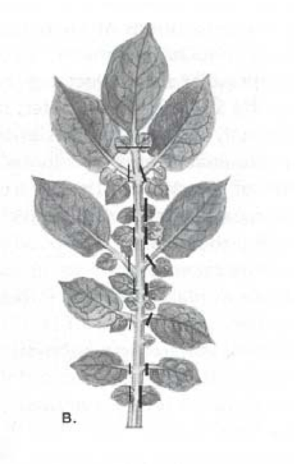
Quantifying Leaf Expansion and Canopy Development in Potato as a Function of Nitrogen and CO_2



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Why Focus on Growth of Individual Leaves When Simulating N Effects?

- Long term growth responses to N are mainly a function of increased leaf area and light interception.
- N also affects structure of the canopy (particularly potato)
- Single leaf growth is necessary for scaling photosynthesis from the leaf to the plant level.

Why Focus on Growth of Individual Leaves When Simulating N Effects?

- Investigate an alternative to simulating the effects of nitrogen on canopy growth at the whole plant level, i.e., the plant is viewed as a "big leaf".

Temperature and CO_2 Effects

- CO_2
  - carbon assimilation rate
  - carbon partitioning
  - N content in the plant
- Temperature
  - Controls potential growth rate when carbon is not limiting

Where Do We Begin?

- Recently, Fleisher and Timlin (2006) presented a method to simulate growth of individual leaves in a potato canopy as a function of temperature and carbon availability.

Objective

- The objective of this study was to quantify leaf expansion rates in potato as a function of nitrogen application rate and CO_2 level and further extend the model.

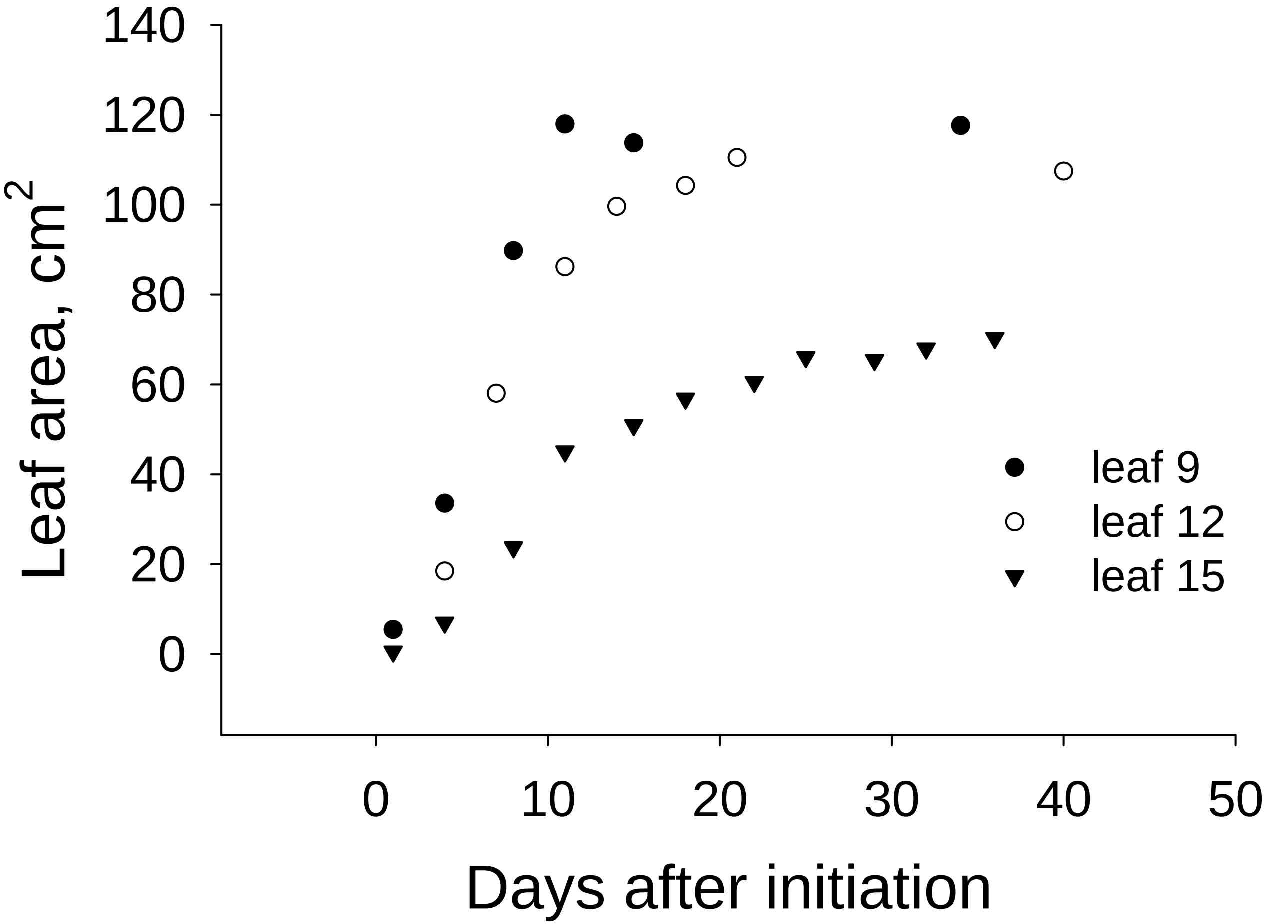
Measurements

- Experiments were carried out in 6 growth chambers
  - Potted plants
  - 6 N levels
  - Two CO_2 levels (applied at early and late summer)

Leaf Measurements

- Mainstem leaves were selected and tagged at three to four insertion points, 6,9, 15 and if available, 18 on five plants in each chamber.
- Leaves on three insertion points on the apical stem were also identified, tagged and measured
- Length, width and leaf addition rates were measured two times a week.

Measured Leaf Growth, 8 mM, High CO_2



Calculation of Growth Duration and Maximum Growth Rate.

- A Gompertz type equation was used to smooth measured leaf expansion data.

