



Effects of nitrogen deficiency on plant growth, physiology and leaf reflectance properties in castor (*Ricinus communis*)

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Presentation Outline

- ✓ Introduction
- ✓ Literature
- ✓ Methodology and measurements
- ✓ Results
 - Growth and development
 - Physiology
 - Remote sensing
- ✓ Summary and conclusions

Introduction

About Castor

- Castor (*Ricinus communis*) is the oldest commercial crop, a native of East Africa.
- Castor has been treated as a “strategic crop” for many years.
- Castor is a C₃ plant and grows up to 6-15 feet tall.
- Castor is a vigorous, indeterminate plant that grows well in highly nutritious soils.

Introduction

About Castor

- Castor contains 40-60% oil in their seeds. Oil has high viscosity.
- The unusual molecular structure of castor oil permits it to transform into several useful forms.
- Oil molecules contains a glyceride called ricinoleic acid.
- It has wide-spread uses in textiles, as a lubricant, and pharmaceutical industry as well as in bio-fuel production.

Introduction

Castor Statistics

- Worldwide:
 - Production: 1.4 million metric tones
 - Yield: about 750 kg ha⁻¹
- Top 5 producers:
 - India
 - China
 - Brazil
 - Ethiopia
 - Paraguay

Source: www.fao.org

Introduction

Why this Study?

- Castor requires high N nutrition due to its rapid and indeterminate growth habit.
- Deficiency in nitrogen fertilization causes reduced growth and final seed yield.
- Early detection of N deficiency helps crop managers to correct nitrogen nutrition.

Introduction

Why this Study?

- Traditional methods of nitrogen estimation involves destructive sampling and laborious laboratory methods.
- Hyperspectral remote sensing has been used to detect leaf nitrogen status in several crop species such as cotton, corn and several forage species.

Literature Review

- Effects of nitrogen deficiency on cell division and expansion in castor was studied by Roggatz et al. (1999).
- Andreas et al. (1994) studied the effect of nitrogen deprivation on the long distance transport of abscisic acid between roots and shoots in castor.
- To date, there are no studies on quantifying the effects of N on various growth and physiological parameters of castor.

Literature Review

- Remote sensing has been used to detect changes in physiology including in-season crop nutrient assessment and management in several crops (Filellea et al., 1995; Daughtry et al., 2000; Zarco-Tejada et al., 2000; Afanasyev et al., 2001 etc.).
- Also, remote sensing information has been used to quantify physiological parameters such as pigments and forage qualities (Gausman, 1982; Chapplle et al., 1992; Pneulas and Filella, 1998; Thoomas and Gausman, 1977; Pneuclas and Fiella, 1998; Zhao et al., 2003; Starks et al., 2004 etc.).

Literature Review

- Nitrogen deficiency causes a decrease in chlorophyll concentration, resulting an increase in leaf spectral reflectance in the visible spectral region (Bucaglia and Varco, 2002; Carter and Estep, 2002; Read et al., 2002; Zhao et a., 2003, 2005 etc.).
- To date, there are no studies dealing with functional relationships between nitrogen and other physiological parameters with remote sensing information in castor.

Objectives

- To investigate the influence of nitrogen nutrition on castor growth and physiology.
- To develop functional relationships between leaf N and growth and developmental rates.
- To detect and to establish functional relationships between leaf reflectance and leaf N and chlorophyll pigments.
- To identify best method to develop relationships between reflectance and leaf N and pigments in castor.

Materials and Methods

Crop Husbandry

- Out-door, pot –culture facility (PVC pots with 12 L capacity).
- Cultivar – ‘Hale’ was seeded 24 May, 2006.
- Row spacing 1 m and one plant per pot.
- 240 pots, 80 pots for each treatment, 4 replications per treatment.
- Irrigation - Half strength Hoagland's nutrient solution from emergence to 34 DAS.



Materials and Methods

Nitrogen Treatments

- From 34 to 66 days of sowing, the following treatments were imposed:
 - Treatment 1: Continued with Hoagland's solution (100% N)
 - Treatment 2: 20% of Treatment 1 (20% N)
 - Treatment 3: 0% of Treatment 1 (0% N)
- Well-watered (3-times a day) and all other nutrients supplied.

Materials and Methods

Growth and Physiological Measurements

- Growth measurements, photosynthesis and pigments were collected at 4-day interval.
- Leaf samples were also collected for nitrogen determination at 4-day interval.
- Biomass was collected at 66 days after sowing.



Materials and Methods

Reflectance Measurements

- Leaf hyperspectral reflectance
 - Collected in 350 –2500 nm region
 - 4 day interval
 - ASD (Analytical Spectral Device, Inc.) spectroradiometer and an artificial light source (ML-902, Makita corporation, Aichi, Japan).
 - A total of 420 spectra were collected through out the growth period over three treatments.



Methodology

Growth and Spectral Analysis

- From the time-series measurements of leaf N, and plant growth and photosynthesis measurements, functional relationships were calculated.
- Five spectra from each for the four replications were first averaged and again averaged over the replications.
- Data averaged over 10-nm intervals to decrease the amount of data for analysis.

Methodology

Spectral Analysis

- Coefficients of determination (r^2) were calculated between leaf nitrogen, chlorophyll amounts and
 - Simple reflectance values
 - First derivatives of simple reflectance values
 - Reflectance ratios

