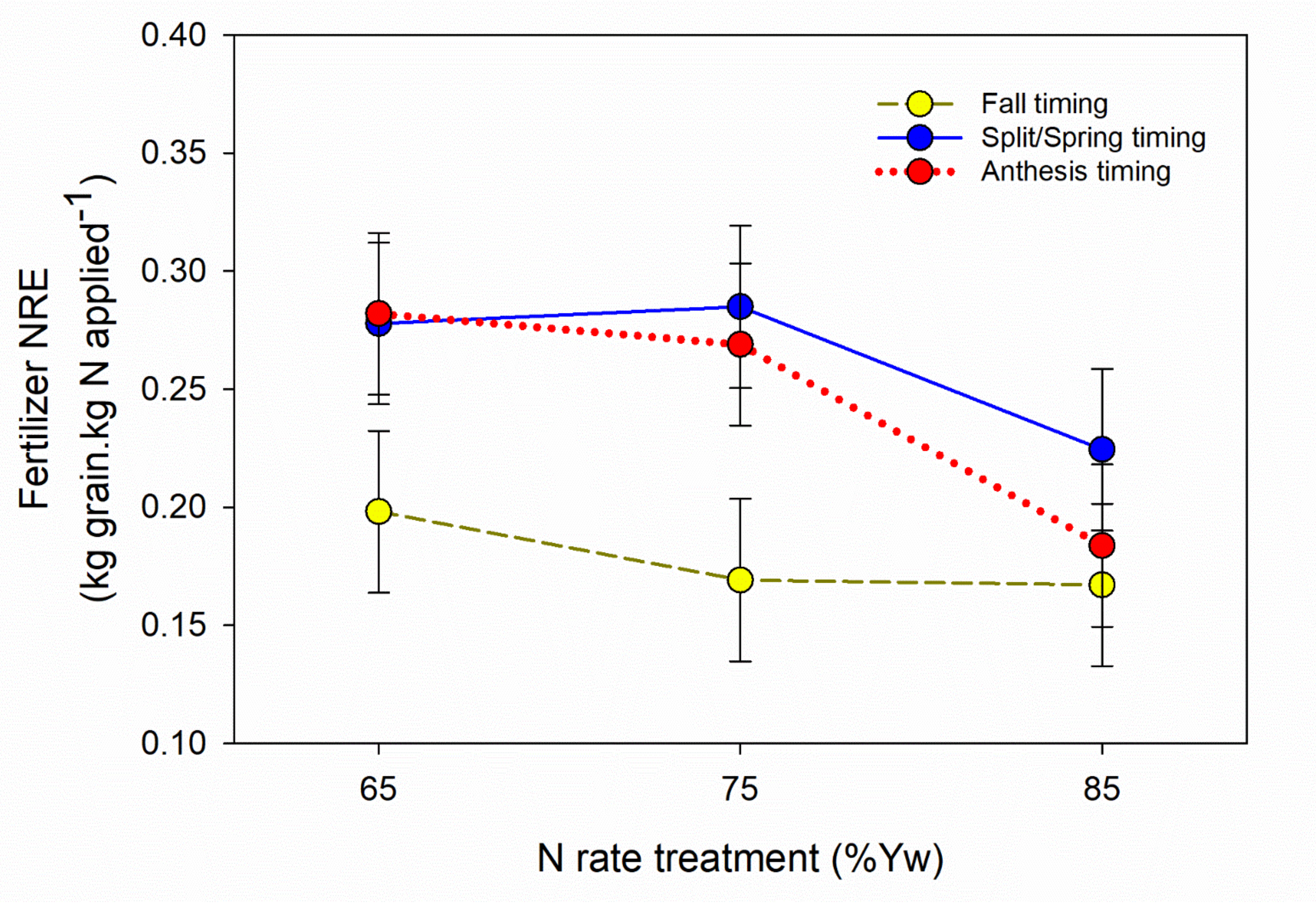
Not accounting for OM mineralization



(A)
y = 35.5 + 421.9e^-0.04*x
r^2 = 0.88
n = 614
BEL18
BEL19
HUT18
HUT19
MAN18
MAN19
NUE overestimated
Not accounting for OM mineralization
Nitrogen use efficiency (kg grain.kg N available^-1)
Total N available (NO3-N at sowing plus applied N)
0
100
200
300
400
500
0
20
40
60
80
100
120
140
160
180