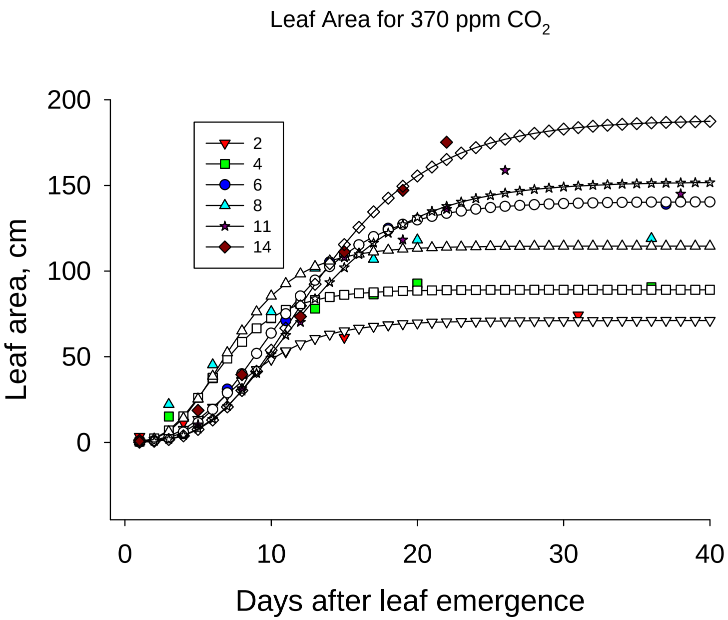
$$A = A_0 Exp\left[\ln\left(\frac{A_f}{A_0}\right)\left(1 - \exp\left(-D \times DAA\right)\right)\right]$$

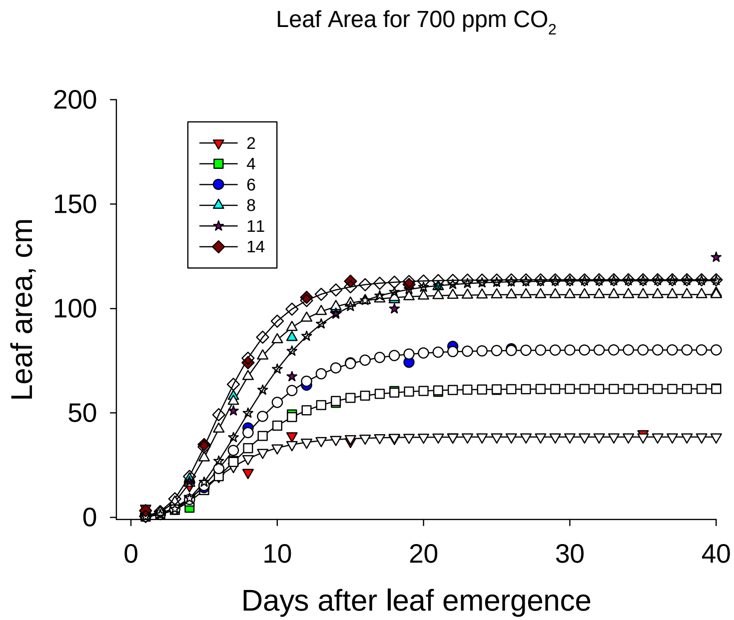
- A is the area of a single leaf (cm^2), A_0 is initial leaf area (0.05 cm^2), A_f is final leaf area, D is decay in specific leaf expansion rate (day^{-1}) and DAA is the days after appearance of the leaf (day).

Derived Calculations

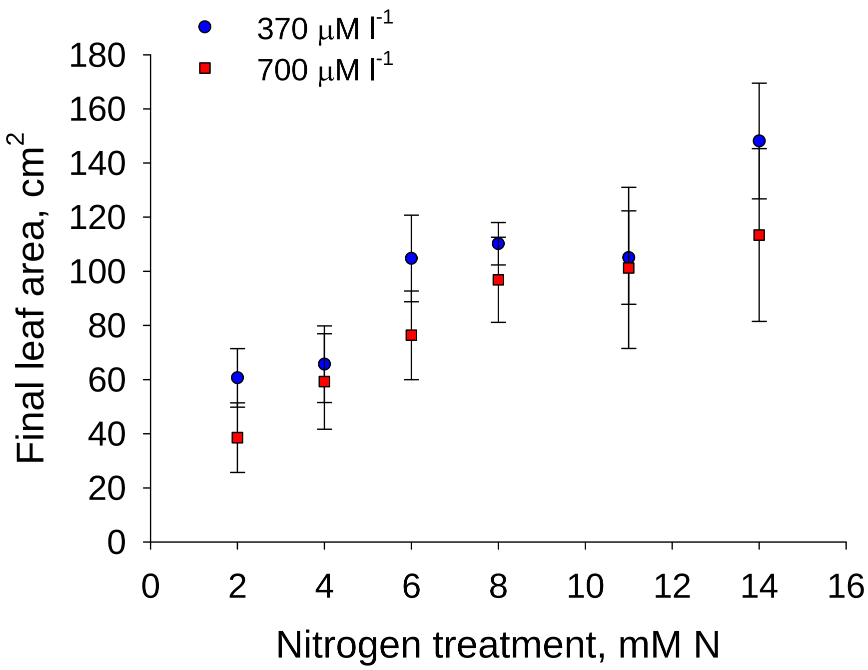
- The first derivative of this equation was used to describe the daily rate of canopy growth (RD_i) at day i.
- Growth duration (the time it takes the leaf to reach 95% of it's final size)
- Average growth rate over that period

