Multi-level management of harvest for fresh fruit: the case of Corsican clementine

Raphaël Belmin, François Casabianca, Laurent Julhia, Jean-Marc Meynard

Agronomy for Sustainable Development (2021) 41: 41
https://doi.org/10.1007/s13593-021-00686-z

RESEARCH ARTICLE

Multi-level management of harvest for fresh fruit: the case of Corsican clementine

Raphaël Belmin [1,2,3] · François Casabianca [1] · Laurent Julhia [4] · Jean-Marc Meynard [5]

Accepted: 11 March 2021 / Published online: 26 May 2021

Abstract

Despite their crucial importance for food product quality, harvest management practices remain understudied. Harvest is particularly challenging in the fresh fruit sector, due to the fruit's perishable, variable, and seasonal nature. In this study, we seek to better understand the agronomic, organizational, and institutional drivers influencing fruit harvest management, using the Corsican clementine harvest as a case study. In that production area, the standard "Clémentine de Corse" protected geographical indication is used by local actors to define and enforce appropriate harvest practices. The data were gathered through interviews with the farmers, packing station managers, and shippers who form the first link in the production chain. We show that harvest practices are shaped by the interactions between three management levels: (i) the plot, where picking teams select the fruit to be picked from those to be left on the tree for the next pass; (ii) the farm level, at which growers synchronize the harvesting dynamics with the ripening process of a set of plots with heterogeneous degrees of maturity; and (iii) the marketing level, where shippers and packers must match up the harvesting dynamics of all their suppliers with the demands of their buyers' market. According to this multi-level perspective, we analyzed the agronomic, organizational, and institutional drivers influencing the diversity of harvest management practices among farmers, and the influence of the protected geographical indication on the harvest process. Our study is the first to highlight how harvest practices are constructed and how various hierarchical levels of agricultural systems act together to shape them. Based on these results, we draw generic lessons and perspectives with a view to improving fresh fruit harvest management.

Keywords Citrus · Geographical indication · Harvest governance · Horticulture · Practices · Quality · Supply chain

1 Introduction

In the current context of globalization and increasing geographical distance between farmers and consumers, ensuring food quality along supply chains has become an important challenge (Trienekens and Zuurbier 2008). The quality of food products results from the cumulative practices of the actors along supply chains, from farmers to retailers. At the production level, farming practices and soil-climate conditions directly affect food product quality. For instance, Iglesias et al. (2007) have shown that citrus quality is influenced by environmental conditions (soil composition and temperatures) and cultivation practices (irrigation and fertilization). Food product quality then evolves along supply chains, under the influence of harvest practices, post-harvest treatments, as well as storage and transportation (Amorim et al. 2012; Akkerman et al. 2010). Hence, supply chain management strongly affects food quality (Ding et al. 2014; FAO and WHO 2003).

The challenges regarding quality management are particularly high in fresh fruit chains. The reason is that the growers' production is highly seasonal (short window of maturity), perishable (short shelf life of mature fruit), and of variable quality (heterogeneous sizes and grades) (de Raymond et al. 2013). On the other hand, the collection firms must provide the

✉ Raphaël Belmin
raphael.belmin@cirad.fr

[1] Laboratoire de Recherche sur le Développement de l'Elevage, INRAE, Quartier Grossetti, F-20250 Corte, France

[2] CIRAD, UPR HortSys, F-34398 Montpellier, France

[3] HortSys, Univ Montpellier, CIRAD, Montpellier, France

[4] UE Citrus, INRAE, F-20230 San Giuliano, France

[5] Université Paris-Saclay, AgroParisTech, INRAE, UMR SAD-AP, F-78850 Thiverval-Grignon, France

markets with a steady and constant supply of homogenous batches. They should take into account the product quality specifications, deadlines, and guarantees determined by their contracts (Le Bail 2005). For these reasons, the fresh fruit subsector is characterized by strong tensions between the product's perishable, variable, and seasonal nature and the functioning of the distribution networks (Soto-Silva et al. 2016).

This article focuses on an under-explored stage of the supply chain, namely the harvest. It is well established that harvest practices have a significant impact on fruit quality. This statement is true for the apple (Drake and Eisele 1997), grapefruit (Pailly et al. 2004), clementine (Chahidi et al. 2007), mango (Saranwong et al. 2004), sweet cherry (Serrano et al. 2009), strawberry (Pelayo-Zaldívar et al. 2005), or peach (Crisosto and Valero 2008). Harvest studies have shown that food product quality can be either affected by harvest date (Dag et al. 2011), harvest frequency (number of harvest passes on each plot, see Wiersma et al. 1998), harvest method (e.g., manual picking vs. mechanical harvesting, see Zipori et al. 2014), or by the degree of ripeness at harvest time (Léchaudel and Joas 2006). A fruit picked before ripe is often too acidic, too firm, and lack sweetness. Its volatile aromas have not yet formed (Watson et al. 2002) or are imperceptible because the sugar/acid ratio is too low (Bonnans and Noble 1993). Conversely, a fruit picked when too ripe is insipid, fibrous, lacks juiciness, and can even taste unpleasant if rot has begun (Kader 1999). Harvest practices not only affect organoleptic quality: in some cases, they also affect agronomic yield (Sanderson et al. 1999) and conservation properties of food products at post-harvest stages (Drake and Eisele 1997; Serrano et al. 2009).

However, despite their crucial importance for food product quality, and particularly fresh fruit, existing harvest studies rarely tackle the question of harvest management practices as such, i.e., understanding how farmers actually harvest their crops and identifying the underlying organizational and institutional drivers of harvest practices. They only assess the impact of particular harvest features (harvest date, frequency, degree of ripeness at harvest) on crop yield and quality, and they subsequently propose adequate harvest practices to optimize these variables (see Sanderson et al. 1999 or Wiersma et al. 1998 for two good examples).

Several studies have, however, emphasized the great diversity of harvest practices in a given production area. In particular, high variability in harvesting dates has been reported for sugar cane (Muchow et al. 2000), clementine (Julhia et al. 2019), common vetch (Tan et al. 2003), and canola (Graham et al. 2017). Such variability results from organizational factors at the farm level or from climate constraints such as rain (Everingham et al. 2001). Harvest practices can also be influenced by supply chain actors. Hence, during the harvest, farmers interact closely with marketing organizations. These actors buy the production of the farmers in their catchment area. In turn, they influence their harvest practices by laying down rules such as payment scales, contracts, specifications, or supply dates (Shukla and Jharkharia 2013).

Geographical indications (GIs) are institutional schemes designed to emphasize and improve quality management of place-based food in small agricultural areas (Vandecandelaere et al. 2009). In Europe, the two main labels are the protected geographical indication (PGI) and the protected designation of origin (PDO). GIs include specification and controls that frame actors' practices at both farm and supply chain levels. Implementation of a GI scheme in a production area often leads to less diversified practices and more uniform product quality (de Sainte et al. 2020). In the fresh fruit and viticulture sectors, GIs often establish rules for harvest and post-harvest operations (e.g., harvest date, maturity on harvest) (Belmin et al. 2018a).

In this study, we seek to analyze the agronomic, organizational, and institutional drivers influencing harvest management in the fruit sector. Specifically, we seek to answer two main questions: *How can we explain the diversity of harvest practices among farmers in a given production area? To what extent can a geographical indication improve individual and collective harvest management?*

We address these questions using the Corsican clementine harvest as a case study (see Section 2.1) (Fig. 1), and by mobilizing a multi-level analytical framework rooted in systemic agronomy (see Section 2.2).

2 Materials and methods

2.1 Case study

As a case study, we chose the clementine harvest in the Corsican clementine production area. This is quite a small area in the eastern part of Corsica island, with 139 citrus farms of

Fig. 1 A clementine orchard ready for harvest. In the Corsican clementine production area, fruits are picked colored and ripe. © R. Belmin

varying size and structure, a total orchard space of 1250 hectares, and an average annual output of 20,000 tons. Almost all the output is sold on the French market, where it represents 10% of clementine sales. The bulk of the output (80%) is sold via supermarket fruit counters. The Corsican clementine production area was chosen as a case study for the following reasons:

- It is a typical example of a fresh fruit chain focused on proposing a high-quality product, the harvest being a highly challenging operation. The fruit is picked colored and ripe (Fig. 1), and is dispatched within 48 h to mainland France, with no storage or degreening. Moreover, the fruit is sold with fresh leaves attached, which allows only 6 days from picking to retail.
- Past studies have emphasized that some farmers apply inadequate harvest practices (Julhia et al. 2019). It suggests that several organizational and institutional drivers can hinder good harvest management.
- The standard "Clémentine de Corse" protected geographical indication (PGI) is used to define and enforce "good harvest practices" (Table 1) for all farmers in the study area. In other words, the PGI specifications provide a benchmark for assessing actual harvest practices. Moreover, a historical study has shown that the recognition of the PGI in 2007 resulted in improved harvest management, due to institutional changes at both individual and collective levels (Belmin et al. 2018a).

