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Using functional-structural plant modeling to explore the response of cotton to mepiquat chloride application and plant population density

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Highlights: The crop growth regulator Mepiquat Chloride (MC) is widely used in cotton production to optimize the canopy structure in order to maximize the yield and fiber quality. Cotton plasticity in relation to MC and other agronomical practice was quantified using a functional-structural plant model of cotton development, ultimately aiming at helping cotton farmers to manage their crops optimally.

Keywords: Cotton (*Gossypium hirsutum* L.), canopy growth, light interception, morphology, pruning, simulation model

INTRODUCTION

In contrast to other crops, cotton (*Gossypium hirsutum* L.) the crop growth must be regulated and eventually terminated by chemical means. The crop growth regulator Mepiquat Chloride (MC) is commonly used in cotton production in China and other places in the world to maximize cotton yield and fiber quality (Oosterhuis and Egilla, 1996). Cotton canopy structure is often determined not only by MC control but also by planting density (Gwathmey and Clement, 2010) and other practices, which influences crop light interception and fruit formation and thereby biomass growth and yield. However, it is a great challenge to manage canopy structure due to the complexity and plasticity of cotton plant architecture.

Cotton has an indeterminate fruiting habit, and produces new foliage event on two different types of branches (vegetative and fruiting branches) (Zhao and Oosterhuis, 2000) with their own particular growth habit, which further complicates crop management. Because of the structural complexity and also the dynamics of leaf senescence, modeling cotton is difficult to realize. New techniques for collection, analysis, and concise representation of topological and geometric data have been applied to create a model of cotton morphogenesis and architecture based on L-systems by Room and Hanan (1995). Furthermore De Reffye et al. (1999) described a hydraulic model of cotton, focussing on vegetative growth. Jallas et al. (1999) added a visualization component to a mechanistic crop-level simulation of cotton. Hanan and Hearn (2003) established well-performed linked models between physiology and architecture of cotton. Functional-structural plant modelling (FSPM) (Vos et al, 2010) has become a promising tool to explore divergent management strategies in cotton.

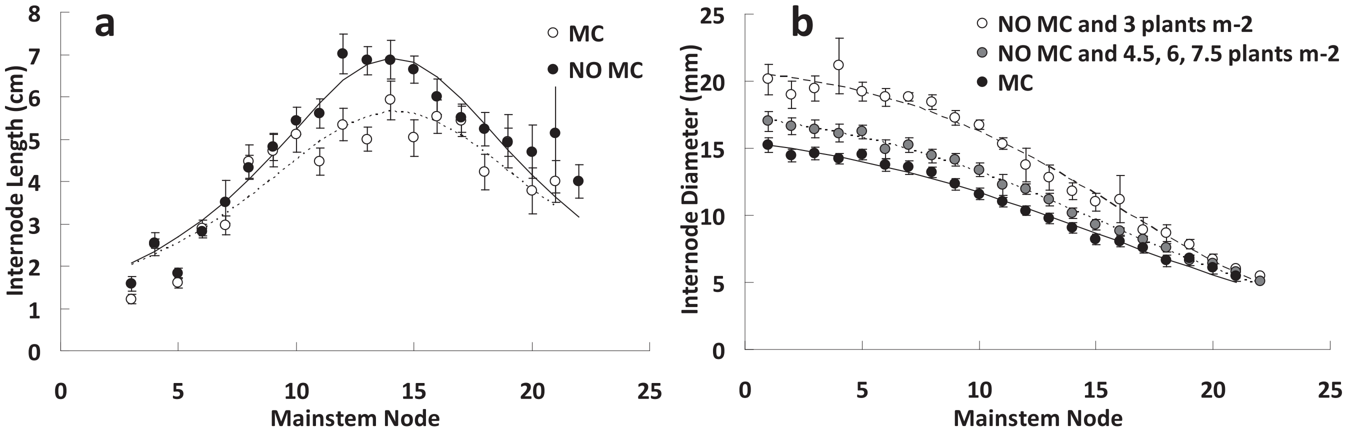

Fig. 1. Experimental data on internode length distribution along the main stem with and without MC (a); internode diameter at different population densities with and without MC (b)

The objective of this study was to optimize plant and crop structure by using a cotton FSPM, particularly to quantify cotton plasticity in relation to agronomical practices, and therefore to help farmers manage their crop optimally in given environmental conditions. Here we present the first results pertaining to leaf expansion and fruit numbers.