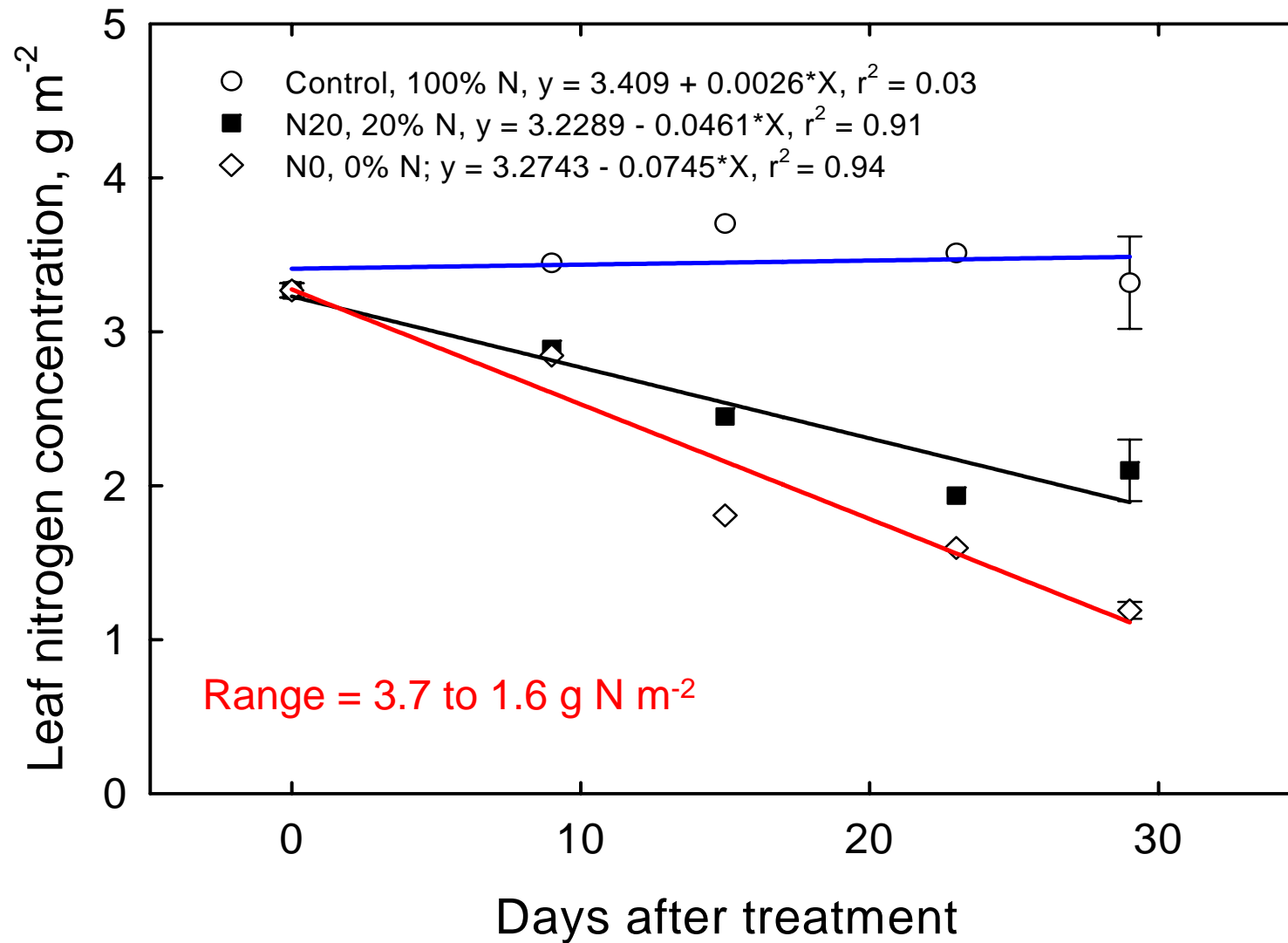
Results

- Growth and development
- Physiology
- Remote sensing



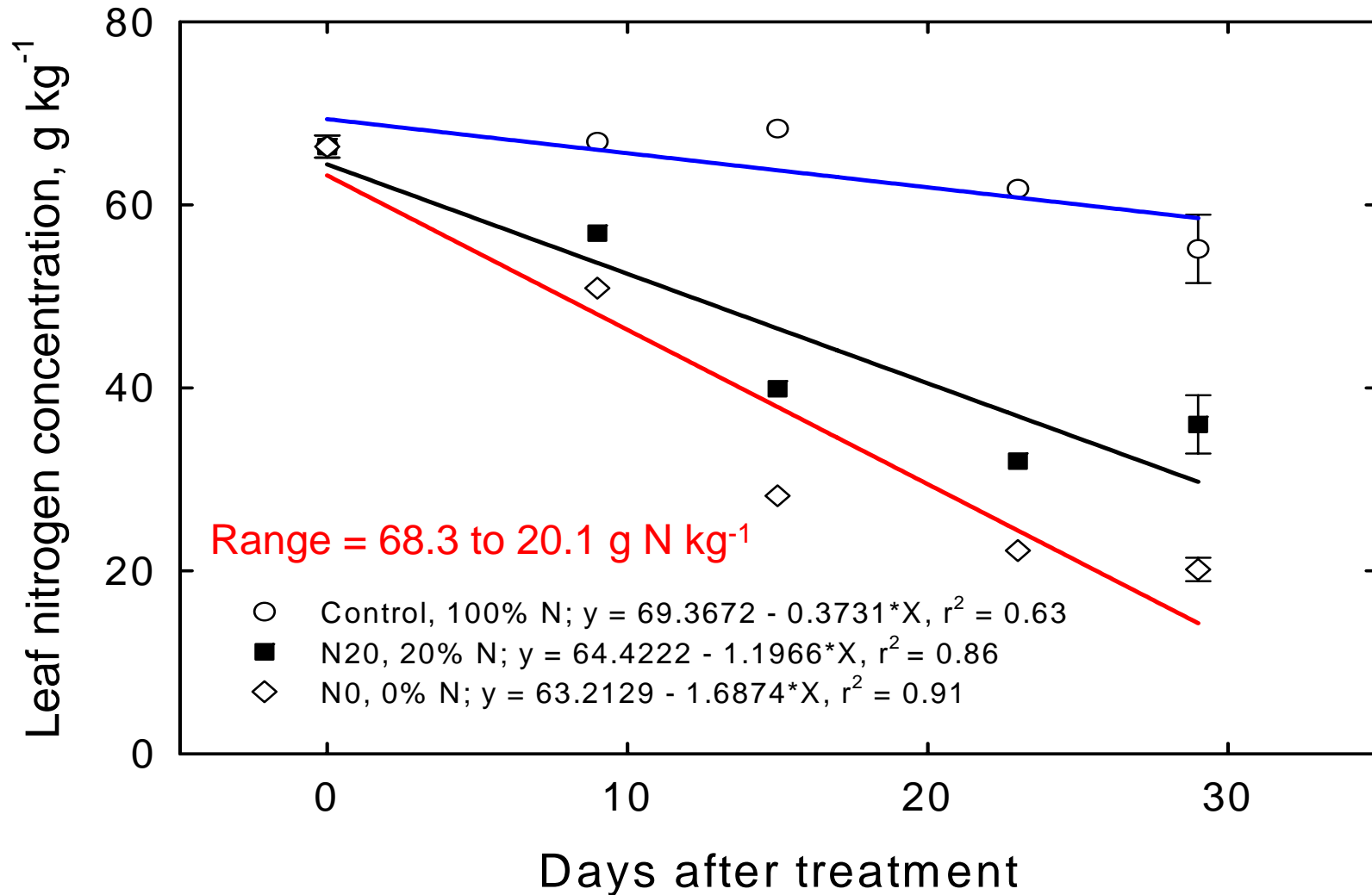
Results – Growth and Development

Temporal Trends in Leaf N



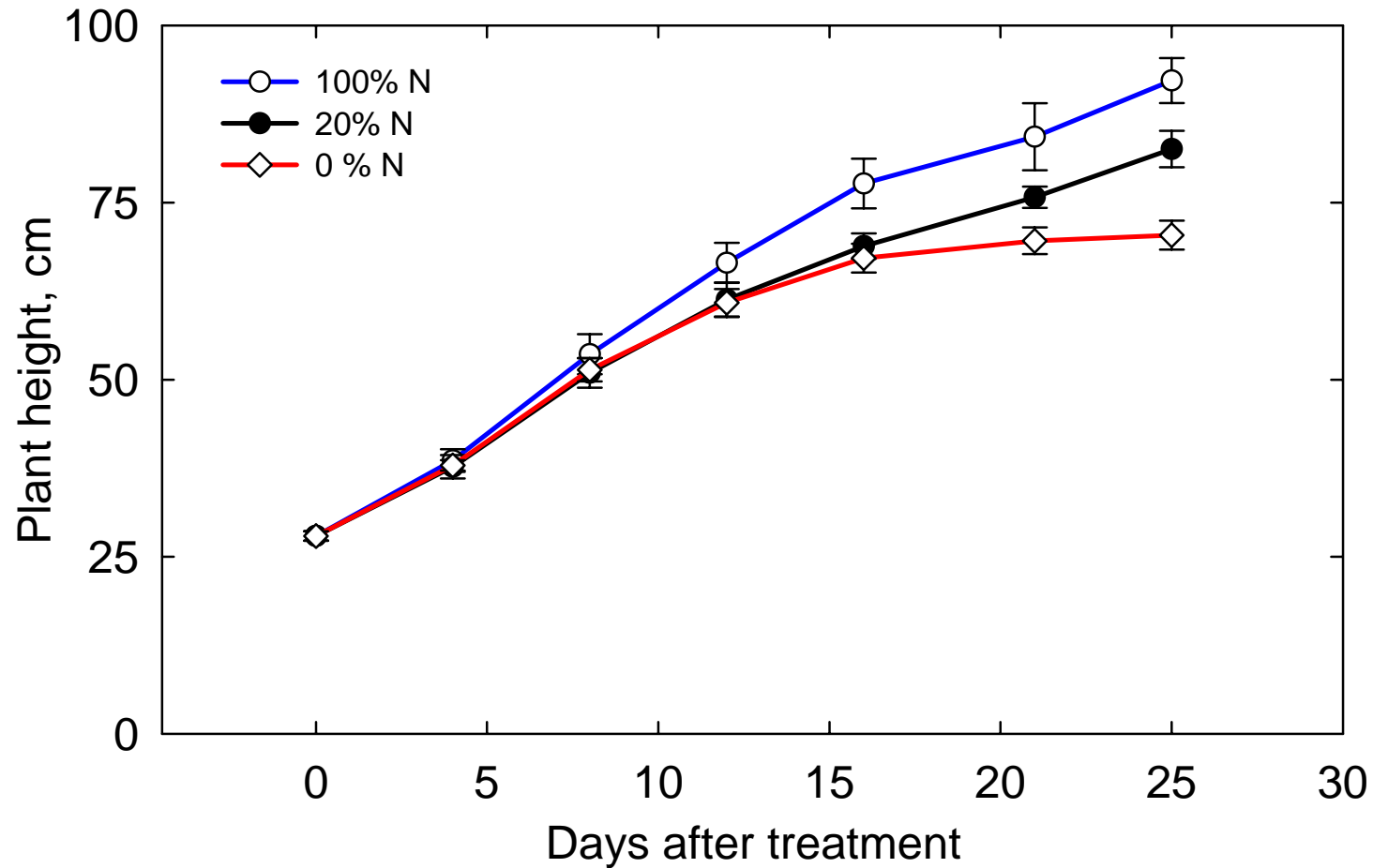
Results – Growth and Development

