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REVATRA: Transition of the Almond Orchard to agro-ecology through redesign

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Abstract

REVATRA project is based on the design of an innovative, multi-performing agrosystem with the aim of reducing IFT from 60% to 80%. This objective has been achieved, mainly through the reduction of insecticides. Regular monitoring of pests and their auxiliaries, the use of a woven tarpaulin and the installation of a net were the main levers used. The latter also makes it possible to consider the management of other almond pests. The management of fungal diseases is still under "chemical" control, with a very slight reduction in treatments through monitoring of climatic conditions. Planting costs are against the innovative agrosystem. The two years of frosts had a severe impact on production in both systems, preventing us from carrying out an economic study.

Keywords: Treatment Frequency Index (IFT) - Levers - Partnership - Transfer - Organic agriculture

1. Introduction

In the south of France, and more particularly in the Provence, Occitanie and southern Rhône-Alpes regions, almond tree plantations are expanding, driven by a favourable terroir, strong demand and a sector that is mobilising to promote local production. This is complemented by the fact that many growers are interested in the possibility of mechanised almond harvesting, a socio-economic factor of great interest today. This strong demand was assessed in more detail in a study by the Centre Technique Interprofessionnel des Fruits et Légumes (CTIFL) (G. Christy, 2017). In recent years, this demand has increased further with the arrival of new regions interested in growing almonds. These include the Nouvelle Aquitaine region, where new almond orchards are being established in various areas, mainly Lot et Garonne but also Charentes and Dordogne.

The current revival follows years of decline in French almond production, the (negative) corollary of which was a sharp drop in national research programmes (fundamental and applied) on this species. Access to foreign research, particularly from Spain, is beneficial, but the lack of local references means that there is no 'scientific autonomy' on which to base research into high-performance almond agro-systems.

The almond-growing sector is in a growth phase; over the last five years, the surface area of almond orchards has doubled, rising from 1,100 ha in 2018 to more than 2,200 ha in 2023 (source: Agreste 2024). This initiative is in line with a recovery plan coordinated by the Provence - Alpes - Côtes d'Azur (PACA) Regional Chamber of Agriculture, and with other initiatives including the Vallée des Baux-Alpilles Community of Municipalities, which has included the almond tree in its territorial development plan, the France Amande interprofession (created at the end of 2018), the Syndicat des amandiculteurs de Provence and other private initiatives such as the creation of the "Compagnie des amandes".

Given the enthusiasm and legitimate expectations of professionals for profitable, environmentally friendly strategies, it cannot do without a reference tool, specifically called the Dephy innovative agro-system, in order to combine savings in inputs with economic performance.



This long-awaited tool (to be supplemented by other programmes) concerns almond growing in general, and organic almond growing in particular. Many food and cosmetics companies ("Les calissons du Roi René", "L'Occitane en Provence", "Un air d'ici", SOFALIP, etc...) are asking farmers to supply them with French almonds from both conventional and organic production. This demand was very strong at the start of the project. It is less pronounced today, but remains significant given the conviction of certain producers to continue in this direction despite the current economic crisis. However, growing almond trees using organic methods is difficult in terms of fungal diseases, but above all it is literally 'blocked' because of the major damage caused by a hymenoptera, *Eurytoma amygdali Enderlein* (Khanmohamadi et al., 2016), against which no strategy applicable at the start of the project was proving sufficiently effective. The aim of the innovative Déphy orchard was therefore, in an approach that favoured redesign (substitutive and efficient proposals alone being too limited), to validate levers enabling a protection strategy applicable to AB. However, it is important to remember that the information that is beneficial and validated in AB will be applicable to conventional farming.

The main objective of the project is to significantly reduce the number of phytosanitary treatments while maintaining the profitability of the plots. In conventional farming, the average number of annual chemical treatment frequency indices (IFT) currently recorded for almond trees varies from 6 to 8 (there is no reference IFT for almond trees, Com. Pers). It is essentially divided between fungal diseases and insect pests (herbicides are used but generally represent less than 1 IFT/ha/year). In organic farming, this number is relatively close due to the use of copper at different periods in the production cycle (as well as Spinosad, or calcium polysulphide if a derogation is granted).

