EcoPêche 2 project: Conceive and evaluate innovative peach orchard management systems designed to reduce pesticide use by 80%

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Abstract

EcoPêche 2 project (2019-2023) is financed by the French Biodiversity Agency (OFB) within the framework of the French national ECOPHYTO Plan and DEPHY farm network. EcoPêche 2 Project follows a previous INRAE - CTIFL co-led project, called EcoPêche 1 (2013-2018), whose aim was to reduce the Treatment Frequency Index (TFI), measuring pesticide use, by 50% compared to current practice. The first project demonstrated that the TFI reduction of 50% could be achieved but the agronomic and technical-economic results decreased to varying degrees depending on the cultivar, the climate conditions and the pest and disease pressure. This present project aims to conceive and evaluate innovative peach orchard management systems designed to reduce TFI by 80% compared to a conventional management system.

At the CTIFL research center of Balandran (Bellegarde, Gard, France), the experiment is being carried out on a yellow flesh peach cultivar (PAJALADE cov). Tested practices focus on tree training, density, irrigation system and rain cover to protect the trees until harvest. 'Non-biocontrol' plant protection products are used as a last resort only. Woven foil is laid on the ground for weed management. Fruits undergo thermotherapy after harvest to reduce losses generated by brown rot. First mid-term results show that the environmental objectives can be achieved; TFI reduction in the innovative compared to Reference system was: 60% in 2019; 69% in 2020 and 93 % in 2021; but involve a loss of 40 to 50 % in yield or irregularity in production and high investment for specific practices. This project highlights how complex it is to develop new orchard management system, taking into account environmental issues.

Keywords: *Prunus persica*, Cropping system, Low pesticide use, Multicriteria evaluation, Pest and disease management

INTRODUCTION

In France, the peach production is one of the main pesticide demanding crops with an average number of phytosanitary treatments of 21.2 per year, after apple production (35.9 phytosanitary treatments per year) (Agreste, 2018). In peach production, many treatments are realized close from harvesting time to control brown rot due to *Monlinia* spp., which is one of the main problematic diseases in French peach orchards in both conventional and organic productions. Peach growers are challenged on various aspects of the production, such as being competitive and economically sustainable, producing healthy fruits (on a sanitary and organoleptic aspect) and taking the environment into account in their practices to answer the

strong societal demand. The DEPHY EXPE ECOPHYTO EcoPêche 2 project aims to design and evaluate innovative peach tree management systems to reduce the Treatment Frequency Index (TFI) by 80% while maintaining the technical and economic results of the orchard and the commercial quality fruits. TFI is a pesticide use indicator used to measure and compare the dependency of cropping systems to phytosanitary products and can be considered as related to the impact of pest management practices on the environment. TFI presented in this article corresponds to the number of registered doses of phytopharmaceutical products applied in the orchard across the season.

On peach and nectarine, the significant reduction in the use of synthetic phytopharmaceutical products is a major challenge due to the really few commercial cultivars that are tolerant or resistant to diseases such as brown rot or leaf curl *Taphrina deformans* (Ruesch *et al*., 2016).

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This project aims to conceive and evaluate innovative peach orchard management systems designed to reduce TFI by 80% compared to a reference management system. Other objectives are to produce pesticide residue free fruits, using a maximum of 4 « non-biocontrol » products and no herbicide. The project involves 6 partners. Innovative orchard management systems are compared on environmental, agronomic and technical-economic performances and health indicator.

This article presents the first results of a trial conducted by CTIFL, at Balandran center between 2019 and 2021 on the yellow peach PAJALADE cov.

MATERIAL AND METHODS

Pedoclimatic conditions

The trial is conducted at the CTIFL, operational center of Balandran, located in Bellegarde (Gard), in South-Eastern France, close to Nîmes. The site is localized in an area called “Costières de Nîmes” characterized by a Mediterranean climate. The soil is a leached fersiallitic type called “gress à gapan”. It is Rhone River alluvium (gravel) partly covered with decalcified loess origin. The textural class of the surface horizon is fine silty-clay-sandy texture (LAS according GEPPA, 1963), with 10-60 % pebbles.