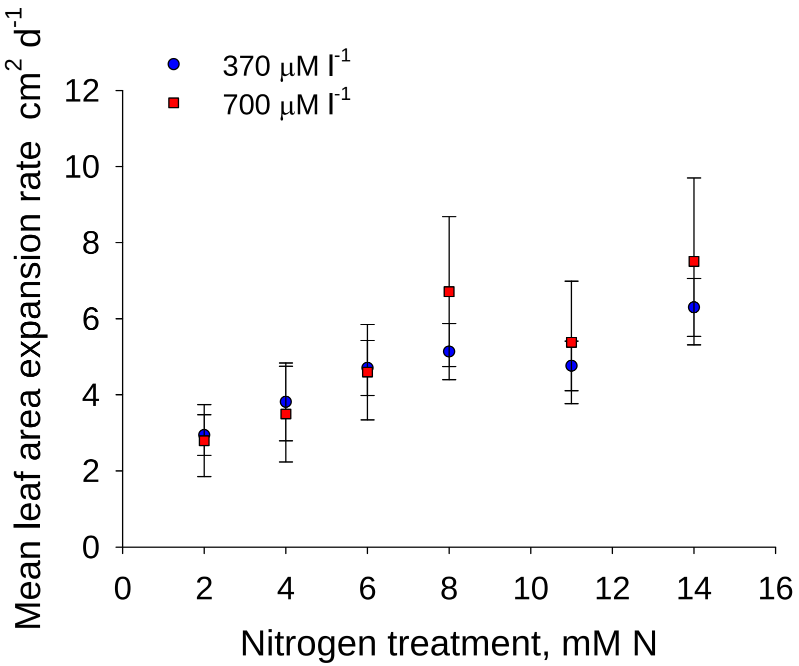
Leaf Area as a Function of Time and CO_2





Measured Final Leaf Area and Leaf Area Expansion Rate



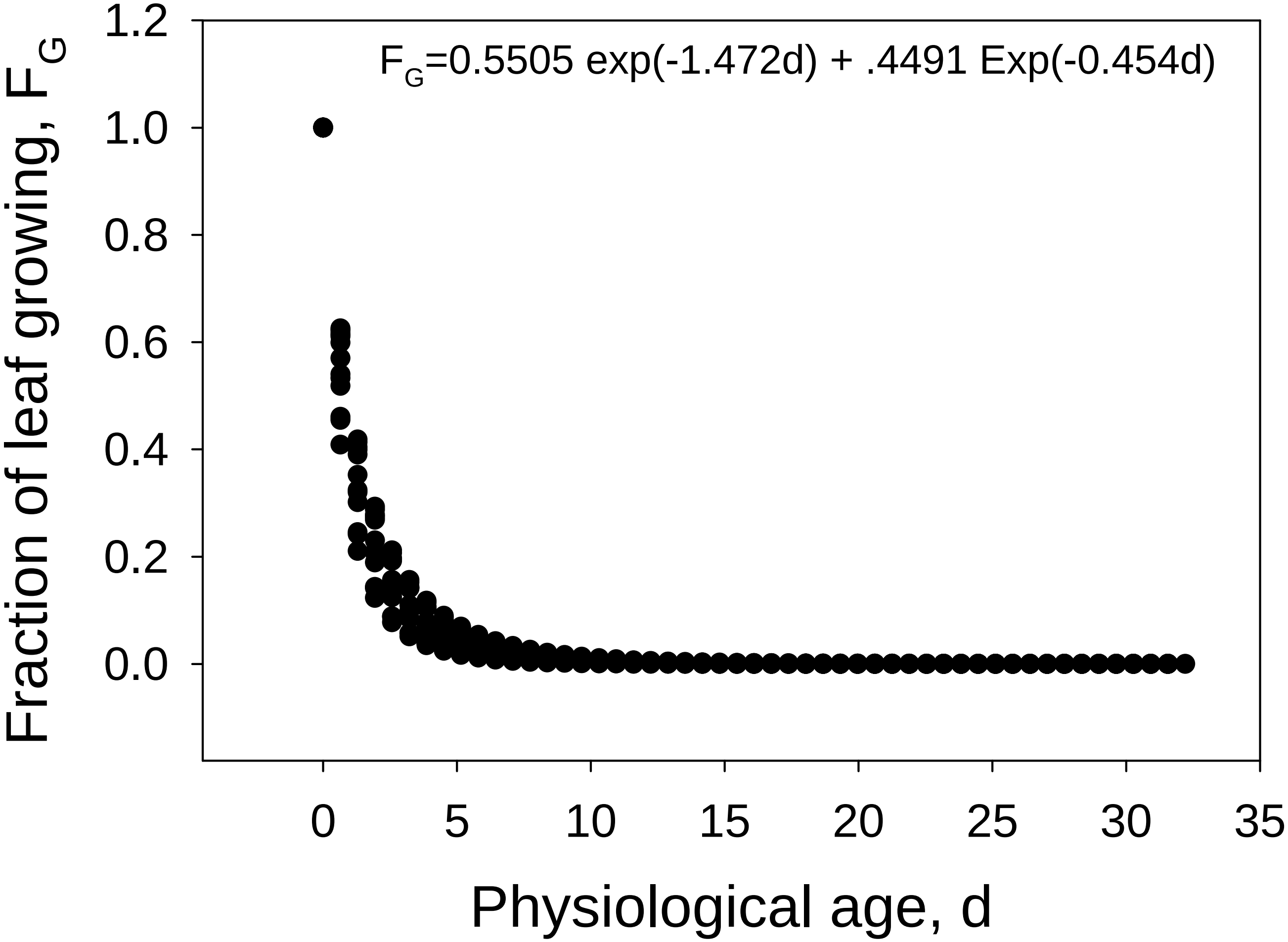


- No significant effect of CO2 treatment. Effect of N was significant only for the low N treatments
- The time to reach 95% of final size was highly variable and not related to N treatment.

- The fraction of leaf growing (F_G)on day i was calculated as:

$$F_{Gi} = \frac{1}{A_{i-1}} \left(\frac{A_i - A_{i-1}}{1} \right)$$

- Time was represented as physiological age, e.g. time scaled by temperature.



