Friendly Fruit outcomes: Environment-friendly innovations in apple production

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Friendly Fruit Outcomes:

Environment-friendly innovations

in apple production

The performance of agronomic practices tested and implemented in the project

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Leaflet editing: Aude Alaphilippe (see leaflets for their respective authors)

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Friendly Fruit

A 3-year Project

Like all agricultural practices, fruit production must adapt to climate change. Fruit supply chains are already experiencing the negative impacts of a warming climate and environmental degradation. Early and erratic crop flowering, a reduction in fruit quality, the emergence of new diseases and water supply issues, as well as rising demand for inputs to sustain production, all present unique challenges.

Funded by EIT Climate-KIC for a period of three years (2018-2020) and coordinated by INRAE, the Friendly Fruit project was designed to address some of these challenges in strawberry and apple fruit production. Its objective was threefold: (i) to test practices, (ii) to evaluate their impacts, and (iii) to implement and disseminate environment-friendly agricultural practices in various areas of the fruit industry.

Friendly Fruit brought together a network of experts from research institutes, universities, industrial organisations and experimental stations in France, Italy, the Netherlands, Spain and Morocco.

The project focused on some key targets which have the biggest impacts on environmental and human health: water use efficiency, soil quality and biodiversity, phytosanitary control, use of new energies, and mitigation of global warming effects. During the three years of the project, 19 practices were tested in apple and strawberry in various environments to test their efficacy and estimate their agronomical, environmental, and financial impacts.

Main applications of the project results

Fruit growing implies an **intensive use of energy-based inputs**, spanning from soil management actions to crop protection and through to harvest. This is largely true for apple orchards whose design is, as for other fruit tree species, multi-annual. After three years of experimentation, important outputs have been reached. The most significant outputs in apple production are described in this document.

The frequency and number of diseases are increasing, emphasizing the need for developments in resistant cultivars and pesticide use, and a change in cultivation methods. **Three biocontrol products** were tested in the Friendly Fruit project and their pros and cons are presented in the leaflets.

Detailed evidence is provided in many studies that the contribution of farm-level activities on overall GHG emissions is mostly related to N2O and CH4 emissions, so a mitigation of GHG emission management of crops in the field is a critical and strategic challenge. Here we tested the **use of organic manures** as a form of carbon and nutrient fertilization. It permitted a **reduction of about 58% of the N** applied compared to classic strategies, with no effects on fruit quality and yield.

Feasible possible management practices for **increasing soil organic content (SOC)** levels through reduced carbon losses and increased carbon inputs were implemented. This consisted of sowing a grass/legume mix in the alley and then mulching it and incorporating it in the tree row. It represented a significant input in terms of biomass and C content in particular. This result has to be confirmed with a soil C content analysis.

