

EcoPêche 2: Conceive and evaluate innovative peach orchard management systems to reduce dependance on phytosanitary products.

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Abstract

EcoPêche 2 (2019-2023) project is financed by the OFB (French Biodiversity Agency) within the framework of the ECOPHYTO Plan and the DEPHY farm network. The EcoPêche 2 Project follows a previous INRAE - CTIFL co-led project, called "EcoPêche 1" (2013-2018), whose aim was to reduce the chemical Treatment Frequency Index (TFI) by 50%. The first project demonstrated that the TFI reduction of 50% could be achieved but the agronomic and techno-economic results decreased to varying degrees depending on the cultivar, climate conditions and pest and disease pressure.

EcoPêche 2 project aims to develop and evaluate innovative peach orchard management systems designed to reduce TFI by 80% compared to a conventional management system. The project involves 6 partners (CTIFL, INRAE PSH Avignon, INRAE Gotheron, SEFRA, SUDEXPE and CENTREX) evaluating different combinations of levers. Innovative orchard management systems are compared using a global approach, including environmental, agronomic and techno-economic performance.

Each partner compares different combination of variable to an Integrated Fruit Production (IFP) management. Many types of variables are mobilized: cultivar choice, orchard management, weed management, biodiversity, phytosanitary protection, and physical variables. First mid-term network results show that the environmental objectives can be achieved (TFI reduction compared to Integrated fruit Production (IFP): -75 % in 2019; -84% in 2020 and -89% in 2021) but involve a loss of production (-20 % of commercial yield) and, consequently, important economic losses (partial margin -13 to -16 % depending on the year).

Keywords: *Prunus persica*, cropping system, low pesticide use, multicriteria evaluation, pest and disease management

INTRODUCTION

"EcoPêche 2" project aims to design and evaluate innovative peach tree management systems to reduce the treatment frequency index by 80% while maintaining the technical and economic results of the orchard and the commercial quality of the fruit.

Significant reduction in the use of synthetic phytopharmaceutical products is a major challenge for peach and nectarine growers due to absence of commercial cultivars that are tolerant or resistant to pests and diseases, in particular, postharvest diseases, a highly competitive market that provides little economic leeway, as well as the importance of fruit quality criteria (taste quality, appearance, etc.).

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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 conventional management system. Other objectives are to use a maximum of 4 « non biocontrol » products and no herbicides (results detailed in the paper) and produce pesticide residue free fruit (data not provided).

MATERIAL AND METHODS

The network built in the frame of this project aim to compare five orchard management systems 1) The IFP (Integrated Fruit Production) system corresponds to a conventional system and serves as a reference; 2) The Eco + system aims to reduce TFI by approximately 70- 80% compared to a conventional management system (*e.g.* IFP) and to produce pesticide residue free fruits. Fruits with zero pesticide residues, excluding any herbicide treatment and use of non-biocontrol plant protection products only as a last resort (formalized objective, at the scale of the project by a limitation to 4 TFI excluding biocontrol); 3) The Eco 50 system combines different variables and should allow a 30-50% reduction in the TFI compared to the IFP reference system; 4) The organic system is managed according to the specifications of organic agriculture ; and 5) The “0 residue” system aims to produce fruits without residues at harvest time. Each partner planted at least two management systems: Eco + and PFI and some partners compared other orchard management: Eco 50, 0 residues, Organic farming” (**Table 1**).

Table 1. Orchard management set up per partner (X: modality present at the partner site).

	Eco +	Eco 50	0 residue	Organic (OF)	Reference (IFP)
CTIFL	X	-	-	X	X
SEFRA	X	-	-	X	X*
CENTREX	X	X	X	X	X
SUDEXPE	X	-	-	-	X
INRAE PSH Avignon	X	X	-	-	X
INRAE Gotheron	X	-	-	X	X

*Modality removed due to excessive *Xanthomonas* pressure

The project partners, the CTIFL (Bellegarde, Gard), also carrying out the project, the SEFRA (Etoile-sur-Rhône, Drôme), the SICA CENTREX (Torreilles, Pyrénées-Orientales), the SUDEXPE station (Saint Gilles, Gard), the INRAE PSH (Avignon, Vaucluse), and INRAE

Gotheron (Saint-Marcel-les-Valence, Drôme) evaluated combinations of variables in orchards specifically dedicated to this project enabling these objectives to be achieved. The strategies used were based on several types of variables, acting according to different modes of action: redesign (tree shape, planting density, orchard cover), efficiency (optimization of spraying) and substitution (use of biocontrol products, pest control) or according to stage of the life of the orchard, at the design stage (planting density, irrigation system, etc.), during the production phase (use of biocontrol products, physical protection of the orchard, etc.) or in the post-harvest phase (thermotherapy).