Tested management systems

The trial was conducted on PAJALADE cov (yellow flesh peach) grafted on Montclar® Chanturge cov rootstock, planted in 2019. Two management systems in conventional agriculture have been evaluated since planting. They were designed by partners, by associating well-known and more experimental technical practices that could permit to reach the environmental objectives.

The reference modality (REF) is led in double Y (Figure 1A, 1B) and planted at a density of 476 trees per ha (6 m x 3.5 m tree spacing design) (Blanc *et al*., 2003); irrigation consists in sprinklers on the soil. Phytosanitary protection is realized following the regional Integrated Fruit Production recommendations. The fruit tree row is managed by chemical weed control.

Figure 1.PAJALADE cov orchard grown on Reference system at the end of 3rd leaf (A). Double Y tree shape seen from above scheme (B).

The 'Eco+ modality' (referred to as 'Eco+', Figure 2A, 2B) is lead in oblique simple Y (Figure 2C), with high density of 1058 trees ha^{-1} with 4.5 m x 2.1 m tree spacing. Water supply is realized by a drip irrigation system laid under woven foil. Weed control is provided by this woven foil laid on the soil. The phytosanitary protection strategy was planned in order to maximize the reliance on biocontrol products and favor alternative methods. Other technical practices are integrated like fruit thermotherapy post-harvest treatment and use of a tangential "sprayer" to reduce sprayed mixture volume. Rain and hail protections are implemented to prevent fruit decay due to brown rot by stopping rainfall on the canopy from the fruitset stage to the end of the harvest.

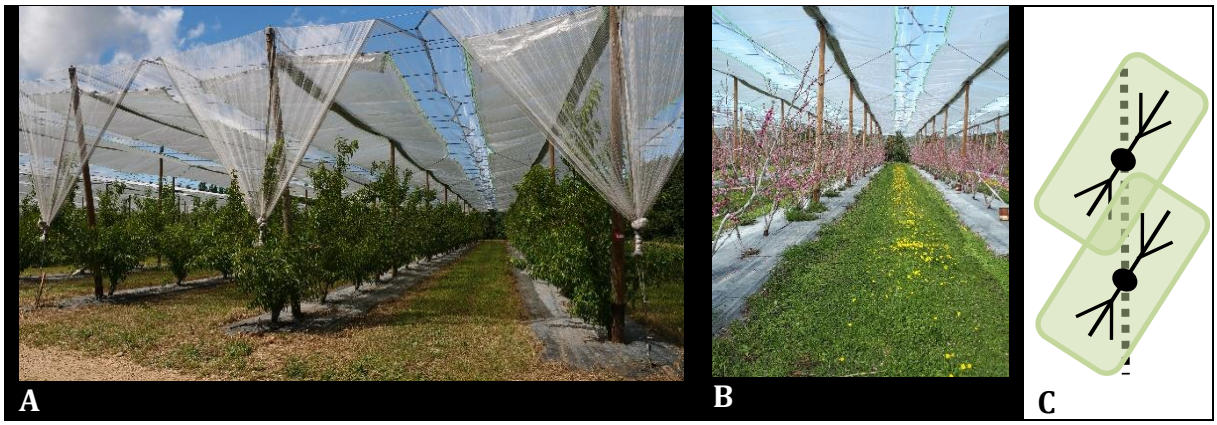

Figure 2. PAJALADE cov orchard grown under the 'Eco+' strategy in 3rd leaf. Rain cover that covers the tree row is extended from small fruits stage to end of harvest (A). Folded rain cover (B). Oblique simple Y tree shape seen from above scheme (C).

For both modalities, irrigation quantities were calculated from the water balance and adjusted with tensiometric sensors. Fertilization was calculated following regional recommendations and adjusted to the tree volume, age, vigor and crop load. Fertilization was done by spreading on the soil and fertirrigation

Multicriteria evaluation: a global approach of performances

Management systems were evaluated on a global approach.