Temporal Trends in Leaf N



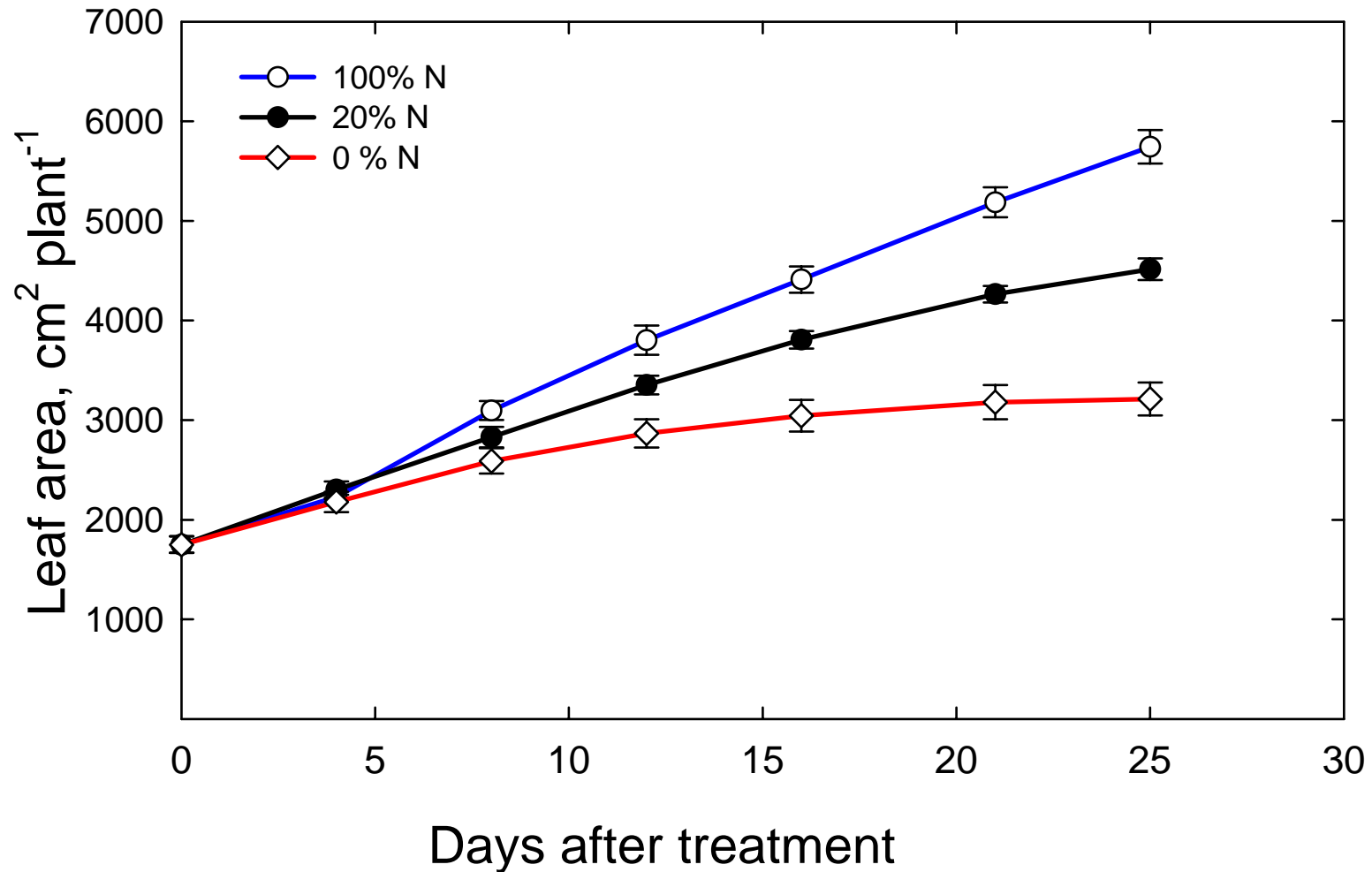
Results - Growth and Development

Plant Height



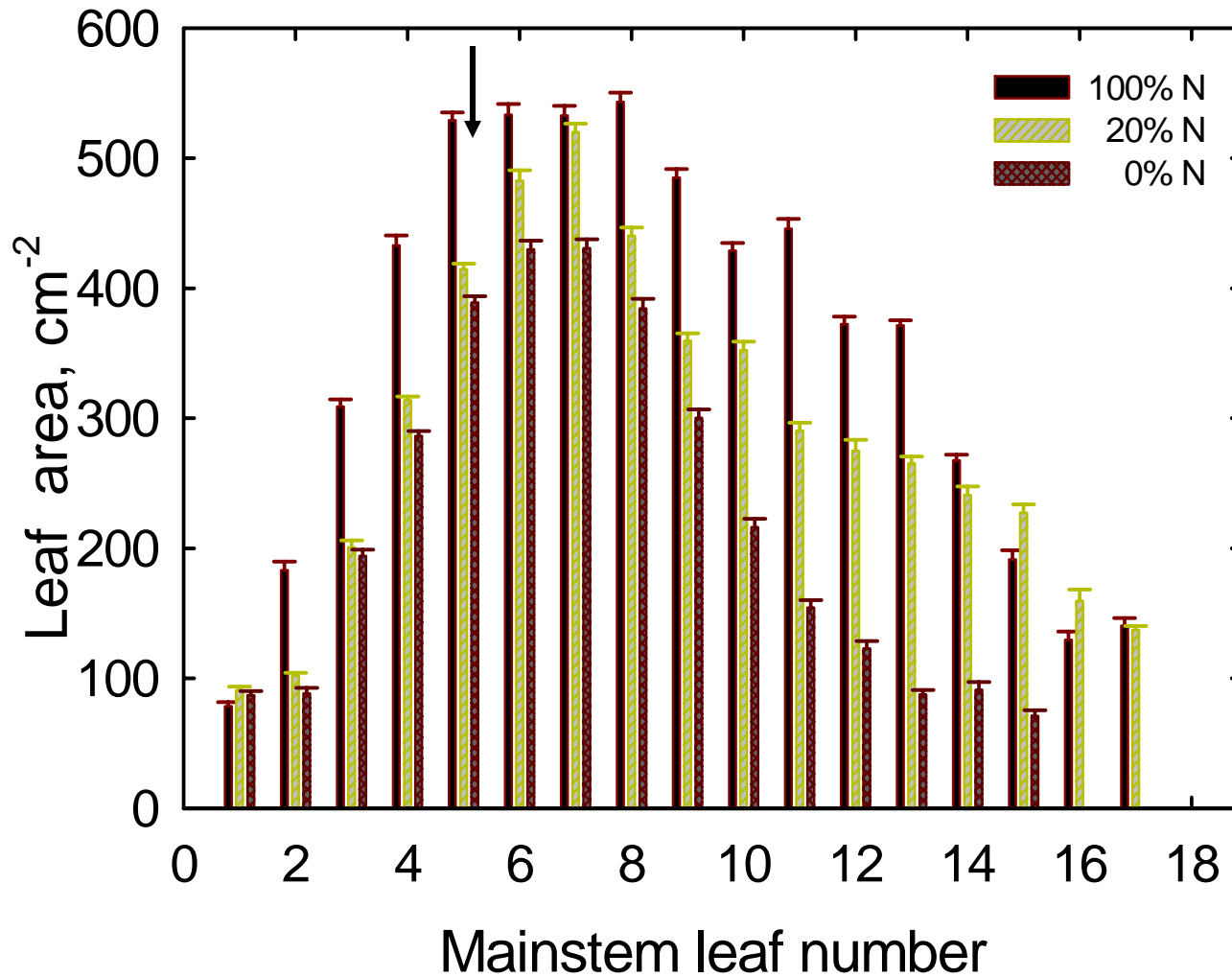
Results - Growth and Development

Leaf Area Development



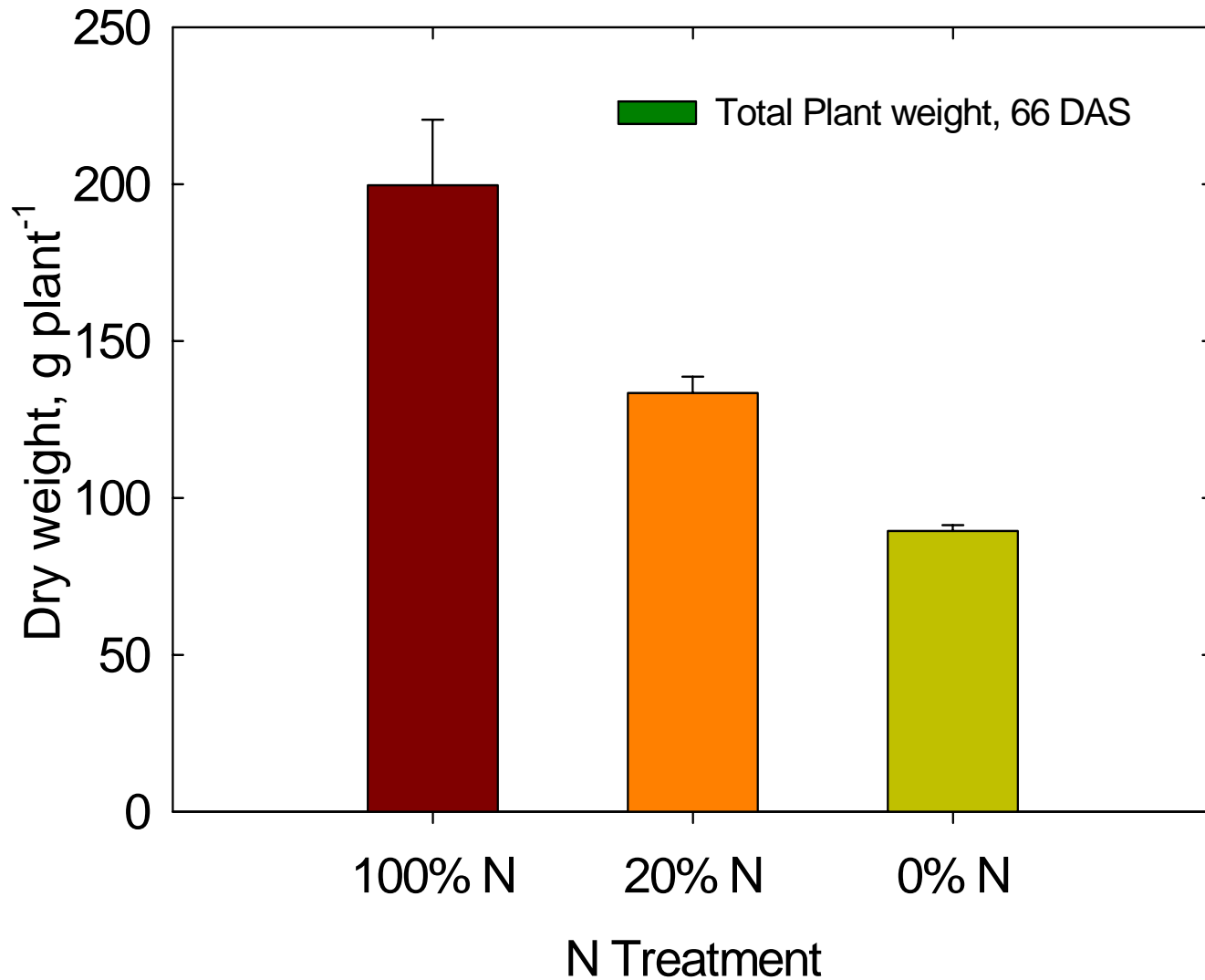
Results - Growth and Development