15 physiological days are required for the leaf to reach full size

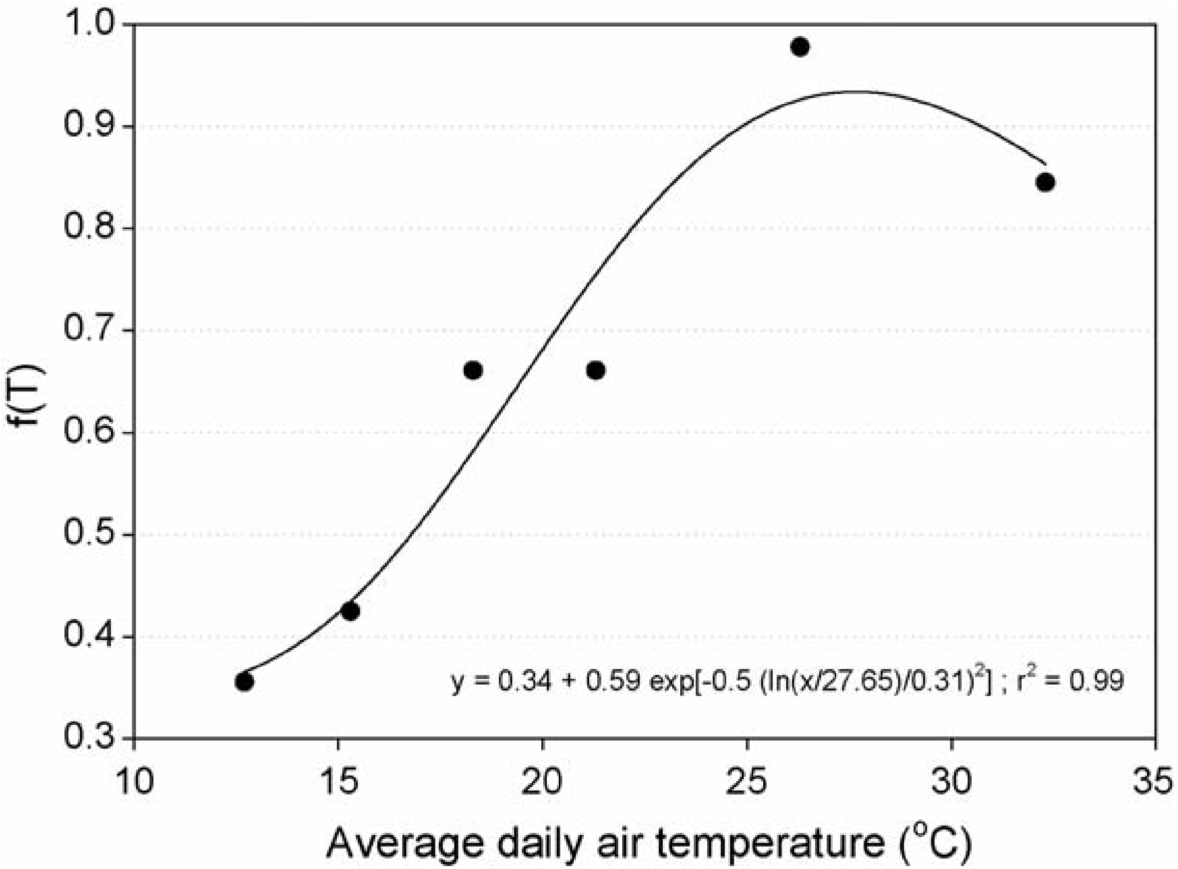
Leaf Size Calculation

- The incremental change in area at the current time step (A_i):

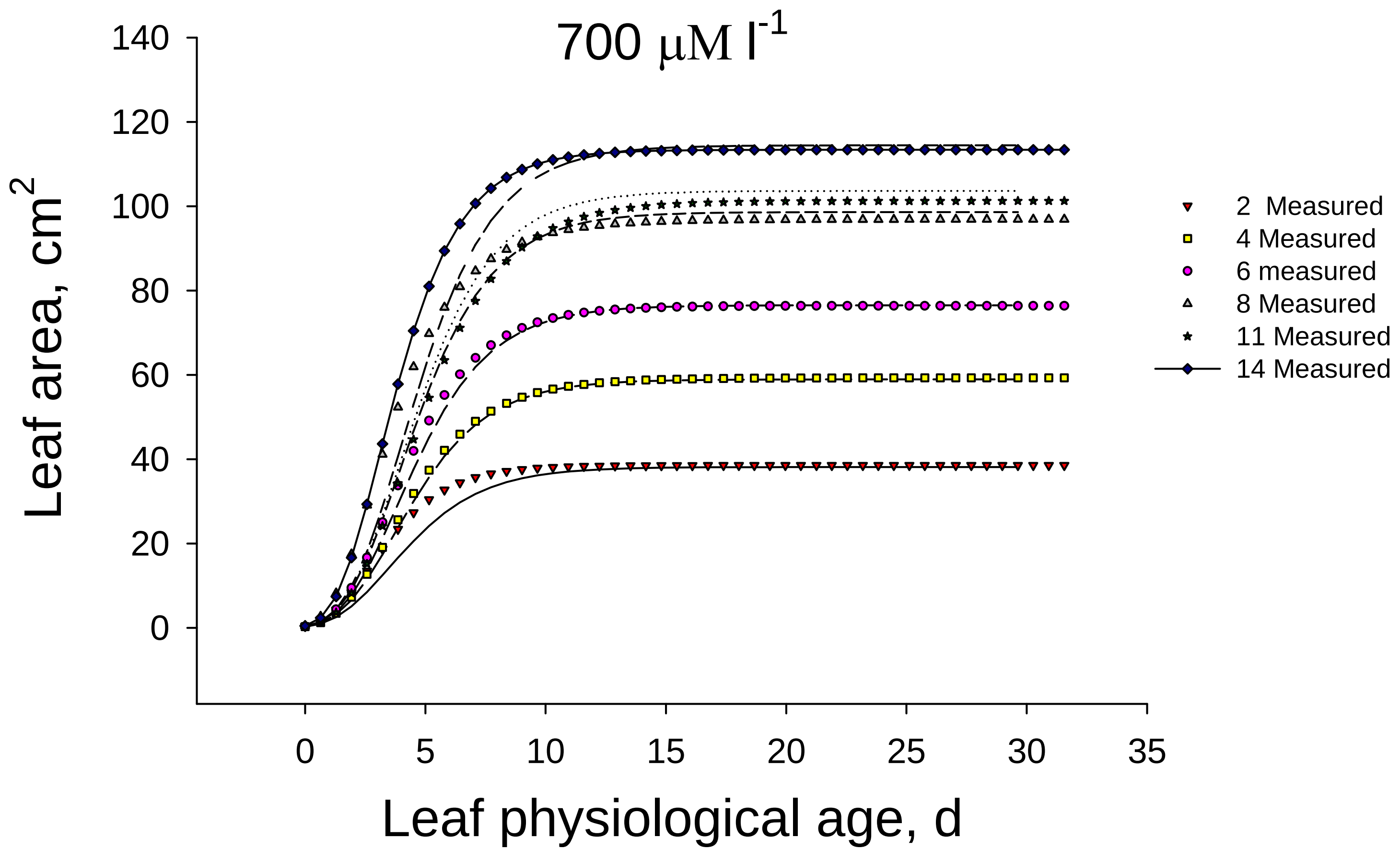
$$\Delta A_i = A_{(i-1)}\left(F_G\right)L_{MAX}\, f\left(T\right)f\left(N\right)$$

