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How do variations of architectural parameters affect light partitioning within wheat - pea mixtures? A simulation study based on a virtual plant approach.

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Highlights: 3D and dynamic models of wheat and pea were used to study light partitioning in virtual wheat-pea mixtures. Our results showed that architectural parameters defined at plant scale (e.g. branches, internode length) significantly affect the interception of light by each component species. The modifications performed on the architectural parameters of both models led to asymmetric variations of light partitioning.

Keywords: *Pisum sativum*, plant architecture, *Triticum aestivum*, virtual plant model, wheat-pea mixture

INTRODUCTION

Light partitioning among intercropped species is highly related to the physical structure of the canopy (Barillot *et al.*, 2011) emerging from the architecture of the individuals growing within the stand (Barillot *et al.*, 2012). Plant architecture is defined as the resultant of i) the inventory of the plant components, ii) the topological relations between these components, and iii) their geometry (Godin, 2000). The multiscale description of the canopy structure reveals the importance of the architectural parameters as underpinning factors that determine light partitioning within mixed cropped systems.

Modelling approaches such as Functional – Structural Plant Models (FSPMs, DeJong *et al.*, 2011) have been proved to be well suited for studying light partitioning within contrasting canopies (Barillot *et al.*, 2011). As a consequence, these models can be considered as pertinent frameworks for assessing the relations between architectural parameters and light partitioning among the component species of intercropping systems.

The aim of the present study was therefore to assess the effect of architectural variations on light partitioning within wheat – pea mixtures. To this end, virtual mixtures were built up from architectural models of both species for which a strong variability of the architecture has been showed among genotypes and environmental conditions (Baccar *et al.*, 2011, Dornbusch *et al.*, 2011, Barillot *et al.*, 2012).

SIMULATIONS

Virtual wheat – pea mixtures were generated from architectural models of wheat and pea. First, we used a dynamic model of wheat development (Adel-Wheat, Fournier *et al.*, 2003). Then an architectural model of pea, hereafter called L-Pea, was built up using the L-Py platform (Boudon *et al.*, 2012). A detailed description of the model will be given in a companion poster (Barillot *et al.*, 2013). Briefly, the development of pea architecture is modelled as a function of the growing degree day. Kinetics of phytomer and branch production are described in a *vegetative module*, based on an experiment conducted in

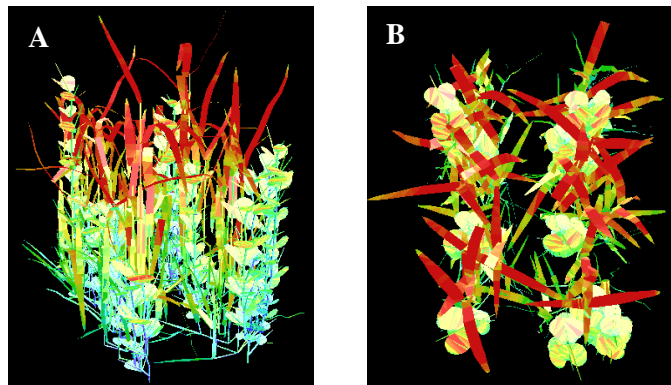


Fig. 1. Illustrations of a virtual wheat – pea mixture. The gradient of colour is a function of the light intercepted by organs (from blue to red).

field on cultivar Lucy grown in mixture with wheat. The elongation and coordination of the organs generated by the *vegetative module* are handled by a *growth module*. L-pea model was then implemented into the OpenAlea platform (Pradal *et al.*, 2008) in order to generate virtual wheat – pea mixtures (Fig. 1). Sowing densities were set to 125 and 45 plant m⁻² for wheat and pea respectively. Finally, virtual wheat – pea mixtures were interfaced with the radiative transfer model Caribu (Chelle and Andrieu, 1998) that allows to estimate the dynamic of light partitioning at each step of the growing cycle. Simulations were processed from 0 to 2000 GDD with a time step of 50 GDD.

Architectural parameters were selected as a function of their contribution to the Leaf Area Index (LAI) and plant height (Table 1) that are known to affect light interception.

Table 1: Architectural parameters selected for modifying the species LAI and height.

Species	Variable	
	LAI	Height
Wheat	Number of tillers (± 25 and 50%)	Internode length (± 25 and 50%)
Pea	Number of branches (± 25 and 50%)	Internode length (± 25 and 50%)

A first simulation with unmodified architectural parameters for both wheat and pea models was run and called *reference simulation*. Based on this simulation, the architectural parameters of wheat and pea were then modified by ± 25 and $\pm 50\%$.