Agronomic performances were evaluated by calculating marketed yield, decay rate and fruit size repartition.

Technical-economic performance was estimated by investment costs, labor time and costs, inputs costs and partial margin calculated as the Turnover – (Labor cost + Input costs excluding infrastructure costs).

Environmental performances were evaluated from the phytosanitary TFI. TFI is an indicator used for monitoring the use of phytopharmaceutical products (pesticides) at the farm or group of farm level. TFI accounts for the number of reference doses used per hectare during a crop year. Crop year is considered from 1st of October to 30th of September. This indicator can be calculated for a set of plots, a farm or a territory. TFI can be divided in two categories: biocontrol and non-biocontrol TFI. These two categories are defined by the French government and detailed in an official list (DGAL, 2021). It can also be sorted by major product category (herbicides; fungicides; insecticides and miticides) (Ministère de l'agriculture et de l'alimentation, 2018). In this project the TFI was calculated at the experimental plot scale. The non-biocontrol TFI of Reference and Eco+ modalities allowed to evaluate the intensity of pest management practices of both management systems and indirectly their possible environmental impact.

A health indicator was also provided by measuring pesticide residue in harvested fruits in 2021. The Table 1 present the phytosanitary treatment schedule realized between the 1st of October 2020 and the 30th of September 2021.

Table 1. Phytosanitary schedule applied on Reference modality (REF) and Eco+ modalities in 2021.

System	Pesticide category	Target	Activ ingredient (date of application)
REF	Fungicide	Leaf curl (*Taphrina deformans*)	Copper compounds (12/01; 4/2; 19/2); ziram (22/01; 19/2); dodin (05/03)
		Brown rot (*Monilinia* spp.*)*	boscalid + pyraclostrobin (09/07; 23/7); thiophanate-methyl (12/02); cyprodinil + fludioxonil (26/02)
		Powdery mildew *(Podosphaera pannosa*)	sulfur (02/04; 16/4; 3/5)
REF	Insecticide	Earwigs *(Forficula auricularia)*	deltamethrin (04/06; 25/6)
		Aphid (*Myzus persicae)*	paraffin oil (22/01; 02/04) ; spirotetramat (02/04)
		Thrips (*Thrips meridionalis)*	lambda-cyhalothrine (26/02)
		Oriental fruit moth *(Grapholita molesta)*	indoxacarb (04/06, 25/6); Mating disruption, straight chain lepidopteran pheromones (16/04)
REF	Herbicide	Weeds	carfentrazon-ethyl + fluazifop-P (04/02); napropamid (17/02) , 2,4-D + cycloxydime (21/04); glyphosat (26/05)
Eco+	Fungicide	Leaf curl	Copper compounds (12/01, 12/2); dodin (26/03)
		Brown rot	BNA (Lime milk) (02/02)
Eco+	Insecticide	Aphid	Paraffin oil (22/01; 2/2)
		Oriental fruit moth	Mating disruption, straight chain lepidopteran pheromones (16/04)

Data analysis

Since this project evaluates orchard management (Havard *et al*., 2017) involving the combination of many practices in a large plot with no replicates to work in conditions close to commercial orchards, it is not possible to realize statistical analysis. The analysis is descriptive and based on means comparisons between modalities.

RESULTS AND DISCUSSION

Agronomic performance

The fruit production of the cultivar PAJALADE cov (**Figure 3**) started in 2020 (2nd leaf orchard) with low yield in both modalities (2.3 t.ha^{-1} on Eco+ versus 0.5 t.ha^{-1} in Reference). A higher yield in 'Eco+' can be explained by the higher plantation density. The non-marketed part of the production was higher in 'Eco+' modality due to reduction in phytosanitary protection. In 2020 and 2021, waste percentage in fruit was 4.3% and 8.8% in Eco+ versus 0.0% and 5.7% in the Reference modality, respectively. Considering cumulated yield on the two years, the commercialized production was from 11.5 t.ha^{-1} in Eco+ versus 20.4 t.ha^{-1} in the Reference modality, respectively. The Eco+ performance was 44% lower than Reference whereas the fruit size was similar between the two management systems (REF. mean fruit weight: 149 g; Eco+ mean fruit weight: 145 g).

