Quantifying the Effects of Temperature and Nitrogen on Switchgrass Growth and Development

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Introduction and Background

- Switchgrass (*Panicum virgatum*) is one of the dominant grass species with C4 syndrome.
- Highly productive, 9 to 14 Mg ha^{-1} across a range of growing conditions.
- Ecologically and energetically important and valuable plant species.
- Temperature- and nitrogen-specific functional relationships will be useful to improve the current models.

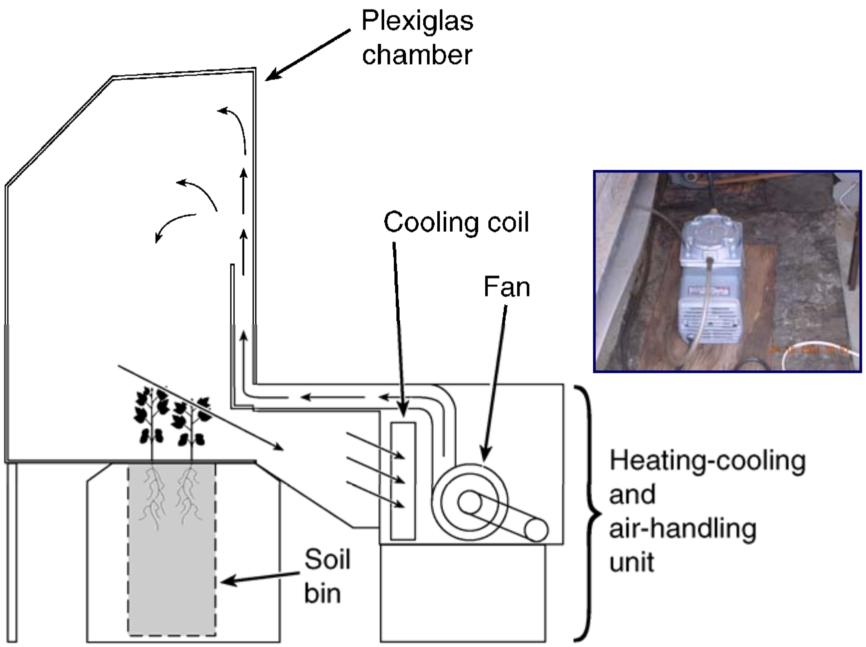
Objectives:

- To investigate the effects of temperature and nitrogen nutrition on switchgrass growth and development.

- To provide temperature- and nitrogen-dependent functional algorithms for switchgrass growth, development and physiology for modeling.

Approach:

- Experiment I was designed to generate functional algorithms between temperature and switchgrass growth and development in the SPAR Units.



www.spar.msstate.edu

Materials and Methods

Experiment I: Temperature study:

- Cultivar, Alamo.
- All plants were grown in the SPAR chambers from sowing to 34 days after sowing at 28/20 °C and 400 ppm [CO_2].
- Temperature treatments were imposed at 34 days after sowing on established plants for 69 days (103 days of sowing).
- Optimum water and nutrient conditions were provided throughout the experiment.

Materials and Methods

Experiment I: Temperature study:

Day/Night temperature, °C	Average temperature, °C	SPAR Chamber [CO_2], ppm
20/14	18.4	400
28/20	23.7	400
34/26	29.0	400
40/32	34.7	400

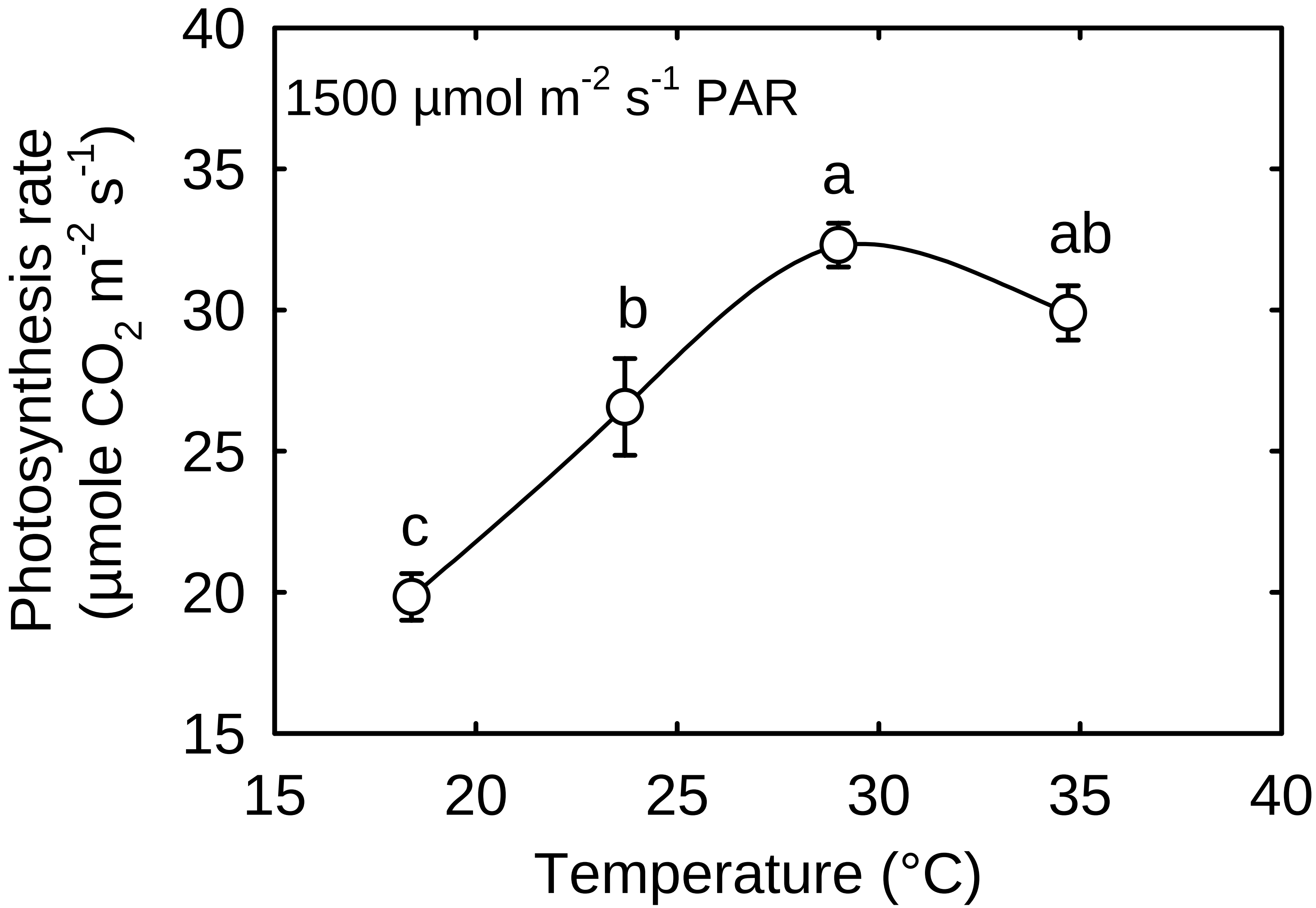
Materials and Methods

Experiment I: Measurements:

- Measured plant height and leaf numbers weekly.
- Panicle appearance was recorded when 50% of the plants showed panicles on the first tiller in each plant.
- Destructive leaf area and dry weights measurements were done three times.
  - 55 DAS and 21 DAT - 6 rows of 10 plants per row
  - 76 DAS and 42 DAT – 2 rows of 10 plants per row
  - 103 DAS and 69 DAT – 3 rows of 10 plants per row
- Monitored photosynthesis twice during the growing season.