- *f(T)* and *f(N)* are functions to adjust for temperature and nitrogen effects (0->1)
- L_{MAX} is the maximum daily growth rate $cm^2\ cm^{-2}\ d^{-1}$
- F_G is the fraction of leaf growing at time *i*
- $A_{(i-1)}$ is the area of the leaf at the previous time step

Temperature Function from Fleisher and Timlin, 2006

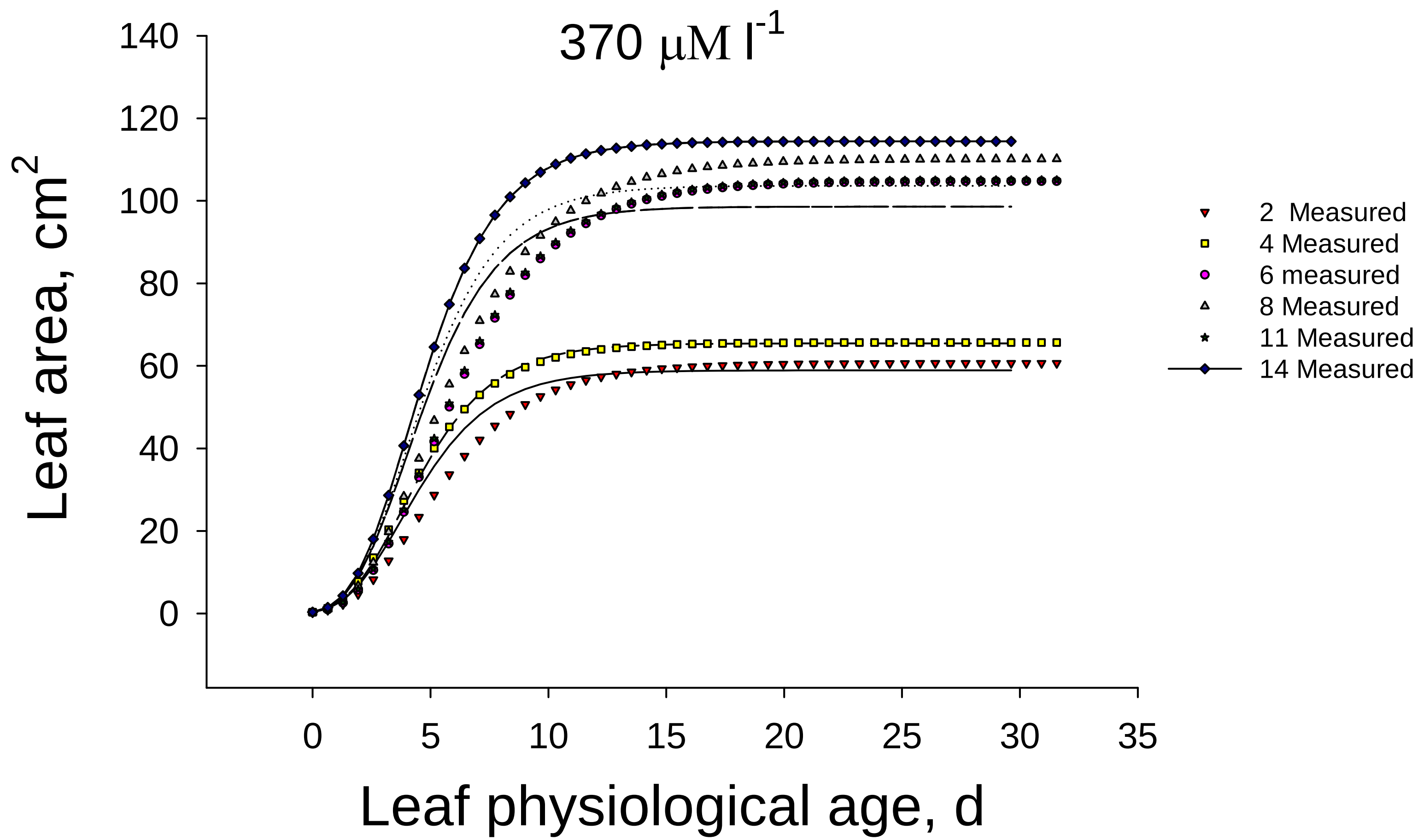


Simulation Results for Elevated CO_2



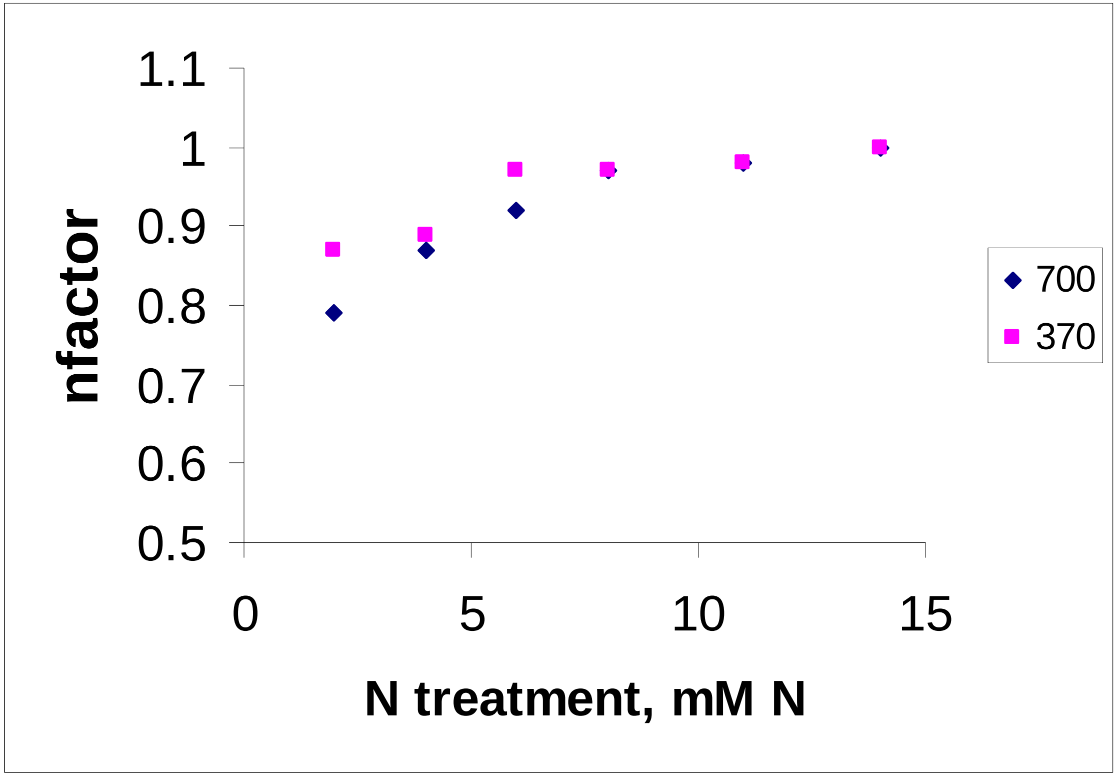
Testing a functional relationship, not a model!