2.2 Theoretical background

For our study of the Corsican clementine harvest, we used the theoretical framework offered by systemic agronomy, describing agricultural practices as shaped by three management levels (Nesme et al. 2010):

- The plot, which is the farmer's basic management level (Canali et al. 2017)
- The farm, the level at which a farmer sets his objectives and organizes his resources (land, capital and labor) to produce goods and services (Meuwissen et al. 2019; Dogliotti et al. 2014)
- The marketing level (composed of packers and shippers), which lays down rules for suppliers in its catchment area (payment scales, contracts, and specifications) and which seeks to limit discrepancies between what the growers harvest and what the downstream links in the chain demand (Le Gal et al. 2011)

2.3 Data collection and analysis

The data were collected via semi-directive interviews with growers, packing station managers, and shippers in order to develop a comprehensive analysis of harvest and post-harvest practices and to understand the systemic processes that frame harvest management. The sample of farms was designed to cover the diversity of clementine farming systems present in Corsica. We used 4 diversity criteria based on hypotheses about the factors that may influence harvest management at farm level: the surface area planted with clementines, the relation with a packing station, the type of marketing channel, and the involvement in organic farming (Table 2). Some of the growers interviewed combined fruit growing with packing and some also with marketing. We sampled 18 clementine farmers (out of a global population of 139), 8 packing station managers (out of 23), and 2 shippers (out of 3). This stratified sampling was meant to describe (i) the features of harvest organization that are shared by all sampled farmers; (ii) the specificity of each type of farm in the management of harvests; and (iii) the links between harvest organization at farm level and the dynamics of upper levels (packing station and marketing).

Table 1 The Corsican Clementine Protected Geographical Indication's pre-harvesting, harvesting and post-harvesting rules

Rules	Details
Pre-harvesting rules	- Analysis of the fruit before harvesting: internal ripeness criteria (permissible acidity range, sugar/acid ratio and juice content) and external ripeness (red-orange colour, green peel on no more than 20% of surface)
Harvesting rules	- Selective picking of coloured fruit, with their leaves, in at least two passes
	- Batches quality-checked on arrival at packing station
Post-harvesting rules	- Maximum of six days from picking to retail
	- Fruit in one layer only for sorting at station
	- Upper limit on non-compliance at exit from packing line: minimum of 30% with leaves, peel defects on maximum 15% of fruits, progressive defects on maximum 7% of fruits, maximum 10% sizing errors.
	- No post-harvest treatment

Table 2 Criteria used for selecting the growers to be interviewed

Criteria	Value				
Sales channel	Grower ships own crop		Shipping via a marketing organisation		
Mode of production	Conventional	Organic or mixed	Conventional	Conventional	Conventional
Growers	4	4	3	4	3
Area under clementine	Large (>5 ha)	Large (>5 ha)	Large (>5 ha)	Large (>5 ha)	Small (< 5 ha)
Own packing station?	Yes	Yes	Yes	No	No

The purpose of the interviews was to collect the following information:

- **General information.** For growers: planted area for the clementine and other crops, marketing channels, varieties grown, and orchard management. For packers and shippers: total acreage of the supplier network for the clementine and other fruit, supplier number and types, customer number and types, and annual volume packed or sold.
- **The management of the harvest.** How is the harvest planned (pre-harvest assessment, start date, order of plots)? What are the criteria that decide the start and end of the harvest? What are the main stages that structure the harvest season?
- **Work organization during the harvest period.** How is the work organized for the farmer (picking), the packer (reception, sorting, sizing, packing, pallet packing, etc.) and/or the shipper? What are the links and interdependencies between these actors? How does information circulate between farmers, packers and shippers?
- **Coordination between actors.** Is there horizontal coordination (between actors at the same organizational level) and vertical coordination (between growers, packers and shippers) during the harvest period? By what means do actors coordinate (instructions, sanctions, contracts, meetings, etc.)? How does the coordination affect the harvest management?
- **Quality objectives.** What criteria are used to assess batch quality (a) at harvest (by the farmer), (b) at the inlet and outlet of packing stations? Are these criteria always the same, or do they change over the course of the harvest period? What means do actors use to achieve their quality targets? What factors can prevent targets from being reached?
- **Agronomic and institutional drivers.** What are the main drivers influencing harvest management? More specifically, how is the harvest affected by orchard features (e.g., field structure, coloring and internal ripeness dynamics), market (price trends, buyers' specifications and sanctions), and PGI rules (specifications, inspections)?

In addition to the semi-directive interviews, we made observations on the harvest during two consecutive years:

- Recording the harvest dates of 21 orchards in 2013 and 27 orchards in 2014. These orchards, respectively, belong to 13 (for 2013) and 14 (for 2014) of the interviewed farmers. The plots were selected to obtain significant variability in soils (low vs. high permeability), rootstocks (Poncirus Pomeroy, Citrange Carrizo, and Citrange Troyer), and agricultural practices (organic vs. conventional farming), based on hypotheses concerning the sources of variability of fruit ripening.
- Size, color, and firmness analysis of fruit samples collected in the same orchards on a biweekly basis during fruit ripening.
- Observation of the harvest implementation in those orchards, spending half an hour in each orchard every fortnight throughout the harvest period (i.e., between 15 October and 15 January).
- Observation of the work of 11 packing stations, spending at least half an hour in each, between one and five times during the harvest season.

Based on the orchard records and observations, we built boxplots showing inter-orchard variability of color, firmness, and size of fruit samples collected in 21 and 27 farmers' orchards, from weeks 40 to 52, respectively, in 2013 and 2014.

Lastly, we used official data on the production and sale of Corsican clementines, provided by the producer organizations' federation "AOP Fruits de Corse". Based on these data, we produced a graph representing gross prices (in euros) and shipments (in tons) of Corsican clementines in weeks 43 to 5 (25 October to 29 January) of the 2014–2015 season.

3 Results

3.1 Harvest management at plot level

At plot level, harvest management consists in careful selection of the marketable fruit from the heterogeneous fruit on the

trees. Farmers send teams of experienced pickers to their plots, tasked with picking only orange fruit with both leaves present. Pickers should leave on the tree all fruit that is too green, and picking and leaving on the ground any unmarketable fruit (overripe, or with insect damage on the peel). All the actors interviewed agreed that in Corsica's climate, orange color on a clementine is a good predictive indicator of high organoleptic quality. The picked fruit is put in pallet crates that can contain 200 kg of fruit and sent to a packing station. Fruit should be handled carefully to avoid fruit stems causing "harvesting holes" in the peel of other clementines. In some farms, a foreman manages the pickers' speed and work quality. When a picker tips fruit into the pallet crate, the foreman inspects and sorts them, sometimes cleaning off sooty mold (a surface fungus). This inspection occasionally leads to correcting a picker who is judged to be working too slowly, picking fruit too green, picking too many without leaves, or causing too many harvesting holes.

According to farmers, adequate harvest management in a given crop leads to high degree of uniformity (of color and visual appearance) of the fruit in the pallet crates. If the picking is not selective enough, the pallet crate will contain a too high proportion of unmarketable fruit. Clementines are unsellable if they are under-ripe (green), overripe (soft, puffy or lumpy), or exhibit evolving defects (mildew, holes caused by stems), or if the peel surface is damaged (insect pricks, scale larvae, marbling, or frost damage).