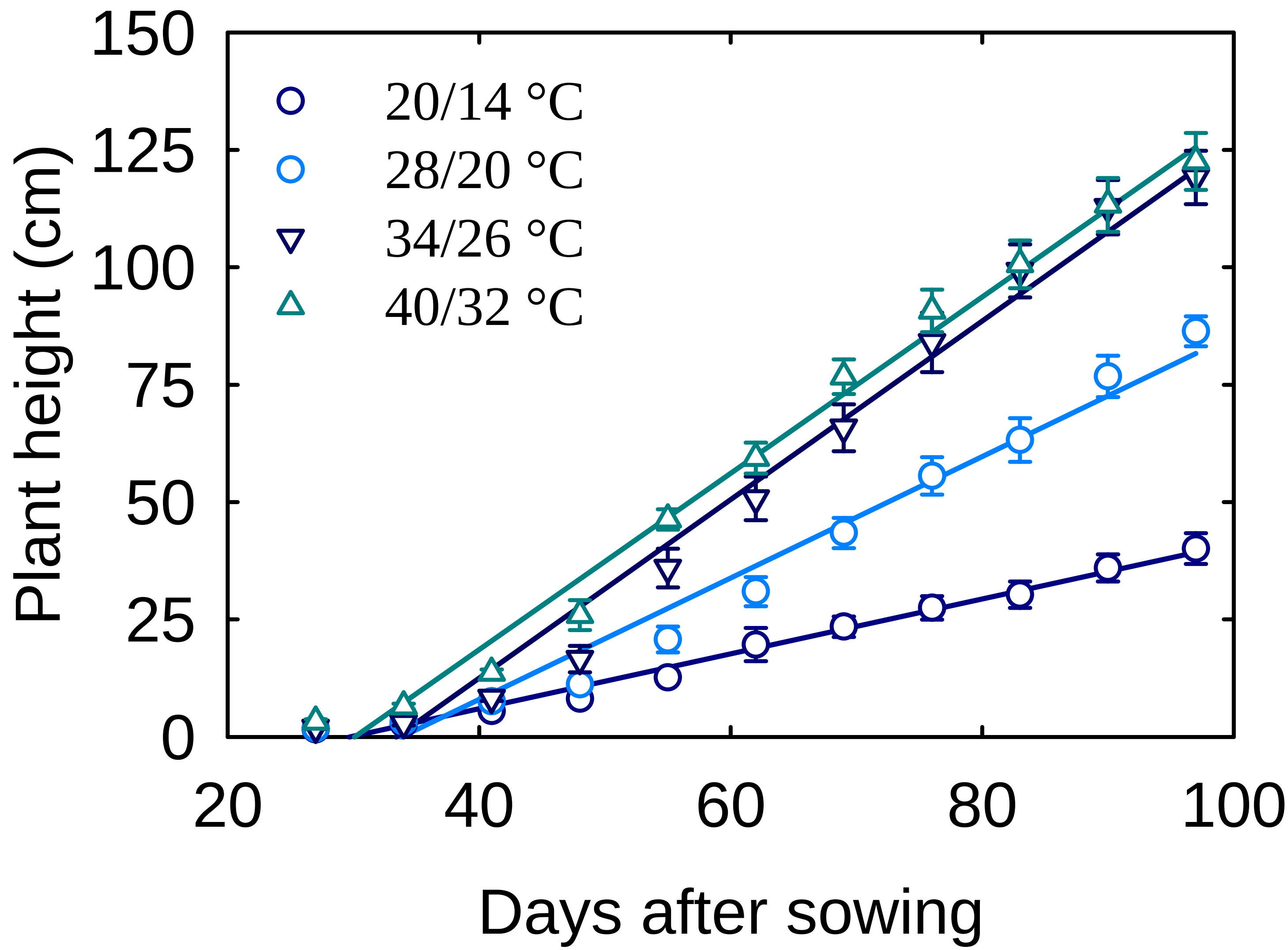
Temperature & Switchgrass Growth and Development

Photosynthesis



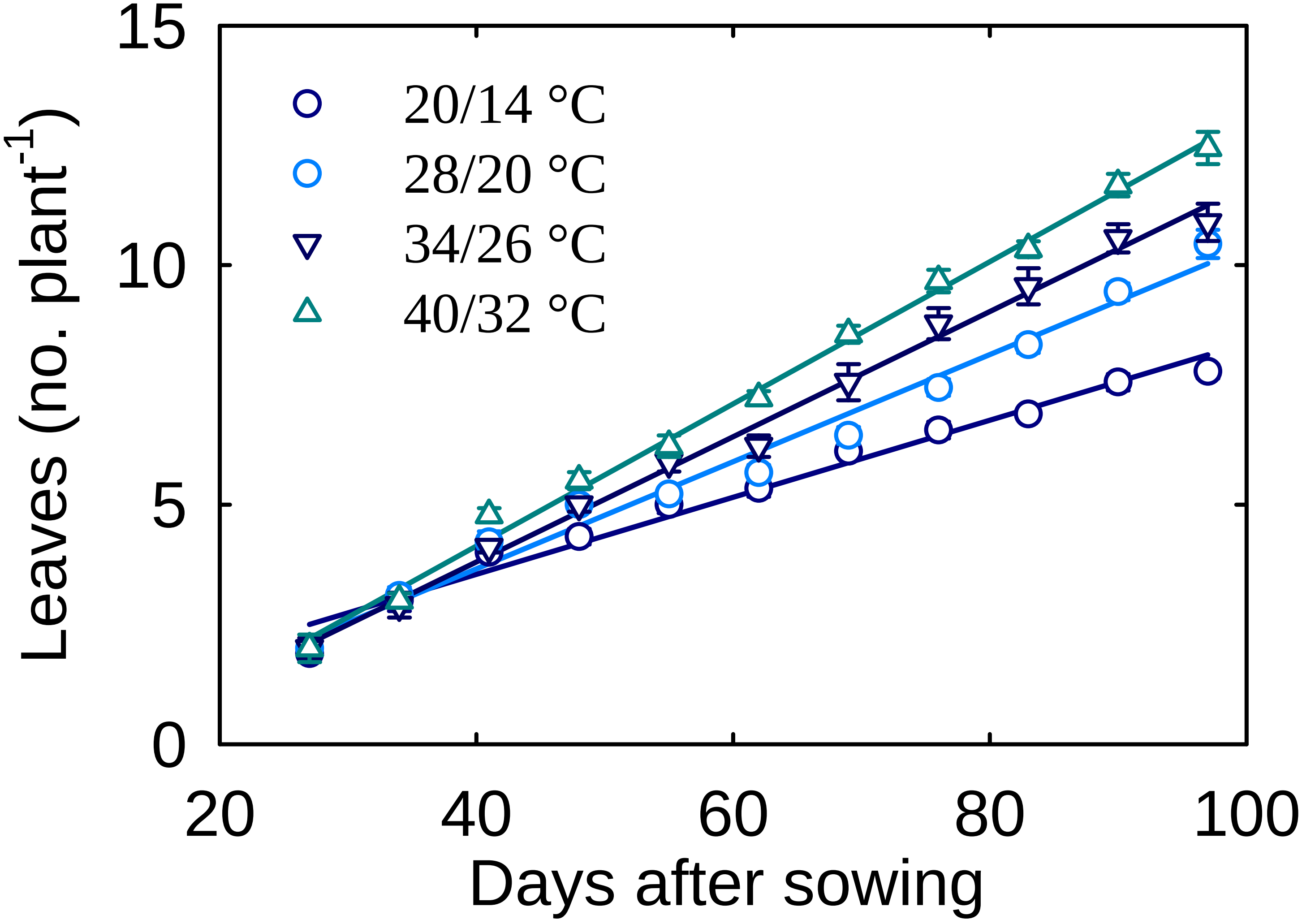
Temperature & Switchgrass Growth and Development

Stem length



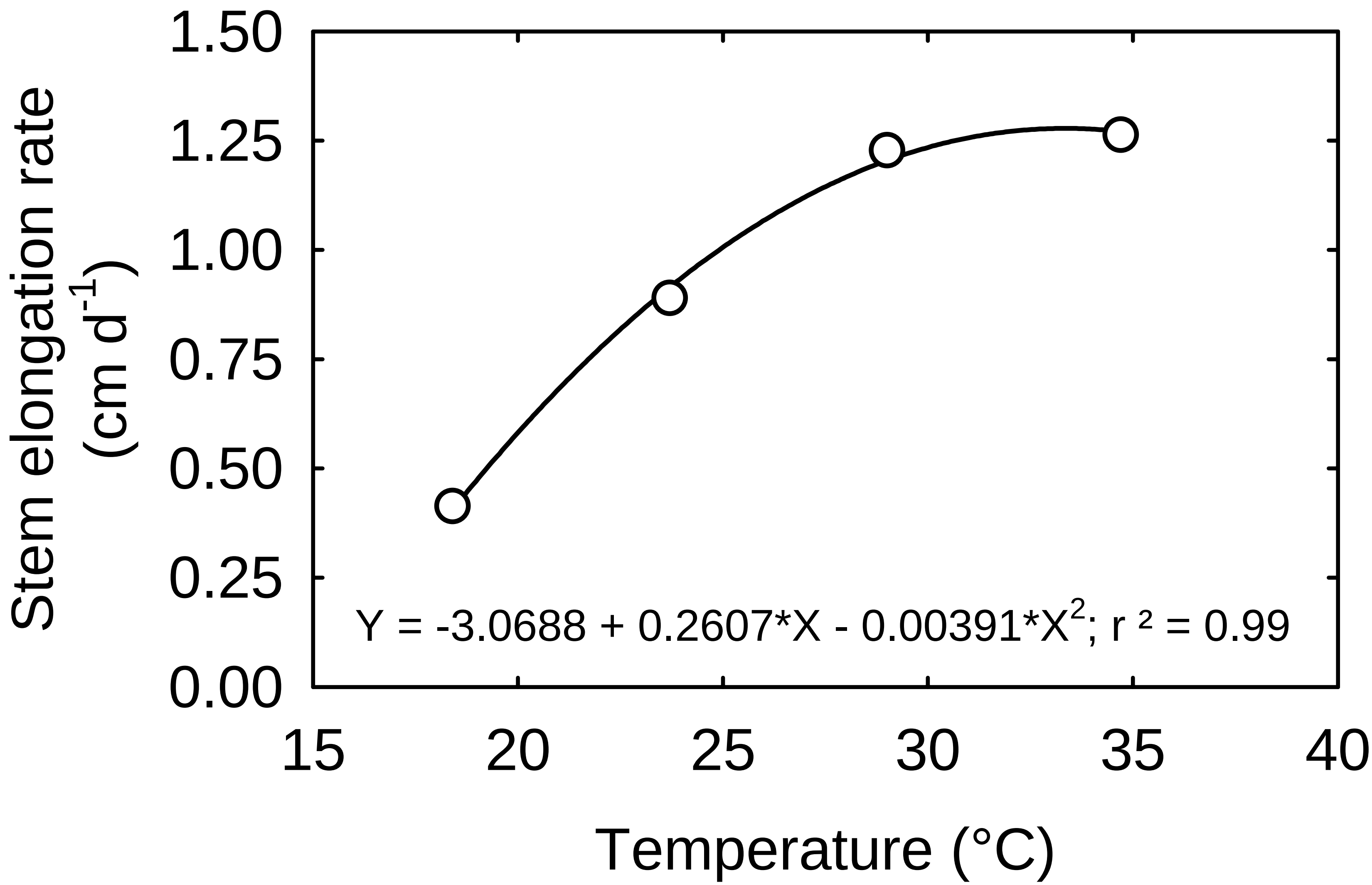
Temperature & Switchgrass Growth and Development