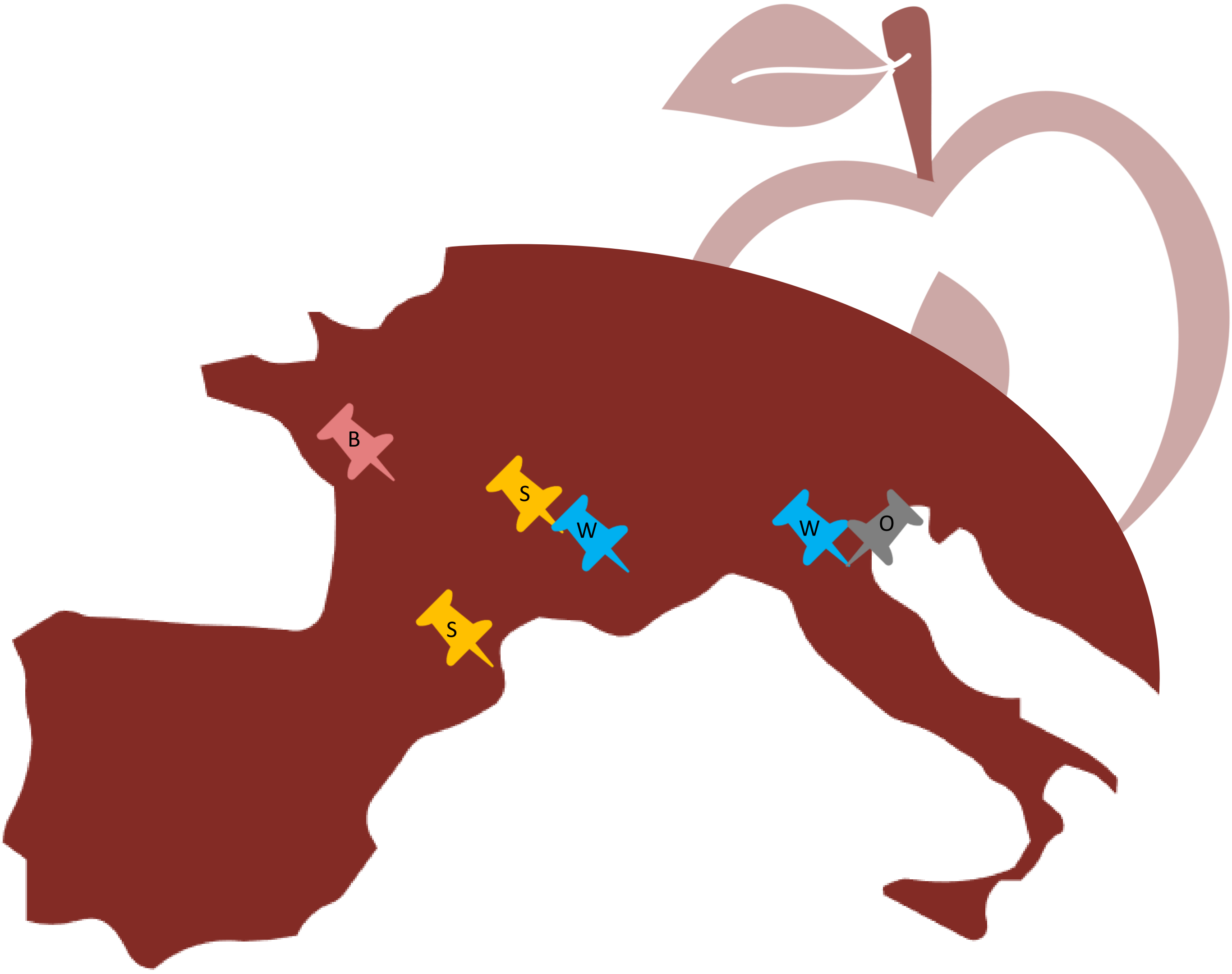
Increasingly, evidence shows that **climate adaptation** in fruit growing is a must. In the Mediterranean area, where irrigation is mandatory, long and frequent heatwaves together with drought has made the availability of water throughout the summer a limiting factor. Evaporative cooling has demonstrated that it can help in reducing temperatures during extreme heatwave events. It is a tool in the farmer's arsenal for tackling climate change and its impacts on tree performance and productivity. It permits **a decrease of 2-4°C** of the canopy temperature during extreme heat events.

Two solutions were tested to **spare water**: coupling drones and Artificial Intelligence reduces the amount of water waste by identifying leaks and possible clogging, and avoids irregularities in watering, thereby improving fruit quality. A simple and readily adoptable solution providing an irrigation scheduling system combining on-site sensors to now-casting meteorological conditions to better fit irrigation water restitutions to actual crop needs makes it possible to achieve a **reduction of around 25 %** in irrigation volumes.

The project included an active dissemination and training policy to empower farmers with key knowledge to enable a practical change towards more sustainable farming and adaptation to Climate Change.