Our interviews with growers showed that picking precision can be impacted by at least three factors:

(i) Rules laid down by growers. Each grower lays down several picking instructions. Growers generally tell their pickers to pick only orange fruit, leaving the green fruit and rejecting overripe fruit and those with damaged peel. Asked about their picking instructions, all the growers said they reflected the rules in the Corsican clementine PGI specifications (Table 1).
(ii) Weather conditions. Weather conditions during the harvest have a major impact on the quality of the pickers' work. For example, plots harvested in low light conditions produced a high proportion of unmarketable fruit.
(iii) Homogeneity of the plot. Watching harvesting in progress, we noticed that the degree of coloring on the whole plot affected pickers' perceptions of what was acceptable or not. When they were working in a plot with a low proportion of orange fruit, we saw a lot of green fruit in the pallet crates. And when a high proportion of fruit in the plot was overripe, the pickers allowed over-soft or puffy fruit into the pallet crates.

To monitor selective picking, the PGI scheme introduces a key rule: selecting only the fruit that is orange over at least 80% of its surface. PGI controllers visit each harvesting team on a regular basis during a harvesting season. In case of a too high proportion of unmarketable fruit in the pallet crate, the PGI controller asks the farmer to change his picking instructions to make fruit selection more rigorous.

3.2 Harvest management at farm level

At farm level, harvest management consists in matching the harvesting dynamics with the ripening process of a set of plots with heterogeneous degree of maturity, in order to obtain colored fruit with good keeping performance from each plot. This work is challenging for farmers because the orchard colors gradually and once the fruit is colored it does not remain sellable for long.

The different plots on a farm can have very different degrees of fruit coloring and firmness. So at farm level, the farmers' job is to manage heterogeneity, not only within plots but also between plots. To decide which plot should be prioritized for harvesting, farmers often use the same three decision-making rules:

- **Rule No. 1: The degree of coloring defines harvesting order**. Fruit color is the first factor taken into account for starting picking. Early in the season, when a small proportion of fruit in their orchards are orange, farmers plan the order in which their plots will be picked, according to their relative degrees of coloring.
- **Rule No. 2: Among plots with orange fruit, firmness determines harvesting order**. Once all the plots have a percentage of orange fruit close to 100% (mid to late season), the plots are competing for labor, and the growers decide the order in which to harvest their plots based on fruit firmness. This is assessed simply by feel, and it is a major criterion for the interviewed growers, who said that (i) the fruit firmness on a tree is a good predictor of the time the grower still has before the clementines become overripe and then rot and fall; (ii) fruit firmness determines its resistance to storage, transport, and handling of various kinds.
- **Rule No. 3: Potential fruit value determines the decision to harvest a plot**. When two plots are at the same degree of coloring and firmness, growers decide the order of harvesting based on their sales potential. The most profitable plots are those with large fruit and a low proportion of unsellable fruit. In 2014, all the orchards were already showing signs of over-ripeness by the first week of December. That year, many growers sacrificed one or more plots, leaving out unharvested fruit on their trees, in order to prioritize orchards where the fruit promised the highest value.

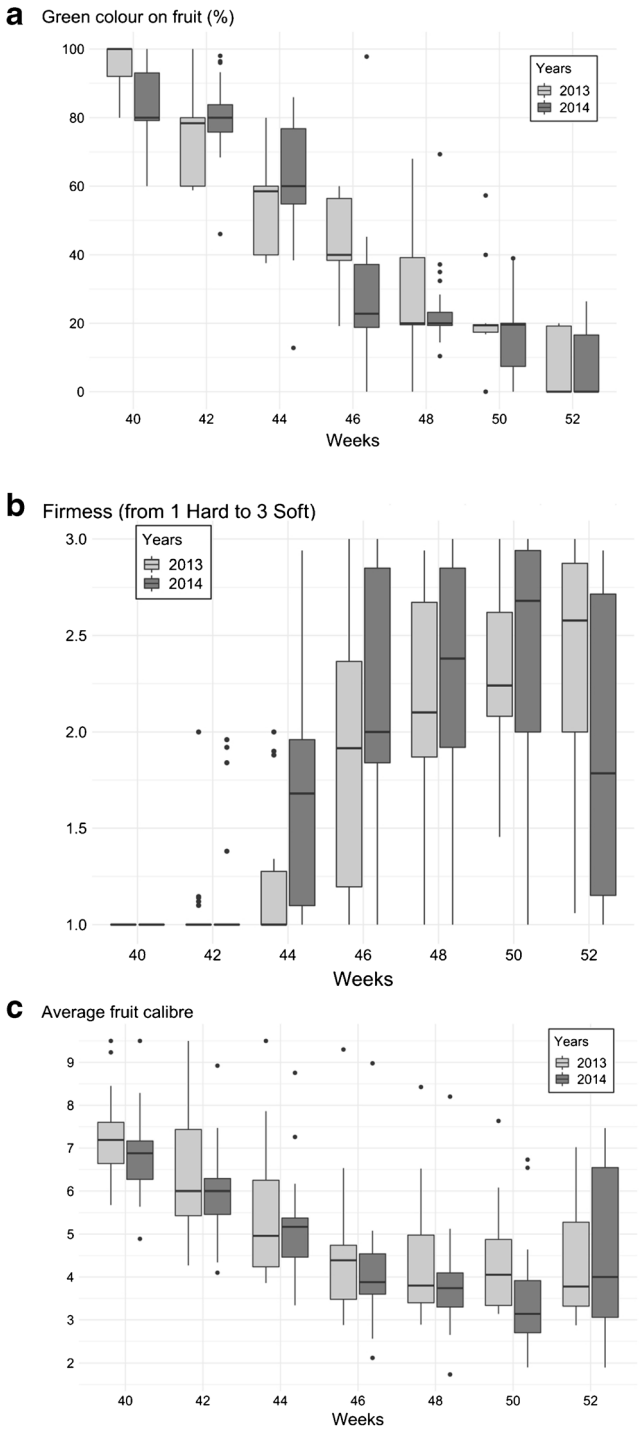

Fig. 2 Color (a), firmness (b), and size (c) of the fruit samples collected in 21 and 27 farmers' orchards, respectively, in 2013 (light gray) and 2014 (dark gray). Green shapes represent quality criteria (fruit color and size) of the Corsican clementine Protected Geographical Indication. Each boxplot shows the inter-orchard variability for a variable (color, firmness, or size), including median value (bold black line), first and third quartiles (limits of the box), maximum and minimum values (end of the thin black line), and outliers (isolated dots). We see the inter-orchard and the inter-year variability of the ripening evolution of the orchards

On-farm observations confirm the high inter-plot and inter-year variability of the coloring, firmness, and fruit size (Fig. 2).

The Corsican clementine PGI specification provides two rules which influence harvest management at farm level: (i) a control of the fruit's maturity level before starting the harvest of a plot. Growers must send a sample of fruit to a laboratory for an analysis of acidity rate, sugar/acid ratio, and peel color. This rule is meant to avoid harvesting unripe or overripe fruit. (ii) A minimum of two harvest passes for each plot. This rule allows an acceptable matching between the ripening dynamics of the plot with the harvesting dynamics. All interviewed actors assert that making several passes on each plot is the only way to pick fruit at optimum ripeness throughout the harvest season.

However, in practice, we saw a wide variety of situations, with the number of passes varying from 1 to 4 depending on the plot, the farm, and the year. Thus, in 2014, 90% of the plots were harvested in 1 or 2 passes, while in 2013, 70% of the plots were harvested in 3 passes or more. The match between ripeness and harvesting appears to be determined by the following factors:

(i) **The ripening dynamics of the orchard plots.** In 2014, when fruits colored up and soften quickly (Fig. 2a), growers made fewer passes and were at greater risk of losses than in years of slow coloring and lasting fruit firmness. Conversely, in 2013, the fruit colored very slowly, growers had to make many more passes and a high proportion of the fruit picked was green.

(ii) **The harvesting dynamics.** The surveyed growers stressed that the ability to harvest colored fruit quickly depends on the number of workers per ton to be picked, the workers' experience, the date chosen to start the picking, and the number of hours worked per week. Surveyed packers and shippers, who have an overall perspective of their supplier networks, noticed that in 2014, when the fruit colored quickly, the growers who launched the harvest early with a large number of pickers achieved a more constant good quality than those who invested less in the harvesting. But whatever the growers' objectives, harvesting can be hampered by rain, wind, snow, or just poor light caused by overcast conditions.