Leaf developmental rates



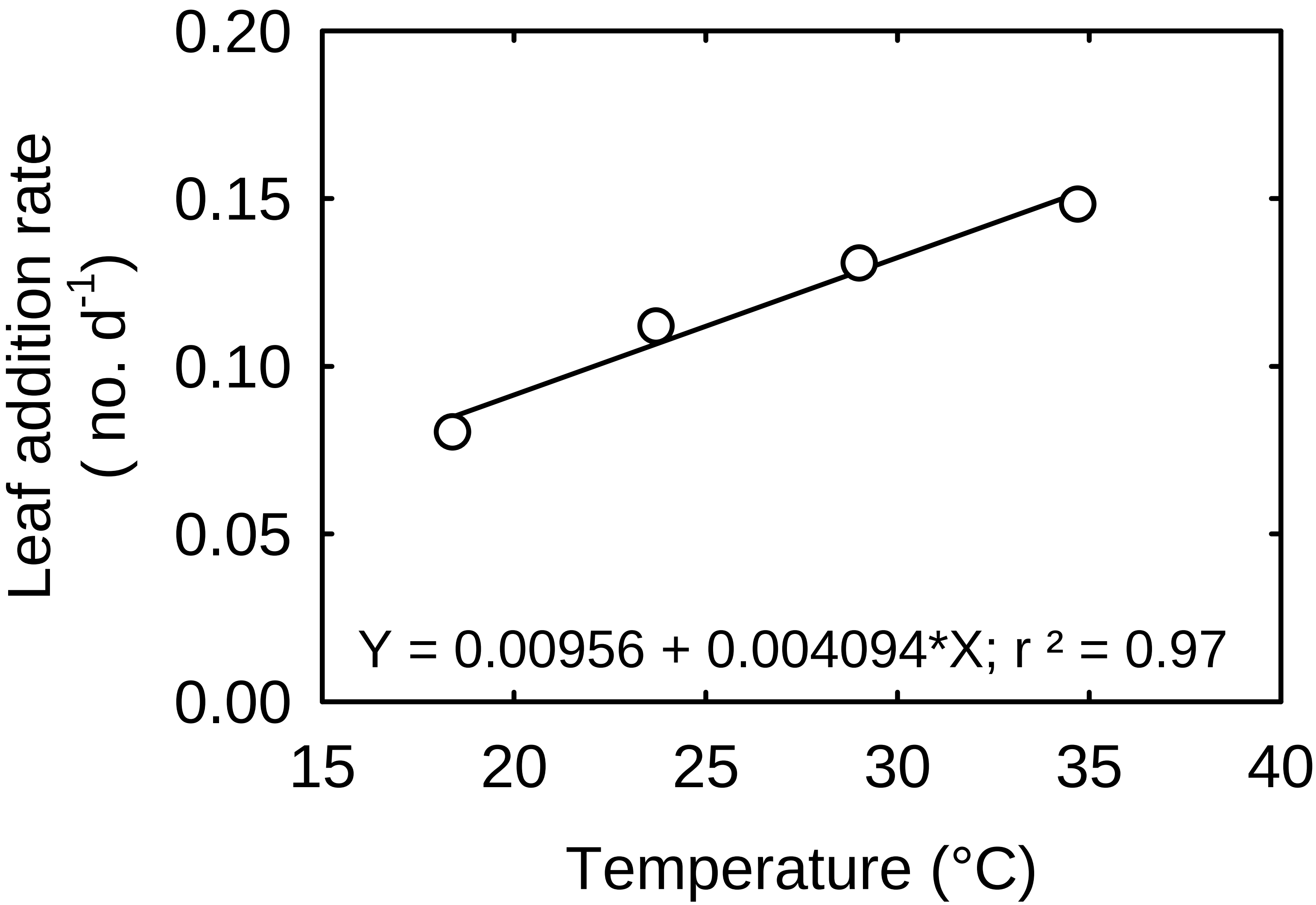
Temperature & Switchgrass Growth and Development

Stem elongation rate



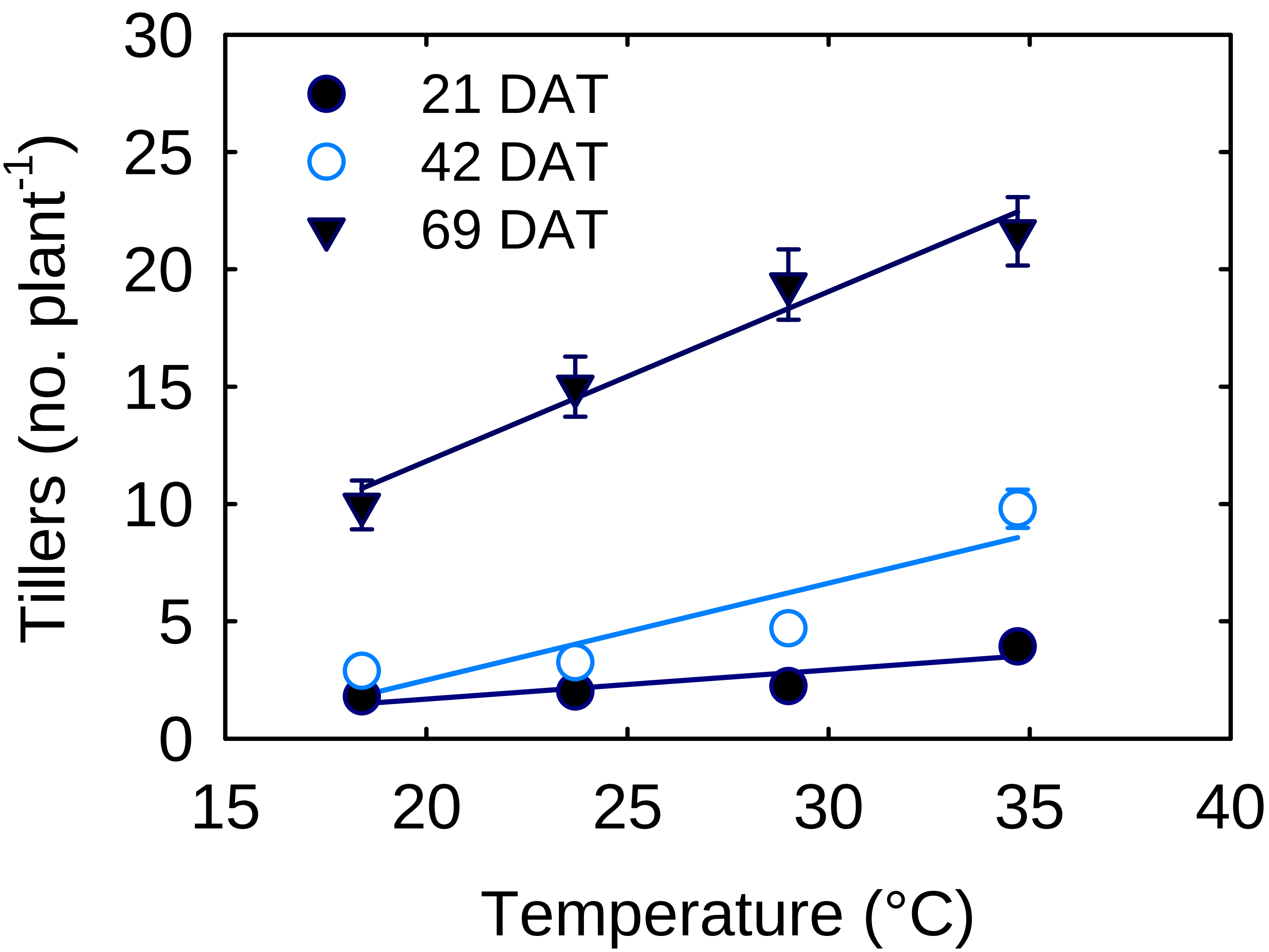
Temperature & Switchgrass Growth and Development