Nitrogen and Mainstem Leaf Area



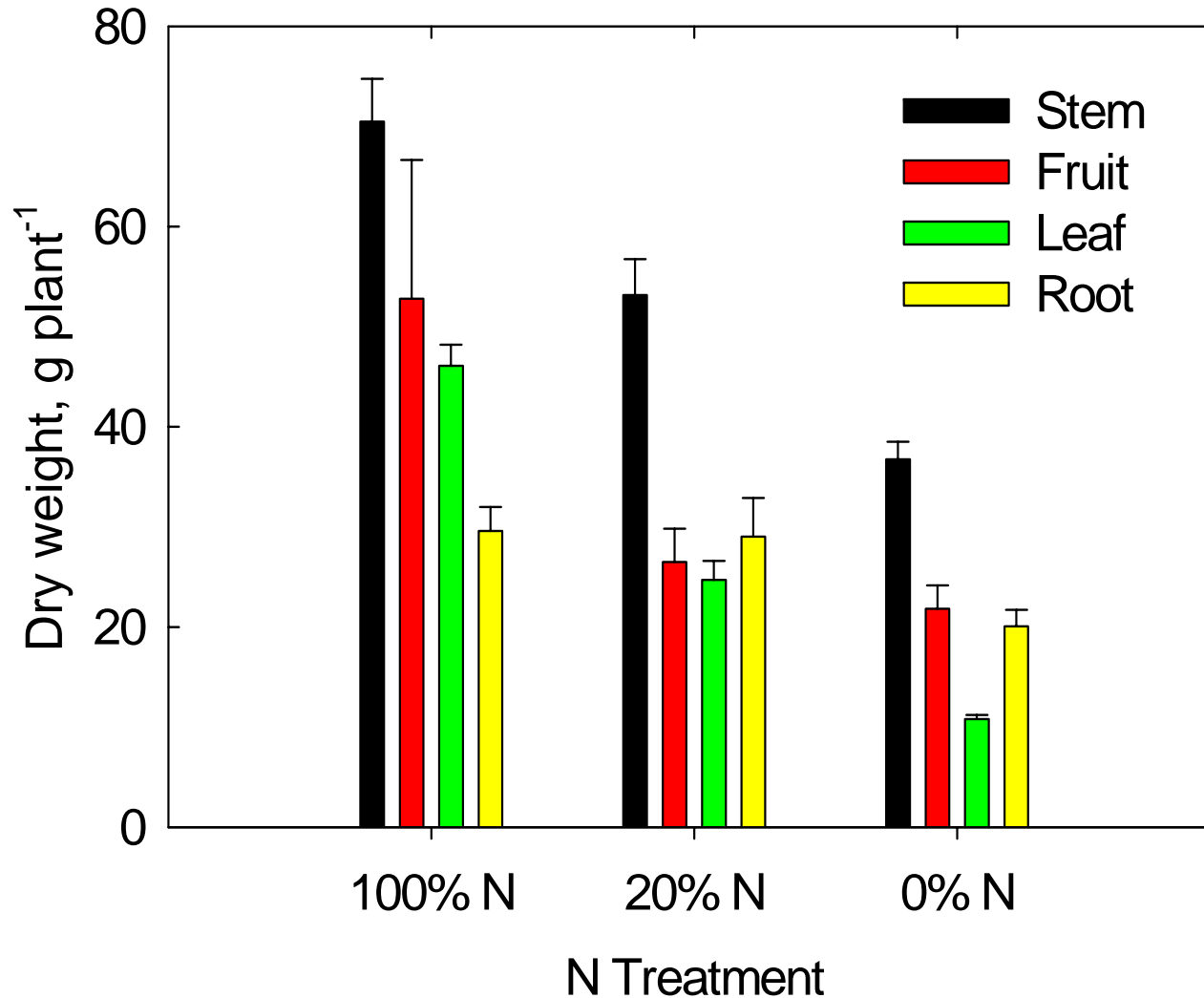
Results- Growth and Development

Nitrogen deficiency and Plant Dry Weight



Results- Growth and Development

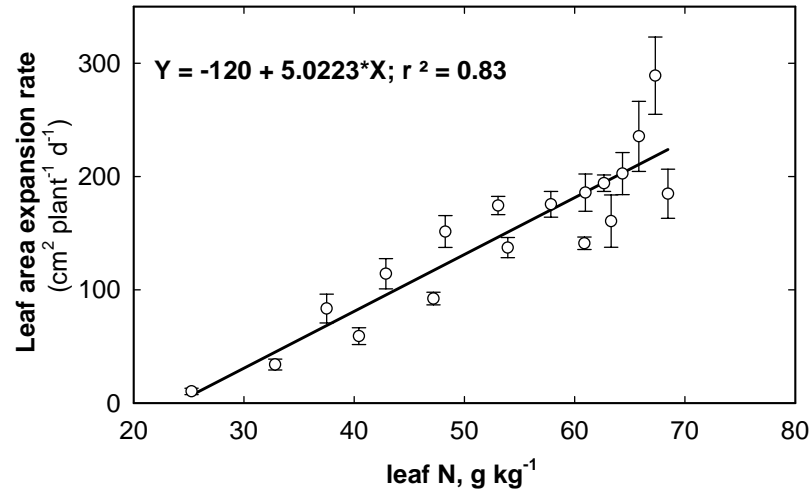
Nitrogen deficiency and Plant-component Dry Weights