The main pests are fungal pathogens such as *Monilia laxa*, *Fusicoccum amygdali* and *Polystigma ochraceum*, which require between 3 and 4 annual chemical IFTs, and *Eurytoma amygdali Enderlein*, which can cause severe crop losses (2 to 3 annual chemical IFTs), as well as the almond aphid (*Brachycaudus amygdalinus*). Other fungi and pests considered secondary may also be the cause of chemical treatments: *Tranzschelia pruni-spinosae* (almond rust), *Coryneum berejinckii*, *Asymmetrasca decedens* (leafhopper), etc. During the period when the project was in place, a new pest, *Monosteira unicastata* or false almond tiger (Grisvard P. 2023), appeared on the scene. This insect travelled up from Spain, taking advantage of the very high temperatures in late spring, and took up residence in the plots, causing leaf discolouration and fall, particularly in AB, which were highly detrimental to the crop.

On the basis of these factors, the quantified objectives of the project to reduce the use of pesticides in almond orchards are as follows:

- To ensure protection against *Eurytoma amygdali Enderlein* without chemical intervention in order to allow cultivation in organic farming and to validate the non-use of insecticides in conventional almond growing.
- Controlling secondary insect pests (aphids, leafminers, etc.) by promoting functional biodiversity
- Limit the presence of pathogenic fungi through the choice of varieties, preventive protection and innovative orchard design using fungicides as a last resort;
- No use of chemical weedkillers

In summary, the main objective is to reduce phytosanitary inputs by 60 to 80% compared with current practice, depending on the year's climatic data. This level of change, which is important for the crop, will require a redesign of the existing orchard, combined with efficiency and substitution levers.



2. System and strategies for achieving objectives

The study involved a comparison of two systems: one known as the 'reference' system, the other described as 'innovative' and a break with the first. The two systems were installed on the same plot of approximately two hectares (1 ha for each system), located at the La Pugère experimental station at Mallemort in the Bouches-du-Rhône region. The soil and environmental conditions are identical for both systems. Planting took place in 2019 (Figure 1).



Figure 1: Plan and layout of the "Innovative" and "Reference" systems

The first system, known as the "reference system", corresponds to the orchard structure found in the vast majority of almond orchards in the region. The planting distance is 6 m between rows and 5.5 m along the row. The trees are staggered to encourage light and are trained in multi-branched goblets. The varieties and rootstocks chosen are very representative of current regional plantations. The scheme adopted is 2/3 Lauranne® and 1/3 Ferragnès, grafted on Peach x Almond GF 677 (Photo 1). The varieties are alternated to ensure good cross-pollination of Ferragnès (Lauranne is self-fertile). The technical itinerary also corresponds to regional practices (with the exception of chemical weeding, which is replaced by mechanical weeding) and harvesting by vibrator and corolla. This method takes into account various decision-support tools, such as weather data, the *Eurytoma amygdali* insect emergence cage, observations of beneficials in the orchard and changes in the presence of pests such as aphids and green leafhoppers. It's also an orchard with decision rules for weeding the rows or the presence of pests. In most cases, the responses correspond to phytosanitary treatments, although tolerance levels are taken into account for pest damage.



Photo 1: REVATRA orchard, Reference variety (credit CTIFL)

The second system, called 'Agro-système innovant Déphy', is based on redesign combined with efficiency and substitution levers. In this system, observation, decision-support tools (OAD) and tolerance levels are also integrated into the strategy. On the other hand, the responses to bio-aggressors are more global and involve innovative levers.

- We opted for a low fruit hedge orchard structure (2.20 m high) with a planting density of 4 m between the rows and 1.5 m in the row. The varieties and rootstocks chosen were Soleta and Lauranne® grafted onto the dwarfing rootstock Rootpac® 20 (Photo 2).