Leaf addition rate



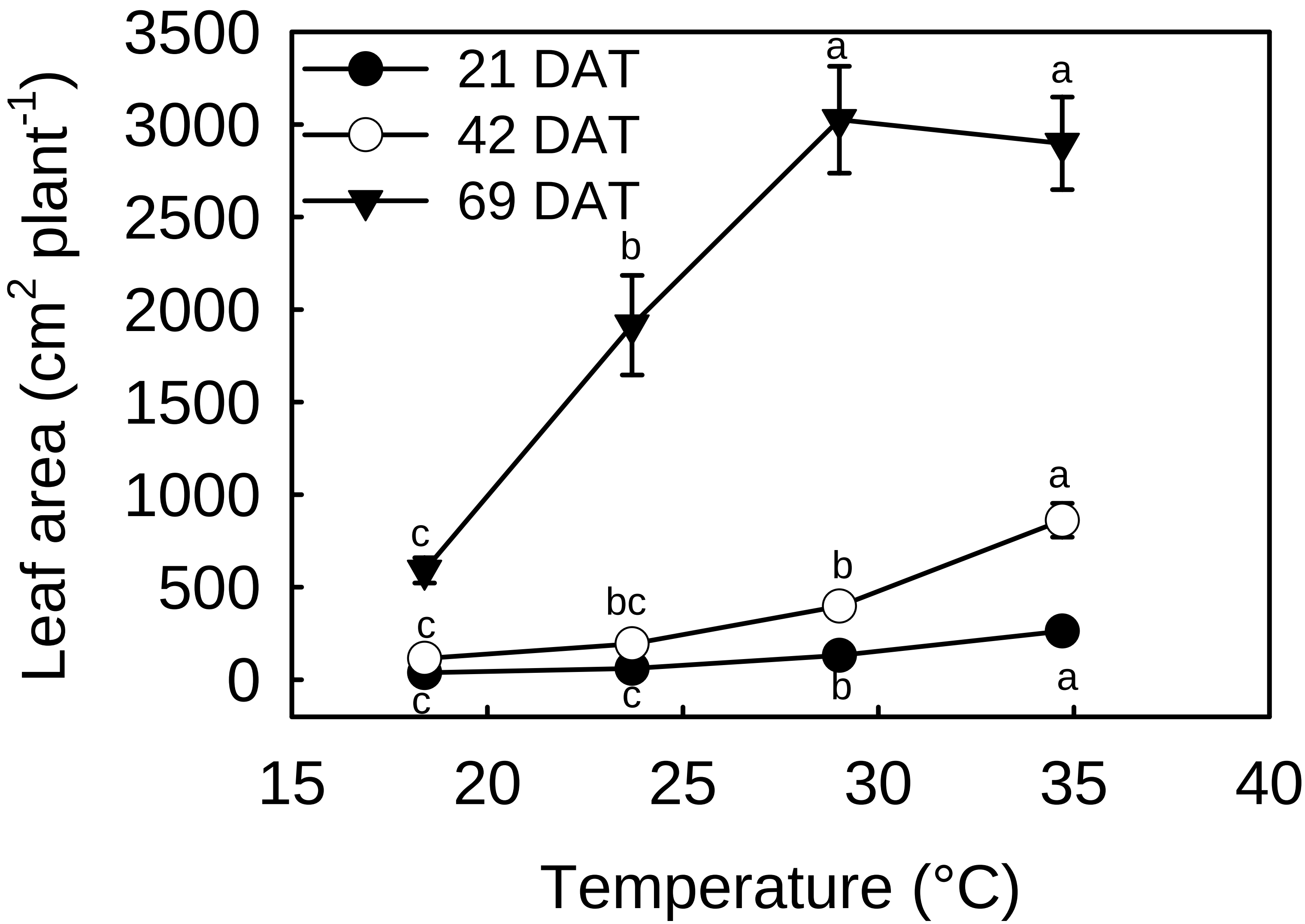
Temperature & Switchgrass Growth and Development

Tiller development



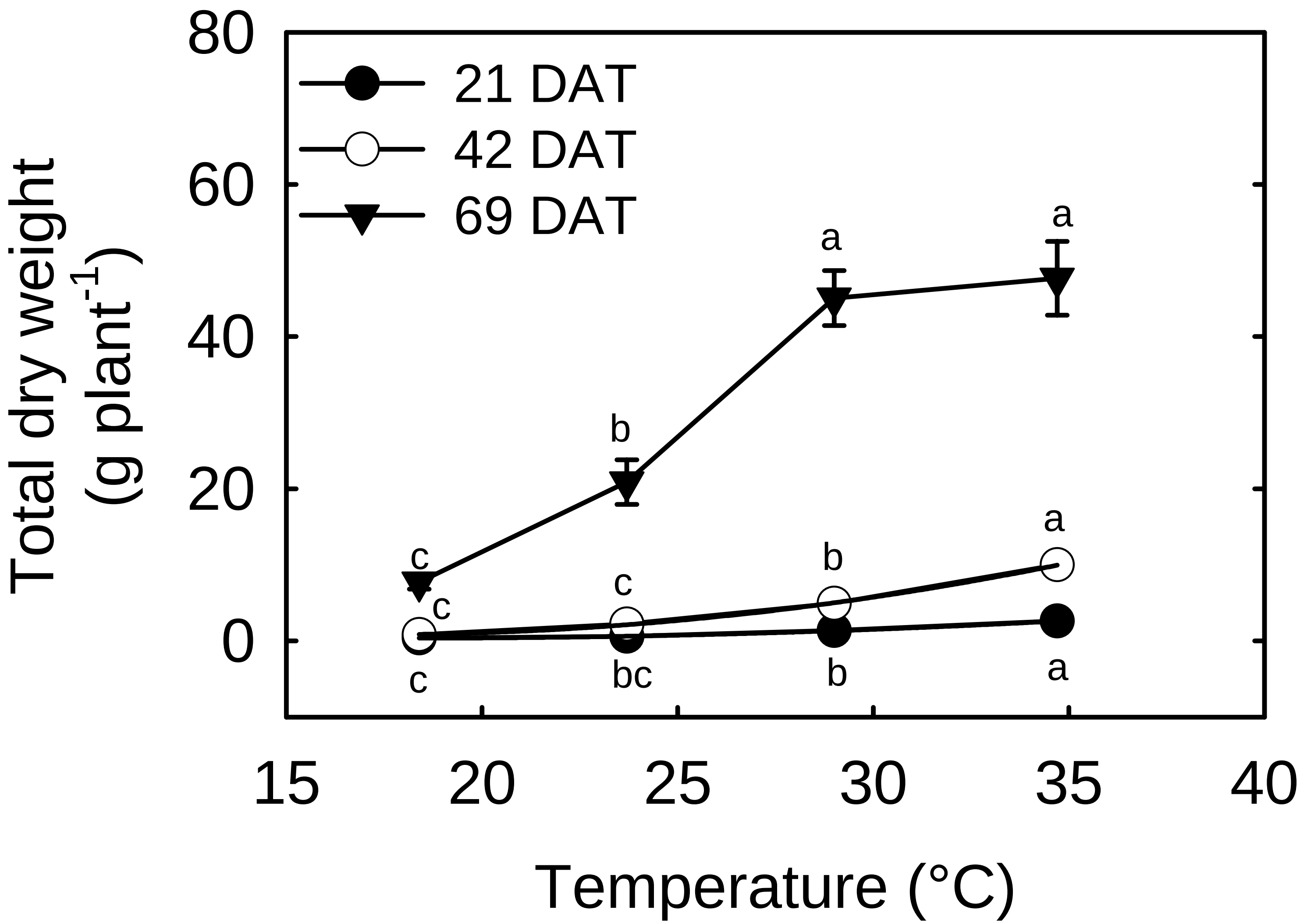
Temperature & Switchgrass Growth and Development