As final outputs, the Friendly Fruit project made it possible to develop standalone leaflets dedicated to farmers and stakeholders to disseminate Friendly Fruit practices. For each practice experimented within the project (about 10 per crop), a leaflet (a two-page summary) describes the practice, the conditions for its implementation, details of its performance, and provides an overview of the experimentation. Our goal with this booklet/compilation of leaflets is to provide summarised and sufficient relevant information to encourage the adoption of practices that best suit a farm’s particular constraints and material capacities.

Friendly Fruit



MAP OF ENVIRONMENT-FRIENDLY PRACTICES TESTED WITHIN THE PROJECT PER TOPIC

2018-2020

Biocontrol

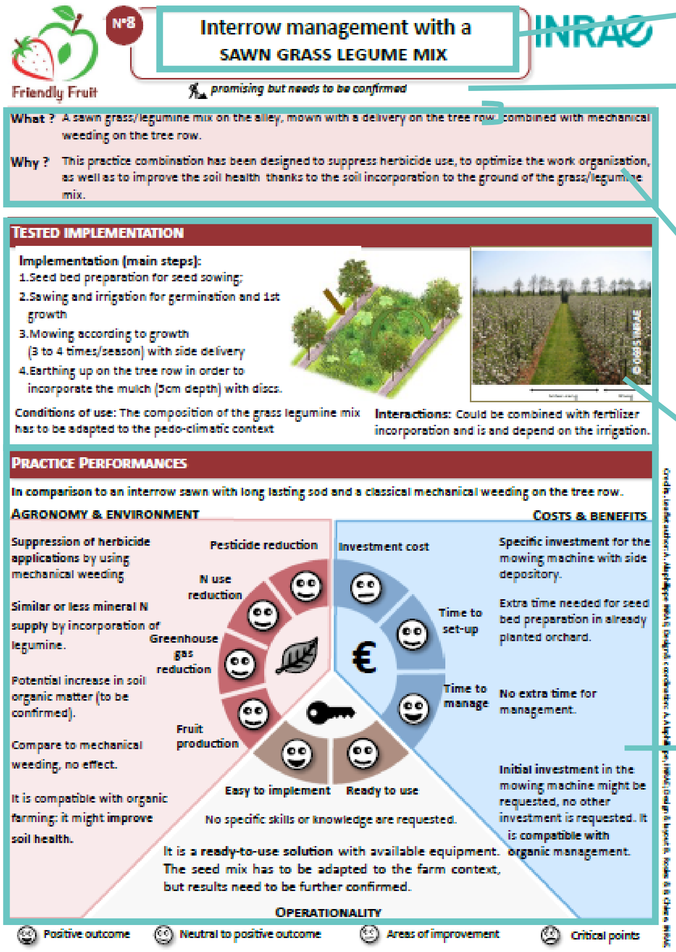
Soil management and fertilisation

Other climate mitigation parctices

Water management

Leaflet titles and topics

How to read a leaflet 1/2



Title of the environment-friendly practice.
And leaflet number

Status of the new practice or innovation:

Ready to use, promising but needs to be confirmed, ongoing experimentation, exploratory research.

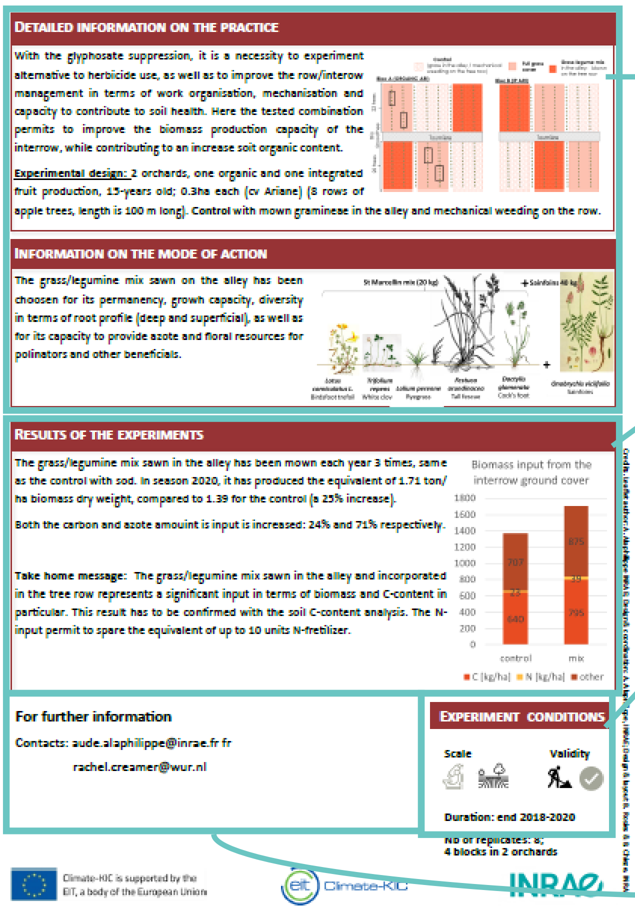
Short description of the purpose and reason for the study.