Photo 2: REVATRA orchard, Innovation method (credit: CTIFL)

- Pest management

This redesign of the almond orchard, with the planting of trees of low vigour, trained as a fruit hedge, makes it possible to install a protective net against insects and in particular against *Eurytoma amygdali*. The net completely covers the trees. There must be no space where insects can



Photo 3 a: Net deployed in the Innovative orchard (Photo credit: CTIFL)



Photo 3b: Net rolled up outside Eurytoma flight period (Photo Credit CTIFL)

get under the net. The net used in this trial was a 5 x 4 mm net with a mesh size of 1.71 x 2.21. The net was set at the beginning of April when the adults emerged (Photo 3 a and 3b). The dates for setting and removing the net were determined on the basis of the hatchlings recorded in an emergence cage.

Limiting vigour by using Rootpac® 20 rootstock also means that the trees are less susceptible to biting and sucking insects. However, we have supplemented aphid control by pruning green in the spring to eliminate outbreaks, and we have encouraged the presence of beneficial insects (in particular hoverflies and lacewings) by installing flower strips in the autumn. These are made up of early-flowering plants that attract these beneficials. They collect nectar and then migrate to the aphids in the trees to eat them.

- Disease management

The strategy envisaged is based primarily on genetic leverage, but also on inoculum management through observation of meteorological data. Work by the Instituto de Investigacion y Tecnologia Agroalimentarias (IRTA) (Miarnau et al. 2021) has made it possible to identify varieties with low (or even very low) susceptibility to fungal diseases. These trials were carried out in Spanish Catalonia, but for us they are relevant references because the climatic and health data are similar. Among the varieties selected as



being very tolerant to disease overall are Marta, Vairo and Constanti. In France, observations have identified the varieties Texas and Ferrastar (Grasselly & Duval, 1997). We have chosen the Soleta variety (Blanquerna x Belle d'Aurons cross, 1996), which is indeed not very susceptible (particularly to monilia and polystigma) but which also stands out for its management and production qualities, which are far superior to those of other tolerant cultivars. It combines late flowering (which limits the risk of spring frost), a tree of average vigour that is easy to manage and a very high production potential in the various trials and among growers (X. Miarnau et al., 2021). In addition, it is self-fertile and representative of production, having been planted in Spain and now France (since 2016). We have added the Lauranne® variety to this system to test its behaviour in this type of orchard and also to provide a link with the reference system. Lauranne® is one of the least susceptible French varieties to disease. The chemical lever will be used when the combinations of alternative levers have failed, i.e. when there is a major risk of losses.

- Weed management

The presence of weeds in young plantations severely limits the growth of scions and also jeopardises their future development. Chemical weedkillers are banned from the proposed agro-system. Withdrawing them will not result in a significant reduction in the chemical Pesticide Treatment Index (PTI), since only 1/4 of the orchard's surface area is affected (i.e. 0.25 annual chemical PTI), but the persistence of herbicide molecules in groundwater suggests that we should be really careful with this chemical lever. The proposed substitution strategy is to lay a woven tarpaulin over the row. A heavy-weight tarpaulin (130g/m²) was installed at the time of planting. Its great thickness prevents weeds from germinating and means that it lasts for a long time (over 10 years). (Supplier data)

The implementation of the various strategies and their development were defined as part of a co-constructive approach within a group including advisors, farmers, researchers and nurserymen. This group met every year throughout the life of the project.

3. Data collection and analysis

3.1. Observations and measurements

The variables to be collected to characterise the agrosystems and the production situation are common to both systems (Table 1).

Table 1 Characterisation of agro-systems: variables collected

Items	Variables to be collected
Orchard health and weeds	Biotic pressure (insects, fungi, mammals, corvids, etc.) Deficiencies, excesses, imbalances... Weed abundance, dynamics and diversity.
Production	Yields and quality of production (shell yield and breaking yield, etc.)
Cultivation practices	Work carried out: pruning, treatments, harvesting, etc. and inputs. Conditions and quality of operations
Functional biodiversity	Auxiliaries (abundance, dynamics, impact) and markers of the agroecosystem that we have selected: hoverflies, lacewings, ladybirds, spiders, etc.
Climate	Information from the on-site weather station
Landscape	Inventory of the agro-ecological infrastructure of the plot and its immediate environment.



3.2. Methods for collecting and processing data and analysing results

The overall method of analysis must take account of a system assessment that uses combined levers. Consequently, the results will be analysed by studying the differences between the reference system and the innovative system.