Whole plant leaf area development



Temperature & Switchgrass Growth and Development

Plant biomass



Temperature & Switchgrass Growth and Development

Flowering or Panicle initiation

Day/night and average temperature, °C	Time to 50% panicle formation, days
22/14 = 18.4	0.0
28/20 = 23.7	96 ± 3.2
34/26 = 29.0	80 ± 2.6
40/32 = 34.7	87 ± 2.0

Temperature & Switchgrass Growth and Development

Reproductive development – 103 days after sowing

Day/night and average temperature, °C	Panicles, no. plant^{-1}	Panicle weight, g plant^{-1}
22/14 = 18.4	0.0	0.0
28/20 = 23.7	3.0 ± 0.60	0.80 ± 0.3
34/26 = 29.0	7.7 ± 0.46	2.94 ± 0.6
40/32 = 34.7	6.0 ± 0.60	1.90 ± 0.4

Summary and Conclusions

- Developmental rates such leaf addition and tiller numbers increased linearly from 15 to 35 °C.
- Time to 50% panicle initiation, however, took 7 additional days at 35°C than at 29°C. Plants grown at 23.4 °C took 96 d, and plants grown at the lowest temperature didn’t initiate panicles during 103-days period.
- Rates of stems, leaf area development, and biomass accumulation increased linearly from 15 to 29 °C, but unaltered or slightly decreased at 35 °C.

Summary and Conclusions

- Photosynthetic rates followed similar trends with that of biomass and leaf area developmental trends in response to temperature.

- Functional algorithms can be developed from these database, and if incorporated into simulation models might improve the predictability of the models in the real-world situations.

Approach:

- Experiment II was conducted to investigate switchgrass growth and development as affected by nitrogen grown in large pots outdoors.

Materials and Methods

Crop husbandry

- Out-door, pot –culture facility (PVC pots with 12-L capacity).
- Row spacing 1 m and 10 plants per pot.
- 120 pots, 40 pots for each treatment, 4 replications per treatment.
- Irrigation - Full strength Hoagland's nutrient solution from emergence to 45 DAS.

Materials and Methods

Nitrogen treatments

- From 45 to 90 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 90 days after sowing.

Nitrogen Switchgrass Growth and Development

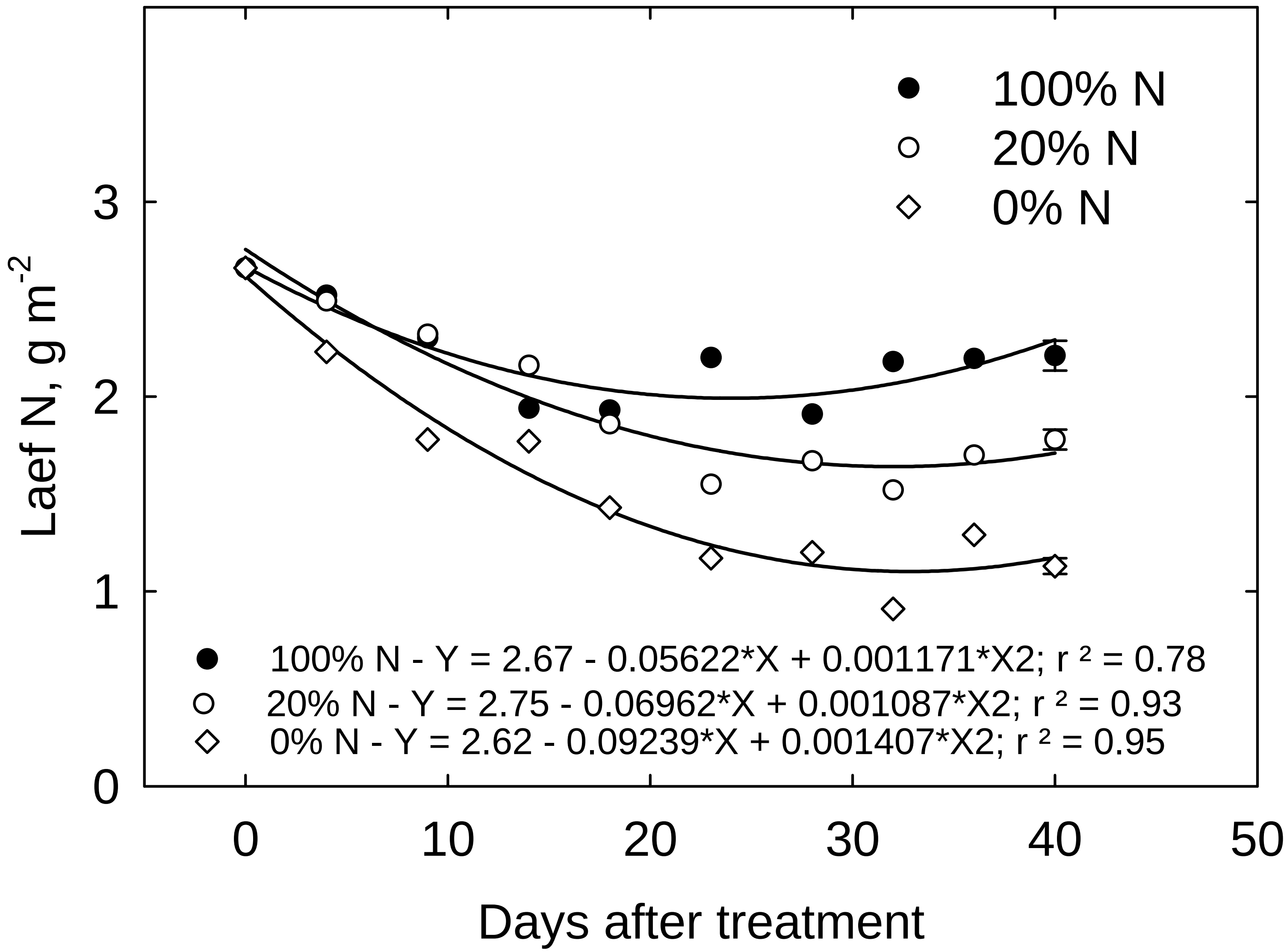
End of the season growth parameters

90 days after sowing or 45 days after treatment

Nitrogen Treatment	Total biomass, g pot^{-1}	Tillers, no. pot^{-1}	Leaf area, m^2 pot^{-1}
100% N	317 ± 28	91 ± 6	1.5 ± 0.09
20% N	276 ± 16	77 ± 2	1.2 ± 0.04
0 % N	219 ± 7	54 ± 6	0.7 ± 0.02