Simulation Results for Ambient CO_2

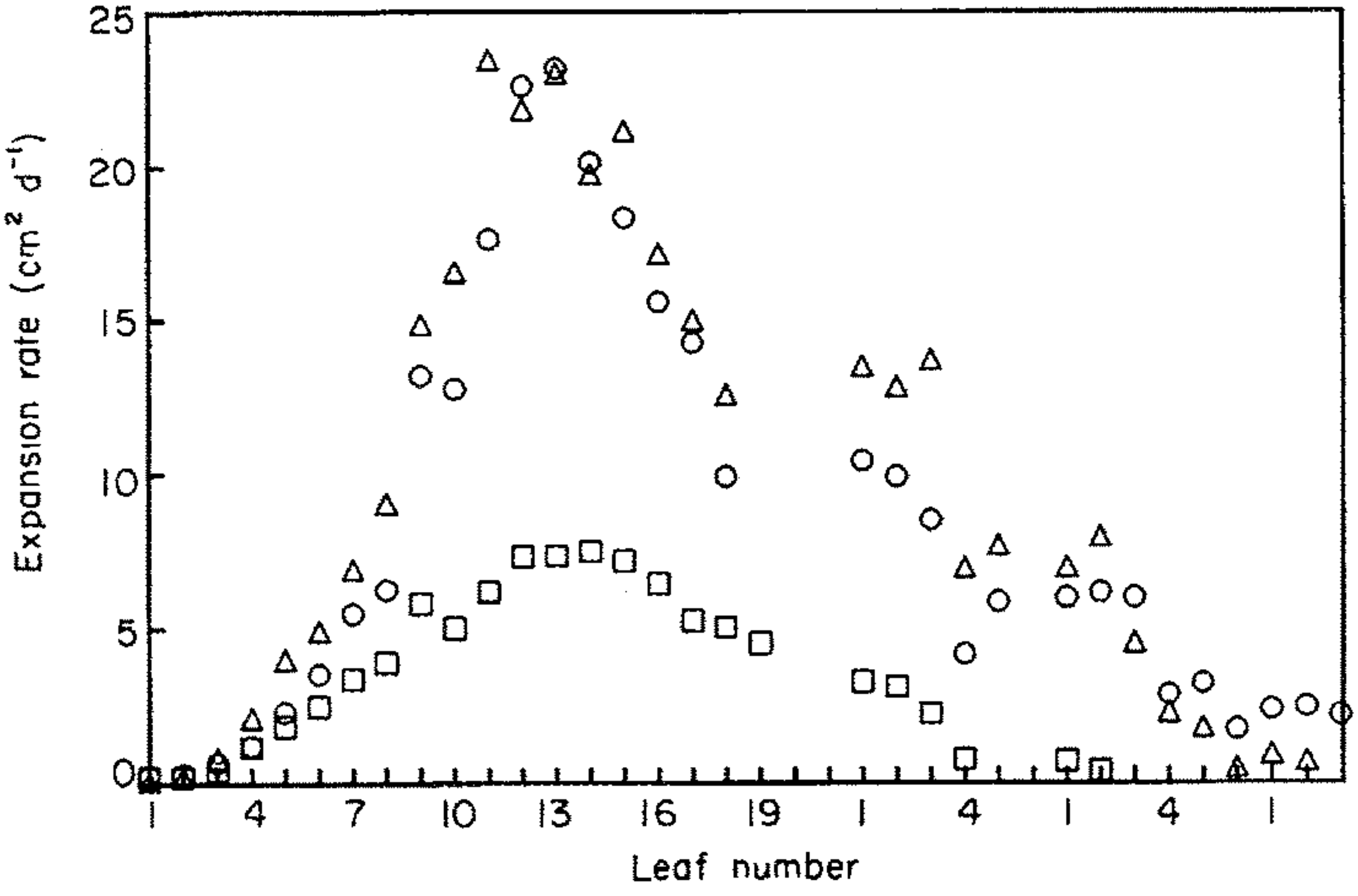


Estimated Nitrogen Response Factor

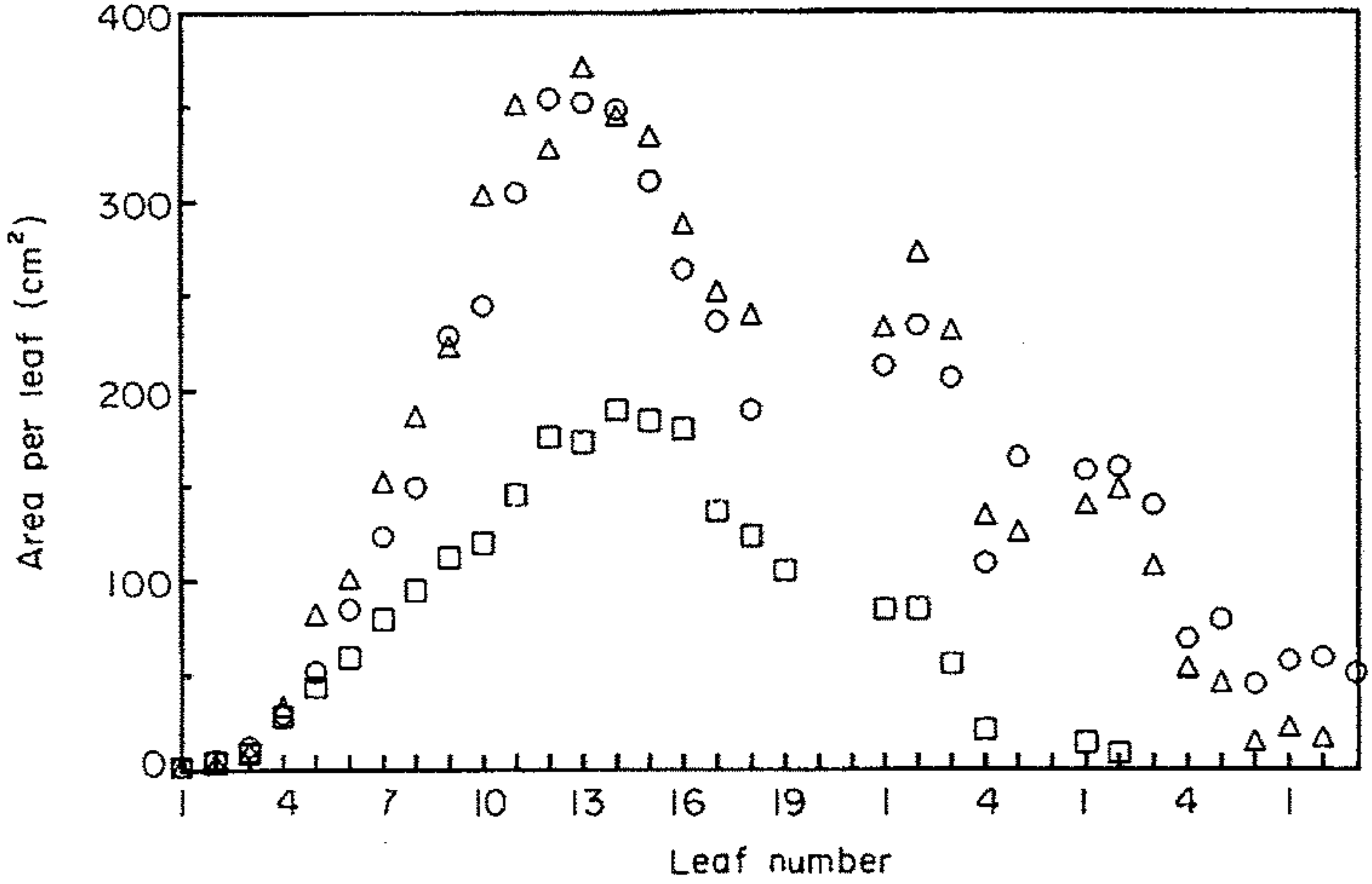
- It is not clear if there is a