Plant Metaphenomics: Building a unified framework for interpreting plant growth responses to diverse environmental variables

Hendrik Poorter, Forschungszentrum Jülich, Germany

EPSO: The European Plant Science Organisation
EPSO Workshop on Plant Phenotyping
November 02-03, 2009
Forschungszentrum Jülich, Germany

Forschungszentrum Jülich, Germany
ICG-3: Phytosphere
Jülich Plant Phenotyping Centre (JPPC)
Website: http://www.jppc.de

http://www.plantphenomics.com/phenotyping2009

Meta-phenomics:

building a unified framework for interpreting plant growth responses to diverse environmental variables

Hendrik Poorter
ICG-3, FZJ

Bayesian statistics:

Data + Prior knowledge → Posterior

Prior knowledge:

Current knowledge:

		Pages / year
1	J. Exp. Bot.	3700
2	New Phytologist	3500
3	Oecologia	3200
4	Glob. Change Biol.	2500
5	Plant Physiology	2400

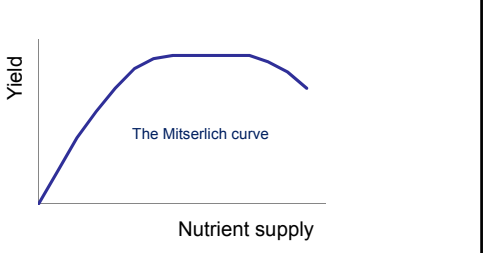
3200 pages * 30 journals ≈

10^5 pages year^{-1} !!!

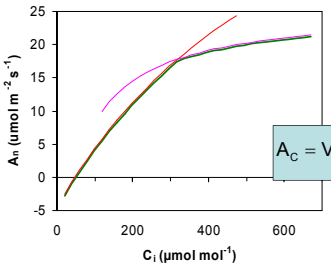
Structured knowledge:

Unstructured knowledge:

Dose-response curves:



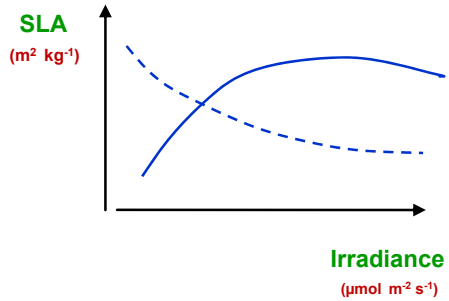
A short-term response curve:



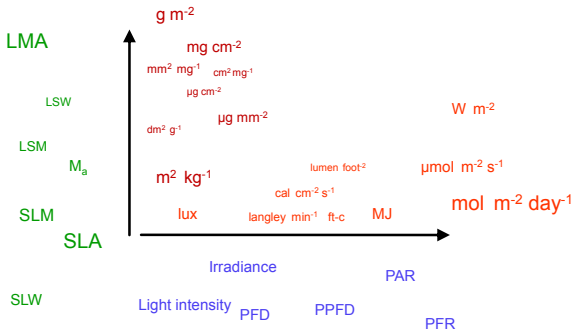
$$A_C = V_{CMAX} \cdot \frac{C - \Gamma_*}{C + K_C(1 + O/K_O)} - R_d$$

$$A_J = J \cdot \frac{C - \Gamma_*}{4C + 8\Gamma_*} - R_d$$

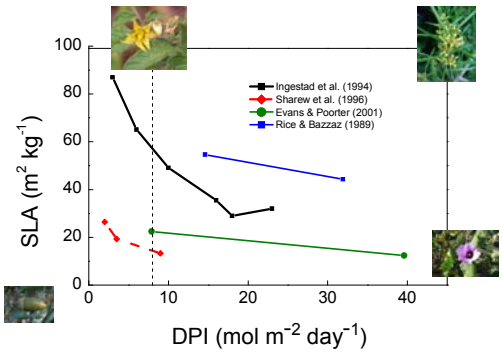
A clear picture:



