3D virtual plants to phenotype differences among genotypes: Taking into account plant-environment interactions to better understand genetic variability in leaf development response to light

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Incident light affects orgnaogenesis and morphogenesis processes involved in leaf development through the amount of radiation absorbed by the plant (Chenu *et al*., 2005). The genetic variability of these responses was investigated on *Arabidopsis thaliana* ecotypes (Col, Di-m, Ler, Ws) and mutants (*se-1*, *rot3-1*, *ron2-2*, *p70S-KOR*) displaying contrasted architectures and radiation use efficiencies (Fig. 1).

Plants were grown under various levels of incident light, with a stable light quality. The local plant-environment interactions were estimated for each genotype, from plant emergence to the end of rosette expansion, using an architectural model (Barczi *et al*., 1997) coupled with a radiative model (Dauzat and Eroy, 1997). Leaf development was assessed in terms of the date of leaf initiation, the relative leaf expansion rate and the duration of leaf expansion.

A reduction in light intensity affected with different extents the final leaf area of the genotypes, through modifications in the leaf development processes. For each genotype, stable relationships were found for (i) leaf initiation and (ii) initial leaf expansion rate with the amount of absorbed radiation, and for (iii) the duration of leaf expansion with the level of radiation intensity. Genotypes displayed different sensitivities in their responses of leaf initiation rate (Fig. 2) and duration of leaf expansion, whereas they all had a similar response in terms of initial relative expansion rate.

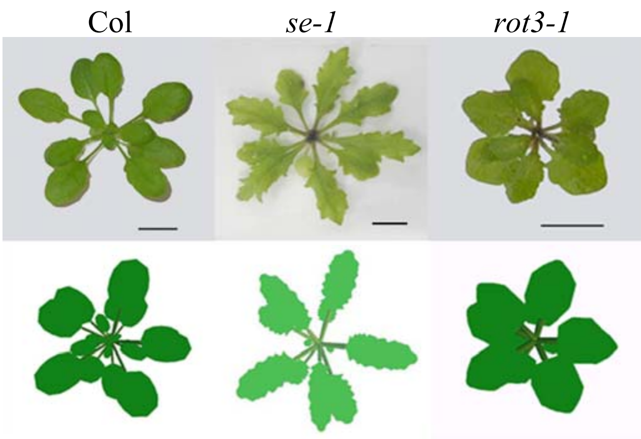

Fig. 1. Photographs of a sampled plant for the ecotype Col and its mutants *se-1* and *rot3-1* (first row) and three-dimensional virtual plants corresponding to the mean representation of the observed plants (second row). Scale bar = 1 cm.

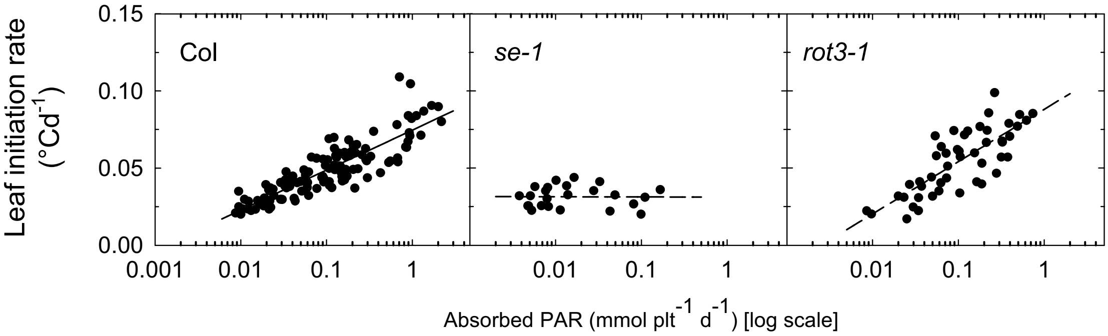

Fig. 2. Leaf initiation rate related to the amount of radiation absorbed by the plant for the ecotype Col and its mutants *se-1* and *rot3-1*.

Using a 3D virtual plant approach allowed us to take into account the genotype-environment interactions through the estimation of the amount of light absorption, and thus to better understand the genotypic differences in physiological responses to light. For example, an unexpected phenotype was revealed in the *se-1* mutant. The SERRATE gene (SE) recently shown to determine early leaf development via leaf organogenesis and morphogenesis patterning (Grigg *et al*., 2005) was demonstrated here to also affect late leaf development and their responses to incident light (Chenu *et al*., 2007). Furthermore, contrary to its wild-type (Col) and the other studied genotypes, the *se-1* mutant displayed a leaf initiation that was totally insensitive to the amount of absorbed radiation (Fig. 1) suggestion a role of carbon metabolism in SE functioning.

The consistent relationships found between plant and light variables had genotype-specific parameters that were independent from the environment. Such parameters can therefore be considered as genotypic characteristics and could be used to identify associated QTL (Reymond *et al*., 2003).

The method developed in this study comprises a new phenotypic tool that allows genotype characterisation for leaf development response to light, for a wide range of radiative environments. This approach was sufficiently precise to characterise the effect of monogenetic mutations and could be applied on a wider range of genotypes to focus on genes and pathways involved in leaf expansion responses to light. The presented results could also be used to integrate the knowledge collected among genotypes in order to predict their behaviour in various light environments.

References

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