How can 3D virtual plant help to better understand plant physiology and genotype-environment interactions?

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Aim – 3D virtual plants allow to take into account the plant architecture in plant modelling. They were developed here in different species and for different genotypes to characterize the local light environment of the plant, to investigate plant physiology in response to light, to better understand the genotype-environment interactions, to quantify the impact of different architectural traits involved in integrated responses and finally to forecast plant development in response to its environment.

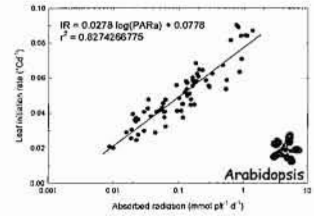
Characterisation of the local plant environment

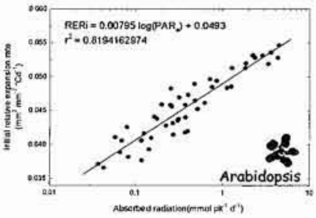
Map of the amount of radiation absorbed by a sunflower plant.

When coupled with microclimatic model, 3D virtual plants allow the characterisation of the environment at the high throughout scale by taking into account the interactions between the plant and the environment (Chelle 2005, Dauzat & Eroy, 1997).

The amount of radiation absorbed by the plant was calculated based on measurements of plant architecture and light environment, for the whole vegetative period (Rey et al. 2004; Chenu et al. 2005).

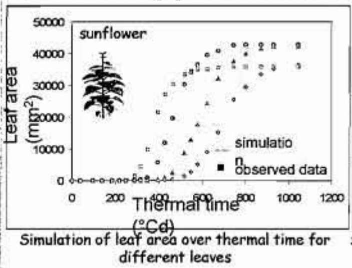
Plant physiology related to plant environment



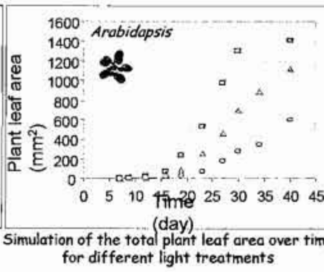


Through the accurate characterisation of the environment, 3D virtual plants allowed us to find out some robust relationships between plant development and plant environment. In *Arabidopsis* and sunflower early leaf development is related to the amount of radiation absorbed by the plant and could then be driven by trophic factors (Rey et al. 2004; Chenu et al. 2005).

Forecasting plant behaviour



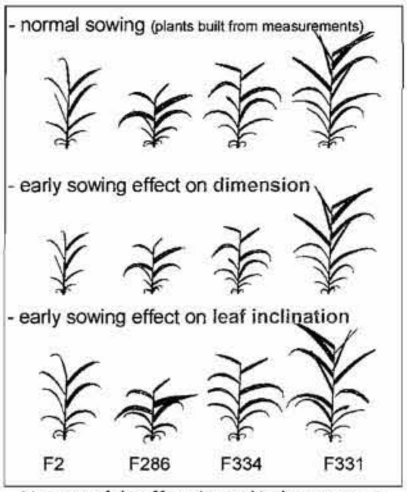
Simulation of leaf area over thermal time for different leaves



Simulation of the total plant leaf area over time for different light treatments

Plant leaf area was simulated in response to temperature and light intensity in sunflower and *Arabidopsis*, during the vegetative phase. The next step is to simulate different genotypes in different climatic scenarios.

Importance of different traits on integrative responses

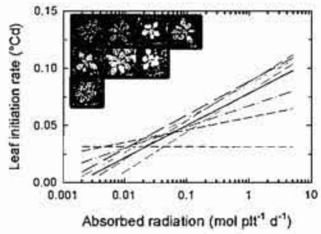


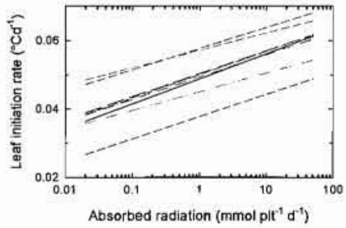
Dissection of the effect observed in the response to early sowing in four inbred lines of maize

3D virtual plants allow the dissection of architectural characteristics (plant dimension, rate of growth, leaf inclination...) on integrative traits such as the amount of radiation intercepted by the plant.

Virtual plants were used in different genotypes of maize to compare the effect of both plant dimension (lamina, sheath and internodes) and leaf inclination on light interception in an early sowing experiment. The aim is to evaluate the impact of the gene-tic and environmental variations of different traits involved in yield (Chenu et al. 2007).

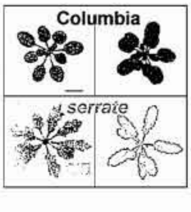
Genotype-environment interactions

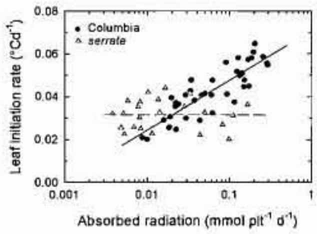




The model developed in *Arabidopsis* allowed us to characterise the behaviour of a genotype by a set of parameters independent of the environment. The parameters of the response curves are genotype specific and stable for a wide range of light environmental conditions. They can be used in further studies to better understand genes and pathways involved in these responses.

Characterisation of mutations





The mutation of the SERRATE gene was found to play a key role in the leaf initiation. Contrary to the wild type, *serrate* mutant had a leaf initiation rate unaffected by light (Chenu et al. 2004).

Conclusion – 3D models allow the estimation of environmental variables that are difficult to measure, e.g. the absorbed radiation of a plant. They allow the detection of phenotypic plasticity that would not be easily observed and the comparison of different genotypes. Genotype-environment interactions can then be dissected to focus on gene effects.

The models developed here allowed the simulation of the plant behaviour in different environments and for different species. With their adaptation to different genotypes, such tools could help to define ideotypes depending on the climatic scenario.

References

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