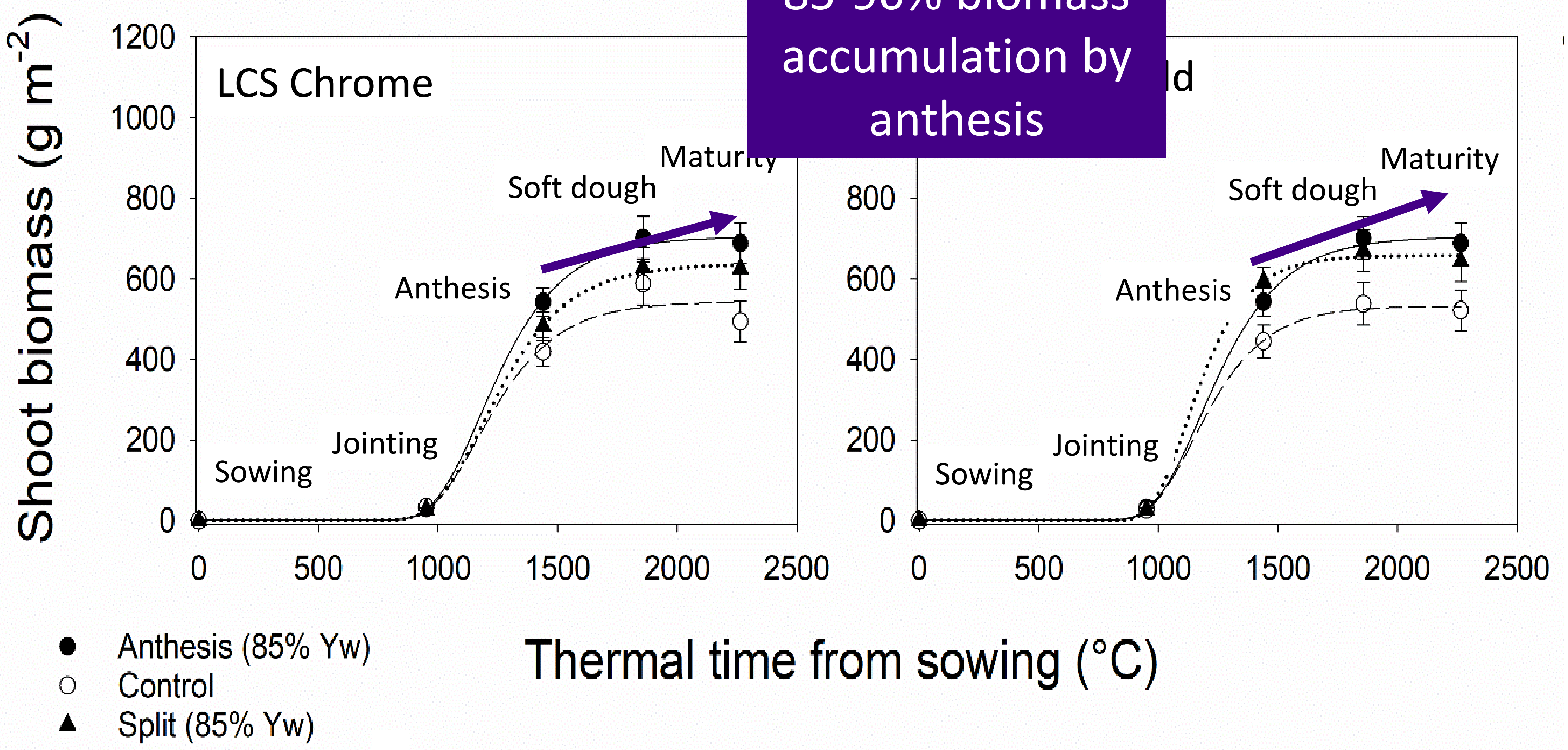

(B)
y = 80+3.6x
r2 = 0.27
p < 0.0001
Nitrogen use efficiency (excluding control)
(kg grain.kg N available-1)
0
20
40
60
80
100
8
10
12
14
16
18
20
22
24
Grain protein concentration (%)

FERT. NRE: RATE x TIME (***) and VAR. (*)



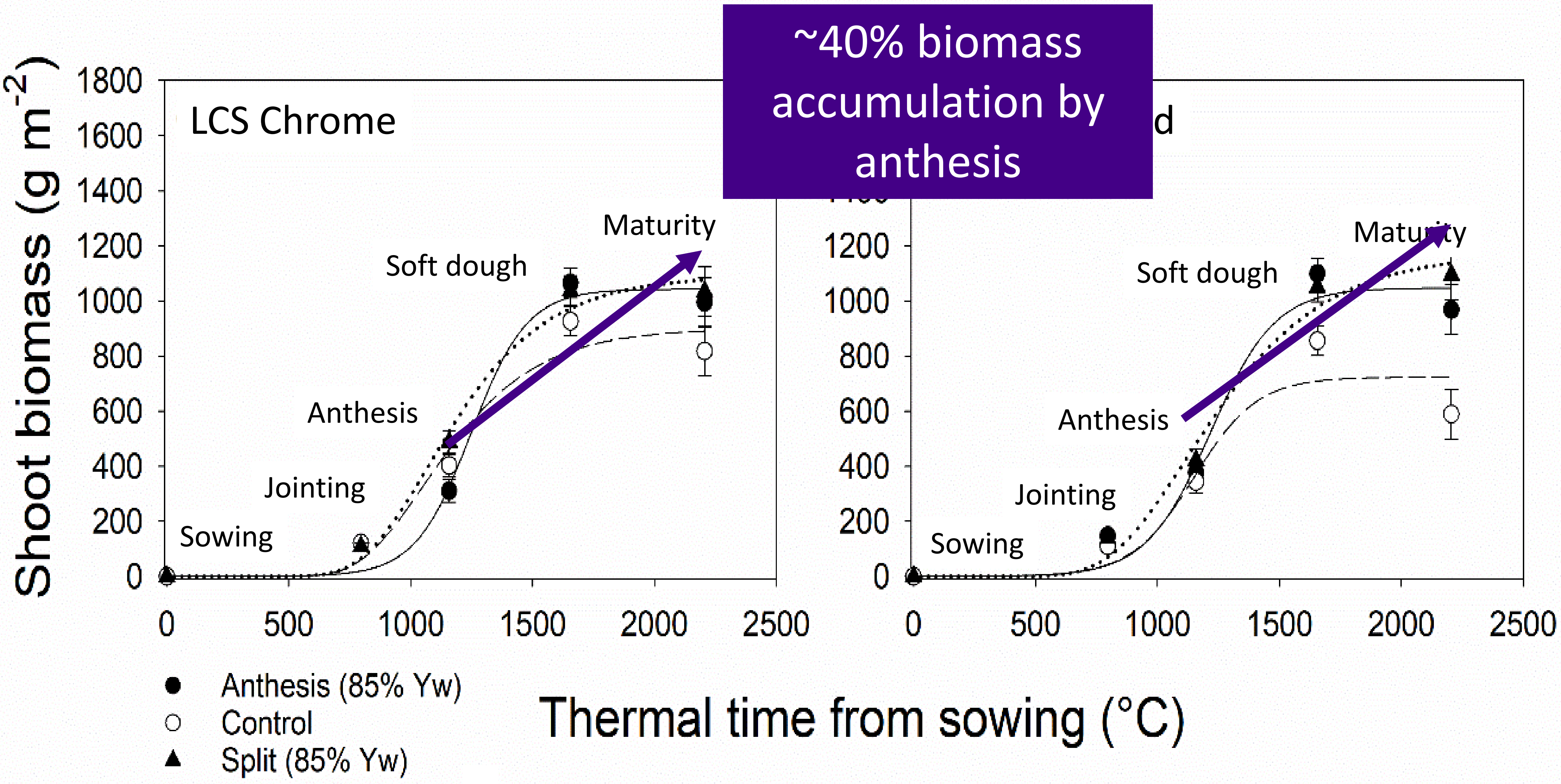
BIOMASS ACCUM.