Operationality aspects:

Conditions for implementation, conditions for use and possible interactions with other practices.

Practice performance evaluation:

Smileys correspond to the level of performance of the practice in comparison with a reference system.
See page 8 for more information.



Details on the **experimental conditions** and the understanding of the environment-friendly practice (mode of action).

A key-result from the experimentation:

Graph and explanation, and a take-home message.

Summary of the experimental conditions:

Scale (laboratory or field) and validity (ongoing or ready to use (see status description on front page).

Duration of the experimentation and the number of repetitions of the experiment in the same year.

To further readers' understanding of the innovation trial, these are the main contacts or references.

How to read a leaflet 2/2

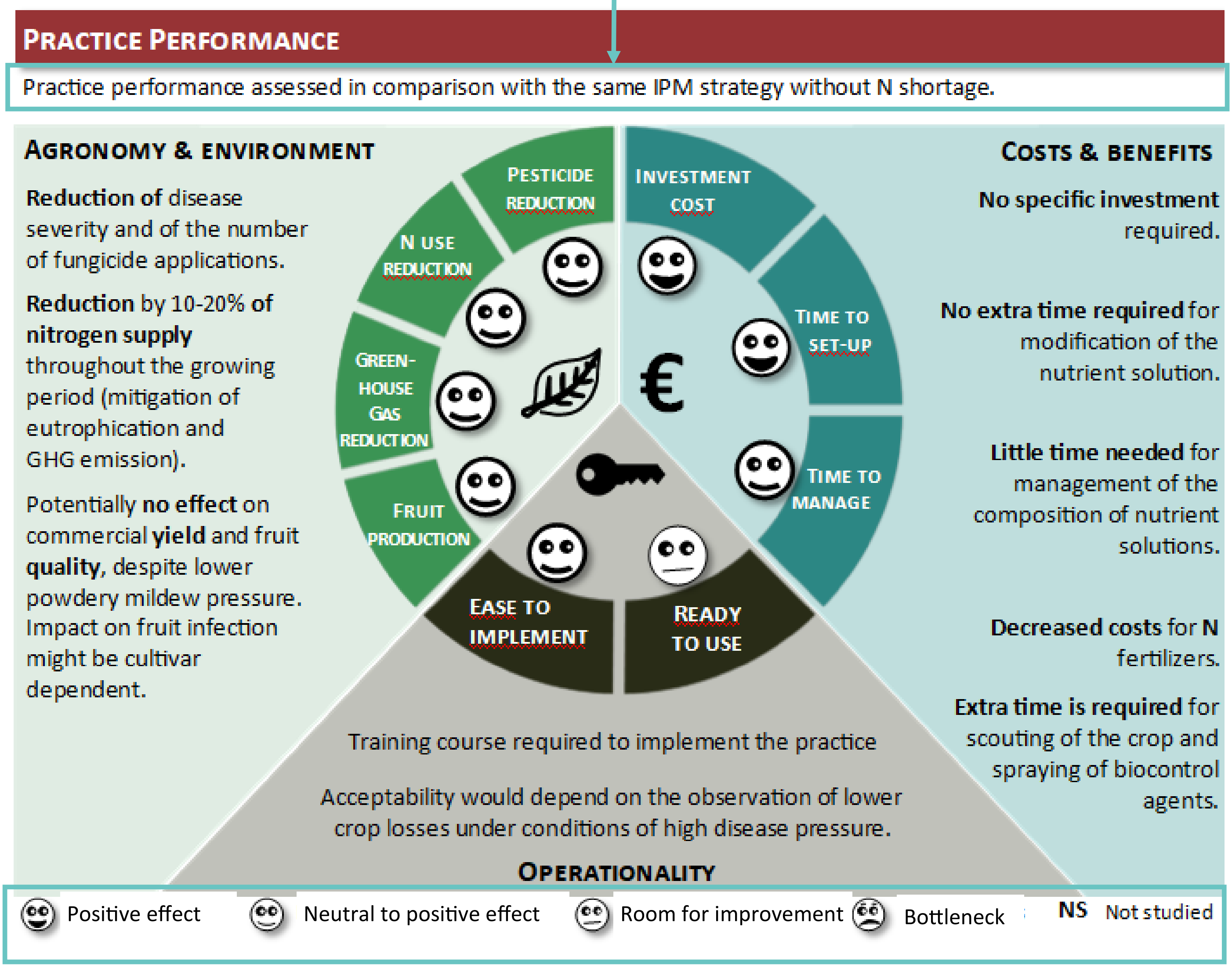
Practice performance

Each practice is evaluated in relation to **three axes**: agronomy & environment, costs & benefits and operationality.

Each axis has two to four indicators evaluated on a **four-level scale**:
(i) positive effect, (ii) neutral to positive effect, (iii) room for improvement, (iv) bottleneck.

For each indicator a short explanation is given and for each axis a summary of the strengths and weaknesses of the practice is given.

*The performance is evaluated in comparison to **a reference system** described at the top of the section.*



***Legend:** Each of the four smileys corresponds to one of the 4 qualitative classes.*

The description of each class for each indicator is given on the following page.

Agronomy & environment

INDICATORS				
Pesticide reduction	All pesticides eliminated.	Some pesticides eliminated.	No pesticide reduction but risk of pullulation of pests is limited.	Not currently known.
