Integrating the effect of light quantity and quality in the V-Mango model to optimize cultural practices

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Introduction

Plant architecture results from species-specific growth processes and constraints exerted by the environment. In particular, light affects photosynthesis and photomorphogenesis processes. In return, architecture influences light interception, transpiration and water transport as well as carbon acquisition and allocation (Da Silva 2014). Thus, optimization of fruit tree architecture can improve fruit production in terms of quantity and quality. Mango (*Mangifera indica* L.) is the fifth most produced fruit in the world, mainly in tropical and subtropical regions. Its cultivation raises a number of issues such as irregular fruit production across years, and heterogeneity of fruit quality at harvest. To address those issues, the FSPM V-Mango (Boudon et al., 2020; Vaillant et al., 2021) was developed simulating vegetative and reproductive development of mango trees. The model can simulate pruning scenarios, and their effects on subsequent vegetative growth (Persello, 2019). However, the effect of light on the tree development is poorly taken into account, leading to unrealistic distributions of growth units (GU) within the crown. For now, light was mainly considered for photosynthesis, but currently relies on empirical light environments given as model inputs.

This work presents the integration of a radiative transfer model in V-Mango and the implementation of the coupled effects of light environment, pruning and GU characteristics on GU development and mortality. Using these extensions, we aimed to (i) validate the estimation of the vegetative growth following pruning at the tree scale, and (ii) explore the effects of pruning on the light distribution within the crown.

Materials and Methods

To parametrize the developmental rules of V-Mango, data was collected in an experimental orchard of a CIRAD research station located in Réunion Island (20°52’48”S; 55°31’48”E, 125 m a.s.l.). Adult mango trees were pruned with a gradient of pruning intensity (defined at the tree scale as the amount of fresh biomass removed per unit volume of tree canopy) in February 2021. Pruned and unpruned GUs were sampled inside and on the periphery of the canopy and their light environments were estimated from hemispherical photographs. The date of appearance and the number of new GUs appearing on the sampled GUS, as well as the occurrence of mortality of the new GUs and the sampled GUs were collected. Hemispheric photographs were regularly acquired in the center of the crown of mango trees until the end of vegetative growth to record crown closure. 3D scans of the orchard were also acquired with drone after pruning and after vegetative growth, from which volume of individual trees at these different periods were extracted.

The coupled effects of light environment, pruning and GU characteristics on vegetative bud burst and GU mortality were characterized using generalized linear models. Those effects were integrated in the existing developmental rules of V-Mango, detailed in Boudon et al.

(2020), and new functions were developed to simulate GU mortality. Light interception was estimated with the PlantGL library (Pradal et al., 2009). The light quantity variable *TrPPFD* (the relative transmitted photosynthetic photon flux density), was computed at the GU scale and averaged to obtain hourly values during one simulated day under a clear sky. The light quality variable ζ (ratio between red to far red wavebands) was estimated using a nonlinear relationship linking ζ and *TrPPFD* (Carrié et al., 2022). The experimental pruning intensities were then simulated on a 3D digitized adult mango tree and vegetative growth was simulated accordingly with V-Mango. To validate such development, different indices such as crown closure and volume were estimated from the generated 3D representations and compared to measurements.

Results and Discussion

Simulation of light distribution within the mango crown was successfully validated in terms of quantity and quality. Implementation of the light dependent developmental rules allowed to simulate realistic crown closure and volume increase due to the vegetative growth induced by tree pruning. Additionally, this new version of V-Mango allows quantifying and comparing the effect of pruning on light distribution and regrowth within the crown. This work opens up great prospects for modeling approaches dedicated to fruit tree systems. However further experiments are needed to simulate the entire growth cycle, taking into account the complex endogenous processes of the mango tree.

Conclusion

In this work, we integrated in V-Mango, a radiative model and implemented the effects of light and pruning on the architectural development of the mango tree. Model simulation accuracy was validated at the tree scale and allowed to quantify pruning effects within the crown. Such a modeling approach makes it possible to optimize cultural practices related to light distribution and thus improve fruit tree production.

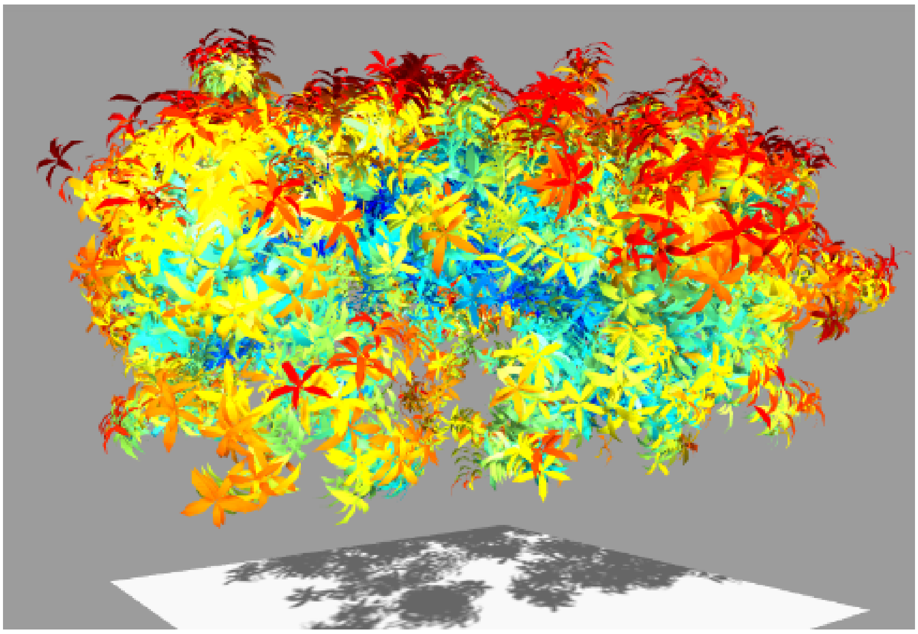

Figure 1: Simulated distribution of the daily average ζ within the mango tree crown in V-Mango

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