CO_2 effect. If anything, leaf expansion rates are more sensitive to N at elevated CO_2



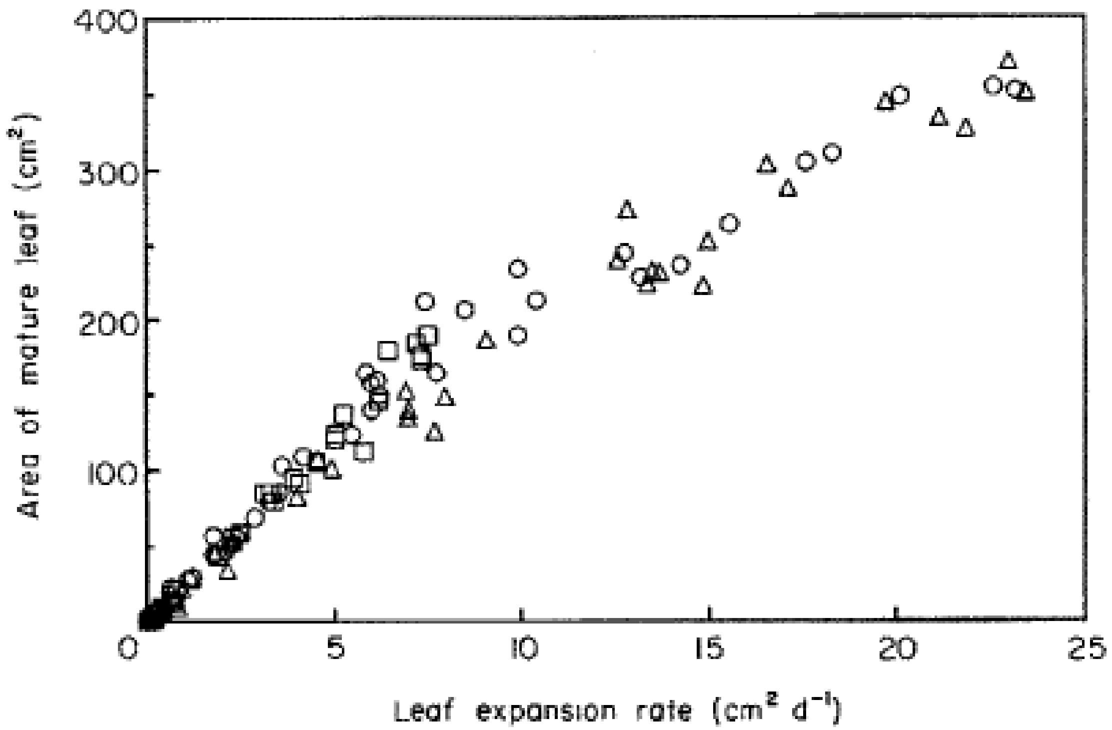
Expansion Rate vs Leaf # and N from Vos and Biemond, 1992



