Demonstrating the functional role of traits for plant performance: a mechanistic modeling approach

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What are plant traits?

A simple definition:

Morphological or physiological characteristics with a function for plant to subsist in its local environment

→ Response traits (Lavorel et al. 2007 for review)
Traits co-vary along axis of specialization:

Notion of trade-off and trait syndrome

Conservative syndrome

Exploitative syndrome

Axis of specialization

Diaz et al. 2004
Traits co-vary along axis of specialization:

Notion of trade-off and trait syndrome

Difficulty to test effect of particular trait on plant performance due to trade-off among traits
A modeling approach to isolate trait effect on plant performance

**GEMINI**

*(Grassland Ecosystem Model with INdividual centered Interactions)*

Environmental variables

Demographic models

Ecophysiologic biochemistry models

**Individual centred**

*Model*

Demography & Morphology

Population Dynamics

Level of biodiversity

Flux Models

C, N, H₂O

Acquisition and Utilisation
GEMINI is composed by different submodels

Overall 74 physiological and morphological parameters are needed for plants

Parameterized and evaluated on 13 grasses species (monoculture) grown in 2003-2004

Maire et al. in prep

More informations see: www2.clermont.inra.fr/discover/gemini/model.htm & www.the-jena-experiment.de
Testing traits effect on plant performance using a sensitivity analysis

4 traits were selected

- two leaf traits (LDMC, Ph0) and two stature traits (D0, L0)

Hypothesis

- Strong linkages within leaf traits (D0 and L0) and within stature traits (LDMC, Ph0) (Wright et al. 2004)

- Independence between Leaf traits and stature traits (Ackerly 2004, Gross et al. 2007)
Testing traits effect on plant performance using a sensitivity analysis

12 grasses species were used

Tested only effect of morphological traits
Monoculture at equilibrium
No Reproductive stage
No water limitation
Environnement 2003-2004

Traits space exploration

10 value of traits per species
in a full factorials design

In total

12 species x 10 value ^4 traits x 2 N conditions = 240 000 simulations ran with monoculture growth conditions 2003/2004
Trade-off at inter-specific level
One trait value maximize plant performance
In the 4D space traits:

traits combinations which maximize plant performance

Trade-off among traits and among species is well predicted by the model which current plant schema (Grime 1977, Westoby 1998)
Some insight coming from the modeling approach

- Plant traits observed in the field maximize resource utilization and plant performance
  
  Best light interception, N absorption, N leaf concentration predicted in the model

- Each species can be viewed as an island, a particular traits combination which locally maximize plant fitness in the traits space

- Our study did not show why species differed in traits syndrome (Selection along ecological gradients...), but can explain why trade-offs among traits exist (all combinations are not equal)
Trade-off at intra-specific level

and interaction among traits
Interaction between tiller density and plant height

Ridge which maximize plant performance

Consistently with our hypothesis there is a negative trade-off between tiller density and plant height

Constraint between traits change depending on plant syndrome
Conclusion and Perspective

**Conclusion**

- By using a modeling approach we demonstrated the functional role of traits for plant performance.

- Species are organize along trade-off of traits where species maximize their performance.

- Trade-off exist both between and within species but are not necessarily the same.

**Perspective**

Studying the impact of plant plasticity in response to change in abiotic conditions.

Linkage between species interactions and plant traits: Plasticity, convergence, divergence...
Thank you!!!
Interaction between tiller density and LDMC

Within species there is a strong linkage between LDMC and tiller density

Not necessary observed at inter-specific level

Constraint between traits change depending on plant syndrome

Some combinations in the traits space are equivalent

→ Not same level of plasticity in function of traits syndromes
Leaf Life Span

SLA

Leaf Life Span
Interactions between two traits: Four possibilities

1. A***
   B ns
   A x B ns

2. A***
   B***
   A x B ns

3. A***
   B ns
   A x B ***

4. A***
   B***
   A x B ***
In the 4D space traits: traits combinations which maximize plant performance

This ACP concordant with the Grime Model CSR (1977)

Trait max predicted by the mode are strongly related with observed traits measured in the field