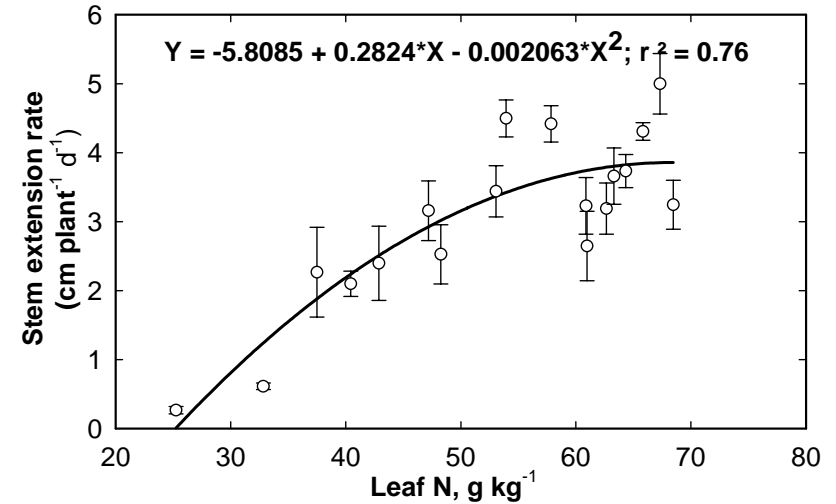
Results – Growth and Development

Nitrogen and Growth and Developmental Rates

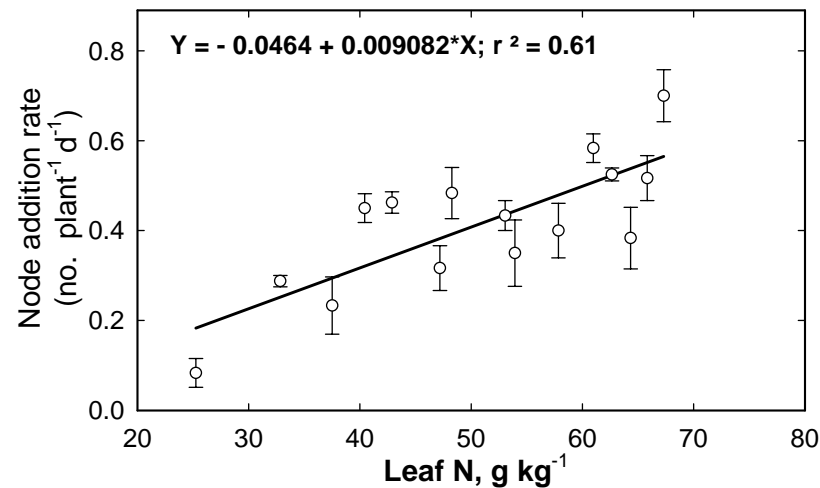
Leaf expansion rates



Stem elongation rates

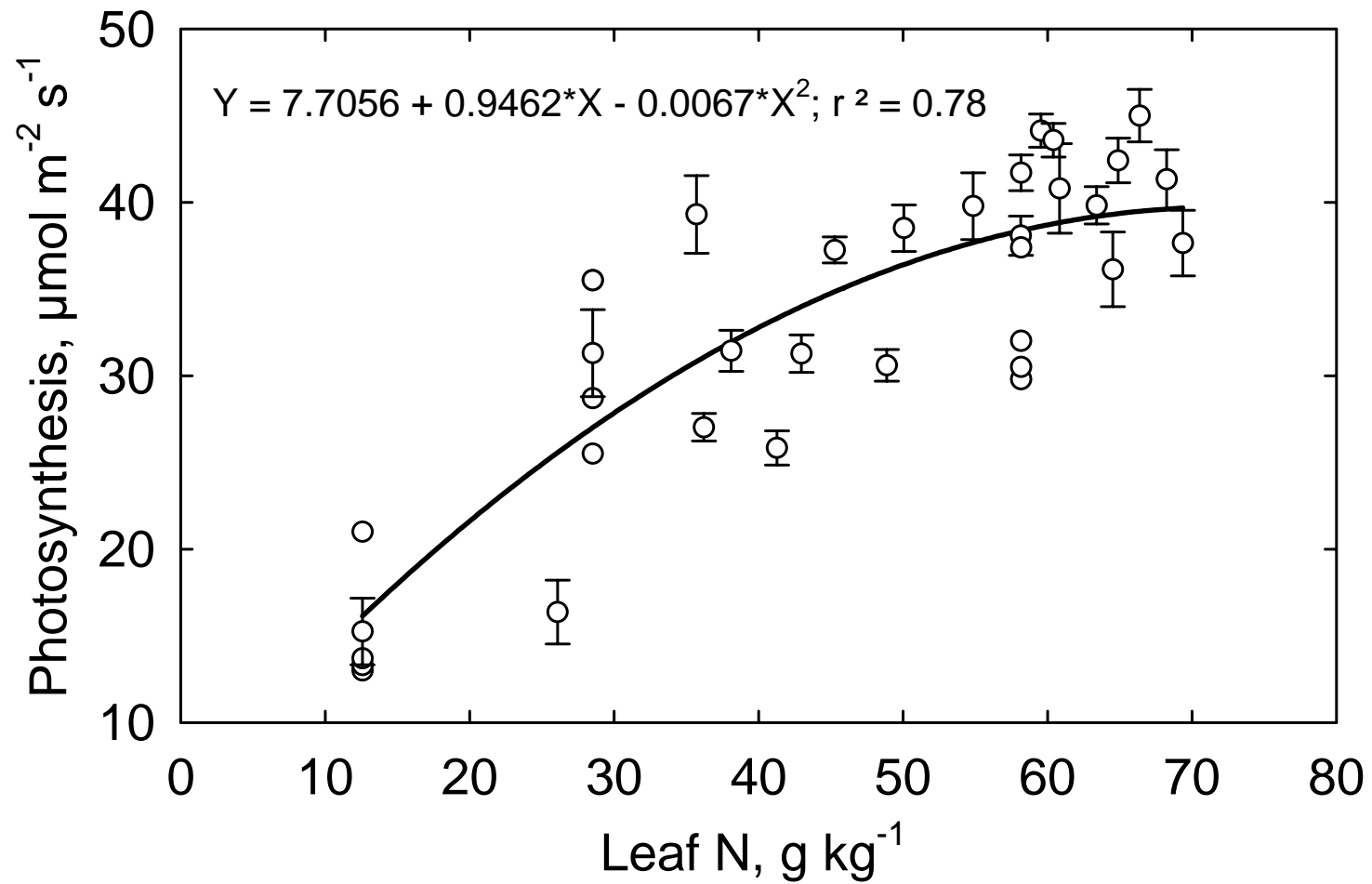