Mature Leaf Area vs Leaf Number, Vos and Biemond, 1992

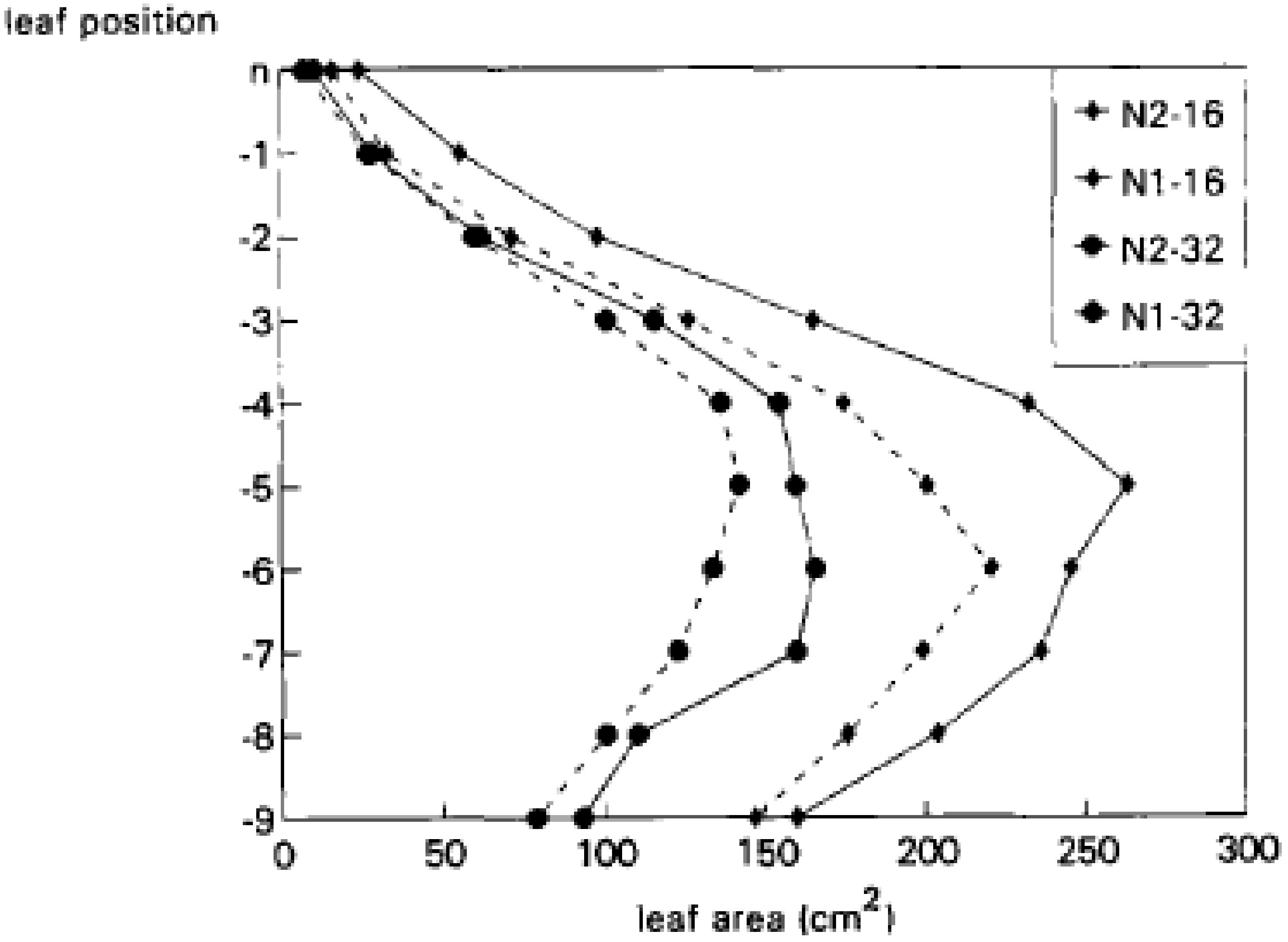


Leaf Expansion Rate and Final Leaf Size



- The slope of this relationship is in units of days and can be understood as the time it takes to reach full leaf size (depends on how the rate is determined). Constant slope implies a constant time to reach full leaf size independent of N rate.

Vertical Distribution of Leaf Area



Conclusions

- The rate of expansion of a leaf and it's final area are functions of nitrogen availability but the growth duration is not.
- A function for leaf expansion rate that accounts for leaf age effects on growth rate with temperature and nitrogen adjustments appears to be a promising method to simulate leaf expansion in potato.

Limitations

- These results were achieved by using mean expansion data from several mainstem leaves. We need to see if this can be extended to single leaves, and to apical and branch leaves.
- Carbon limitations also affect leaf expansion rates, especially for higher order leaves in potato. This also will be addressed in the model.