2017-18 Hutchinson

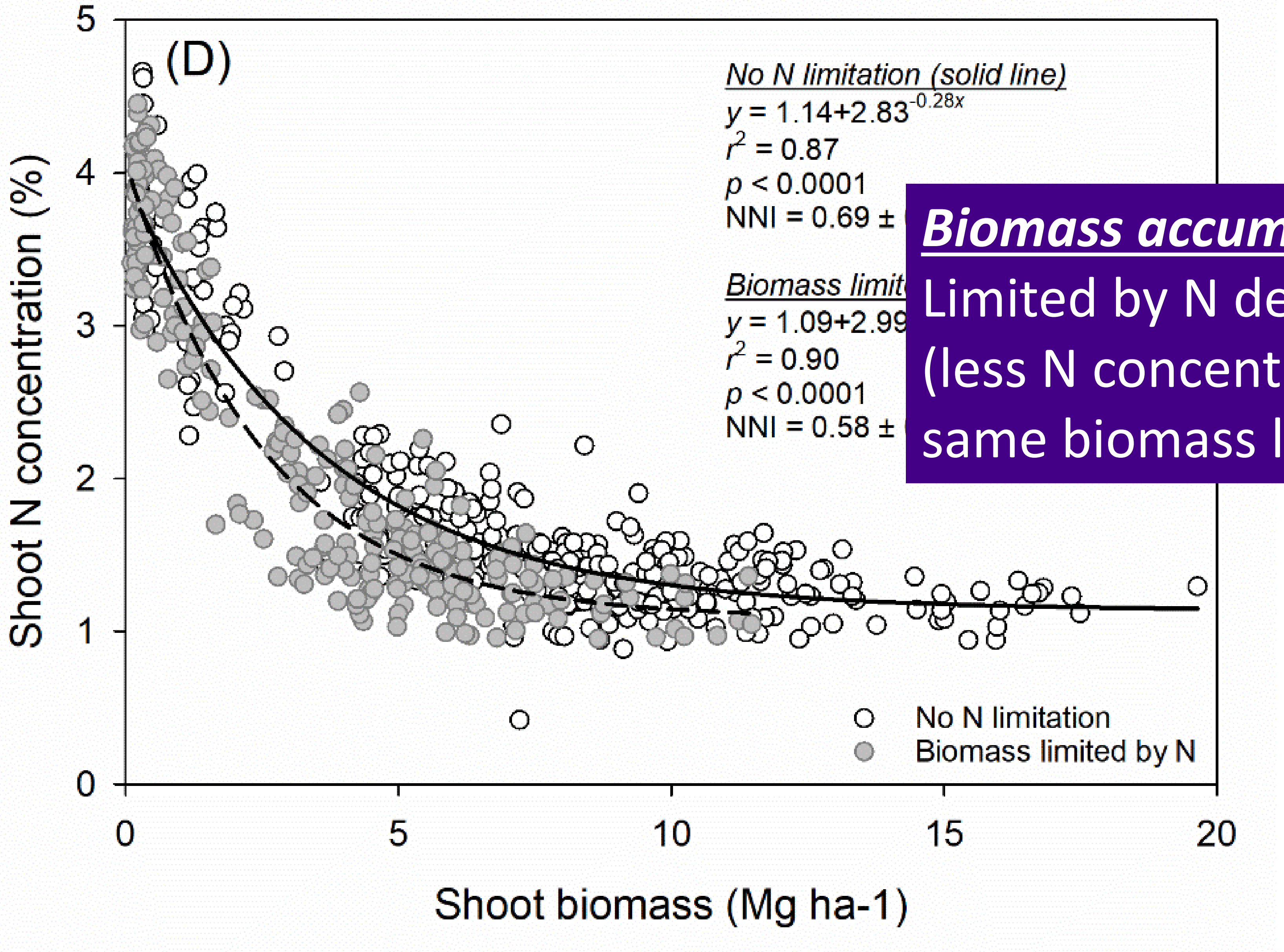


85-90% biomass accumulation by anthesis

2018-19 Hutchinson



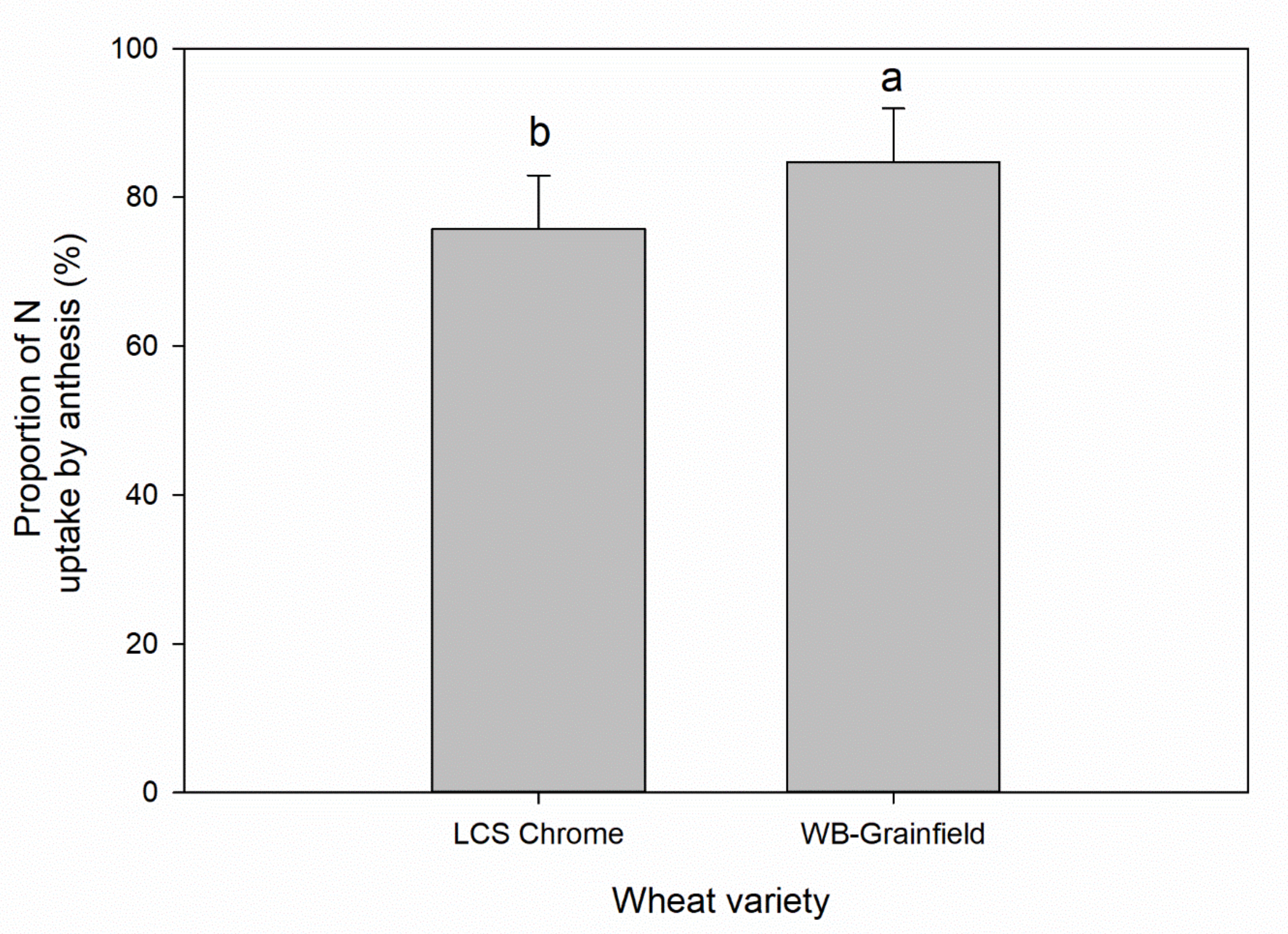