Leaf developmental rates



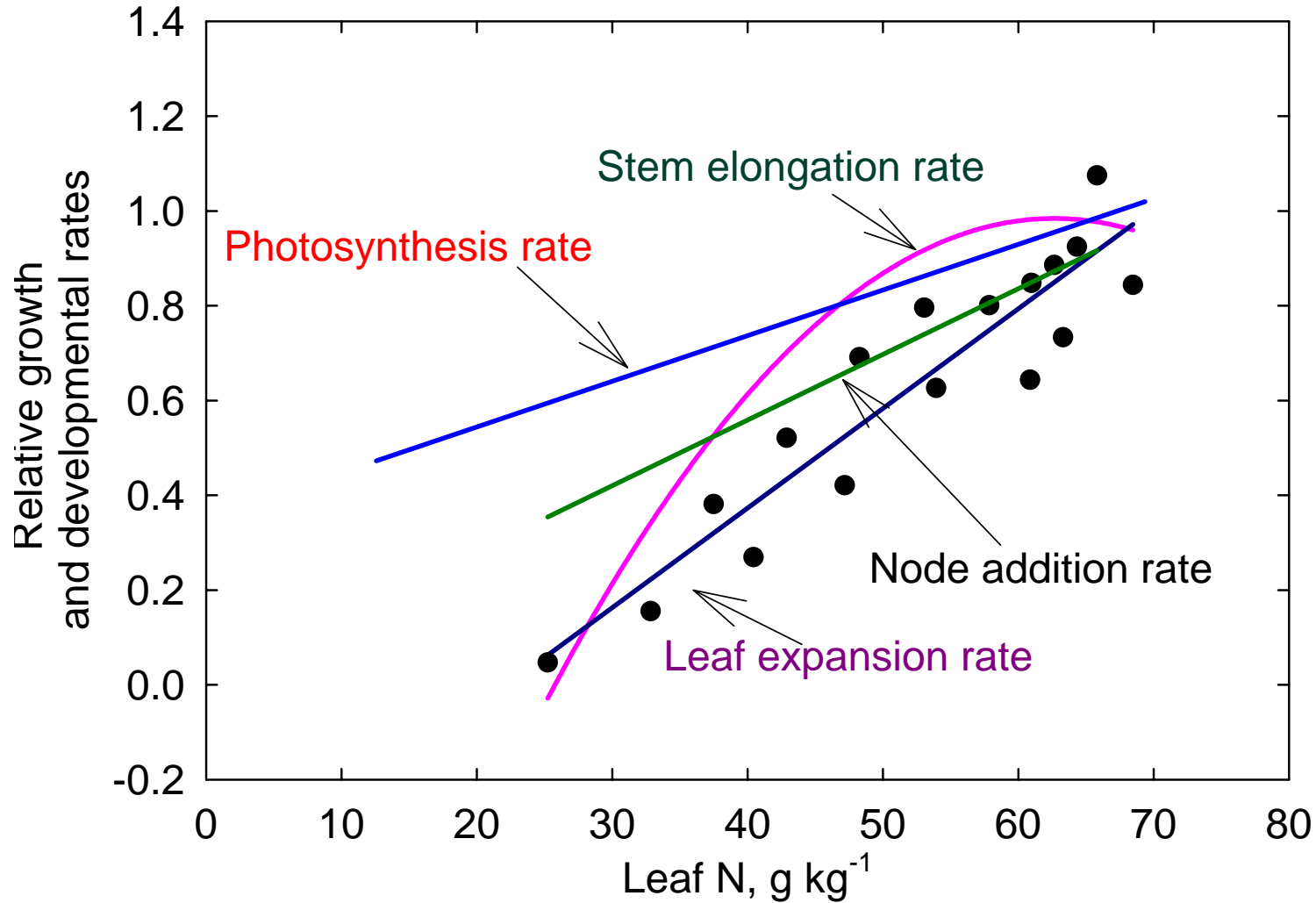
Results- Physiology

Leaf N and Photosynthetic Rates



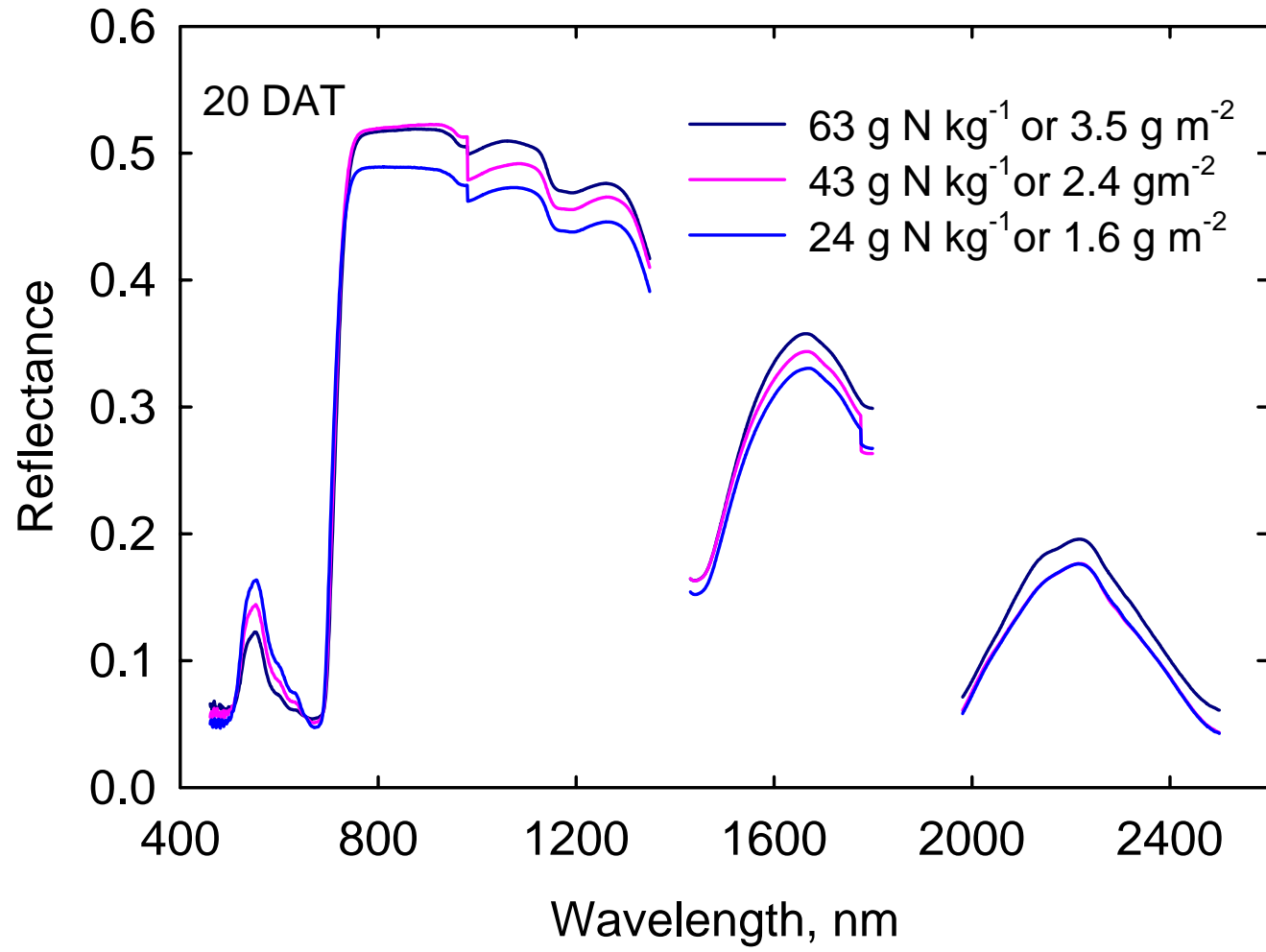
Results- Growth and Development, physiology