3.3. Indicators to assess system performance

Depending on the reduction targets set, the indicators envisaged for each of the two systems are as follows.

Agronomic indicators

It concerns the control of pests (including emerging pests) and weeds. It is calculated by assessing their presence (evolutionary dynamics, duration, periods, etc.) and their impact on the crop: damage rating, damage and loss (D.D.L.).

Economic indicators :

The main economic indicators recorded will be: fruit set, yield, regularity of production, quality (breaking yield, size), production costs and gross margin.

Environmental indicators

Chemical and biocontrol phytosanitary treatment frequency indices (IFT).

4. Results: comparison of the two systems

The REVATRA project began in April 2018. The plots were planted at the beginning of 2019. The latter was devoted mainly to training the trees on the two systems until 2020. For the reference orchard, the trees were cut back as soon as they were planted. A first selection pruning of the branches took place in May, as well as two 'topplings' in June and at the end of August to strengthen and multiply the branching. Both varieties responded well to this pruning. For the trees in the innovative system, three green pinches were carried out to encourage strong branching, but the lack of vigour at the start of the season meant that branching did not develop as much as had been hoped. The trees are now well established, however, and judicious green pruning combined with good growing conditions have made up for this shortcoming.



The installation of the woven tarpaulin on the "innovative" system enabled excellent weed management without penalising the development of the trees. This is fundamental, as the young trees planted were less than 1 year old in the nursery, and therefore very sensitive to hydromineral competition. On the other hand, this tarpaulin needs to be perfectly taut when planted and swept once a year to avoid silt deposits. In addition, the perennials growing at the foot of the tarpaulin (particularly nightshades) had to be removed by hand.

Another piece of information is that the tarpaulin has encouraged the arrival of voles (*Microtus duodecimcostatus*) (Photo 4). These were not present when the orchard was planted (unpalatable previous crop). The first lesson to be learned from this experiment is that, despite its advantages (absence of weeds and water retention), the woven tarpaulin has a major disadvantage that needs to be taken into consideration. It should be pointed out that this observation cannot be generalised completely, as voles are more or less present depending on the nature and depth of the soil in question.



Photo 4: Lauranne sweat vole-Rootpac 20 (Photo credit: CTIFL)

***Eurytoma amygdali* pressure** was low in both modalities due to frosts in 2021 (-6.8°C) and 2022. These frosts caused the death of a large proportion of the larvae present on the wild almond trees in the sector and thus limited the presence of the adult insect the following year. The chemical strategy used on the "Reference" model, i.e. two synthetic pyrethroids at the start and peak of the flight, was very effective. Similarly, protection by netting proved beneficial, with no stings recorded (on a sample of 15,000 fruits in 2022 and 16,000 fruits in 2023). On the other hand, in 2023, the untreated control did not report any stings, probably due to the frosts mentioned above. It should be noted that another trial (Elzéard programme), using the same type of net (Filpack 5*4, 1.71 x 2.21) provided effective protection for the plot, with no fruit pricked under the net (20% of fruit pricked on the untreated control). The leverage provided by the installation of the net represented an innovation for almond growing. The very satisfactory results in terms of protection mean that it should be seen as a real solution for dealing with *Eurytoma amygdali*, particularly for organic farming. This is indeed a possibility, but it will have to be confirmed over the long term. In fact, only observation over several years will enable us to assess whether the insect has adapted to the net, by developing bypass strategies. Similarly, given that insect pressure is considered to be low during the trial years (following the frost in 2021, which limited insect populations), it is important to observe the behaviour of the net during periods of high pressure, as a complement to our work.

Protection against aphids (*Brachycaudus amygdalinus*) was marked by different behaviour in the two varieties. On the "Reference" model, the damage recorded in 2020 on the second leaf, with no preventive treatment, prompted intervention on the 3rd leaf with paraffin oil before flowering (i.e. 1 biocontrol IFT). No other intervention was carried out thereafter. Green pruning, the presence of beneficials and the restoration of vigour made it possible to significantly limit the impact of these aphids on the young trees (Figure 2a). For the 'Innovation' model, the presence of flower strips (when weather conditions allowed them to develop) meant that there were no active outbreaks. This was also helped by the low vigour of the shoots in this variety, linked to the dwarfing rootstock. The difference in aphid behaviour between the 2 orchards is difficult to explain on the basis of a single parameter. We considered vigour, measured by the length of shoots identified. The use of a weak rootstock, Rootpac 20®, in the innovation part of the orchard might lead us to believe that there would be

less shoot vigour and, logically, fewer aphids. However, during the period of aphid colonisation, between 9 and 15 April, these differences between the 2 methods were very slight, if not non-existent. Vigour, at least during the colonisation period, therefore had no effect (Figure 2B).