PATTERNS OF BIOMASS ACCUMULATION



Biomass accumulation

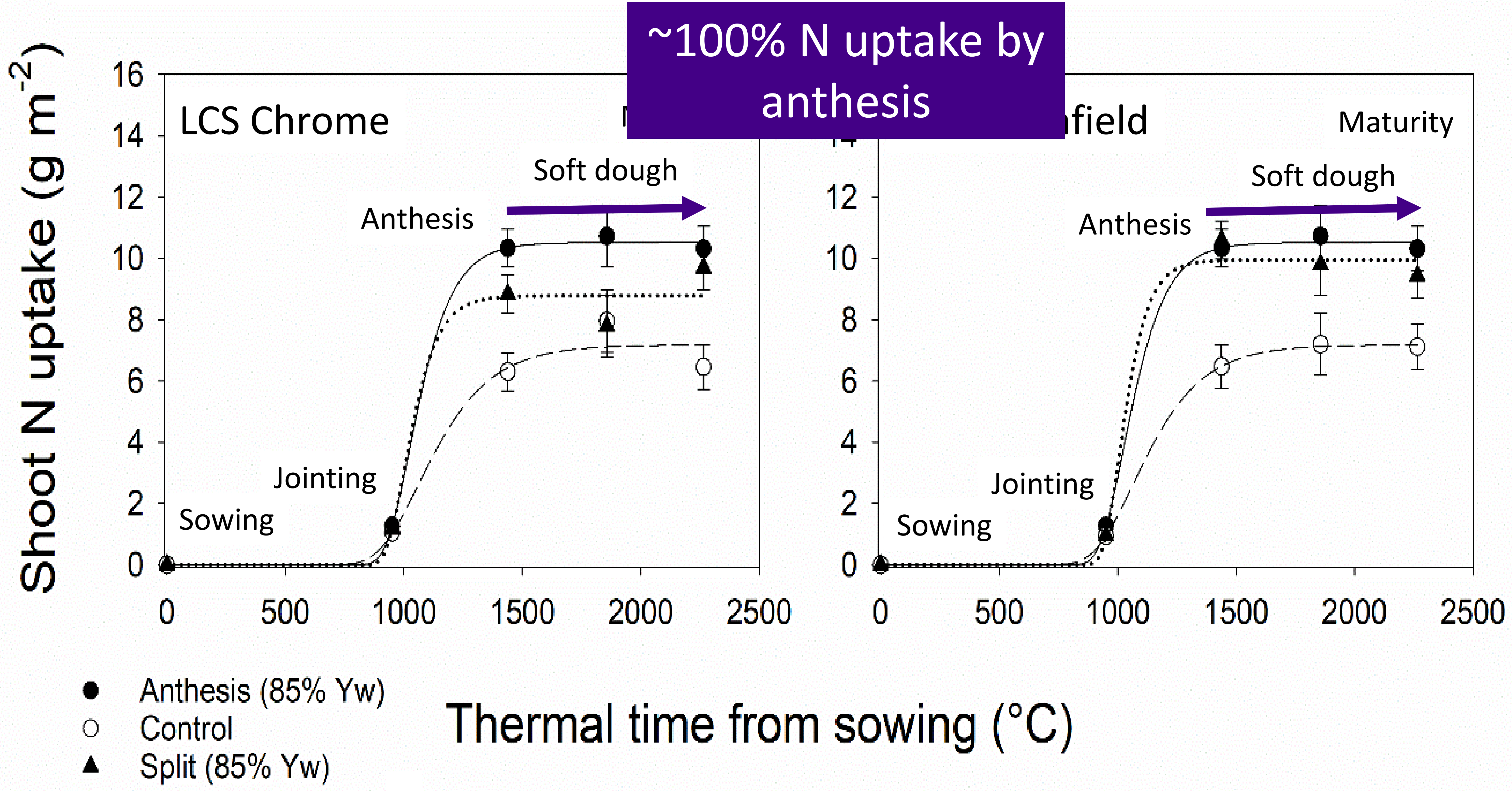
Limited by N deficiency (less N concentration at same biomass levels)

