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Abstract: Improving fruit quality while reducing pesticide and water use supports both consumers' requirements and environmental and health concerns. This objective promotes some alternative technical scenarios that use more cultural than chemical control for pest management. Our study focused on the peach-brown rot system (*Monilinia laxa*). It aims at determining sets of cultural options providing an optimal trade-off between revenue build-up, consumers' requirements and environmental impacts. We used a modelling approach to simulate technical scenarios by using a virtual fruit model describing the seasonal changes in peach fruit quality traits during final swelling under the influence of climatic, biotic and cultural factors. We defined 243 virtual scenarios based on agronomical and epidemiological inputs (time and intensity of thinning, irrigation, cultivar choice and disease control). Virtual scenarios were evaluated on a multi-criteria profile of performance integrating storage potential, organoleptic and environmental factors, according to different objectives of profitability, water saving and no pathogen entry (cuticular crack) on fruits. Scenarios including water stress during final swelling are promising while requiring an evolution of market standards.

Key words: brown rot, cuticular crack, fruit quality, irrigation, modelling, peach, profitability, thinning, storage potential, water saving

Introduction

Integrated fruit production (IFP) objectives are to produce high quality fruits in an economically sustainable way by minimizing pesticides and resources use to preserve both health and the environment (Cross & Dickler, 1994). The question of the reduction of pesticides points out the necessity to study the interactions between fruit-trees and pests under the influence of cultural practices in order to find some alternatives for pest management. But how can we design technical scenarios integrating agronomical and environmental considerations? A modelling approach is well adapted in a first step to evaluate a large range of production systems to better target an experimental stage. Moreover, the complexity of fruit quality profiling also requires this approach to represent underlying processes, their interactions and the influence of environmental (climatic or biotic) and cultural variations (irrigation and crop load) on their expression. We focused our work on the peach-brown rot system (*M. laxa*). Thinning and irrigation are the main cultural practices modifying peach fruit growth (Naor *et al.*, 1997). By using and improving an existing virtual fruit model (Lescourret & Génard, 2005), we constructed various technical scenarios reflecting various cultural practices and evaluated them on their ability to provide a correct trade-off by considering a multi-criterion profile of quality. Results are presented.

Materials and methods

Description of the integrated virtual fruit predicting outputs of agronomical interest (quality and storage potential)

The virtual peach fruit model simulates the seasonal changes in several peach fruit quality traits during the final swelling of a "mean" fruit on the shoot-bearing-fruit (Lescourret & Génard, 2005). The model runs at a daily time step. It was developed by integrating three existing process-based models describing fruit dry mass growth, sugar accumulation and water accumulation, respectively (Figure 1). It was improved by integrating (i) the variation of fruit surface conductance and its components (cuticle, stomata and cuticular cracks) in relation with the fruit growth (this variable being implicated in fresh mass and sugar content) and (ii) an epidemiological function predicting the storage potential according to fruit growing conditions and the inoculum pressure of *M. laxa*. The integrated model is fully described in Gibert (2007).

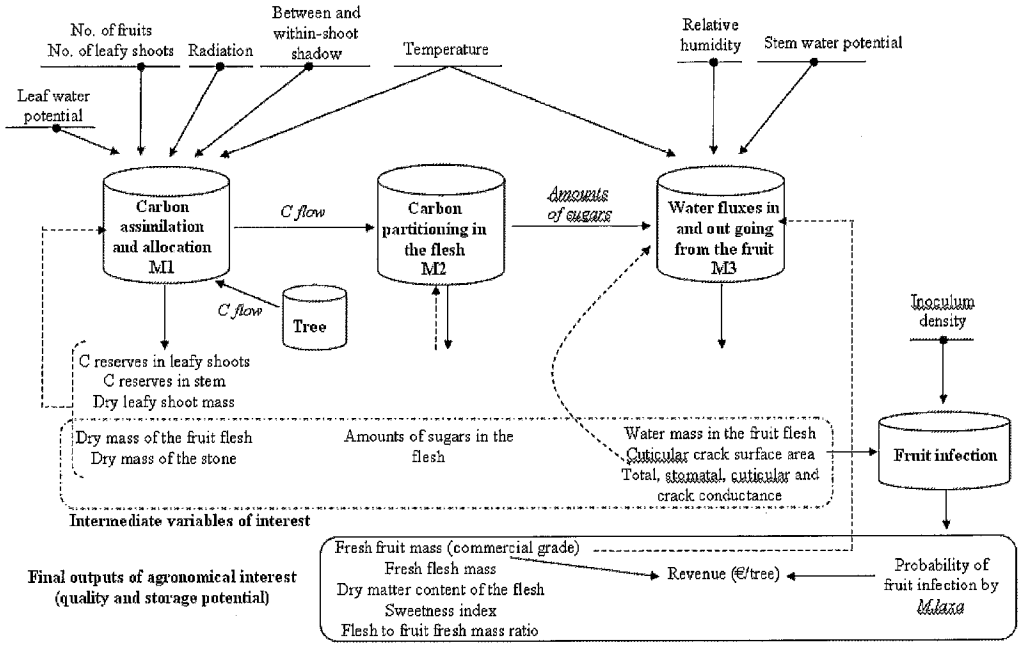

Figure 1. General scheme of the modified virtual peach fruit mo del. External variables are underlined arrows indicate data flows and dashed lines represent feedback information (adapted from Lescourret and Génard, 2005).