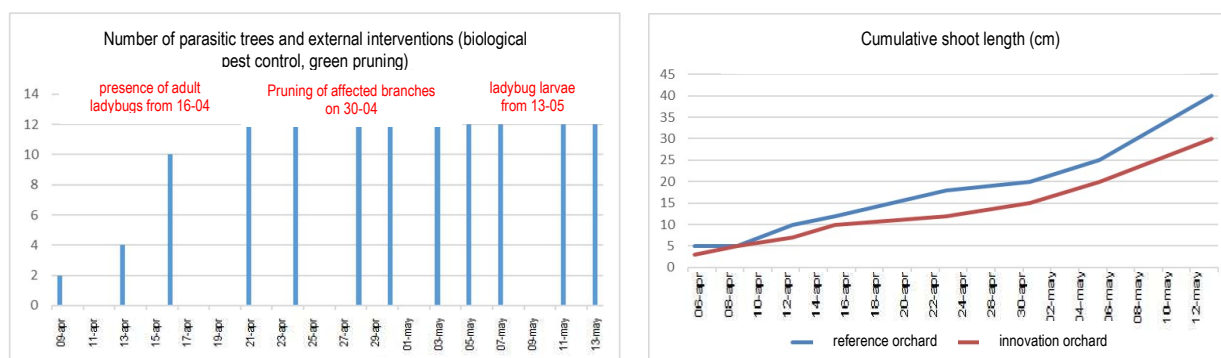


Figure 2: (A) Number of trees parasitized and external intervention. (B) Cumulative shoot length on the Lauranne variety for both modalities.

The levers proposed for protection against the almond aphid, in particular the flower strip and the low vigour associated with the dwarfing rootstock, are therefore effectively effective. The benefits of flower strips, which are attractive to beneficial insects, have been confirmed in other almond-growing research programmes (Elzéard and LEVEAB).

Concerning protection against the "couple" *Fusicoccum amygdali* / *Monilia laxa*; these fungi are considered virulent and perennial because of the cankers that can develop on almond trees and serve as an annual spore reserve. As such, the decision rules issued by the Steering Committee and the Technical Committee (COPIL/COTECH) at the launch of the project were to protect both methods preventively. However, preventive treatments were not carried out on the first two leaves because the entry points for these fungi, in particular petal fall, were not yet active.

Over the 5 years of observations, we did not find any evidence of *Fusicoccum* in the orchards studied. Some *Monilia laxa* damage appeared, but it was rare and did not develop. On the whole, these two fungi were well controlled in both modalities.

Control of rust (*Tranzchelia pruni-spinosae*) and *Coryneum beijinckii* varied greatly from year to year. In 2020, no protective treatment was applied to the 2nd leaf. Rust appeared in June and developed in July/August and September. The first symptoms appeared on the Soleta variety. This variety, which was not considered to be very susceptible to *Fusicoccum* and *Monilia*, turned out to be very susceptible to rust. Its proximity to the rows encouraged the disease to develop on the other varieties, Lauranne® and Ferragnès. Damage was extensive, with widespread leaf discolouration on both varieties (but first and foremost on the "Innovation" variety). *Coryneum* followed the same pattern as rust. From 2021, 3rd leaf, the decision rule was to protect the trial plots if there was rain and high temperatures during the susceptibility period (March to 15 June). This was the case in 2023 (5th leaf).

Based on this decision rule, both fungi were well controlled. Unfortunately, we do not have a predictive model for contamination of almond trees. In fact, protection is triggered on the basis of an empirical estimate that takes into account the intensity of rainfall and, above all, the duration of wetting, which is an essential factor in the risk of contamination.