PROPORTION N UPTAKE BY ANTHESIS



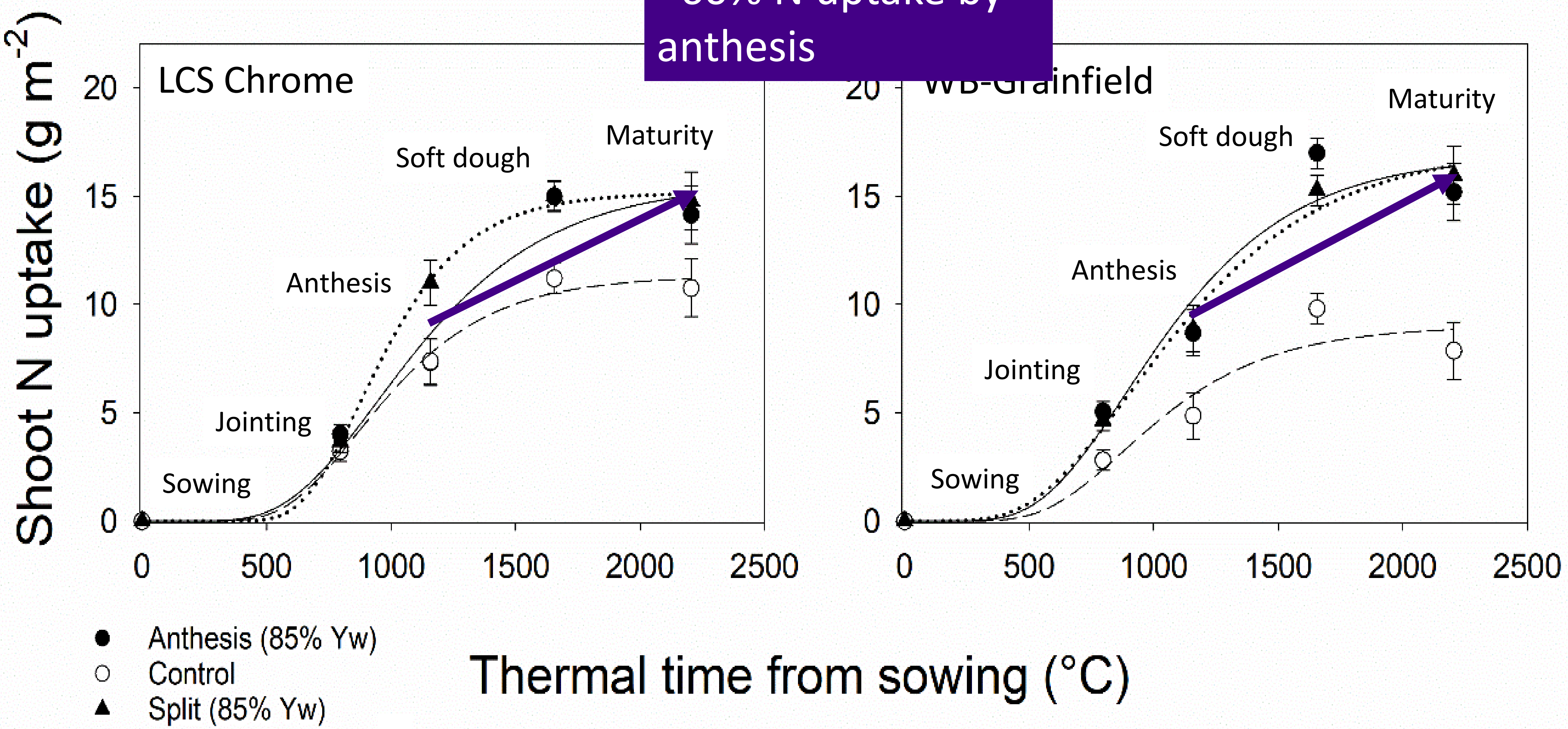
2017-18 Hutchinson

~100% N uptake by anthesis