The maturity stage at picking varies widely because farmers integrate many factors into their harvesting strategy: sale price, organization of labor, access to labor, and combining clementine production with other activities. These constraints and incentives vary according to the farm. Based on our interviews and observations, we noticed that:

(i) On **large farms** (the 15 farms of more than 5 hectares, Table 2), growers seek to start picking as early as possible and routinely make a preliminary thinning pass. These growers explain that aiming for earliness is part of a commercial strategy of selling the fruit when prices are

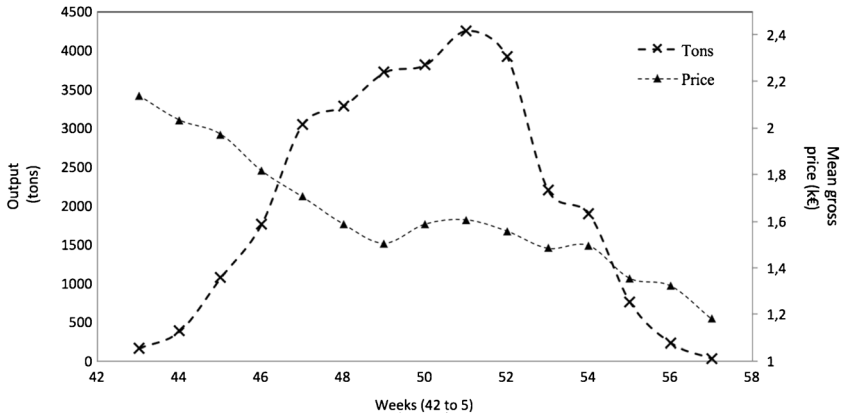

Fig. 3 Gross prices and shipments of Corsican clementine in 2014 from October (week 42) to January (week 5). Source: AOP Fruits de Corse

highest (Fig. 3, price curve with triangular markers). An early start is also a way to spread workload over time and limit the risk of over-ripeness. A few growers cited a third reason for starting early: the presence of temporary pickers on the farm. To ensure a job well done, large-scale growers use several picking teams spread around their orchards. These workers are paid by the day and urge the grower to let them start work as soon as possible.

(ii) On **small farms** (the 3 farms of less than 5 hectares), harvesting strategy is constrained by the difficulty of hiring seasonal labor. According to the growers, recruitment is difficult because with a small area they cannot provide continuous employment to a team of pickers for the whole season. These growers therefore rely on contractors or on other growers' picking teams, and their harvesting schedule depends on the availability of these resources. The large-scale growers make their workers available when their first pass is finished, which means that the small farms have to start relatively late, when the coloring on their orchards is well advanced. A thinning pass is rarely performed on these small farms.

3.3 Harvest management at the marketing level

At marketing level, the shippers must articulate the harvesting dynamics of several farms with post-harvest operations and shipping to meet the demands of their buyers' market. Two kinds of actors are involved:

(a) The **packing stations** are service providers mandated by the shippers to pack the clementine fruit. The stations' tasks were defined by the surveyed actors as: (i) receiving the crates of fruit; (ii) washing, sorting and sizing the fruit; and (iii) packing the fruit into homogeneous size and visual quality classes (Extra, I and II). The clementines are packed in 6 to 12-kg boxes or 1 to 2-kg punnets (for the small grades), stamped "IGP" or "*clémentine avec feuille origine France*" ("Clementines with leaves, grown in France"). To ensure that the work is well done, the stations apply procedures laid down in the PGI specifications: a fruit quality assessment on receipt, adjustment of the sorting line's speed according to the quality of the incoming batch and fruit in a single layer for sorting (Table 1). Our interviewees agreed that the stations act as information transmission hubs: (i) They inform the shippers about available stocks and ongoing and upcoming harvests. (ii) They send growers orders to stop or slow down the picking. (iii) They play a direct role in regulating shipments, through adapting their pace of work to fluctuations in market demand.

(b) The **shippers** are service providers who handle wholesaling for individuals or groups of growers. A shipper's supply catchment area consists of 1 to 5 packing stations and 1 to 70 growers. The shippers negotiate with buyers in mainland France and then pass the orders to the packing stations, which pass them on to their supplier growers. The shippers' task is to convert heterogeneous crates of fruit arriving from farms within their catchment area into batches that are homogeneous in terms of color, appearance, size, and internal ripeness and then dispatch them to buyers continuously through the season, in line with the demand pattern. They therefore have to coordinate sales of their supplier growers' crops, which means that they have a direct influence on their harvesting practices: everyone we interviewed agreed that the shippers play a part in decisions to start, stop, or speed up picking.

According to shippers, adequate harvest management is achieved when: (i) the fruit is homogeneous in size and appearance (color and look of the peel, firmness) and match the product indicated on the packaging; (ii) the degree of ripeness (color and firmness) is stable from one batch to the next; and (iii) the fruit is shipped fresh, in the quantities according to buyer demand.

According to the shippers interviewed, inadequate management of harvest and post-harvest operations can result from:

- **Lack of rigor in sorting and sizing in the packing shed.** We observed that sorting and sizing precision are influenced by the technology employed by the packer (e.g., a roller grader is less precise than a weight grader), by the fruit throughput on sorting lines (sometimes packers accelerate it to meet an order), and by the homogeneity of the crops brought in by the growers.
- **Lack of synchronization between fruit coloring, picking, and shipping.** A good match between these three processes is essential for (i) each plot to be picked at optimum ripeness, and (ii) each batch of fruit arriving at the packing shed to be quickly packed and shipped out. A short time interval between picking and shipping ensures fruit and leaves freshness. However, the synchronization can be affected by unpredictable events impeding shipping, such as storms or strikes among shipping companies.

We observed variations in harvest and post-harvest management according to the type of shipper. (i) The growers who own a packing station mainly supply fine grocery stores through wholesale greengrocers. They are particularly demanding as regards the visual quality of the fruit and the packaging's presentation. They therefore pay special attention to sorting quality in the orchard and to the work in the packing shed. The functioning of packing stations also provides incentive for meticulous harvest: At the packing station, work time per ton of fruit dispatched varies in proportion to the fruit throughput on the sorting and packing line, which in turn depends on the uniformity of the fruit coming in. So the more uniform the harvested fruit, the better margins from packing. (ii) Most of the output is sold through three large-scale shippers to the supermarket chains' central purchasing facilities. Because they are supplied by a large number of growers, large-scale shippers encounter variable quality between incoming fruit batches. They therefore sell to a range of outlets so as to find buyers for each single batch. Clients of central purchasing facilities are relatively flexible as regards batch homogeneity because they prioritize aligning the volumes delivered with the volumes demanded. Large-scale shippers and their packing stations can therefore allow themselves a little less sorting precision than the previous group. (iii) Last, a very small proportion of Corsican clementines (4% of the 2014/2015 campaign) are marketed via organic channels. Compared to the conventional marketing chain, buyers are not very demanding as regards appearance or size. Small or marked fruit fetches better prices than in the conventional chain. The result is less precision at the sorting level.

3.4 A typology of vertical coordination

Based on our sample of farmers, packers, and shippers, we have identified four different systems of vertical coordination between plot, farm, and shipper (Table 3).

3.4.1 The grower-shipper chain

The first type of vertical coordination concerns growers who have large planted areas of clementine, and handle their own packing and marketing, supplying the greengrocer market. This is a highly profitable market, but to break into it, one must keep tight control over visual and packaging quality. To meet the requirements, growers invest a lot in the harvest. They hire only experienced pickers, issue strict instructions, and arrange three or four passes on each plot. Among the growers, those that are engaged in this chain start the harvest earliest (Fig. 3). Similarly, having their own packing stations, they can ensure optimum sorting, precise sizing, and attractive, original packaging (individual labels, wooden crates with farm names, etc.). Growers adopting this strategy of distinctively high visual quality do not use biological pest control methods as they consider the results uncertain; they rely entirely on chemical pest control for their clementine crops. Along the same lines, one of them has invested in anti-hail nets.

3.4.2 The grower-packer chain

The second type of coordination concerns growers who do their own packing, but sell through a large-scale shipper. Shippers supply the supermarket chains which constitute a stable outlet for large volumes and are moderately demanding in terms of quality (batch homogeneity, fruit firmness, percentage of leaves). As these buyers provide narrower profit margins than the wholesale greengrocers, the growers issue less strict instructions for picking and sorting than the grower-shippers, especially at the start of the season when the supply is low in comparison with the demand. However, they always take good care of their orchards and harvesting because any quality problem in the field (soft, damaged, or pierced fruit) impacts on the profitability of the packing operation. With a farm and packing station in one entity, harvesting pace can be adjusted to short-term demand trends. To obtain stable quality and reduce the risk of fruit becoming soft, grower-packers use well supervised picking teams and get organized to start picking early, making two or three passes on each plot.