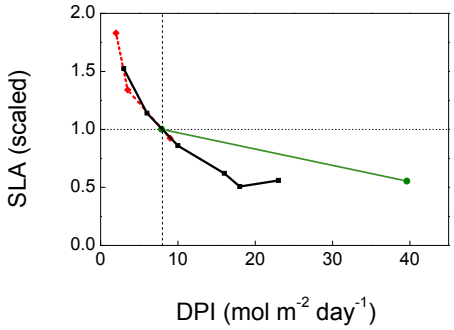
SLA vs Light: Babylonian confusion



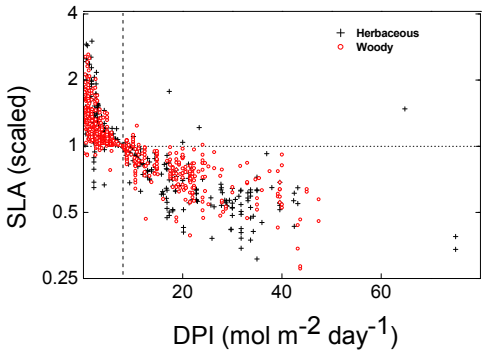
The idea: generalise across experiments



After normalisation:



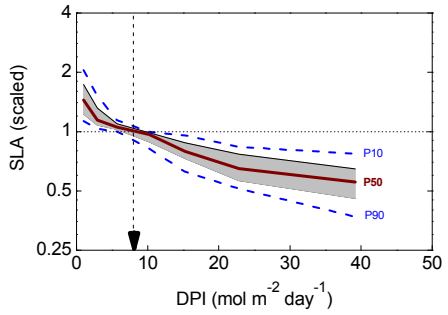
>1000 data points from >150 experiments on >300 species:



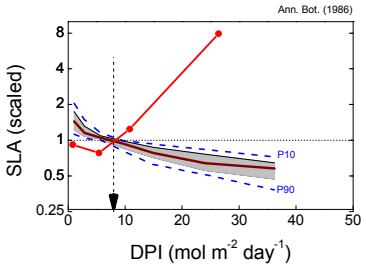
Can we make any generalisations?

- Is the response positive or negative?
- Is the response linear or not?
- What are the 'normal limits' ?

Median and the interquartile range for 7 light classes:

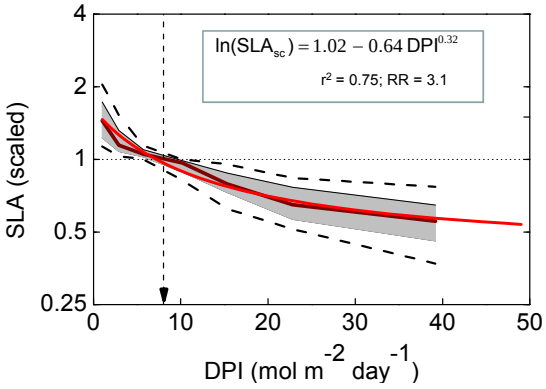


A tropical outlier:

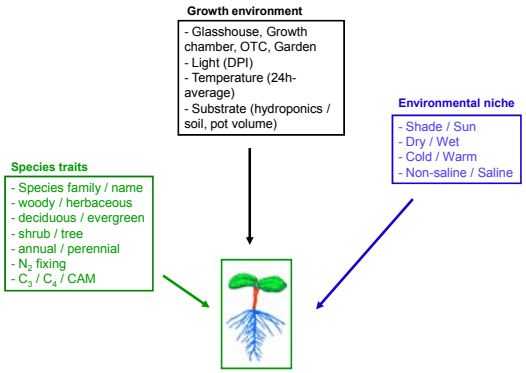


Terminalia ivorensis

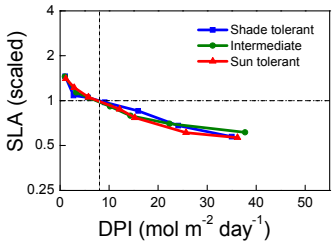
An overall non-linear equation:



Are there differences between subgroups?