Greenhouse gas emissions	2 items below: reduced input use (pesticides or mineral N), reduced energy use (machinery, warming or cooling), carbon sequestered (increased soil organic matter), and/or green energy production	1 item below: reduced input use (pesticides or mineral N), reduced energy use (machinery, warming or cooling), carbon sequestered (increased soil organic matter), and/or green energy production	No increase in input or energy use, no carbon sequestration or green energy production	1 item or more below: increased input use (pesticides or mineral N), increased energy use, and/or GHG emitted
Fruit production	Increased fruit production quantity OR quality	No effect on quantity and quality	Not known or contradictory effect (i.e. quality improves but quantity reduced or the opposite)	Reduced fruit production quantity and/or quality
OPTIONAL INDICATORS				
N, water or energy use	Large reduction in quantity (>20%)	Small reduction in quantity (10-20%)	Identical to standard use	Increased use

Costs & benefits

INDICATORS				
Investment cost	No extra cost	Low or possible to build	Investment needed	Large investment needed
Time to set up	None	Low	Labour intensive	Labour intensive and at a peak period
Time to manage	None	Low	Labour intensive	Labour intensive and at a peak period

Operationality

INDICATORS				
Ease of implementation	No specific knowledge or skills needed OR easy to implement	Training course needed for implementation	Complex to implement	Not ready for implementation
Availability	Available and widespread practice	Practice being disseminated	Validated on station	Ongoing experimentation

N°1

Use of potassium phosphonate (Soriale®) to control storage diseases

Friendly Fruit

La Morinière – Station d'expérimentations

Status: Ready to use (minimum interval of 35 days between application and harvest)

What? Potassium phosponate (Soriale®) is a biocontrol product to be applied before announced low-risk rain (not eligible for use in organic farming).