RESULTS AND DISCUSSION

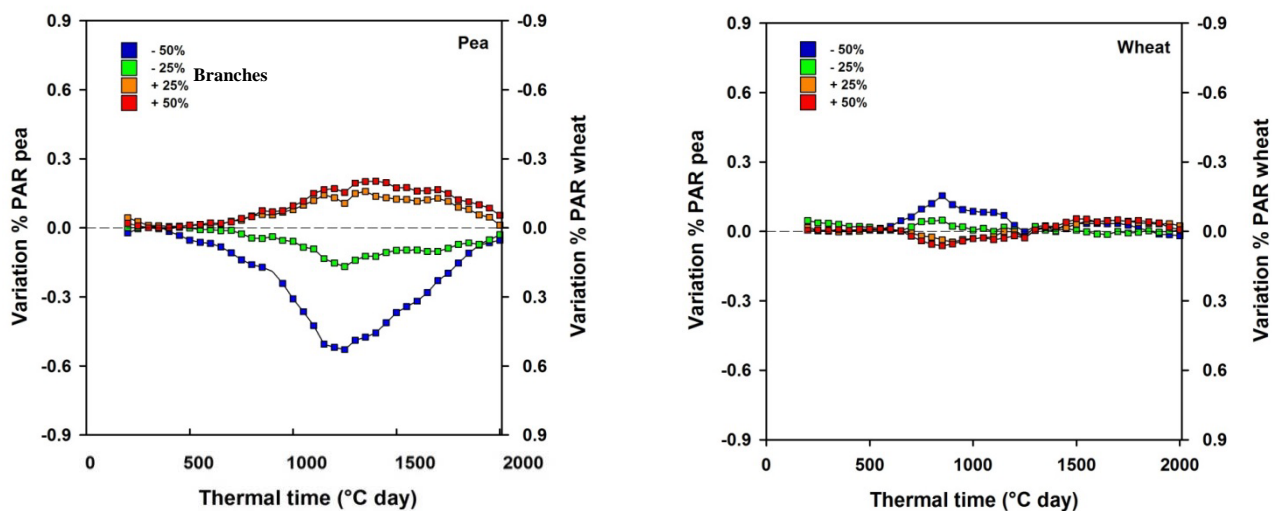


Fig. 2. Relative variations of light interception (%PAR, estimated from the reference simulation) by pea and by wheat (secondary axis in reverse order). Light interception was computed consecutively to a modification in the number of i) branches of pea (left) and ii) tillers of wheat following the gradient of colours.

The modifications performed on the final number of branches and tillers led to variations of light partitioning compared to the *reference* simulation (Fig. 2). The highest variation of light partitioning resulted from a reduction by 50 % in the number of branches of pea (Fig. 2, left). Lower absolute variations of light partitioning were observed consecutively to an increase of the number of pea branches, thus defining *asymmetric* variations. Compared to pea, alterations of the number of tillers produced by wheat (Fig. 2, right) led to slighter relative variations of light partitioning (at most 15 %).

Modifications of internode length appeared to have the most dramatic effects on light partitioning compared to branching (Fig. 3). These effects were observed earlier in pea, since the internode elongation of wheat began around 1000 GDD. A strong asymmetry was found in the variations of light partitioning between plants subjected to an increase of their internode length and those whose internodes were reduced. Similar variations of light partitioning were observed after an increase of the internode length of pea or an

equivalent reduction of wheat internodes. In contrast, increasing the internode length of wheat did not bring a similar gain of light interception as an equivalent reduction of pea internodes.

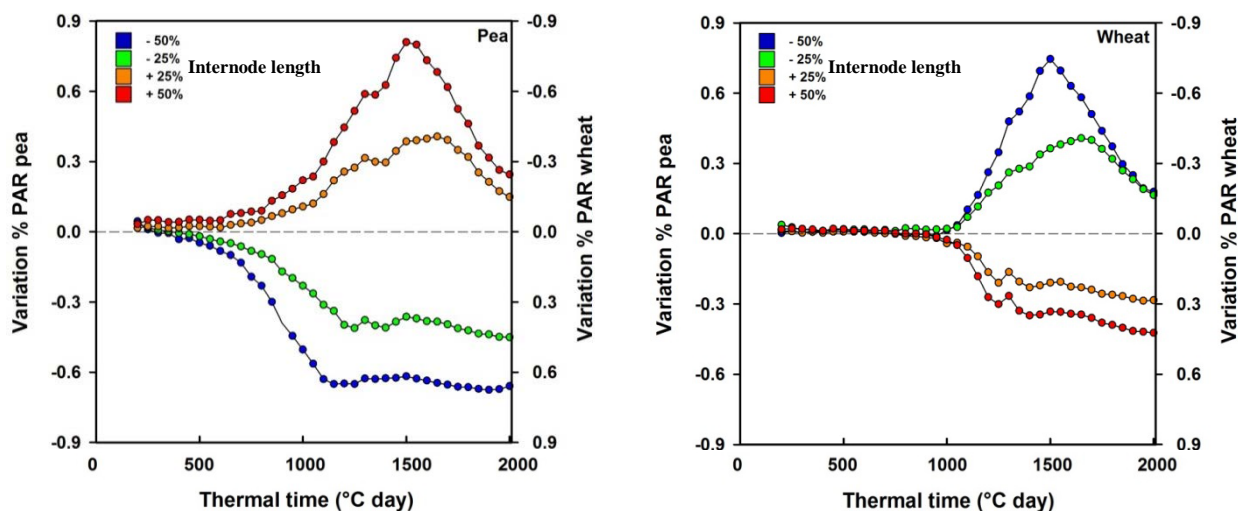


Fig. 3. Relative variations of light interception (%PAR, estimated from the reference simulation) by pea and by wheat (secondary axis in reverse order). Light interception was computed consecutively to a modification of internode length for pea (left) and wheat (right) following the gradient of colours.

The preliminary results presented here stemmed from a simulation study where the plasticity of plants in response to environmental variations was not included in the model. Therefore, further works have to be conducted in order to study how morphological variations can affect the interactions between the component species and their development. However, we used the FSPM approach to assess the *theoretical* sensitivity of light partitioning to the architecture of wheat and pea plants. These results therefore provide information that enables to identify / design suitable cultivars / ideotypes for intercropping systems towards light partitioning.

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