Are there differences in plasticity within subgroups?

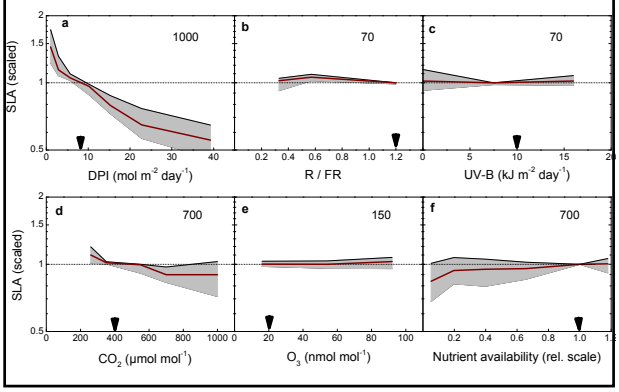


How about other environmental factors?

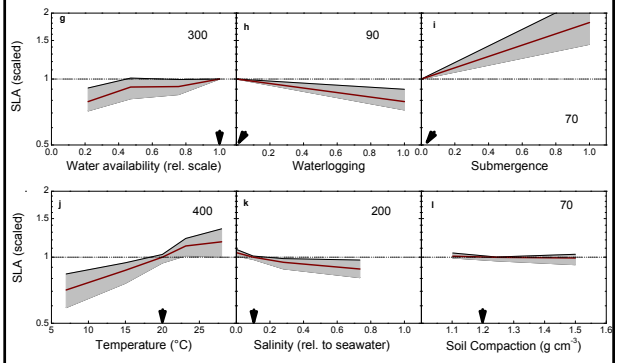
Stress box

1. Light quantity (DPI)
2. Light quality (R/FR)
3. UV-B
4. CO_2
5. O_3
6. Nutrient availability (N, P, G)
7. Drought stress
8. Waterlogging
9. Submergence
10. Temperature
11. Salinity
12. Soil compaction

SLA responses to light, gases, and nutrients:



SLA responses to water, temperature, salinity and soil compaction:



Response Ratios:

	Range		RR
Irradiance	1 – 50	mol m-2 day-1	**3.1**
CO_2	200 – 1200	µmol mol-1	1.4
Salinity	0 – 100	% seawater	1.2
Waterlogging	- – +		1.1
Compaction	1.0 – 1.6	g cm-3	1.1

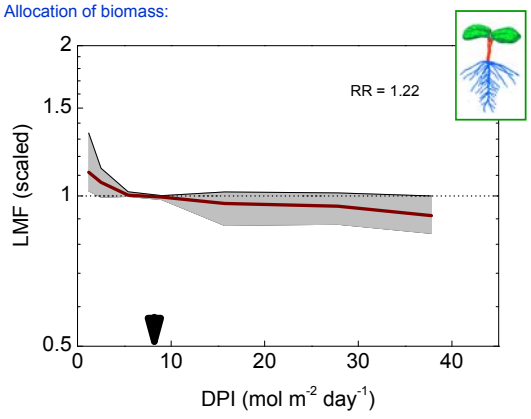
R : FR	0.2 – 1.2	mol mol-1	1.0
UV-B	1 – 20	kJ m-2 day-1	1.0
O_3	5 – 100	nmol mol-1	1.0

Nutrients	0.05 – 1	rel. units	1.1
Water (Drought)	0.05 – 1	rel. units	1.3
Submergence	- – +		**1.8**
Temperature	5 – 35	°C	**2.3**