Why? Product used in strategies to combat storage diseases including *Gloeosporium* rot replacing synthetic preventive fungicides.

Practice tested

Implementation (major steps):

Treatment to be applied before rain more than 6 weeks pre-harvest (attention: pre-harvest interval of 35 days).

Conditions for implementation: No specific implementation conditions apply.

Interactions: Do not mix with potassium bicarbonate and do not apply close to a treatment with potassium bicarbonate.

Practice performance

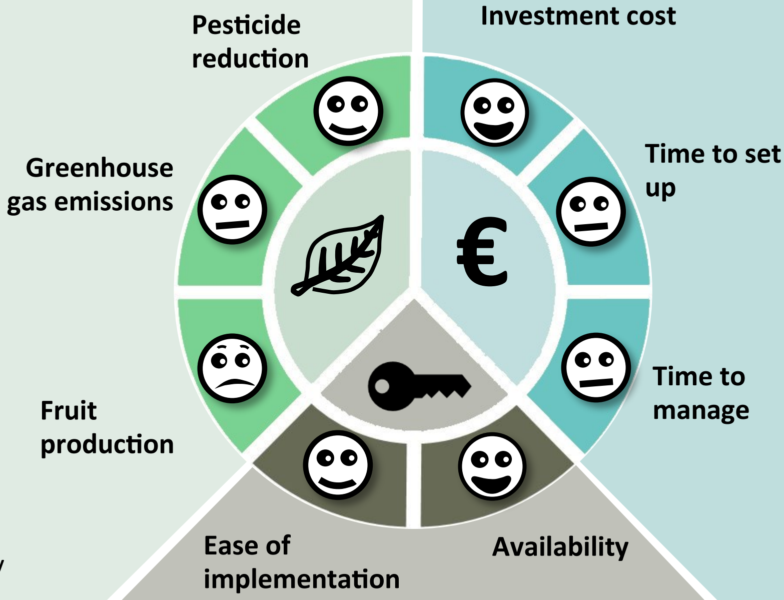
The practice's performance is expressed in comparison with conventional protection using synthetic fungicides.

Agronomy & environment

Replacement of synthetic preventive fungicides for the control of storage diseases.

No yield loss but residues at harvest and the following year.

Good fungicidal efficacy, but residues on fruit make its use incompatible with baby food and organic production.



Costs & benefits

This is the substitution of an active ingredient that does not generate any additional cultivation operations or any **additional cost.**

Use is incompatible with baby food or organic production due to residues on the harvest both in the year of harvest and the one that follows.

Approved for scab on apple but with a pre-harvest period of 35 days, therefore **prohibited for use during the risk period for *Gloeosporium* rot.**

Operationality

Positive effect — Neutral to positive effect — Room for improvement — Bottleneck

Credits. Authors C. Coureau, CTIFL C. Tessier, La Morinière; A. Alaphilippe, INRAE; Design & coordination: A. Alaphilippe, INRAE; Design & layout B. Rosies & B. Chieze, INRAE

Detailed information on experimentation

A treatment programme with potassium phosphonate (Soriale®) was applied preventively before rain or in a sequence (PDS effect) and compared to a reference programme based on synthetic fungicides. The apples were harvested, stored in normal cold conditions and the rate of rot on fruit was observed during storage. The potassium phosphonate dose applied was 1.4 kg/ha.