The management systems were evaluated on a global approach on their environmental (TFI), agronomic (yield, fruit size, waste rate, etc.) and technical and economic performance (production costs, economic margins, etc.) compared to control plots. The project is also identifying the advantages and limits of variables used in real production conditions and providing technical solutions to stakeholders that can be transposed within their farms. The resilience of control systems over several production campaigns is an important evaluation criterion that will be better understood at the end of the project, in 2023.

Here we present comparative results of the Eco + management option present at all sites with the exception of the SEFRA, (where it was removed due to excessive *Xanthomonas* pressure), compared to the reference (IFP), for 5 cultivars: TONICSWEET ® Sweetstar cov at CTIFL, ORINE ® Monerin cov at CENTREX; NECTASWEET ® Nectarlove cov at INRAE PSH Avignon; SURPRISE cov at INRAE Gotheron and SANDINE ® Monrun cov at SUDEXPE. The cultivars planted in 2019 are not included in the summary because they were in the production entry phase between 2019 and 2021. Results issued from Eco 50, 0 residue and Organic Farming modalities are not included in this paper because they were not present on all sites

RESULTS AND DISCUSSION

Agronomic performance

Agronomic performances were evaluated by different traits: yield ($T\ ha^{-1}$); fruit size and waste ratio. The cumulative yield from $88.5\ T\ ha^{-1}$ and $102.5\ T\ ha^{-1}$ for Eco+ and IFP, respectively, was observed for 3 years (2019, 2021) with an average reduction by -14% (-9% in 2019; -19% in 2020; -12% in 2021) (**Figure 1**). Considering the commercialized yield which was $70.4\ T\ ha^{-1}$ and $87.5\ T\ ha^{-1}$ for Eco+ and IFP, respectively, the difference in reduction of yield between the two modalities increased to -20% for the Eco + modality compared to the IFP (2019: -14%; 2020: -25%; 2021: - 26%). This difference could be explained by a higher rate of waste on Eco + modality compared to IFP. Waste rate was very variable depending on the year and the pest and diseases pressure and was around 12-25 % in Eco + modalities versus 11-14 % for conventional orchard management (IFP). The 2021 yield was heavily penalized by the frost on April 8, 2021, which affected the entire French territory. This caused significant, even total, crop losses on certain sites in the network.