3.4.3 The chain of small growers supplying large-scale shippers

A third way of organizing the chain is when growers with a small- or medium-sized areas of clementine orchards deliver their crop to a packing station and market it through a large-scale shipper. Like the previous group, these growers are ultimately supplying the supermarket chains, and are therefore subject to the same quality requirements. Not having their own packing sheds, they are more limited in their quality control goals in the field. They generally only make two

Table 3 Interactions between plot, farm, and marketing are handled through four types of vertical coordination

	Grower-shipper chain	Grower-packer chain	Chain with small growers supplying collective stations	Organic chain
Number of growers met	3	5	7	3
Supply catchment area				
Shipper	Grower	Large-scale shipper	Large-scale shipper	Grower or large-scale shipper
Type of packing station	Small, run by grower	Small or medium, run by grower	Large, cooperative	Collective or individual
Main sales channel	Wholesale greengrocers	Central purchasing facilities	Central purchasing facilities	Organic chain
Price for caliber 5 (data 2014)	1.0	1.0	1.0	2.1
Farm				
Business system	Grower-packer-shipper	Grower-packer	Supplier	Supplier or grower-packer
Area under clementine	Large (> 5 ha)	Large (> 5 ha)	Variable	Large (> 5 ha)
Labor	Employed direct	Employed direct	External service provider	Employed direct
Harvesting practices at plot level				
Date of first pass	Very early	Early	Late	Very late
Mean number of harvesting passes	3 to 4 passes	2 or 3 passes	1 or 2 passes	2 or 3 passes

harvest passes. As previously explained, for the smallest growers, the harvesting schedule is determined by the availability of a picking team from another grower, which results in picking starting late, and the risk of overripe batches.

3.4.4 The organic chain

The market for organic-certified clementines is particularly profitable, even for small fruit, and relatively tolerant of visual defects; it is this that enables growers to run their orchards on an organic basis. According to the interviewed actors, the potential size of organically grown clementines is limited; this is counterbalanced by the high prices for small organic fruit. Moreover, although integrated pest control does not eliminate visual defects, this is not a drawback because the organic market tolerates imperfect fruit. Organically grown clementines ripen later than the rest, so these growers start their harvest later than the grower-shippers. Moreover, the fruit maintains good firmness after ripening—perhaps because the tree doesn't receive mineral nitrogen—so two or three passes are enough to ensure high quality.

4 Discussion

4.1 Interdependencies between levels

As shown in the previous sections, each harvest management level has its own working and its own particular problems to solve. Hence, for each level, specific incentives and constraints may affect harvest management. However, the three organization levels—plot, farm, and marketing—interact closely (Fig. 4). From the top downwards, the functioning of a given level can impair the work from the levels below. Inadequate harvest planning of harvest in time and space at the farm level can lead to pickers working on under-ripe orchards (too soon) or overripe orchards (too late). At marketing level, the shippers normally encourage good harvest timing and batch homogeneity by giving real-time instructions to the packing stations and growers. However, in certain circumstances, shippers can encourage inadequate harvest practices (too early, too late, etc.) in order to meet the quantitative demands of their buyers. On the other hand, actions performed at lower levels impact systematically on higher levels. Growers highlighted that picking efficiency (plot level) has a strong influence on the overall harvest organization at farm level. If the picking team's rate of progress is too low, the grower will register a delay, and won't be able to achieve additional passes on his plots. The picking work also affects the shipping stage: packers claimed that bad sorting precision in the orchard leads to lack of rigor and low profitability of the packing. In fact, when fruit batch quality is too heterogeneous, the sorting process is costly, and it is impossible to completely eliminate the unmarketable fruit: batches leaving the packing station are of low quality (commercial class II in the UNECE standard) and thus hard to sell. Lastly, the shippers stressed that the harvest management at farm level impacts their work: the harvesting speed of the growers supplying the shippers determines the shippers' ability to dispatch fruit continuously and on time.

Agronomists generally agree on the importance of considering jointly the various hierarchical levels of agricultural systems—i.e., plot, farm, and marketing—in order to shed light on farmers' decision-making processes (Le Gal et al. 2011). However, with few exceptions, past studies of farming practices have only focused on one level, generally the plot or sometimes

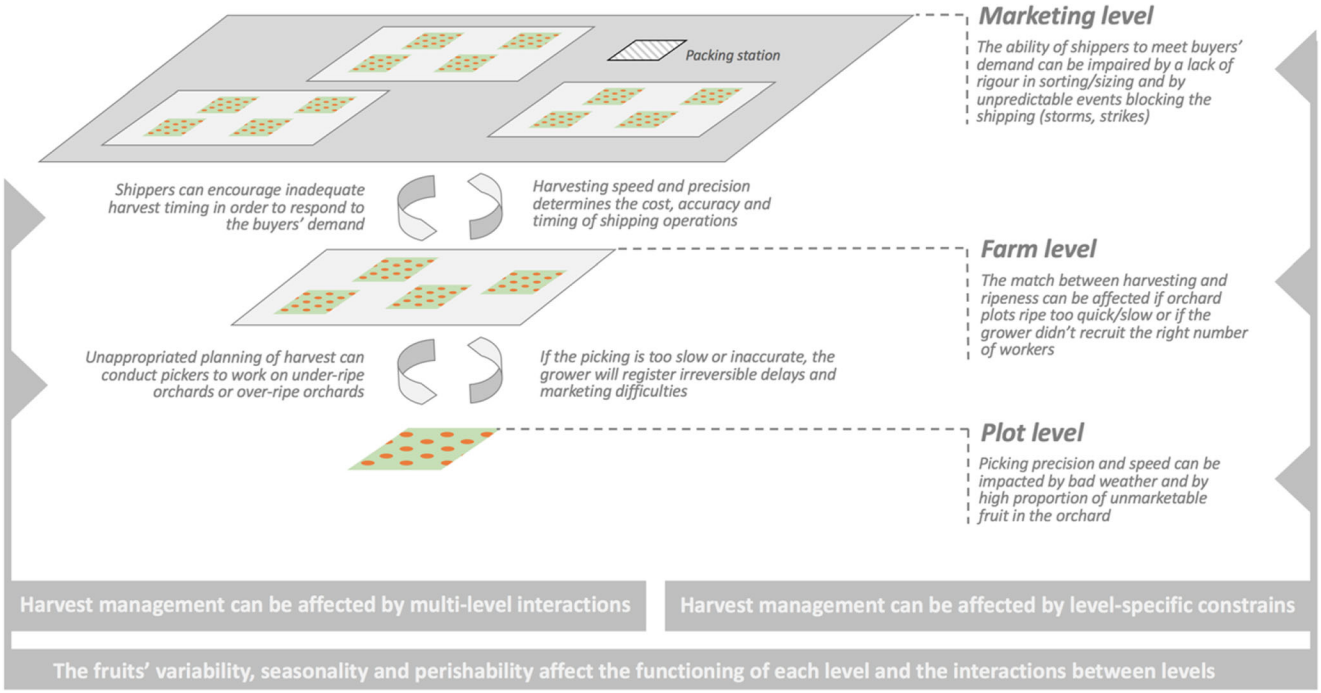

Fig. 4 Harvest management as framed by level-specific constraints, multi-level interactions, and by fruit variability, seasonality, and perishability

the farm (Dogliotti et al. 2014). In line with the pioneering works of Capillon and Valceschini (1998), Navarrete et al. (2006), and Tordjman et al. (2005), our study illustrates the value of a systemic, multi-level perspective for understanding the diversity of harvest practices and their institutional drivers.

Our multi-level perspective on the harvest sheds light on the variability of harvest practices and quality performances. In the Corsican clementine production area, the diversity of harvest management practices seems to result from different systems of vertical coordination between plot, farm, and shipper. In each type of vertical coordination, actors have agreed on specific objectives of quality for the shipped products, which are consistent with their cropping, harvest, and post-harvest practices. Their practices are shaped and stabilized by institutional constraints which result from the workings of each level and from multi-level interactions. Past studies have highlighted the importance of better understanding the relationships between cropping practices and marketing channels in order to better understand the diversity of farming systems in a given agricultural area (Morel and Léger 2016; Navarrete et al. 2006). Other studies have developed similar typologies of supply chain organizations in the fresh fruit and vegetables sector. In these studies, the focus is mainly put on the institutional arrangements and the other factors which influence supply chain governance (Capillon and Valceschini 1998; Zuurbier 1999) and on how food quality and safety are managed in each type of vertical coordination (Tordjman et al. 2005; Ait Hou et al. 2015). Our study, while showing similar findings, brings original results on how each type of vertical coordination affects harvest management at farm level.