Leaf N and Relative Growth and Developmental Rates



Results – Remote Sensing

Leaf N and Reflectance – An Example



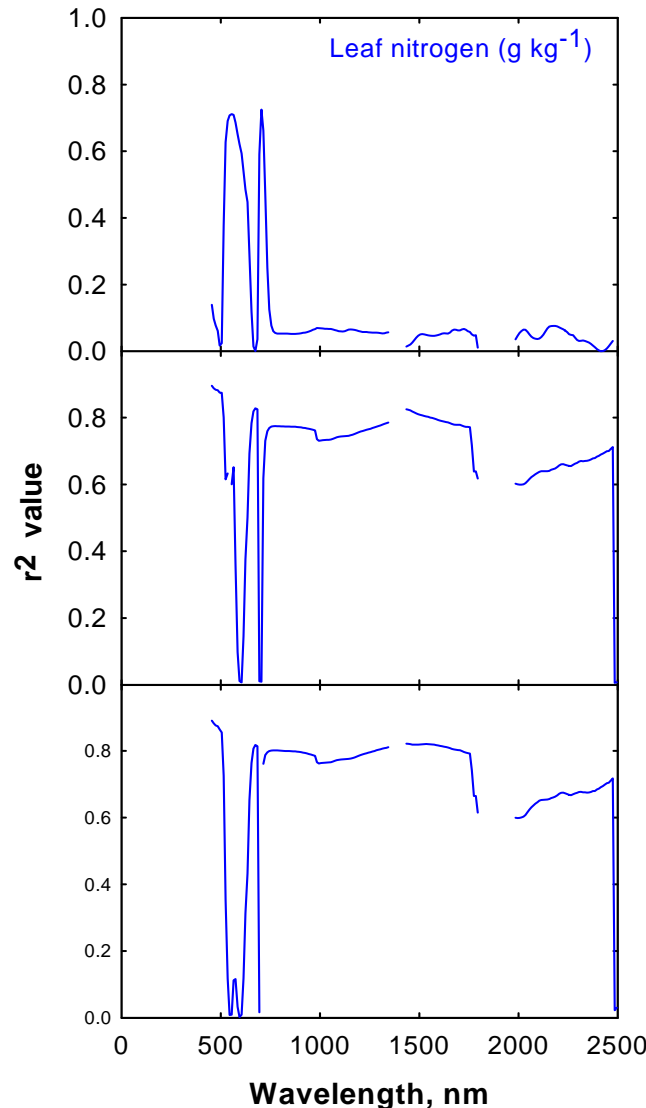
Results – Remote Sensing

Steps in Best Band Estimation for Leaf N

Spectral reflectance values were regressed with leaf N values, and bands with maximum r^2 were selected.

Then, these bands were used to calculate reflectance ratios which were used again to regress against leaf N and pigments.

Band ratios with maximum r^2 values were selected to derive the functions between leaf N and reflectance.



Maximum R^2 values
 $R_{545} = 0.71$
 $R_{705} = 0.72$

Maximum R^2 value
 $R_{545}/R_{455} = 0.90$

Maximum R^2 value
 $R_{705}/555 = 0.89$

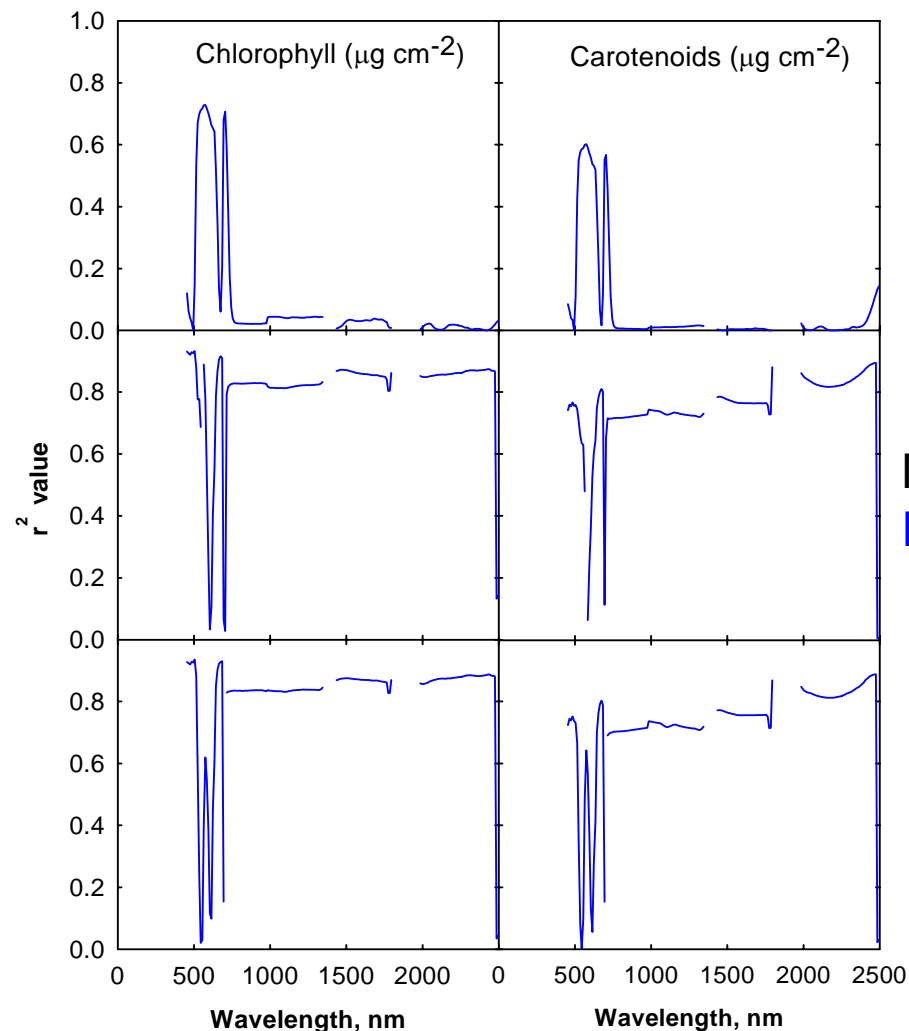
Results – Remote Sensing

Plots of Best Band Ratios for Pigments

Maximum R^2 values
 $R_{555} = 0.72$
 $R_{705} = 0.70$

Maximum R^2 value
 $R_{555}/R_{455} = 0.93$

Maximum R^2 value
 $R_{705}/R_{665} = 0.92$



Maximum R^2 values
 $R_{575} = 0.60$
 $R_{705} = 0.56$

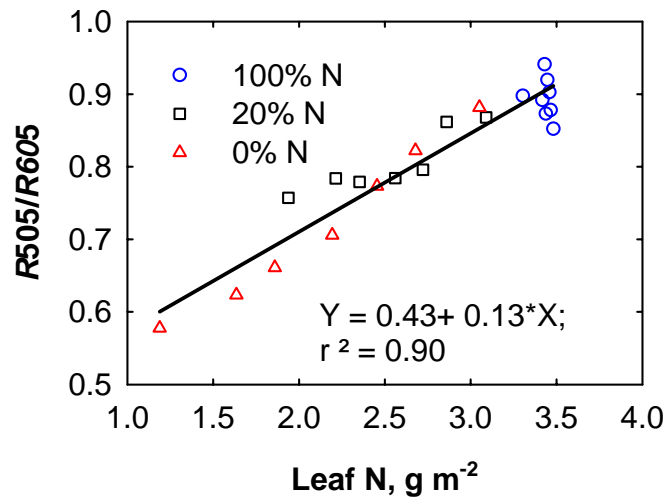
Maximum R^2 value
 $R_{575}/R_{675} = 0.80$