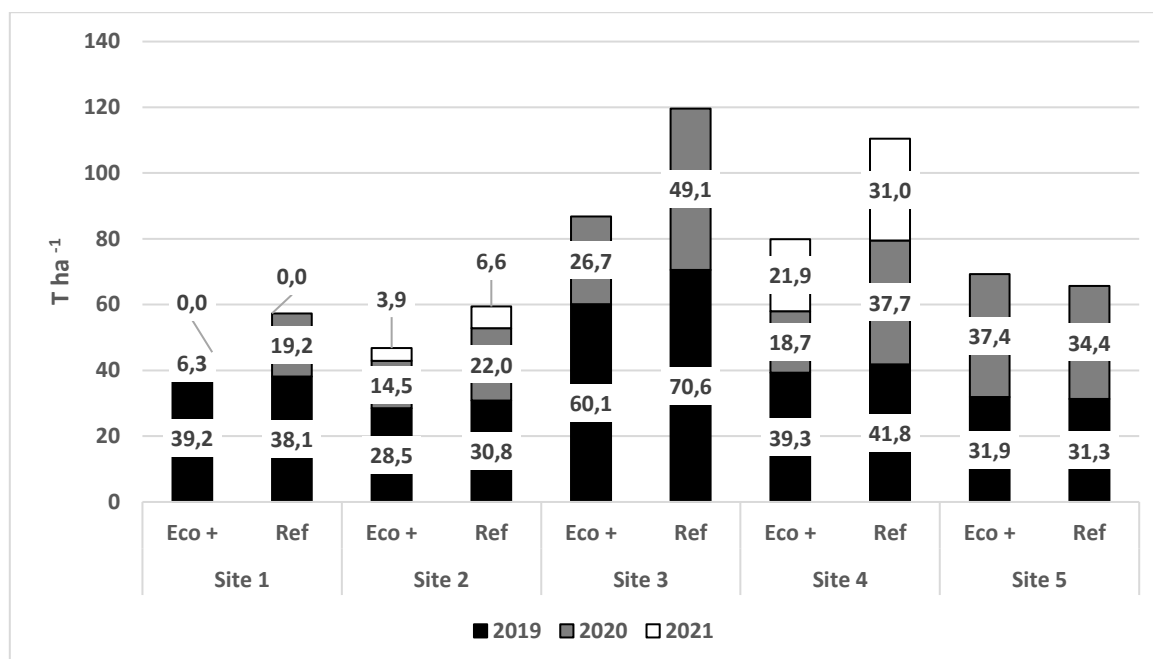


Figure 1. Cumulative commercialized yield per site and modality across three seasons (2019-2021) (expressed in T ha⁻¹). Site 1: INRAE Avignon, cv NECTARLOVE; site 2: INRAE Gotheron, cv SURPRISE ; site 3: CTIFL, cv SWEETSTAR ; site 4: SUDEXPE, cv SANDINE ; site 5: CENTREX, cv ORINE.

Technical economic performance

Techno-economic performances were evaluated using various criteria. The labor required per ha were very variable and lower for Eco + modality (462-1067 h ha⁻¹) compared to IFP (607-1250 h ha⁻¹). The Eco+ modality showed reduction in labor by 15 % in 2019 and 2020, and 42 % in 2021, and by 20% in 2019 and 2020 and 15% in 2021, with or without including labor required for harvest, respectively. Overall, without harvest, Eco + modality needed less labor per ha. This difference could be explained by the lower vigor under Eco + modality, due to tree weakening caused by diseases and pests. The ratio between the labor and commercialized weight (expressed in h T⁻¹) shows the Eco + modality as less efficient especially during last two years (-3% in 2019, +31% in 2020 and +10% in 2021). The ratio was particularly high in 2021 for both modalities, due to a lack of production (spring frost) (data not shown).

The production costs were 22% lower under Eco +, compared to IFP modality. The difference is essentially due to labor costs, which represent about 60-70 % of total costs. The production cost per kilogram (expressed in € kg⁻¹) was around 0.48-0.82 € kg⁻¹ for Eco + modality versus 0.41-0.75 € kg⁻¹ for IFP modality. The difference in production costs between the two modalities were highly variable, depending on the production level and the season, with no difference observed in 2019, +41% and +10% observed in 2020, and 2021, respectively, with more often the advantage on the side of IFP orchard management. The economic margin (expressed in € ha⁻¹) was lower for Eco + comparing to IFP (-16% in 2019, -29 % in 2020 and -13% in 2021). The reduction in production cost (labor) did not make it possible to compensate for the loss of production. This resulted in a positive economic result but lower than for the reference orchard system.

Environmental performance

The objective of using non-biocontrol treatment frequency index (TFI) only as a last resort (formalized, at project level by a limitation to 4 non-biocontrol TFIs) was achieved in 2019 and 2021 and almost achieved in 2020 (influenced by strong disease and pest pressure) (**Figure 2**). Considering only non-biocontrol TFIs in weed control, we report almost complete elimination of chemical herbicides (-92%). They were replaced by the installation of woven tarps on the row or by tillage. The use of synthetic insecticide products has also been greatly reduced (-90%). The main reason for their persistence is the fact that sustainable peach cultivation is particularly difficult, without synthetic fungicide treatments (-74%).

Non biocontrol TFIs were reduced from $82 \pm 7\%$, with TFI mean values of 2.9 and 16.1, for Eco+ and IFP, respectively.