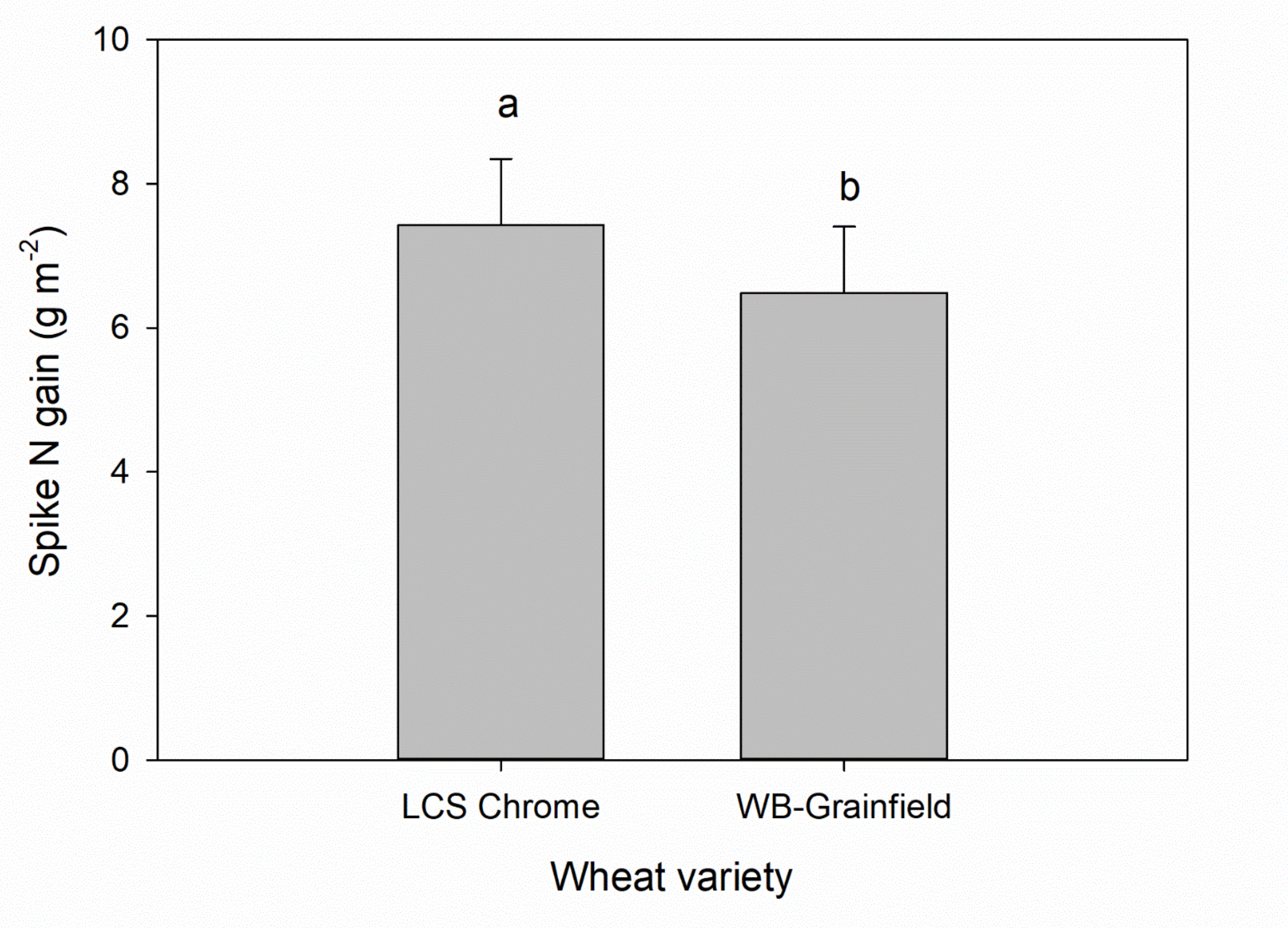


2018-19 Hutchinson

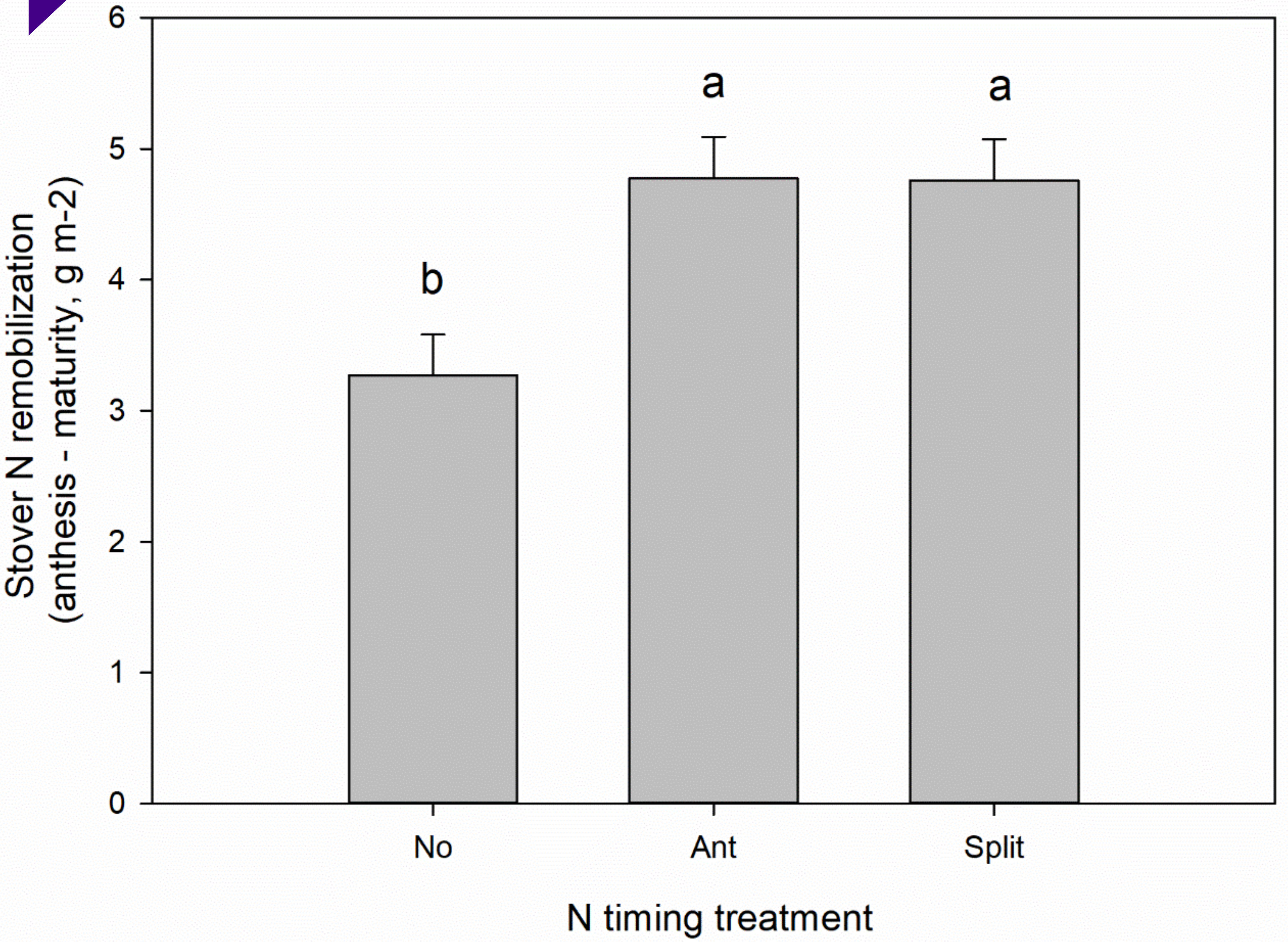
~60% N uptake by anthesis