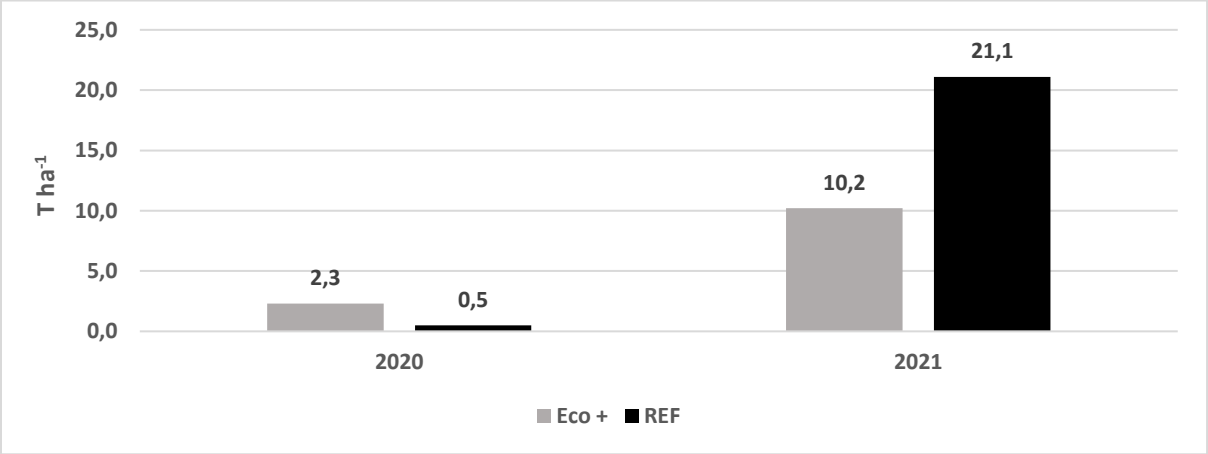

Figure 3. Production expressed in tonne per hectare harvested in 2020 and 2021 in the two management systems (PAJALADE cultivar).

Technical-economic performance

Investment costs were about eight times higher for Eco+ modality (82,400 €.ha^{-1} of equipment) than Reference (9,800 €.ha^{-1}). The reasons are multiple: higher planting density, woven ground cover, and hail and rain protection. The turnover follows the marketable yield evolution; thus, it was twice higher on Reference modality in 2021 compared to 'Eco+' modality (Table 2).

Table 2. Technical-economic indicators measured in the two management systems from 2019 (planting year) to 2021.

	2019		2020		2021	
	REF	Eco+	REF	Eco+	REF	Eco+
Marketable yield (t. ha^{-1})	0	0	0.5	2.2	19.9	9.3
Labor time (hrs. ha^{-1})	75	157	90	218	526	858
Partial margin (€. ha^{-1}) without investment costs	-1,572	-2,581	-1,880	+1,175	+35,634	+6,695
Production costs (€. kg^{-1} fruit)	/	/	5.9	1.8	0.5	1.5

Labor time represents an important part of the total production cost (70-80%) and was heavily impacted by sanitation practices in Eco+ in 2021 to remove leaf curl most infected leaves. Partial margin (calculated without including investment costs) started to be positive in the 2nd leaf for Eco+ and 3rd leaf for Reference. Production costs were particularly high in both modalities

(except in 2021, on Reference system) due to the juvenility of the orchard and the low level of productivity.

Environmental performance and pesticide use

On the three first years, the total TFI was lower on Eco+ modality compared to Reference system (-53% in 2019, -58% in 2020, -69% in 2021). If we consider only the non-biocontrol TFI category, Eco+ modality permitted to reduce TFI by 60 % in 2019, 69 % in 2020 and 93% in 2021 (Figure 4).