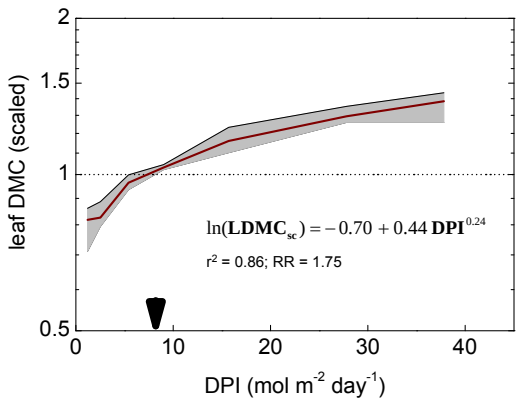
The matrix has a 3rd dimension:

Env. Factor	SLA	Trait 2	Trait 3	Trait 4	....	Trait n
1	✓	✗	✗	✗	✗	✗
2	✓	✗	✗	✗	✗	✗
3	✓	✗	✗	✗	✗	✗
4	✓	✗	✗	✗	✗	✗
5	✓	✗	✗	✗	✗	✗
6	✓	✗	✗	✗	✗	✗
...	✓	✗	✗	✗	✗	✗
12	✓	✗	✗	✗	✗	✗

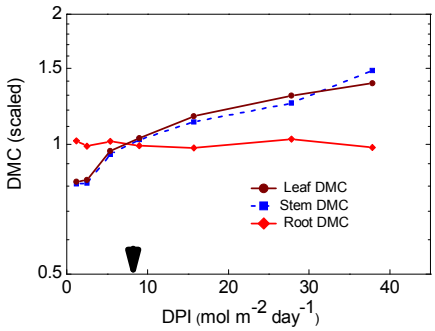
Allocation of biomass:

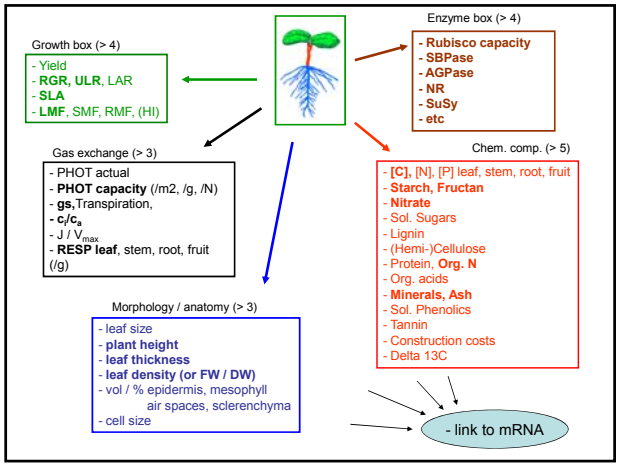


There are many other relevant plant traits:



DMC of leaves, stems and roots:





Current status:

Collated Database:

# of experiments	> 1000
# of species	> 800
# of env. factors	12
# of variables	9

Conclusions:

This approach :

- Is able to summarise data across many experiments and species
- Yields quantitative response curves
- As well as normal limits

- Is applicable to (almost all) environmental factors
- Is applicable to all plant traits
- Useful for modeling

More info:

- www.metaphenomics.org

- Poorter H, Niinemets Ü, Poorter L, Wright I, Villar R. (2009) Causes and consequences of variation in leaf mass per area (LMA): a meta-analysis. New Phytol. 182: 565-588.

- Poorter H, Niinemets Ü, Walter A, Fiorani F, Schurr U. (2010) A method to construct dose-response curves for a wide range of environmental factors and plant traits by means of a meta-analysis of phenotypic data. J. Exp. Bot., in press.

Thanks to:

Ülo Niinemets, EMU
Achim Walter, FZJ
Fabio Fiorani, Crop Design
Uli Schurr, FZJ

Francesco Ripullone
Catherine Roumet
Peter Ryser
Dylan Schwilk
Jan Henk Venema
Rafael Villar

Ismael Aranda
Owen Atkin
Corine de Groot
Yulong Feng
Jurg Franzaring
Keith Funnell

Vaughan Hurry
Maarit Mäenpää
Leo Marcelis
Thijs Pons
Lourens Poorter
Dina Rhonzina