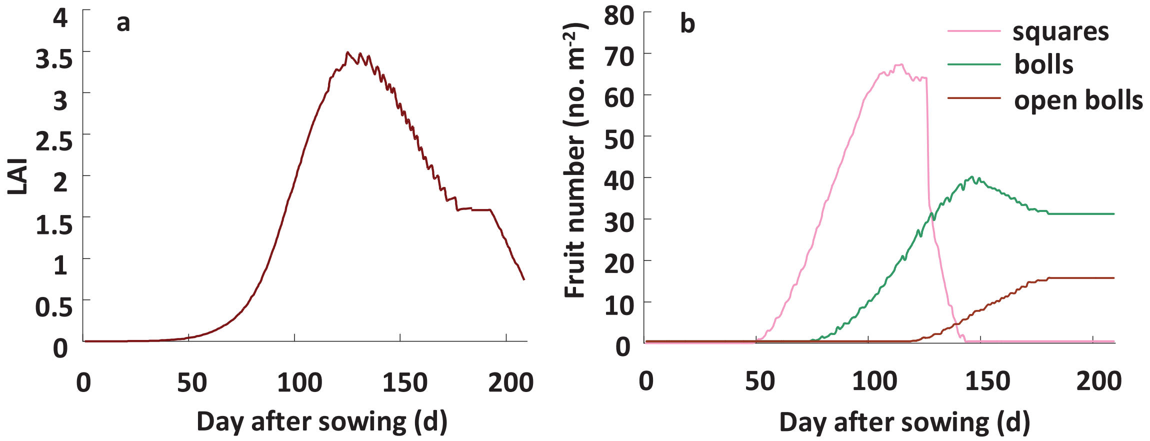

Fig. 2. Time-course changes in leaf area index (a), fruits number (b). The scenario shown here is for Anyang (eastern China) in 2002, MC applied, top cut-out at 30 July and side cut-out at 30 August, at a population density of 3.6 plants m^{-2}

SIMULATIONS

Field experiments were conducted that included treatments of plant with and without MC at four populations densities (3.0, 4.5, 6 and 7.5 plants m^{-2}) in 2011 and 2012 in the Yellow River region of China. The measured data on plant structure (as an example internode length and diameter with or without MC application at different population densities is shown in Fig. 1), were used to calibrate an FSPM of cotton, CottonXL, based on the simulation modeling platform GroIMP. The model simulates cotton leaf area expansion, and fruit number dynamics in terms of square, flower and boll development (exemplified in Fig. 2), plant height, vegetative/fruiting branch pattern and overall plant geometry (Fig.3), light interception and fiber quality. Input variables are daily temperature, planting density, MC application, cut-out time (termination of shoot tips of main stem and/or branches to prevent further phytomer development)

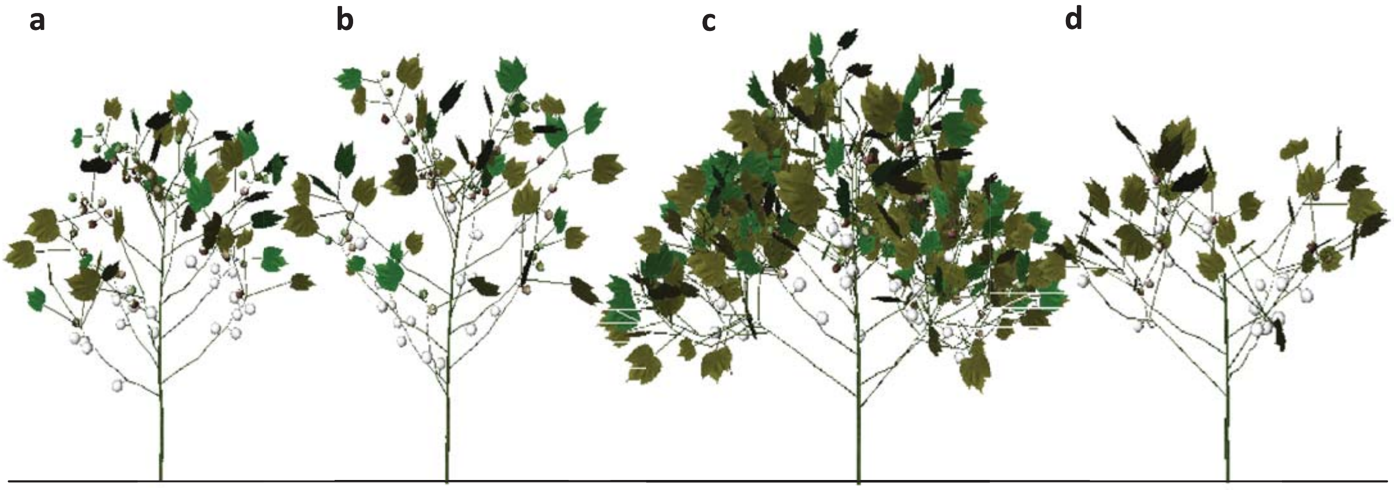

Fig. 3. Visual comparison between MC (a) and no MC application (b), without vegetative branches at a population density of 4.5 plants m^{-2}; between normal (c) and earlier (d) cut-out time with vegetative branches at a population density of 3 plants m^{-2}.

RESULTS AND DISCUSSION

MC application resulted in more compact plants, which is evident from the reduced internode length (Fig.1a). Internodes were also thinner under MC application, as well as at high population densities (Fig. 1b). The model simulated leaf area development and fruit numbers satisfactorily, although proper validation still needs to be performed. Plant compactness as a result of MC application can be observed from the visual output of the model (Fig. 3a, b), as well as the effect of early top and side cutting (Fig. 3c, d).

From these preliminary results we conclude that the model well simulates development of cotton structure as affected by sowing time and agronomical practices. Validation based on independent data will be done. The model can be applied as a systematic tool to explore the interaction between crop structure and functioning, and to optimize agronomic managements related to the morphology and productivity. However, to properly address such questions the FSPM still requires further development, taking partitioning of dry matter and further agronomical practices into consideration.

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