System performance analysis

- *Agronomic performance*

The fact that there are two different varieties in each system complicates the comparison factors for almond in shell yield. To present consistent data on this aspect of yield, we have isolated the Lauranne® variety, present in the 2 modalities ("Reference" with goblet management and "Innovation" with fruit hedge management) by reducing production to the hectare (Figure 3).

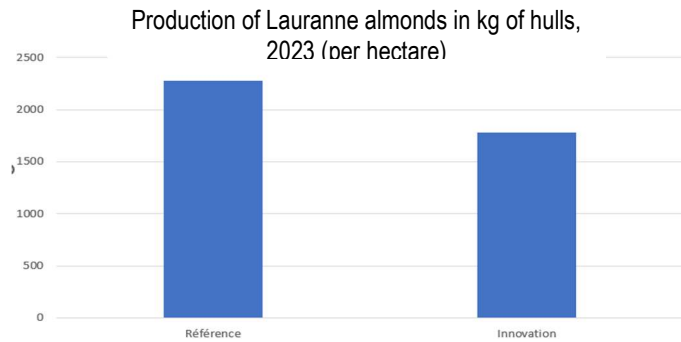


Figure 3: Lauranne ® yields per hectare (ha), 2023

Following an accident and stoppage of the irrigation pump, both plots were subjected to severe water stress. The lack of water affected the 'Innovation' orchard much more severely. The trees in the 'Innovation' system, which were on weak rootstock with poor roots, suffered more from the lack of water, with greater consequences for production potential (Figure 3).

The other production years (third and fourth leaf) cannot be compared because of frost damage (no production in 2021, frost at -6°C, low and irregular production depending on the different points of the plot in 2022).

- *Environmental performance*

In the first leaf (year 2019), no treatment was carried out on the two modalities. At this stage, fungal diseases are generally not very prevalent. Similarly, following observations, the absence of aphids led us not to carry out any protection against this pest.

In the second leaf (year 2020), we decided not to carry out fungal protection. This decision proved to be detrimental as we suffered combined damage from Rust (*Tranzchelia pruni-spinosae*) and *Coryneum*. This fungal attack forced us to carry out two treatments (or even three on the Soleta variety, which proved to be very sensitive) to limit the impact of these fungi. These contaminations showed the importance of preventive protection against the main fungal diseases, which modified the initial decision rules. From the 3rd leaf, preventive protection was implemented. The only exception, the possibility of doing without copper protection was tested in the 5th leaf (year 2023) on the "Innovation" section, and was apparently successful, as it had no negative impact on the disease protection of this option.

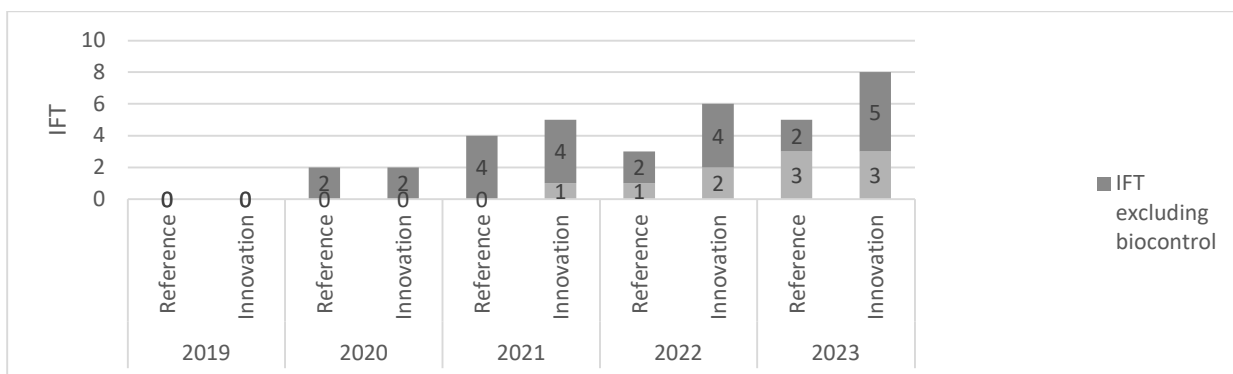


Figure 4: IFT breakdown by type and year

The reduction in IFT for the "Innovation" option mainly concerns protection against pests (Figure 4). It is concentrated on two insects, aphids and the hymenoptera *Eurytoma amygdali*. For the latter, the 5 x 4, 1.71 x 2.21 mesh net installed in the "Innovation" orchard prevented the insect from passing through, with no damage recorded on the 4th and 5th leaves. The two years of severe frost (2021 and 2022) not only penalised production but also killed the insect's larvae in the