Construction of 243 virtual technical scenarios

Virtual technical scenarios were developed to reflect various cultural practices (cultivar choice, time and intensity of thinning, irrigation level, disease control). These agronomical and epidemiological factors were described through a parameter characterising the susceptibility to cuticular cracking (*SCC*), the fruit dry mass at thinning (*FDMT*), the shoot:fruit ratio (fruit crop load, *FLC*), the sequences of leaf and stem water potentials (*IL*) and the inoculum density (*ID*). For each factor, three distinct levels were applied to simulate contrasted situations, that is altogether 243 virtual scenarios detailed in Table 1. Irrigation levels were considered to vary with the fruit crop load (Naor *et al.*, 1997) when water was limited.

Table 1. Details about the construction of the 243 virtual technical scenarios

Agronomical and epidemiological factors	Levels of variation		
Susceptibility to cuticular cracking (*SCC*)	Low	Moderate	High
Fruit dry mass at thinning (*FDMT*)	Small	Median	Large
Fruit crop load (*FCL*)	Low	Intermediate	Normal
Irrigation level (*IL*)	Water stressed during pit hardening	Water stressed during final swelling	Well irrigated
Inoculum density (*ID*)	Low	Moderate	High

Definition of multi-criteria profile of performances

The five quality traits of interest were studied at harvest for each virtual scenario: the sweetness index (*SI*; Kulp *et al.*, 1991), the flesh dry matter content (*FDMC*), the ratio of flesh per fruit fresh mass (*FFFM*), the cuticular crack density (*CCD*) indicative of shrivelling during storage, the fruit fresh mass which corresponds to a commercial grade and the probability of fruit infection by *M. laxa*. These two later variables were associated into the revenue calculation (*R*; €/tree). Each quality traits were separated into four classes described by colours in Table 2.

Table 2. Description of classes for quality traits constituting the profile of performances

Quality traits	Classes			
	Very low	Low	Intermediate	High
Sweetness index (%, *SI*)	≤ 5.5	5.5 < ≤ 6.5	6.5 < ≤ 7.5	> 7.5
Flesh dry matter content (%, *FDMC*)	≤ 10	10 < ≤ 12.5	12.5 < ≤ 15	> 15
Flesh per fruit fresh mass ratio (%, *FFFM*)	≤ 90	90 < ≤ 92.5	92.5 < ≤ 95	> 95
Cuticular crack density (%, *CCD*)	≤ 3	3 < ≤ 6	6 < ≤ 9	> 9
Revenue (€/tree, *R*)	0	0 < ≤ 100	100 < ≤ 200	> 200

Evaluation of scenarios according to distinct objectives: profitability, water saving and no pathogen entry

We analysed and classified the different scenarios by considering the profile of performances at harvest in relation with distinct objectives corresponding: (i) to the present market standards or profitability, which only consider the fruit commercial grade, (ii) to a will of water saving or (iii) to an avoid of the chemical protection by deciding to produce fruits presenting no cuticular crack, that is no pathogen entry.

Results and discussion

Results of the evaluation of the scenarios according to the distinct objectives mentioned above are presented in Table 3. The most beneficial scenarios corresponded to what is currently done

and recommended: big commercial grade that is very interesting in terms of revenue for growers, irrigation restricted during a short period (pit hardening) and a lot of applications of fungicide to control the disease pressure. Fruits from these scenarios present a poor quality profile: big size, slightly sweetened and presenting a short shelf life (very high *CCD*). In comparison, another set of cultural options only differing by a long but moderate water restriction during the final swelling leads to a better trade-off for the fruit quality profile. It improved the sweetness index, the flesh dry matter content and its post-harvest shelf life. Moreover, this scenario could be very attractive for producers and consumers since they contribute to water saving. Fruits without any cuticular crack required a normal crop load, to choose small fruit at thinning date, and a water restriction during the final swelling. Although they are no lucrative nowadays (commercial grade out of standards), this scenario produced fruits of good quality (high *SI*, *FDMC*, *FFFM*). Moreover, it could be adopted to a large range of situations of production, *i.e.* different cultivar susceptibility to cracking and various inoculum densities. Such scenarios, though economical in terms of water use and fungicides while preserving fruit quality and environment, do not meet the present standards but could be considered in the future, in case of segmentation of supply proposed to consumers by retailers (Parker, 1993), or for technical practices based on IFP guidelines.

The model presented here gave the opportunity to evaluate several technical scenarios on their profile of agronomical performances according to a large point of view combining the present market standards, which only consider the fruit commercial grade and IFP requirements that include the consumers' satisfaction and environmental concerns.

Table 3. Virtual scenarios selected for their adequacy with objectives of profitability, water saving and fruits presenting no cuticular crack (no pathogen entry)

Objectives	Inputs					Criteria of performances				
	SCC	*ID*	*FDMT*	*IL*	*FCL*	*SI*	*PDMC*	*FFFM*	*CCD*	*R*
Profitability										
Water saving										
No pathogen entry										

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