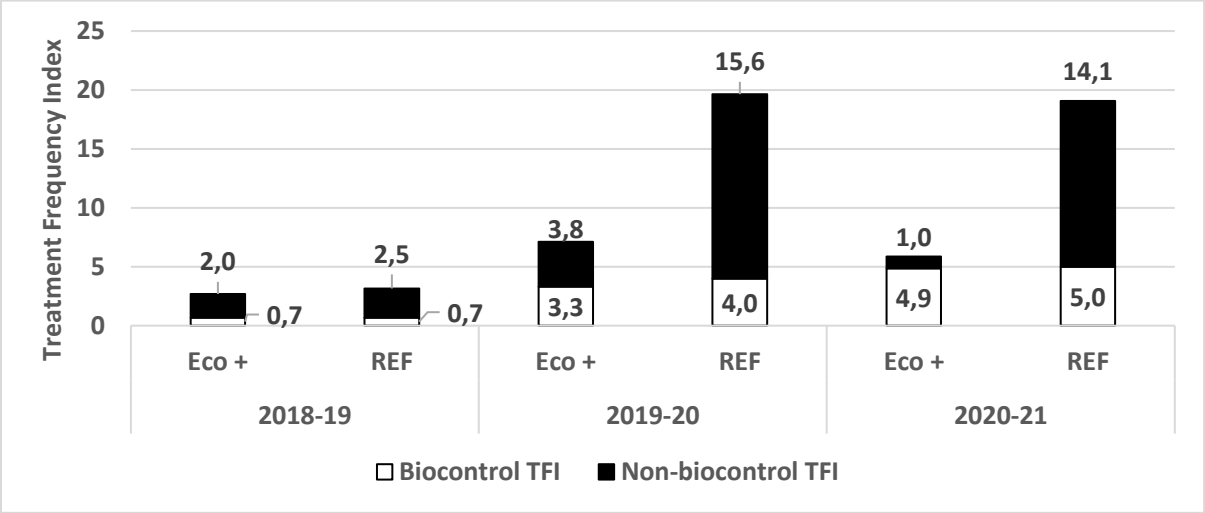

Figure 4. Biocontrol and non-biocontrol TFI per season and management system. Biocontrol and non-biocontrol phytosanitary products are sorted according to French agricultural ministry official list (DGAL/SDSPV/2021-953, 14/12/2021). Biocontrol products have less impact on environment and operators compared to non-biocontrol phytosanitary products.