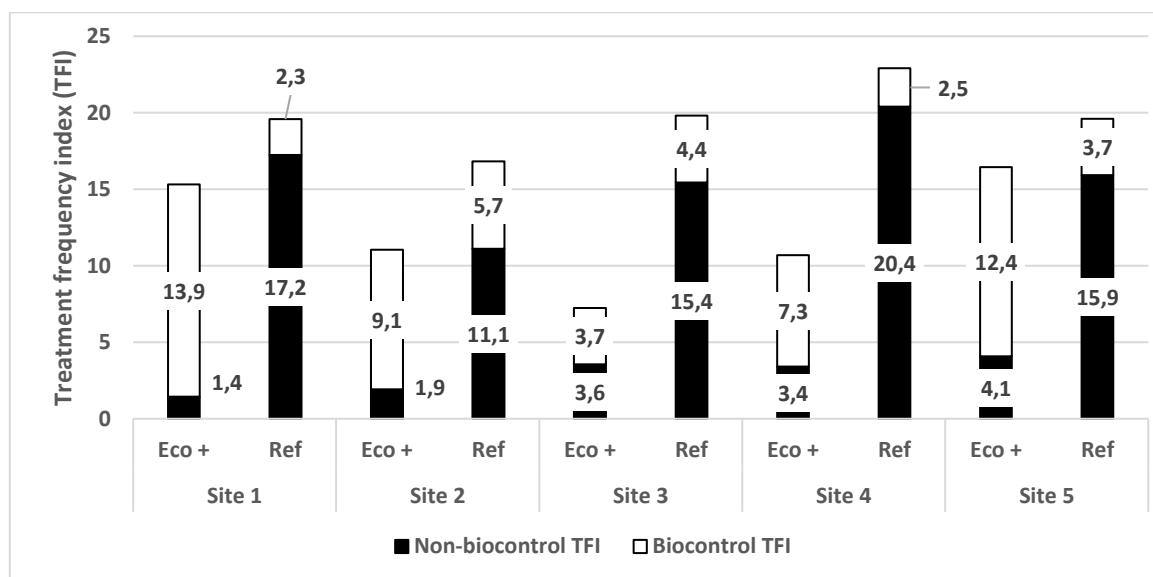


Figure 2. Average biocontrol and non-biocontrol treatment frequency index (TFI) per site and modality, calculated on 2019-2021 period. Site 1: INRAE Avignon, cv NECTARLOVE; site 2: INRAE Gotheron, cv SURPRISE ; site 3: CTIFL, cv SWEETSTAR ; site 4: SUDEXPE, cv SANDINE ; site 5: CENTREX, cv ORINE.

SYNTHESIS

This project seeks to identify the combination of variables in orchard management system offering the best compromise between environmental, agronomic and techno-economic performance. As part of this project, the "minimization of environmental impact" slider is deliberately very ambitious. It is therefore necessary to take a certain distance from the figures presented below which come from experimental systems with high risk taking and do not necessarily reflect the reality of farms which have different operating methods. The relationship between TFI excluding biocontrol and economic margin shows that Eco + management is very well positioned from the point of view of their environmental impact (median TFI excluding biocontrol of 2.9 against 16.1 for IFP). However, from the point of view of economic performance, the results are less good, with a median of the partial margins positioned around $17,820 \text{ € ha}^{-1}$ against $25,970 \text{ € ha}^{-1}$ for the IFP, *i.e.* approximately -31%. In addition, the Eco + management economic results were less effective (**Figure 3**).