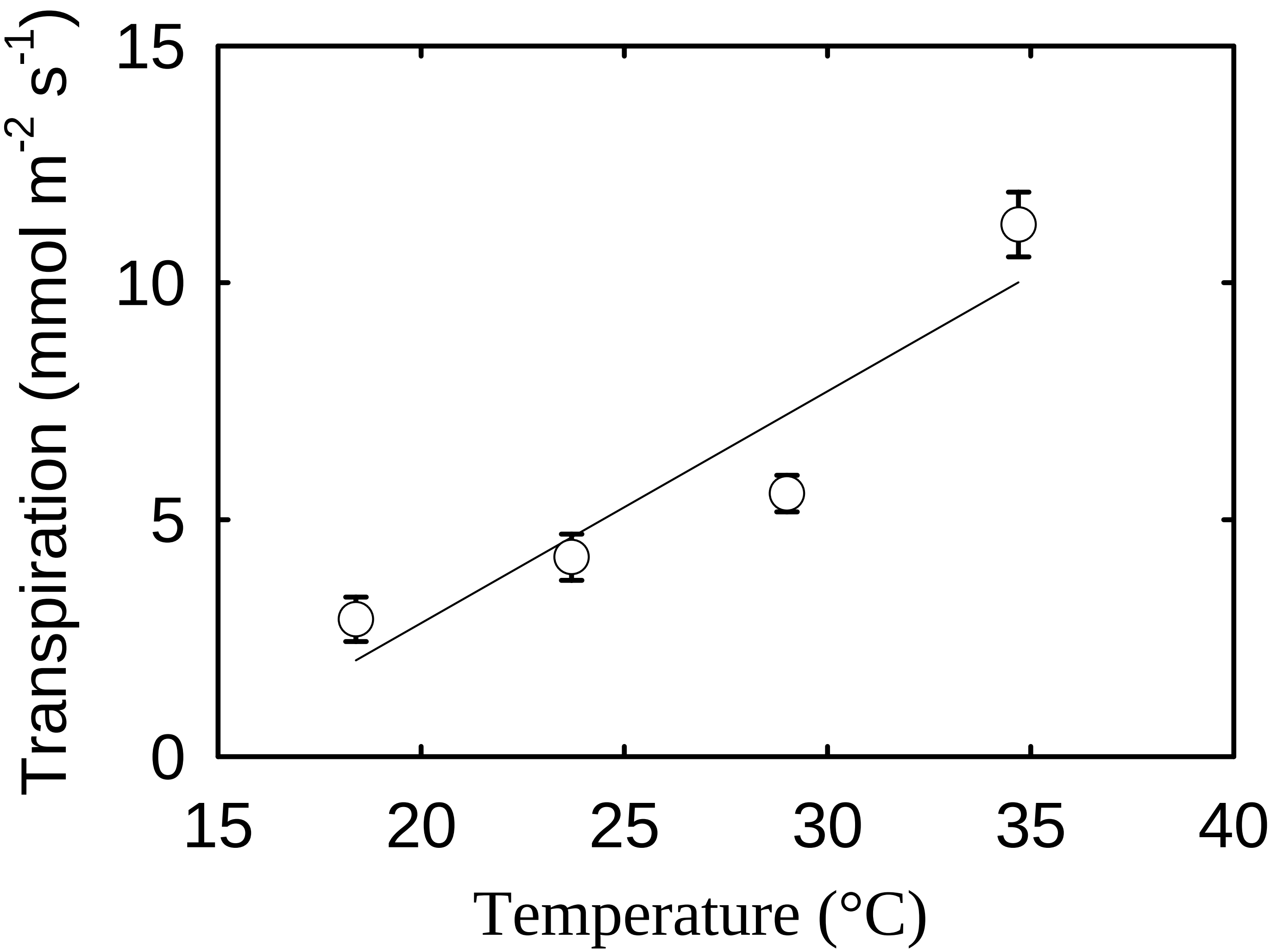
Leaf Nitrogen and Photosynthesis

Switchgrass – Temporal Trends in leaf Nitrogen



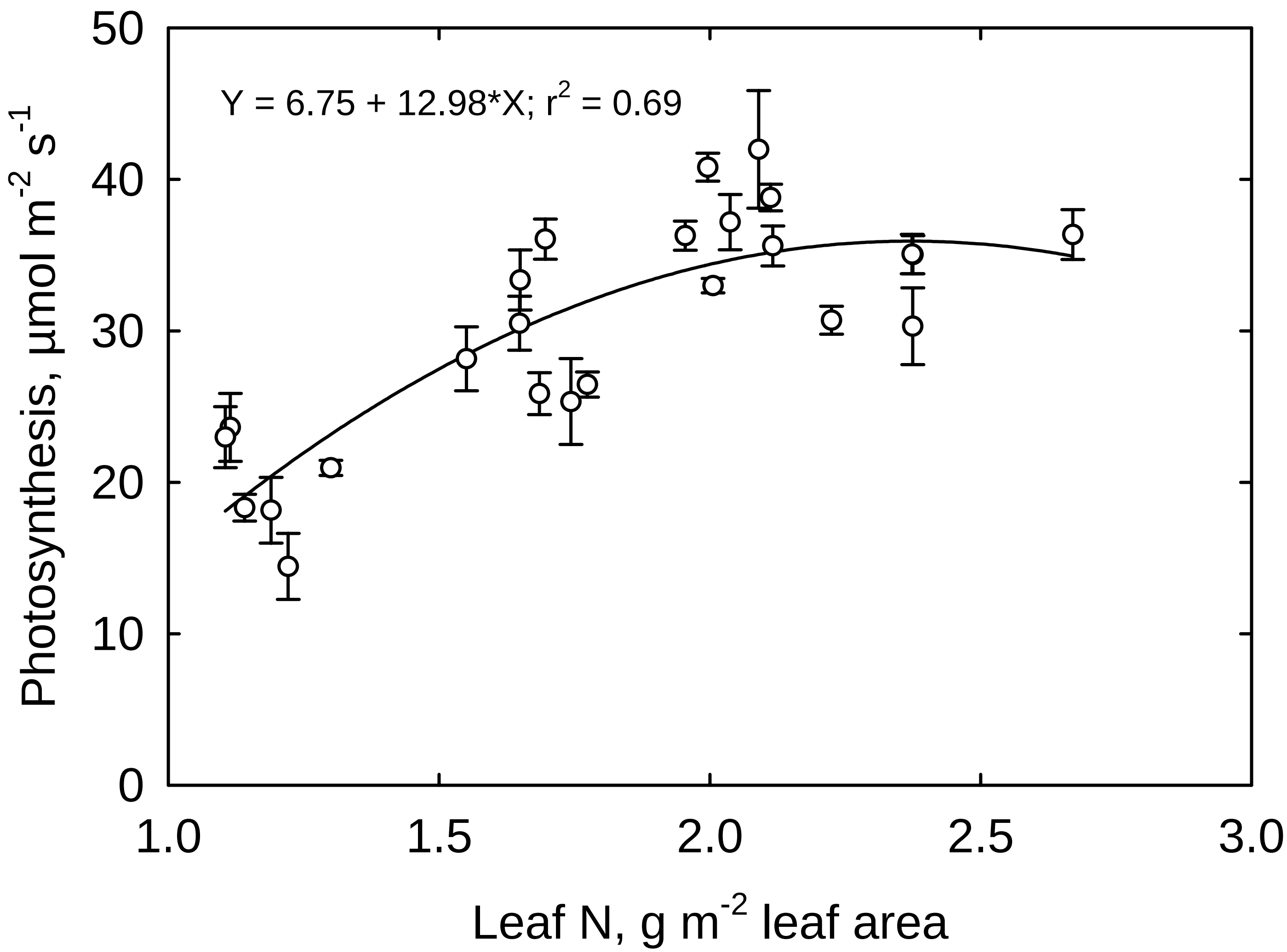
Leaf Nitrogen and Photosynthesis

Switchgrass Photosynthesis and Leaf Nitrogen



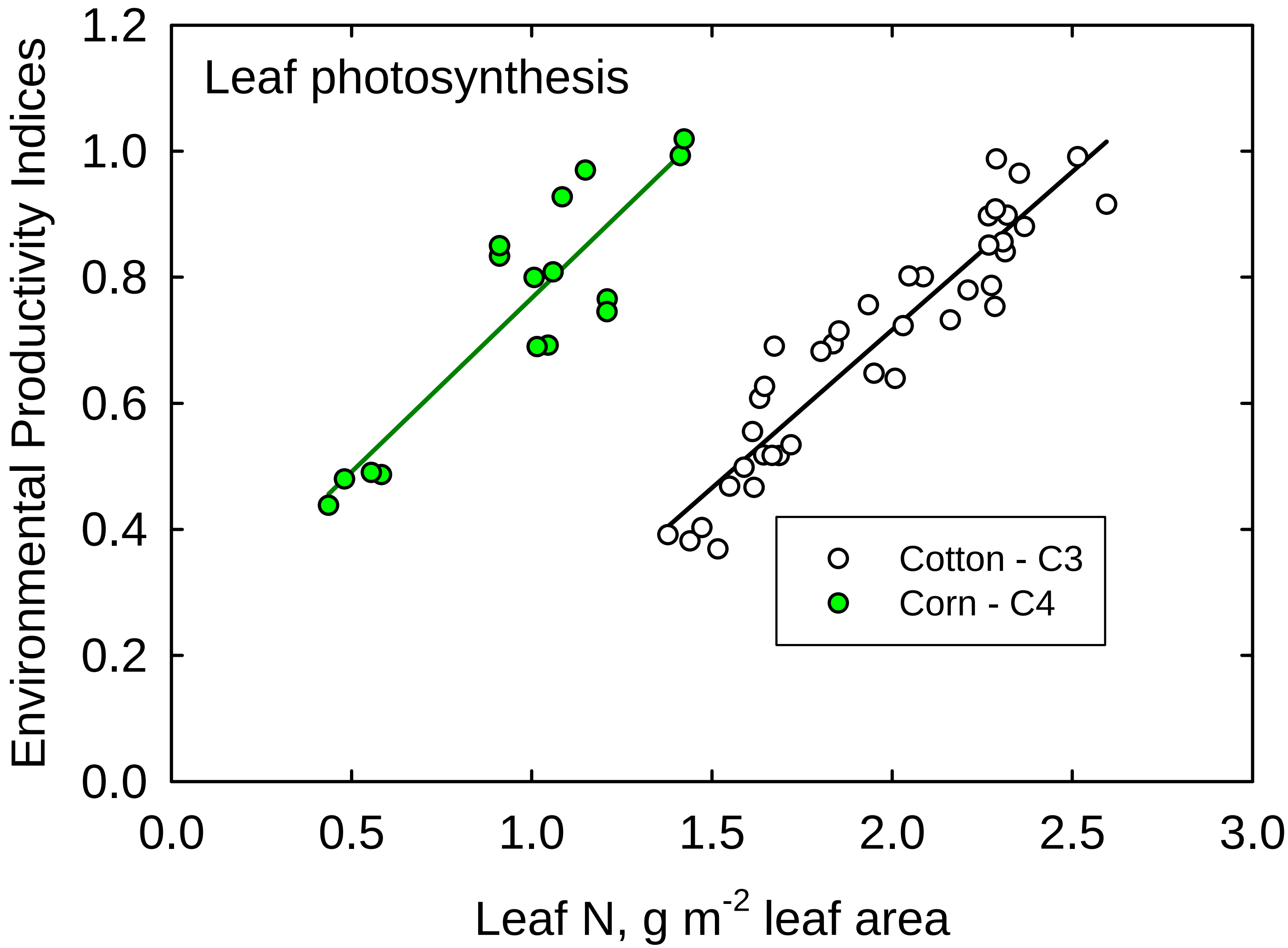
Leaf Nitrogen and Photosynthesis

Switchgrass Photosynthesis and Leaf Nitrogen



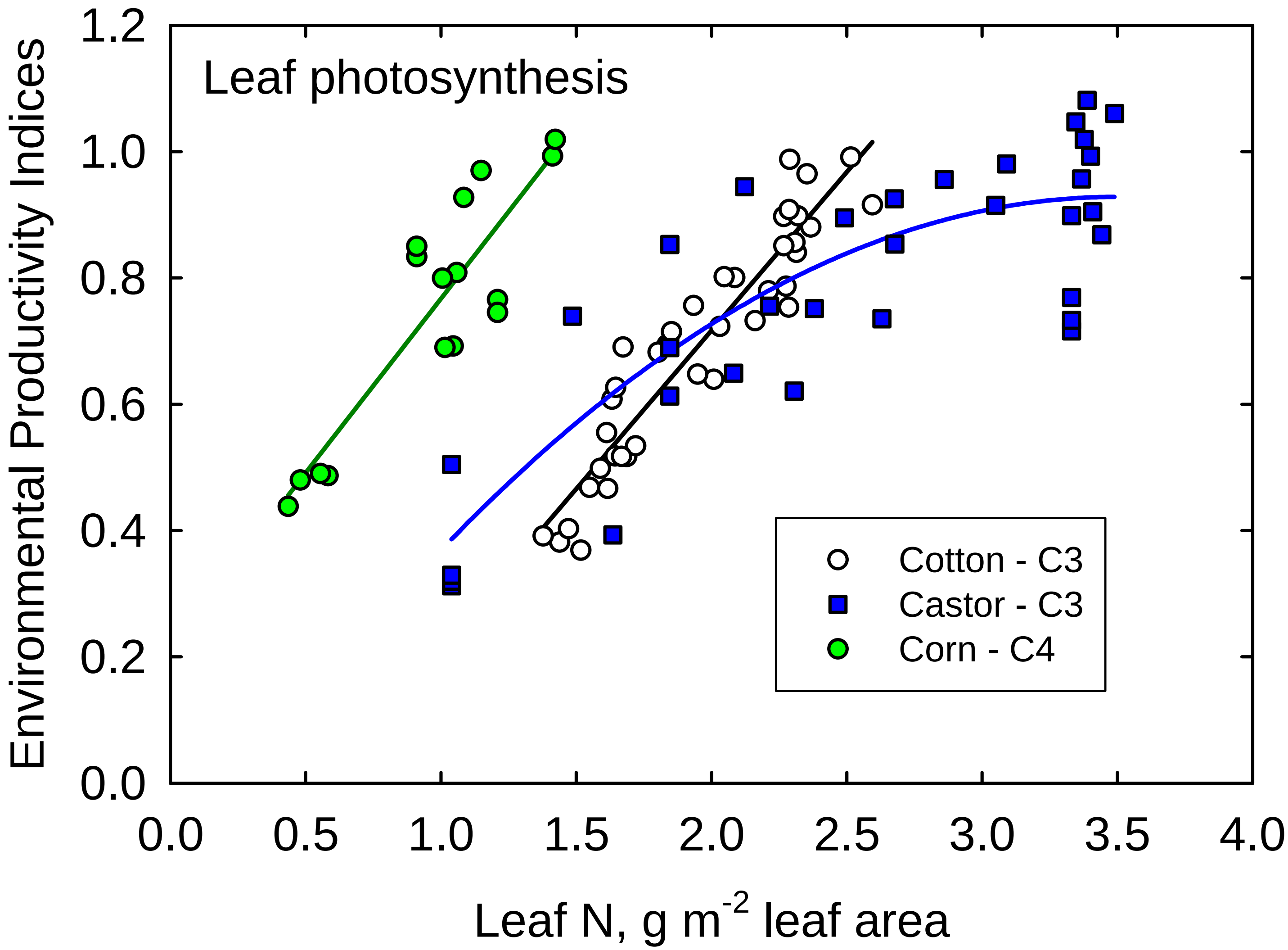
Leaf Nitrogen and Photosynthesis

Functional Groups



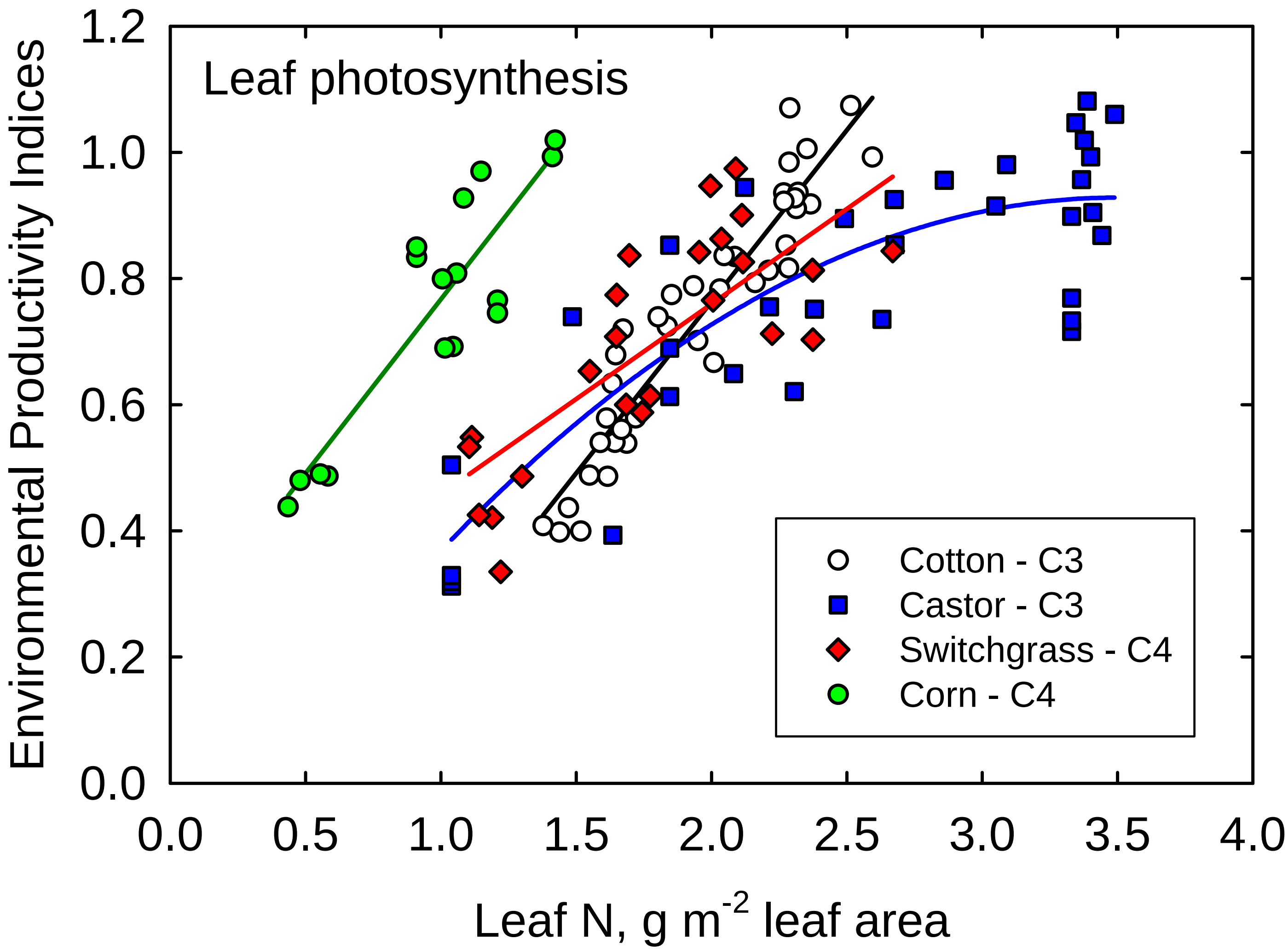