4.2 Tensions between coloring and picking

The multi-level organization of harvest is challenged by the orchard coloring process. At the start of the season (weeks 44-46, see Figs. 2a and 3), there are little colored fruits in the orchards, but the actors are keen to make an early start and launch sales. The large-scale growers stressed that an early start means they can sell some fruit when prices are at their highest and spread the picking over a longer period. Shippers highlighted that early shipments are important for supplying all their customers at the times specified in their contracts. This is a major issue, because the supermarket chains are quick to turn to other suppliers if one delivers late. For all these reasons, the large-scale growers harvest their plots as early as possible. They tell their workers to "do what it takes to get the fruit out", at the risk of picking fruit that is still greener than the PGI requires. During these first weeks of the season, the central purchasing facilities do not impose sanctions on batches with under-ripe fruit because it is more important to them to get the quantities the market demands than to have fruit that perfectly meets all the quality criteria. In mid-season (weeks 48 to 52, Figs. 2a and 3), the different actors must sell an overabundance of colored fruit in danger of going soft. At that period, growers do not always have the labor resources to pick the fruit in their orchards as fast as it is ripening. Furthermore, the shippers ask their supplier growers to slow down the picking, because they want to avoid a sudden price drop. Meanwhile, the packing stations and shippers can face difficulties to find buyers for the fruit their growers supply. As a result, the fruit stays too long in the orchards or in

the packing stations, leading the fruit to reach the retailer not very fresh (withered leaves, progressive defects etc.). This happened in 2014, so that from week 52 onwards, fruit was being picked too ripe—puffy and insufficiently sharp in taste.

Tensions between ripening and picking have been reported for crops such as sugar cane (Muchow et al. 2000), tomato (Chomchalow et al. 2002), and clementine (Julhia et al. 2019). To enable improved harvest management, researchers have explored the relationship between maturity (acidity, sugar/acid ratio, color, ethylene emissions) and organoleptic quality (taste, volatile profile) and subsequently developed innovative technologies to screen ripe fruit (Maul et al. 1998). For other fruit chains, the tensions between orchard ripening and picking are managed in a completely different manner: the harvesting of under-ripe fruit, cold storage, and sometimes post-harvest ripening or degreening (Dong et al. 2001; Morales et al. 2020). With this technical package, harvesting can be concentrated in a narrow time frame, and batches can be dispatched as needed, unconstrained by the biological dynamics of the orchard. But this strategy has its drawbacks: post-harvest chemical treatments and cold storage impair the product's organoleptic quality (Salunkhe et al. 1991), and consumers are mistrustful of some post-harvest techniques. Operators in the greengrocer sector reject storage and degreening; they want to market fresh, perfectly ripe produce of good organoleptic quality.

Past harvest studies have often adopted a normative posture to define optimal harvest procedures and subsequently describe inadequate harvest practices among the studied farmer communities (see for example Sanderson et al. 1999 or Wiersma et al. 1998). Our study goes beyond these works: it shows that in the Corsican clementine production area, the so-called inadequate harvest practices are in fact the results of level-specific constraints as well as a trade-off between objectives structured at different levels (Fig. 4).

4.3 Influence of the geographical indication on harvest management practices

The "Corsican clementine" PGI rules and inspections influence the workings of each management level, as well as the interactions between the three management levels.

- **The PGI sets outcome objectives.** It defines enforceable criteria for assessing quality at each stage of the harvest process. For the picking, the specifications define what fruit should be picked. The criteria to be met concern internal ripeness (within a certain range of acidity, sugar/acid ratio, and juice content) and external ripeness (red-orange color, with up to 20% of the peel surface green). For fruit leaving the packing station, the PGI lays down the maximum percentage non-compliance with the different specifications: a minimum of 30% fruit with leaves, progressive defects on 7% of fruit at most, and 10% size defects at most. The existence of these enforceable criteria tends to limit opportunistic practices and facilitate coordination and negotiation between actors operating at the different levels.
- **The PGI sets resource objectives** for each organizational level. For example, by imposing a minimum of two harvesting passes, the PGI obliges growers to stagger their harvest, resulting in more homogenous fruit batches throughout the season. Another example is the obligatory quality check on arrival at the packing station, which enables the shipper to adjust the speed of the sorting and packing line to the quality of the batch. As a last example, the limit of 6 days from picking to retail leads packing stations and shippers to bring the dynamics of picking and dispatch into line with each other. Shippers ask their suppliers to spread out the harvest as much as possible by making several passes on each plot.
- **The PGI inspection plan is designed to "supervise" the harvest.** The PGI checks focus on two critical stages of the process: (i) The launch of the harvest: starting the harvest too early or too late leads to irreversible quality problems of green or overripe fruit. Before starting to harvest a plot, the grower must send a fruit sample to an independent laboratory. (ii) The exit from the packing line, which is a key stage that encapsulates the quality produced at all the previous stages.

It is well established that implementation of a geographical indication (GI) scheme can result in a modified governance of upstream food supply chains (Bowen 2010). GIs not only frame individual practices through specifications and controls. They are also used to build collective strategies to differentiate products, segment the market (Belmin et al. 2018a), and increase farmers' negotiating power (Ponte 2009). In our study, we highlighted a new mechanism through which a GI can influence actors' practices and upstream supply chain governance: The "Corsican clementine" PGI rules and inspections not only regulate practices at each individual level of harvest management, they also influence the way the levels interact one another, so that the whole harvest system achieves acceptable and stable batch quality throughout the season.

4.4 Prospects for future research on harvesting

Many research works have explored the effect of harvest practices on crop performances, but to the best of our knowledge, our article is the first to highlight how harvest practices are constructed. By focusing future research on harvest management, agronomists would address a huge gap in our knowledge of agricultural systems. Studies of harvest management may concern not only the question of the quality of fresh fruit and vegetables but also other performative aspects of

agricultural systems such as work organization, batch valorization, or management of pests such as fruit flies.

Agronomic researchers have developed models and decision-making tools with a view to providing growers, packers, and shippers with accurate yield estimates (Sarron et al. 2018), or to defining optimal harvest dates so as to achieve a targeted fruit yield or quality (Caixeta-Filho 2006; Soto-Silva et al. 2016). Based on our results, we suggest that sharing such information is a necessary but not sufficient condition to improve harvest management. Indeed, harvest practices are not only guided by orchard features (fruit maturity, yield, etc.). Farmers base their decision-making by looking for trade-offs between the dynamics of plots, farm, and shipping. Further than looking for optimal physiological dates of harvest, future models and decision-making tools should be designed to help farmers and other actors to reach the best compromise between maturity and the various sources of incentives and constraints which result from the multi-level organization of the harvest.

5 Conclusion

Past harvest studies have assessed the impact of harvest methods or dates on crops performances (quality, yield, etc.) in order to propose prospects for improved harvest management. However, these studies have often overlooked the institutional and organizational factors constraining farmers' actions. Our study is the first to highlight how harvest practices are constructed, and how various hierarchical levels of agricultural systems act together to shape them. As our results suggest, harvest practices are shaped by the functioning of three management levels: (i) the plot, where the picking team selects the fruit to be picked from those to be left on the tree for the next pass; (ii) farm level, at which the growers synchronize the harvesting dynamics with the ripening process of a set of plots with heterogonous degree of maturity; and (iii) the shippers, who must match up the harvesting dynamics of all their suppliers with their buyers' demands.

This multi-level perspective sheds a light on the diversity of harvest management practices. It results from level-specific incentives or constraints such as rain (plot level) or work organization (farm level). It also comes from multi-level interactions, since inadequate practices at one level can affect the workings of the other two. Eventually, the whole vertical organization of the harvest system is highly challenged by the fruit's perishable, variable, and seasonal nature: During the harvest, sharp tensions arise between an orchard, subject as it is to regulation by natural processes such as ripening and biotic and abiotic pressures, and a human system whose operation is shaped by the constraints of its vertical organization. These tensions lead to inadequate harvest practices that explain many of the quality problems connected with harvesting. We have also shown that harvest practices and quality objectives are pushed in different directions by each system of vertical coordination between plot, farm, and shipper.