environment. In fact, in the following years, the untreated control was not affected. However, a trial carried out in 2023 on another programme with the same net protection also showed the absence of damage with an untreated control with 20% of fruit bitten.

For the other insect pests: *Anarsia lineatella* and Cicadelle (*Assymetrasca decedens*), the very regular observations (1 rigorous control per week from the beginning of March to the end of September), made it possible not to treat. Symptoms did appear (the effect of stings) but the damage was deemed insufficient to trigger treatment. As the damage threshold for these insects had not yet been established, we decided not to intervene until the trees had stopped growing, which was not the case during our observations.

It should be noted that we do not present the herbicide IFT because no herbicides are used on the two methods. For the "Reference" orchard, this was a choice made by the COPIL/COTECH, with priority given to mechanical weeding, and for the "Innovation" orchard, it was interesting to study the benefits of the woven tarpaulin. Mechanical weeding was found to be effective, but required three passes per year. The woven tarpaulin was very effective against weeds. However, as mentioned above, annual maintenance by sweeping is compulsory. On the other hand, we observed the development of vole populations under the tarpaulin, which led to the death of some trees. In summary, the two methods reduced the IFT by 0.25 to 0.5 compared with chemical weed control.

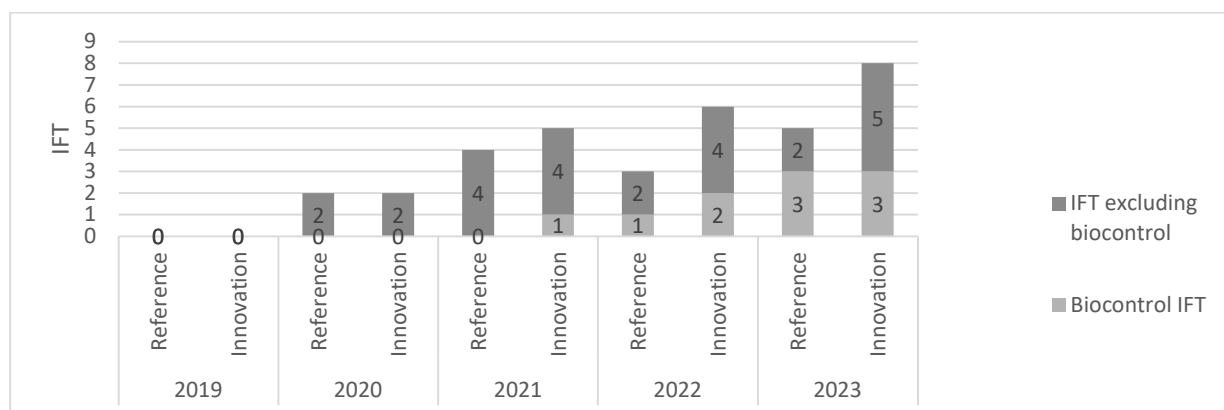


Figure 5: Non-biocontrol IFT and biocontrol IFT by modality and year

Few biocontrol products are available for almond trees (for example, to date there is no mating disruption against *Eurytoma amygdali*). The difference between the two systems stems from the fact that winter paraffin oils are not used to control aphids in the "Innovation" system, without the insect developing (the low vigour of the trees and the presence of auxiliaries mean that the IFT can be reduced) (Figure 5).

The project objective of reducing the number of IFTs by 60-80% was achieved overall (Figures 4 and 5). However, the unpredictable weather conditions and technical constraints (irrigation failure) that we encountered during the project meant that we were unable to assess the profitability of the system, given their impact on the harvest. The costs, including work time and investment, are much higher for the 'innovative' orchard. In view of the productive potential of 'innovative' orchards, as they are used in part in Spain, it is possible that this type of system could be profitable with a critical surface area. To date, this is only a hypothesis that needs to be evaluated and validated in France.