Leaf Nitrogen and Photosynthesis

N and Photosynthesis – Several Crops



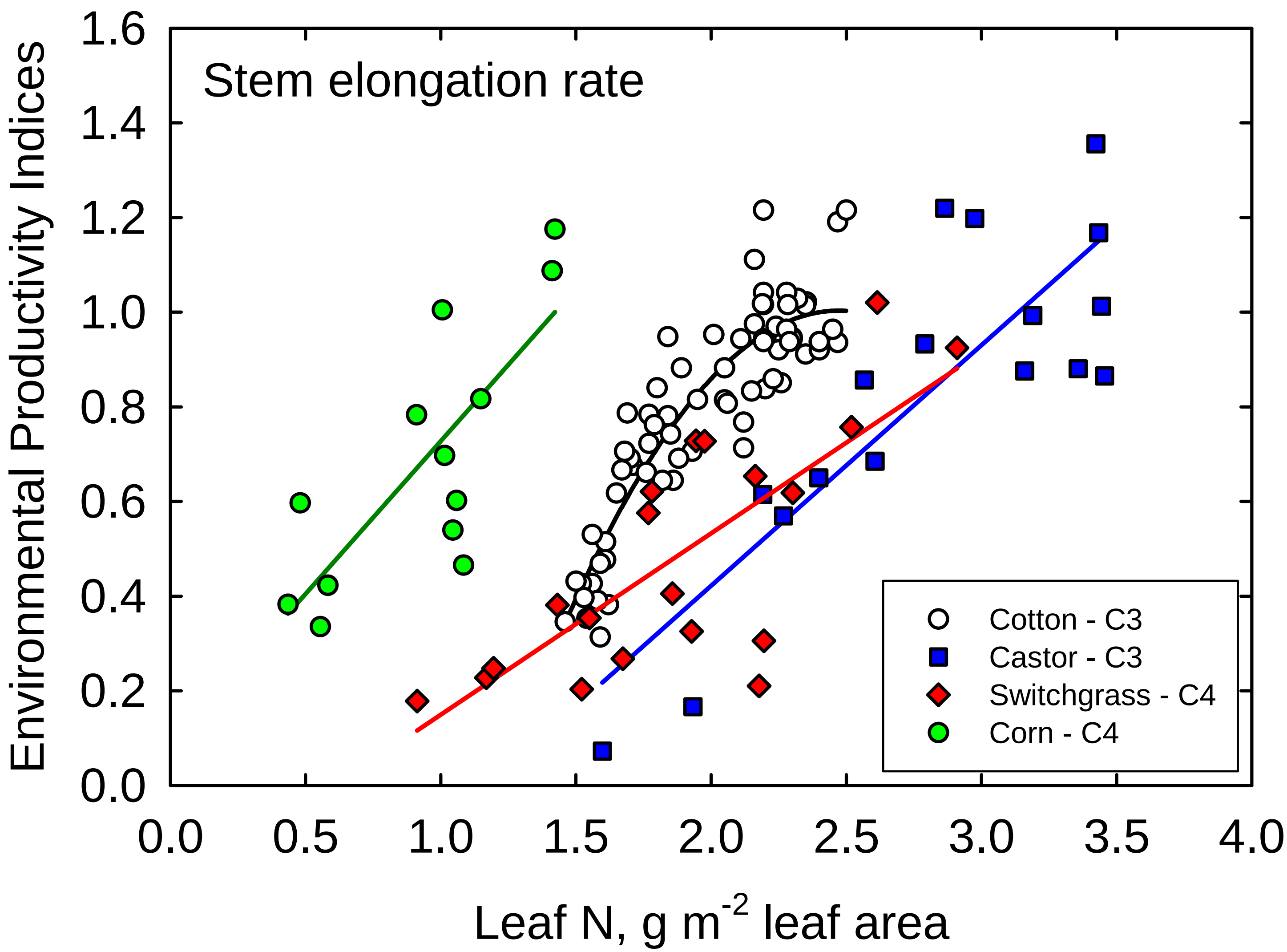
Leaf Nitrogen and Photosynthesis

N and Photosynthesis – Several Crops



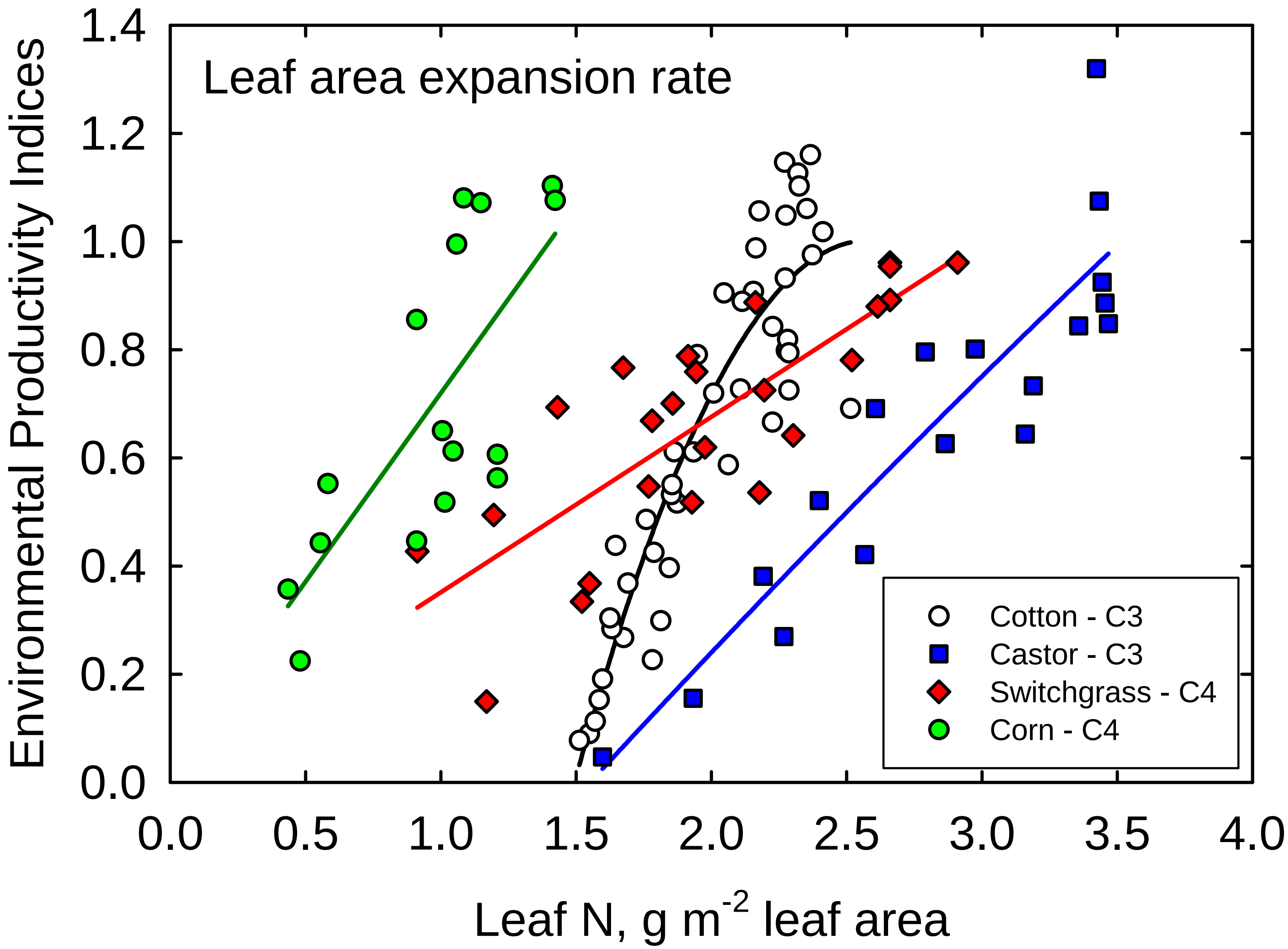
Leaf Nitrogen and Crop Growth and Development

N and Several Crops – Stem Elongation Rates



Leaf Nitrogen and Crop Growth and Development

N and Several Crops – Leaf Area Expansion Rates



Summary and Conclusions

Nitrogen Responses across Species and Processes

- Functional algorithms varied among crop species and even among crop species within the functional physiological group such as C_3 and C_4 species.
- Functional algorithms also varied among crop processes in a given species.
- Among the growth, developmental and physiological processes, leaf growth was more responsive to leaf N in all crops.
- The N-specific functional algorithms will be useful in developing models for various crops.

Acknowledgements

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