Finally, we have shown that a geographical indication, through its rules and inspections, can have a powerful impact on harvest management. Specifically, the "Clémentine de Corse" PGI has improved the workings of each management level, as well as their interactions, via three levers: (i) by setting outcome objectives for each stage of the harvesting process, organize enforceable quality assessment criteria; (ii) by setting resource objectives that contribute towards stable quality throughout the chain and a good match between fruit color and picking; and (iii) by concentrating its inspections on the harvest launch and the exit from the packing line, two key stages in the construction of quality and coordination between actors.

Our study opens up new prospects for researchers and actors who design innovations targeting fruit tree growers, packers, or shippers. Knowing the strong interdependencies between the three levels of plots, farms, and marketing, one should design innovations by choosing between two possible pathways. The first pathway consists in making sure that any innovation designed at one level will fit with the workings of the other two. This option is well suited to incremental innovations that improve systems without upsetting them (e.g., adoption of a new clementine variety, see Belmin et al. 2018b for an example). The second pathway is to design a coherent set of innovations that are structured at all three levels in order to build a sociotechnical niche (Meynard et al. 2017). Hence, coupling innovations of various kinds along the supply chain will allow the development of breakthrough innovations (organize innovations that unfit the dominant sociotechnical system) such as agro-ecological farming systems involving a combination of various horticultural crops (e.g., vegetables, fruit trees of various species).

Acknowledgements This paper benefited from the contribution made by Harriet Coleman and James Brownlee, who improved the quality of the written English. We would also like to thank all the stakeholders from the Corsican clementine production area who kindly agreed to answer our questions. The authors are particularly grateful to the Association of Growers' Organizations (AOP Fruits de Corse) who provided the economic data.

Authors' contributions Conceptualization, R.B., L.J., J.M.M., F.C.; Methodology, R.B., L.J., J.M.M., F.C.; Validation, R.B.; Formal analysis, R.B., L.J.; Investigation, R.B., L.J.; Resources, F.C.; Writing–original draft, R.B.; Writing–review and editing, R.B., J.M.M., F.C.; Visualization, R.B., L.J.; Supervision, F.C., J.M.M.; Project administration, F.C.; Funding acquisition, F.C., J.M.M

Funding This work was supported by the French Research Institute for Agriculture, Food and Environment (INRAE) and by the Territorial Authority of Corsica (Collectivité Territoriale de Corse).

Data availability The datasets generated during and/or analyzed during the current study are available from the corresponding author on reasonable request.

Declarations

Research involving human participants The study was conducted according to the guidelines laid down in the 1964 Helsinki Declaration and its later amendments.

Informed consent All study participants gave informed consent to participate in the study.

Consent for publication The authors affirm that human research participants provided informed consent for this publication.

Conflict of interest The authors declare no competing interests.

References

Ait Hou M, Grazia C, Malorgio G (2015) Food safety standards and international supply chain organization: a case study of the Moroccan fruit and vegetable exports. Food Control 55:190–199. https://doi.org/10.1016/j.foodcont.2015.02.023

Akkerman R, Farahani P, Grunow M (2010) Quality, safety and sustainability in food distribution: a review of quantitative operations management approaches and challenges. OR Spectr 32:863–904. https://doi.org/10.1007/s00291-010-0223-2

Amorim P, Günther H-O, Almada-Lobo B (2012) Multi-objective integrated production and distribution planning of perishable products. Int J Prod Econ 138:89–101. https://doi.org/10.1016/j.ijpe.2012.03.005

Belmin R, Casabianca F, Meynard J-M (2018a) Contribution of transition theory to the study of geographical indications. Environ Innov Soc Tr 27:32–47. https://doi.org/10.1016/j.eist.2017.10.002

Belmin R, Meynard J-M, Julhia L, Casabianca F (2018b) Sociotechnical controversies as warning signs for niche governance. Agron Sustain Dev 38:44. https://doi.org/10.1007/s13593-018-0521-7

Bonnans S, Noble AC (1993) Effect of sweetener type and of sweetener and acid levels on temporal perception of sweetness, sourness and fruitiness. Chem Senses 18:273–283. https://doi.org/10.1093/chemse/18.3.273

Bowen S (2010) Embedding local places in global spaces: geographical indications as a territorial development strategy. Rural Sociol 75:209–243. https://doi.org/10.1111/j.1549-0831.2009.00007.x

Caixeta-Filho JV (2006) Orange harvesting scheduling management: a case study. J Oper Res Soc 57:637–642. https://doi.org/10.1057/palgrave.jors.2602041

Canali S, Ortolani L, Campanelli G, Robačer M, von Fragstein P, D'Oppido D, Kristensen HL (2017) Yield, product quality and energy use in organic vegetable living mulch cropping systems: research evidence and farmers' perception. Renew Agric Food Syst 32:200–213. https://doi.org/10.1017/S1742170516000314

Capillon A, Valceschini E (1998) La coordination entre exploitations agricoles et entreprises agro-alimentaires : Un exemple dans le secteur des légumes transformés. In: Gestion des exploitations et des ressources rurales : Entreprendre, négocier, évaluer. INRA Ed, Etudes et Recherches sur les Systèmes Agraires et le Développement, pp 259-275

Chahidi B, El-Otmani A, Luro F et al (2007) Fruit quality characterization of seven clementine cultivars. J Appl Hortic 9:162–166

Chomchalow S, Assi NME, Sargent SA, Brecht JK (2002) Fruit maturity and timing of ethylene treatment affect storage performance of green tomatoes at chilling and nonchilling temperatures. Hort Technol 12:104–114. https://doi.org/10.21273/HORTTECH.12.1.104

Crisosto CH, Valero D (2008) Harvesting and postharvest handling of peaches for the fresh market. In: The peach: botany, production and uses. CAB International, Wallingford, pp 575–596

Dag A, Kerem Z, Yogev N, Zipori I, Lavee S, Ben-David E (2011) Influence of time of harvest and maturity index on olive oil yield and quality. Sci Hortic 127:358–366. https://doi.org/10.1016/j.scienta.2010.11.008

de Raymond AB, Bonnaud L, Plessz M (2013) Introduction : Les fruits et légumes dans tous leurs états. La variabilité, la périssabilité et la saisonnalité au cœur des pratiques sociales. Rev Etudes Agric Environ 11. https://doi.org/10.4074/S1966960713011016

de Sainte MC, Mariani M, Millet M et al (2020) Can raw milk cheese and pasteurised milk cheese coexist? Unthinkable or never really considered? Rev Agric Food Environ Stud 101:287–309. https://doi.org/10.1007/s41130-020-00106-y

Ding MJ, Jie F, Parton KA, Matanda MJ (2014) Relationships between quality of information sharing and supply chain food quality in the Australian beef processing industry. Int J Logist Manag 25:85–108. https://doi.org/10.1108/IJLM-07-2012-0057

Dogliotti S, García MC, Peluffo S, Dieste JP, Pedemonte AJ, Bacigalupe GF, Scarlato M, Alliaume F, Alvarez J, Chiappe M, Rossing WAH (2014) Co-innovation of family farm systems: a systems approach to sustainable agriculture. Agric Syst 126:76–86. https://doi.org/10.1016/j.agsy.2013.02.009

Dong L, Zhou H-W, Sonego L, Lers A, Lurie S (2001) Ethylene involvement in the cold storage disorder of 'Flavortop' nectarine. Postharvest Biol Technol 23:105–115. https://doi.org/10.1016/S0925-5214(01)00106-5

Drake SR, Eisele TA (1997) Quality of 'gala' apples as influenced by harvest maturity, storage atmosphere and concomitant storage with 'Bartlett' pears1. J Food Qual 20:41–51. https://doi.org/10.1111/j.1745-4557.1997.tb00450.x

Everingham YL, Stone RC, Muchow RC (2001) An assessment of the 5 phase SOI climate forecasting system to improve harvest management decisions. In: Proceedings of the 2001 Conference of the Australian Society of Sugar Cane Technologists, Mackay, pp 44–50

FAO, WHO (2003) Assuring food safety and quality: guidelines for strengthening national food control systems. Joint FAO/WHO Publication, Rome