SPIKE N GAIN (ANTHESIS-MATURITY)



STOVER N REMOBIL. (ANTHESIS-MATURITY)



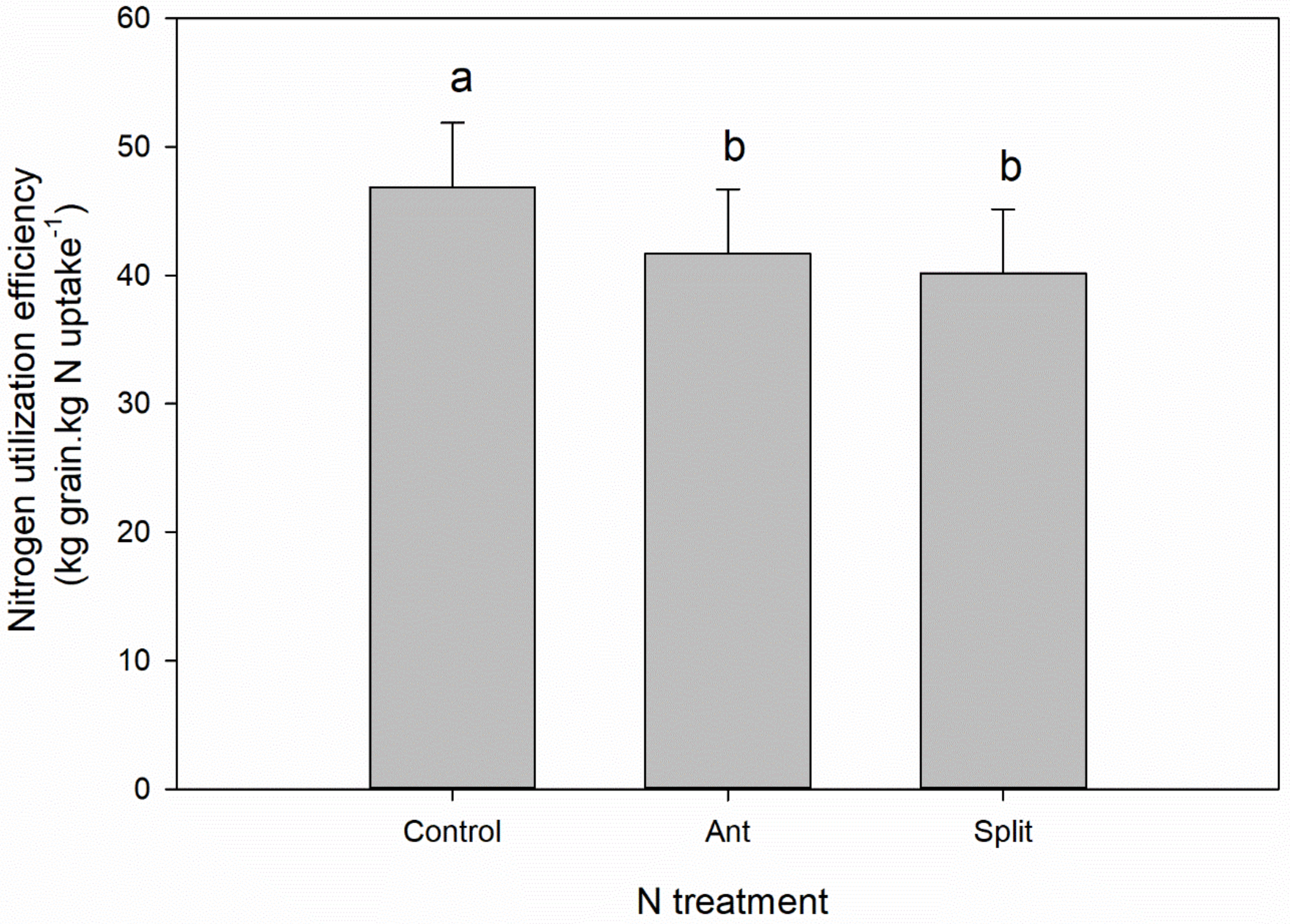
2018 (dry/hot)