Maximum R^2 value
 $R_{705}/R_{575} = 0.80$

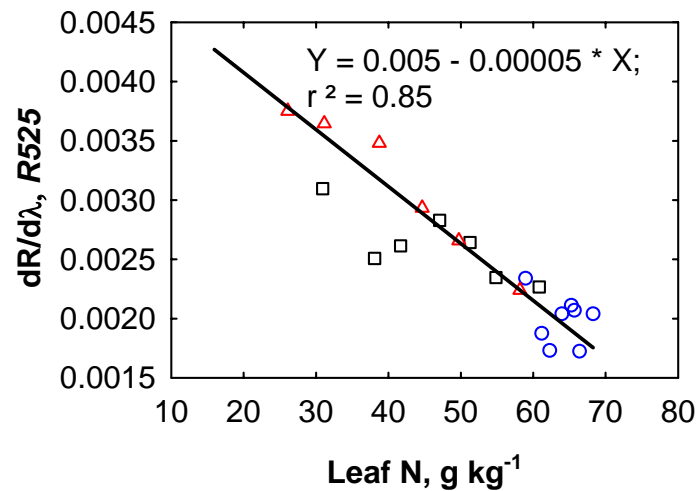
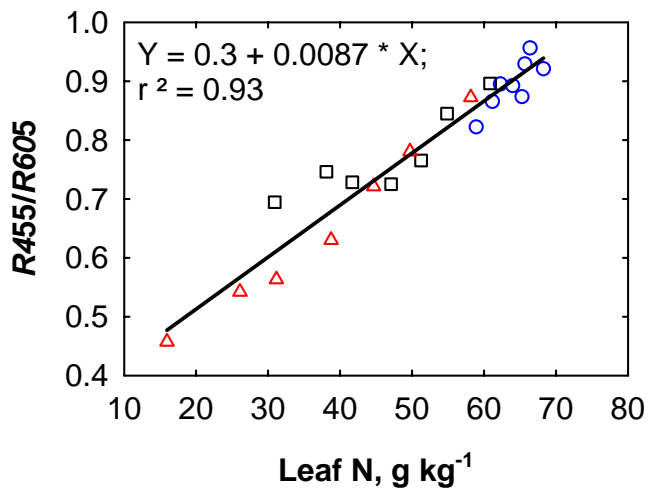
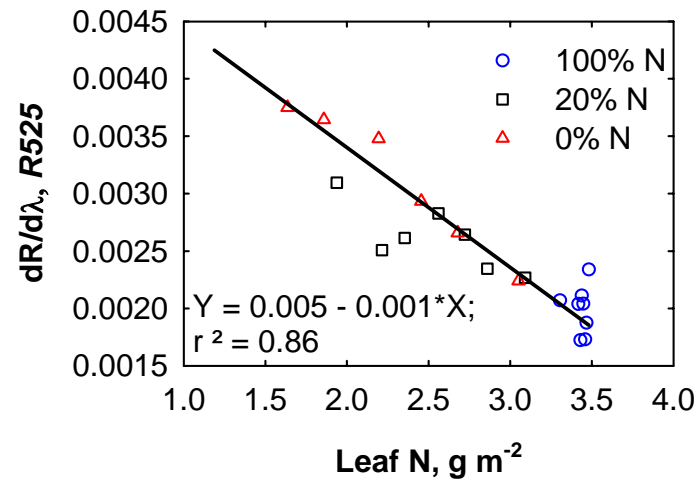
Results – Remote Sensing

Leaf N and Reflectance Correlations

Reflectance ratios



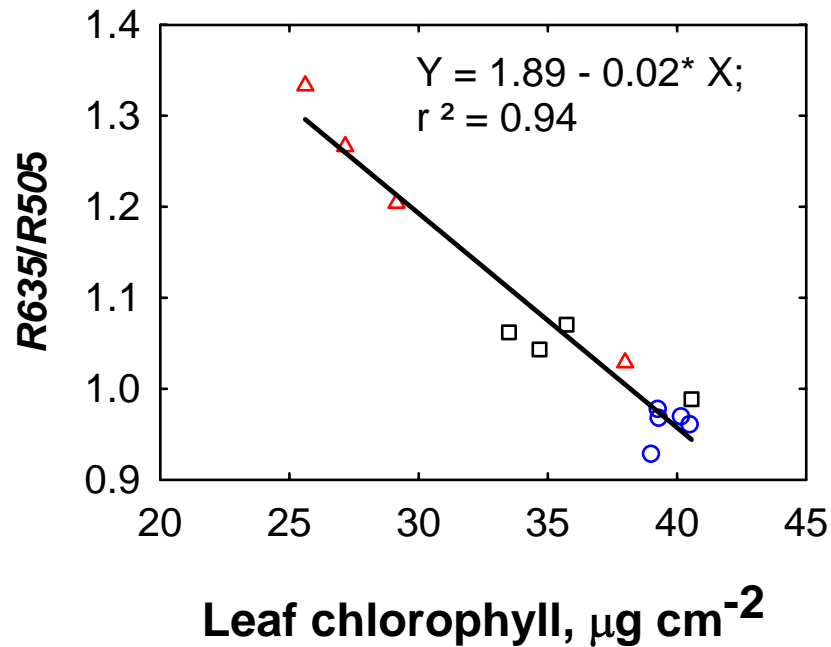
First derivatives



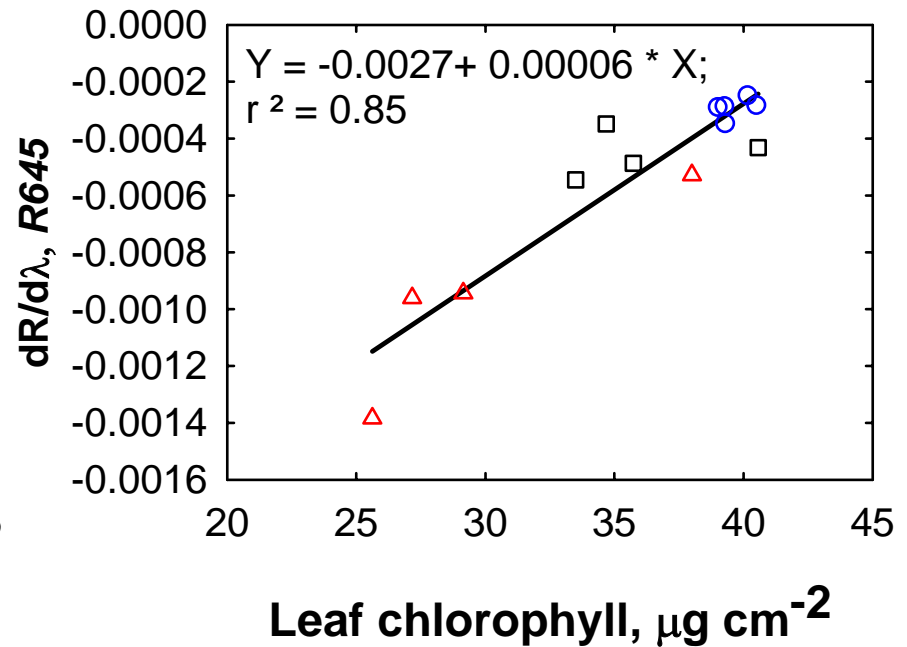
Results – Remote Sensing

Leaf N and Leaf Pigment Correlations

Reflectance ratios



First derivatives



Results – Remote Sensing

Best Bands for Predicting Leaf N and Pigments

Parameter	Best bands	Function	R ²
Nitrogen (g m ⁻²)	505, 605	Y = 0.43 + 0.13 * (R505/R605)	0.90
Nitrogen (g kg ⁻¹)	455, 605	Y = 0.3 + 0.0087 * (R455/R605)	0.93
Chlorophyll (μg cm ⁻²)	635, 505	Y = 1.89 - 0.02 * (R635/R505)	0.94
Carotenoids (μg cm ⁻²)	705, 675	Y = 7.68 - 0.53 (R705/R675)	0.80

Summary and Conclusions

- Castor responds very well to N nutrition due its indeterminate growth habit.
- N deficiency resulted in reduced growth and development.
- Leaf expansion rate was more sensitive to N deprivation followed by rates of stem elongation, node addition and photosynthesis.
- Partitioning of biomass to leaves decreased more than the other plant components under N deficiency.

Summary and Conclusions

- Reflectance ratios are found to be best to estimate leaf N and pigments.
- Nitrogen estimated on percent dry weight basis found to be better correlated than estimated on area basis.
- The wavebands identified in this study could be used to estimate castor leaf N and pigments, and thus might be useful in managing crop N during the growing season.

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