Graham R, Jenkins L, Hertel K et al (2017) Re-evaluating seed colour change in canola to improve harvest management decisions. "Doing More with Less". In: Proceedings of the 18th Australian Agronomy Conference, Ballarat, pp 1–4

Iglesias DJ, Cercós M, Colmenero-Flores JM, Naranjo MA, Ríos G, Carrera E, Ruiz-Rivero O, Lliso I, Morillon R, Tadeo FR, Talon M (2007) Physiology of citrus fruiting. Braz J Plant Physiol 19:333–362. https://doi.org/10.1590/S1677-04202007000400006

Julhia L, Belmin R, Meynard J-M, Pailly O, Casabianca F (2019) Acidity drop and coloration in clementine: implications for fruit quality and harvesting practices. Front Plant Sci 10. https://doi.org/10.3389/fpls.2019.00754

Kader AA (1999) Fruit maturity, ripening, and quality relationships. In: International symposium on effect of preharvest and postharvest factors on storage of fruit. International Society Horticultural Science, Leuven, pp 203–208. https://doi.org/10.17660/ActaHortic.1999.485.27

Le Bail M (2005) Le bassin d'approvisionnement : territoire de la gestion agronomique de la qualité végétale. In: Agronomes et territoires : Deuxième édition des entretiens du Pradel. L'Harmattan, Paris, pp 213–228

Le Gal P-Y, Dugué P, Faure G, Novak S (2011) How does research address the design of innovative agricultural production systems at

the farm level? A review. Agric Syst 104:714–728. https://doi.org/10.1016/j.agsy.2011.07.007

Léchaudel M, Joas J (2006) Quality and maturation of mango fruits of cv. Cogshall in relation to harvest date and carbon supply. Aust J Agric Res 57:419–426. https://doi.org/10.1071/AR05159

Maul F, Sargent SA, Balaban MO et al (1998) Aroma volatile profiles from ripe tomatoes are influenced by physiological maturity at harvest: an application for electronic nose technology. J Am Soc Hortic Sci 123:1094–1101. https://doi.org/10.21273/JASHS.123.6.1094

Meuwissen MPM, Feindt PH, Spiegel A, Termeer CJAM, Mathijs E, Mey Y, Finger R, Balmann A, Wauters E, Urquhart J, Vigani M, Zawalińska K, Herrera H, Nicholas-Davies P, Hansson H, Paas W, Slijper T, Coopmans I, Vroege W, Ciechomska A, Accatino F, Kopainsky B, Poortvliet PM, Candel JJL, Maye D, Severini S, Senni S, Soriano B, Lagerkvist CJ, Peneva M, Gavrilescu C, Reidsma P (2019) A framework to assess the resilience of farming systems. Agric Syst 176:102656. https://doi.org/10.1016/j.agsy.2019.102656

Meynard J-M, Jeuffroy M-H, Le Bail M et al (2017) Designing coupled innovations for the sustainability transition of agrifood systems. Agric Syst 157:330–339. https://doi.org/10.1016/j.agsy.2016.08.002

Morales J, Tárrega A, Salvador A, Navarro P, Besada C (2020) Impact of ethylene degreening treatment on sensory properties and consumer response to citrus fruits. Food Res Int 127:108641. https://doi.org/10.1016/j.foodres.2019.108641

Morel K, Léger F (2016) A conceptual framework for alternative farmers' strategic choices: the case of French organic market gardening microfarms. Agroecol Sustain Food Syst 40:466–492. https://doi.org/10.1080/21683565.2016.1140695

Muchow RC, Higgins AJ, Andrew WT, Haynes MA (2000) Towards improved harvest management using a systems approach. In: Proceedings of the 2000 Conference of the Australian Society of Sugar Cane Technologists, Bundaberg, pp 30–37

Navarrete M, Le Bail M, Papy F et al (2006) Combining leeway on farm and supply basin scales to promote technical innovations in lettuce production. Agron Sustain Dev 26:77–87

Nesme T, Lescourret F, Bellon S, Habib R (2010) Is the plot concept an obstacle in agricultural sciences? A review focussing on fruit production. Agric Ecosyst Environ 138:133–138. https://doi.org/10.1016/j.agee.2010.04.014

Pailly O, Tison G, Amouroux A (2004) Harvest time and storage conditions of 'Star Ruby' grapefruit (Citrus paradisi Macf.) for short distance summer consumption. Postharvest Biol Technol 34:65–73. https://doi.org/10.1016/j.postharvbio.2004.04.005

Pelayo-Zaldívar C, Ebeler SE, Kader AA (2005) Cultivar and harvest date effects on flavor and other quality attributes of california strawberries. J Food Qual 28:78–97. https://doi.org/10.1111/j.1745-4557.2005.00005.x

Ponte S (2009) Governing through quality: conventions and supply relations in the value chain for South African wine. Sociol Rural 49:236–257. https://doi.org/10.1111/j.1467-9523.2009.00484.x

Salunkhe DK, Bolin HR, Reddy NR (1991) Storage, processing, and nutritional quality of fruits and vegetables. Volume I. Fresh fruits and vegetables. In: Storage, processing, and nutritional quality of fruits and vegetables. Volume I. Fresh fruits and vegetables. CRC Press

Sanderson MA, Read JC, Reed RL (1999) Harvest management of switchgrass for biomass feedstock and forage production. Agron J 91:5–10. https://doi.org/10.2134/agronj1999.00021962009100010002x

Saranwong S, Sornsrivichai J, Kawano S (2004) Prediction of ripe-stage eating quality of mango fruit from its harvest quality measured non-destructively by near infrared spectroscopy. Postharvest Biol Technol 31:137–145. https://doi.org/10.1016/j.postharvbio.2003.08.007

Sarron J, Malézieux É, Sané CAB, Faye É (2018) Mango yield mapping at the orchard scale based on tree structure and land cover assessed by UAV. Remote Sens 10:1900. https://doi.org/10.3390/rs10121900

Serrano M, Díaz-Mula HM, Zapata PJ et al (2009) Maturity stage at harvest determines the fruit quality and antioxidant potential after storage of sweet cherry cultivars. J Agric Food Chem 57:3240–3246. https://doi.org/10.1021/jf803949k

Shukla M, Jharkharia S (2013) Agri-fresh produce supply chain management: a state-of-the-art literature review. Int J Oper Prod Manag 33:114–158. https://doi.org/10.1108/01443571311295608

Soto-Silva WE, Nadal-Roig E, González-Araya MC, Pla-Aragones LM (2016) Operational research models applied to the fresh fruit supply chain. Eur J Oper Res 251:345–355. https://doi.org/10.1016/j.ejor.2015.08.046

Tan M, Temel S, Yolcu H (2003) Effect of harvest management on the mineral composition of common vetch. Optimal forage systems for animal production and the environment. In: Proceedings of the 12th Symposium of the European Grassland Federation, Pleven, pp 423–425

Tordjman S, Navarrete M, Papy F (2005) Les formes de coordination technique entre une structure de première mise en marché et ses fournisseurs : le cas de la salade en Roussillon. Cah Agric 14(1):479–484

Trienekens J, Zuurbier P (2008) Quality and safety standards in the food industry, developments and challenges. Int J Prod Econ 113:107–122. https://doi.org/10.1016/j.ijpe.2007.02.050

Vandecandelaere E, Arfini F, Belletti G et al (2009) Linking people, places and products: A guide for promoting quality linked to geographical origin and sustainable geographical indications. FAO, Rome

Watson R, Wright CJ, McBurney T, Taylor AJ, Linforth RS (2002) Influence of harvest date and light integral on the development of strawberry flavour compounds. J Exp Bot 53:2121–2129. https://doi.org/10.1093/jxb/erf088

Wiersma DW, Smith RR, Sharpee DK, Mlynarek MJ, Rand RE, Undersander DJ (1998) Harvest management effects on red clover forage yield, quality, and persistence. J Prod Agric 11:309–313. https://doi.org/10.2134/jpa1998.0309

Zipori I, Dag A, Tugendhaft Y, Birger R (2014) Mechanical harvesting of table olives: harvest efficiency and fruit quality. Hort Sci 49:55–58. https://doi.org/10.21273/HORTSCI.49.1.55

Zuurbier PJP (1999) Supply chain management in the fresh produce industry: a mile to go? J Food Distrib Res 30:1–11