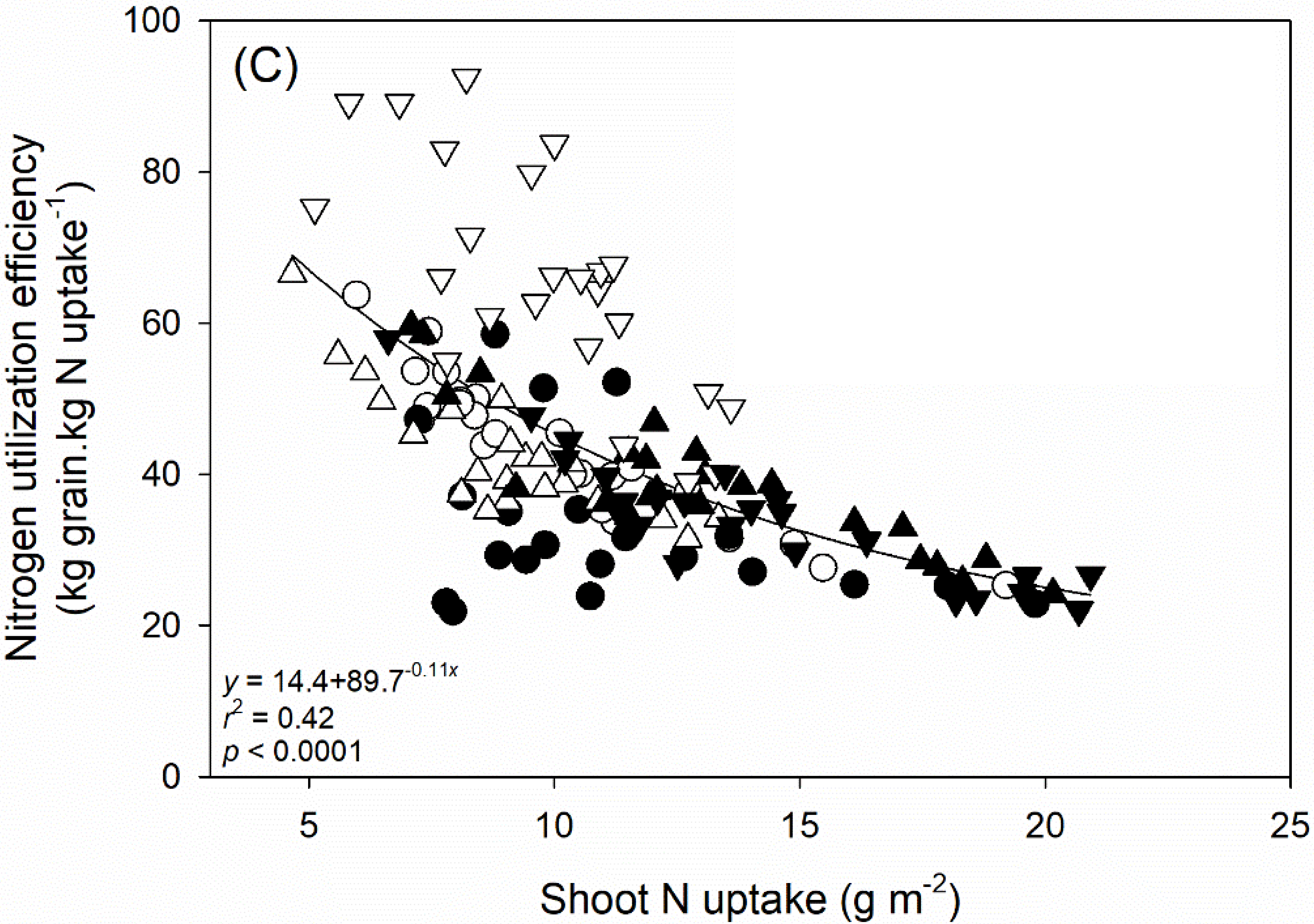
~100% of spike N gain resulted from stover N remobilization

2019 (cool/moist)

~46-54% of spike N gain resulted from stover N remobilization

NUtE (Yield/Maturity N uptake)





(C)
Nitrogen utilization efficiency
(kg grain.kg N uptake-1)
Shoot N uptake (g m-2)
y = 14.4+89.7-0.11x
r2 = 0.42
p < 0.0001
0
20
40
60
80
100
5
10
15
20
25

CONCLUSIONS

Grain yield:

- Spring N timing resulted more consistent yields for winter wheat after soybeans (little development in the fall)
- Fall timing required more N than spring- or split-applied-N

Grain protein

- Greater N rates, greater protein
- Spring or Anthesis > Split > Fall
- Physiological components of wheat variety protein accumulation:
  - Greater spike N gain at same N remobilization (more uptake post Anthesis)
  - Greater NUE at similar grain protein concentration levels
  - Greater fertilizer NRE
  - Greater N removal at the same yield level (consequence, not determinant)

Biomass accumulation

- Affected by weather conditions (50-100% by Anthesis)
- Limited by N deficiency (lower N concentration)

ACKNOWLEDGMENTS

Fluid Fertilizer Foundation

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Questions?

Romulo Lollato, Ph.D.
Assistant Professor, Extension Wheat and Forages Specialist
Kansas State University
lollato@ksu.edu

@KSUWheat

KSU Wheat

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