5. Conclusion: lessons learned and how can they be transferred to farms?

Transfer of the entire Innovation system. The systemic dimension favours this type of transfer. The 'Innovation' method allows the net to be installed and therefore saves on IFT against insect pests (the *Eurytoma amygdali* results should, however, be supplemented by trials on other pests present or to come in the almond orchard). Yields in this type of orchard were affected by frost and an irrigation accident, but seem to be at a very good level compared with regional orchards with the same management method (Com. Pers.). Before installing this type of orchard, however, it is important to ensure that the specific harvesting system is available (elevated harvesting machine) and that the hydro-mineral supply is carefully monitored.

Transfer of certain trial levers.

Varietal leverage: the Soleta variety, given as not very susceptible to wound fungi (*Fusicoccum amygdali* and *Monilia*), proved to be particularly susceptible to Rust (*Tranzchelia pruni-spinosae*) and *Coryneum*. This is essential information which will guide the choice of variety and/or justify the implementation of very rigorous fungal protection on this variety.

The woven tarpaulin on the ground: its effectiveness is optimal if it is well maintained. In this way, we can transfer the idea of an effective, reasonably-priced system that allows you to completely forget about the problem of weeding the planting row. On the other hand, it is not to be recommended where there is a risk of voles.

Flower strips are also transferable, and give good results if they get off to a good start and are maintained. This is naturally linked to the presence of rain after sowing. These flower strips attract auxiliary insects such as Syrphid flies and Chrysopes, which come to feed on the nectar. They then move onto the almond trees to consume the aphids present. However, it can be difficult to manage, due to the bee decree requiring the flowers to be mown in season if insecticides are used.

The net cannot be dissociated from the management method, i.e. it can only be transferred to orchards with fruit hedges. It should be noted that the effectiveness of the net (5x4, 1.71 x 2.21) is real in our trials, but will clearly need to be confirmed in the event of heavy insect pressure.

The efficiency of treatments: we have noted that it is possible to do without a copper IFT if the flowering period is rigorously managed and if the interventions are relevant in season according to the duration of wetting. With regard to leafhoppers (*Assymetrasca decedens*) and the lepidopteran *Anarsia lineatella*, attacks were considered to be average in the trial orchards and did not require any intervention. However, this means that the notion of acceptable damage must be clearly identified.

Areas for improvement, lessons learned and outlook

This research is the first step towards a more efficient almond orchard in terms of production, but also in terms of respect for the environment. In fact, a programme called ELZEARD is based on the "Innovation" concept of the REVATRA study to propose a more efficient fruit hedge orchard. The trees are planted at 5 m x 3 m with an expected height of 3.50 m (vigorous rootstock and control of vigour required). The hedge allows the net to be laid, and initial results have shown that it is watertight against *Eurytoma amygdali*. Further trials are planned to study the barrier effect of the net on other insects, including *Monosteira unicastata*, which develops in hot weather. In the 3rd leaf, the yield was higher than the 6m x 6m goblet control.

Other current programmes (such as LEVEAB) and future programmes will complete the quest for triple performance: economic, environmental and social.

Areas for improvement include the choice of varieties with low susceptibility to pests and high yields. They will also involve improving non-herbicide weed control with new physical equipment



(low-impact vole tarpaulins) or mechanical weed control to reduce costs and interventions. Finally, there is a need for more research into ways of limiting the damage caused by *Eurytoma amygdali*. This involves kairomones to attract the insect (initial laboratory trials to be completed), oviposition hormones and research into auxiliaries.

Ethics

The authors declare that the experiments were carried out in compliance with the applicable national regulations.

Declaration on the availability of data and models

The data supporting the results presented in this article are available on request from the author of the article.

Declaration on Generative Artificial Intelligence and Artificial Intelligence Assisted Technologies in the Drafting Process.

The authors used artificial intelligence in the translation process from French to English

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Declaration of interest

The authors declare that they do not work for, advise, own shares in, or receive funds from any organisation that could benefit from this article, and declare no affiliation other than those listed at the beginning of the article.

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