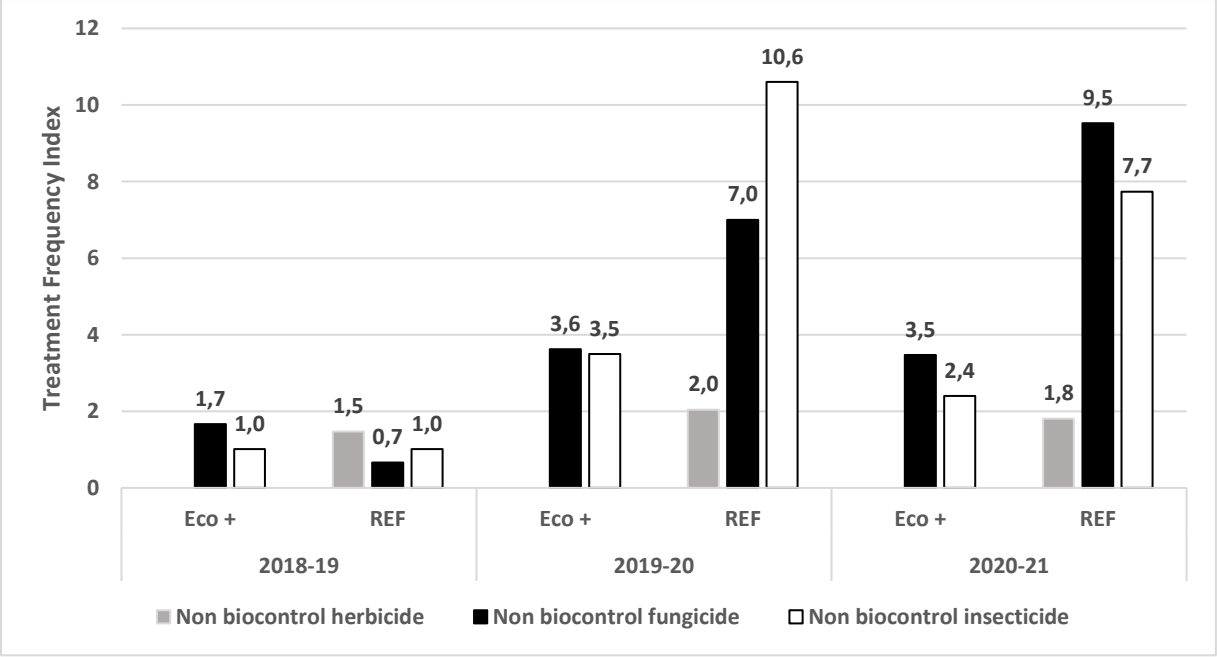

Figure 5. Non-biocontrol TFI per season and management system, detailed per target category (herbicide, fungicide and insecticide). Biocontrol and non-biocontrol phytosanitary products are sorted according to French agricultural ministry official list (DGAL/SDSPV/2021-953, 14/12/2021). Biocontrol products have less impact on environment and operators compared to non-biocontrol phytosanitary products.

Considering only non-biocontrol phytosanitary protection (Figure 5) and the repartition according to main targets (insect pests, diseases, weeds), Eco+ was managed without any herbicide application (0 TFI herbicide) vs. a mean yearly 1.8 TFI herbicide in Reference. Except in the first year of the trial, the use of fungicides and insecticides were highly decreased in Eco+ compared to Reference system, with -48% to -63% non-biocontrol fungicide and -67 to -69% non-biocontrol insecticide use, for 2020 and 2021, respectively. However, this Eco+ phytosanitary strategy induced losses of production due to an increased waste rate (3.7% and 4.1% for Reference modality vs. 6.9% and 13.3 % for Eco+ modality in 2020 and 2021, respectively) induced by a less efficient protection against pests and diseases (earwigs, brown rot).

Pesticide residues in fruits, were analyzed for the first time in the 3rd year (2021) on fruits sampled during the first harvest. Two active ingredients were identified on Reference modality: boscalid (0.16 $mg.kg^{-1}$) and pyraclostrobine (0.03 $mg.kg^{-1}$) with concentration levels far below the authorized limit (maximum residue limits are: 5 $mg.kg^{-1}$ for boscalid and 0.3 $mg.kg^{-1}$ for pyraclostrobine). These molecules are issued from Signum®, applied twice a year (respectively 27 and 13 days before first harvest) to control brown rot.

CONCLUSION

These first three-year results displayed that heavily decreasing the use of phytopharmaceutical products could lead to the reduction of marketable yield. This loss of production is not economically compensated by a higher selling price. However, these observations will have to be confirmed and consolidated over seasons.

This project aims to provide technical solutions to professionals by identifying the practices that work best and those that may present limits to control pests, diseases and weeds in peach orchards. The two tested management systems in this project are intended as a toolbox for professionals to build management systems adapted to their problems and constraints on their farms.

As part of this project, the environmental slider was very ambitious with a corresponding -80% TFI objective. Ultimately, in a "realistic" and economically viable production context, it would be necessary to achieve the best tradeoff between the number and types of practices to be mobilized; the performance objectives (*i.e.* fruit loss acceptance) and the economic viability of the system. Another key point that emerges from this project is that an environmentally virtuous approach may induce an economic loss, or at least a greater production hazard depending on the year. If this risk-taking is not economically compensated, management systems that use less synthetic plant protection products will be less applied by producers and be less economically sustainable. These aspect pose a great challenge for the fruit supply chain.

ACKNOWLEDGMENTS

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