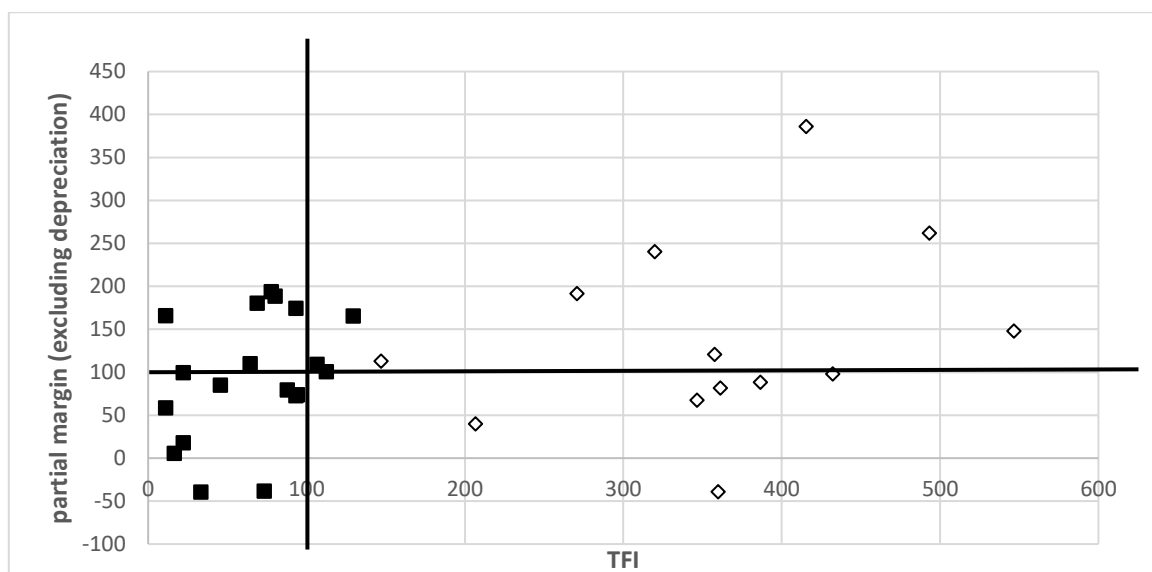


Figure 3. Correlation between Treatment Frequency Index (TFI) values and economical partial margin. Data normalized centered on the median value (black square: Eco+; white circle: Reference IFP).

To allow comparison of different criteria with different variables, representing environmental, agronomic and technical-economic performance, at network scale the difference between the Eco + and IFP management for the three years (2019-2021 and average), for sites planted before 2019 were expressed as % where IFP = 100 (**Table 2**).

Table 2. Compared performance on a IFP 100 basis of different modalities. Mean data of three years (2019, 2020 and 2021).

Eco + / IFP	Environ. Perf.	Agronomic performance					
	TFI/commercialized prod.	Production	Commercialized production	% A and more fruit size	% waste	N fertiliz./commercialized prod.	Irrig water/commercialized prod.
2019	28%	91%	86%	128%	104%	101%	92%
2020	21%	81%	76%	134%	176%	157%	164%
2021	15%	89%	73%	148%	188%	127%	124%
Average	21%	87%	78%	136%	156%	128%	127%

Eco + / IFP	Techno-economic performance				
	Total hours / ha	Nber of hours / commercialized prod.	Production costs / kg	Production costs / kg*	Average partial margin**
2019	85%	96%	100%	89%	84%
2020	84%	131%	142%	87%	71%

2021	76%	109%	110%	76%	34%
Average	82%	112%	117%	84%	63%

*Without mechanization cost

** Average partial margin = annual sales – production costs

While the environmental performance is clearly achieved, the agronomic performance is generally worse under Eco + management than the IFP (except for fruit size, which is a consequence of the lower tree load level). Finally, techno-economic performance is worse in Eco + than IFP over the first three campaigns of the project. The last two years of the project should confirm or invalidate the observations made since 2019. They would allow for better assessment of the performance and resilience of the various systems. The EcoPêche 2 project makes it possible to acquire production cost references from which a culture is economically viable. It also highlights the importance of the various technical solutions, such as the choice of variety, the hydromineral diet or even alternative methods of protection.

CONCLUSION

This project aims to provide technical solutions to stakeholders by identifying the variables that work best and those that do not work so well. The various systems put in place as part of this project are intended as a toolbox for stakeholders to build, on their farms, management systems adapted to their problems and constraints.

As part of this project, the environmental slider was pushed very far (-80% IFT). Ultimately, in a “realistic” and economically viable production context, it will be necessary to find the best compromise between the number and types of variables mobilized; the performance objectives (loss acceptance) and the economic viability of the control systems. Another important point that emerges from this project is the fact that an environmentally friendly approach usually induces 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 efficient and less economically sustainable.

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