Principal action of the practice

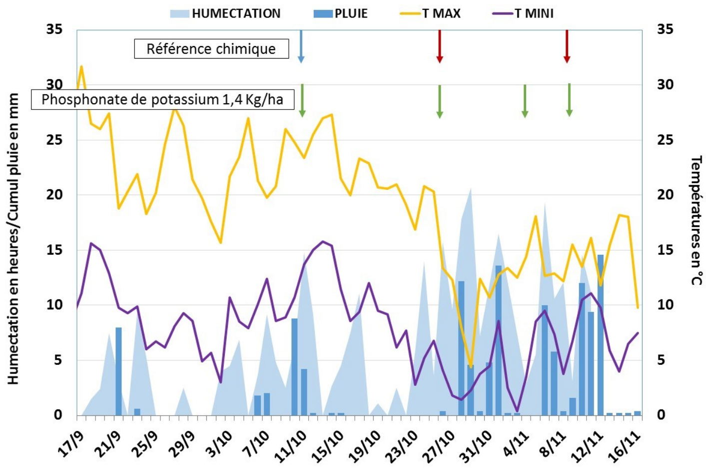
Gloeosporium rot (*Neofabrae alba* E.J. Guthrie Verkley, 1999) is one of the main storage fungal diseases of apples in Western Europe, responsible for long-term storage losses in susceptible varieties. It is a latent parasite, with infection occurring in the orchard, especially during the month before harvest. If well positioned, fungicide treatments applied pre-harvest make it possible to partly control disease expression, but as they are likely to leave residues, the number of interventions tends to be reduced and the use of certain substances is often limited (M. Giraud, CTIFL 2017).

Two modes of action have been identified for potassium phosphonates:

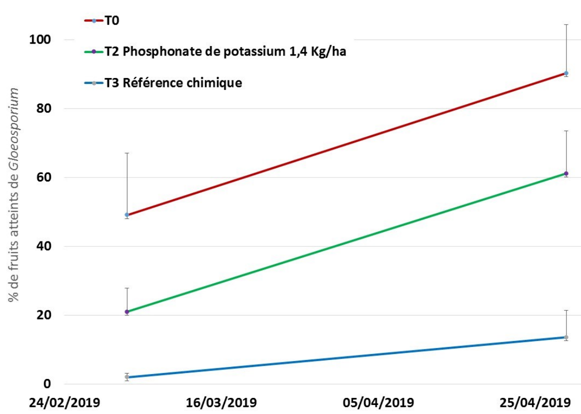
- Fungicide: inhibiting the development of the pathogenic fungus in the plant.
- Plant defence stimulator (PDS): strengthening a plant's natural defences, in particular phytoalexins.

Results of the experiments

Pre-harvest weather and positioning of treatments



Efficacy on the development of *Gloeosporium* rot of the different methods studied



Potassium phosphonate is effective in managing *Gloeosporium* rot during storage. Its efficacy lies between the untreated control and the chemical reference method (Captan/Fludioxonil/Fludioxonil). Small phosphite residues can be detected on fruit after storage.

For more information

Contact: claude.coureau@ctifl.fr

Trial characteristics

Scale

Validity ✔

Duration: 2017-2018

No. of repetitions: 4

The project Friendly Fruit (2018-2020) was coordinated by INRAE with the financial support of the EIT KIC.

Climate-KIC is supported by the EIT, a body of the European Union

Credits. Authors C. Coureau, CTIFL C. Tessier, La Morinière; A. Alaphilippe, INRAE; Design & coordination: A. Alaphilippe, INRAE; Design & layout B. Rosies & B. Chieze, INRAE

Friendly Fruit

N°2

USE OF THE BIOCONTROL AGENT *S. CEREVISIAE* (ROMEO®) TO CONTROL PRIMARY SCAB

La Morinière – Station d'expérimentations

Status: Experimentation ongoing

What? Cerevisane (Romeo®): A treatment based on cell walls of a yeast (strain LAS117 of *Saccharomyces cerevisiae*). Wettable powder for spraying.

Why? Biocontrol product to be applied for the management of primary scab, plant defence stimulator (PDS).

PRACTICE TESTED

Implementation (major steps):

Treatment to be applied every 7 days, replacing synthetic fungicides at peaks of contamination with low to medium risk of primary scab (according to modelling). Test carried out post-flowering.

Conditions for implementation: No specific implementation conditions.

Interactions: No interactions observed with other phytosanitary products usually used on apple trees.

PRACTICE PERFORMANCE

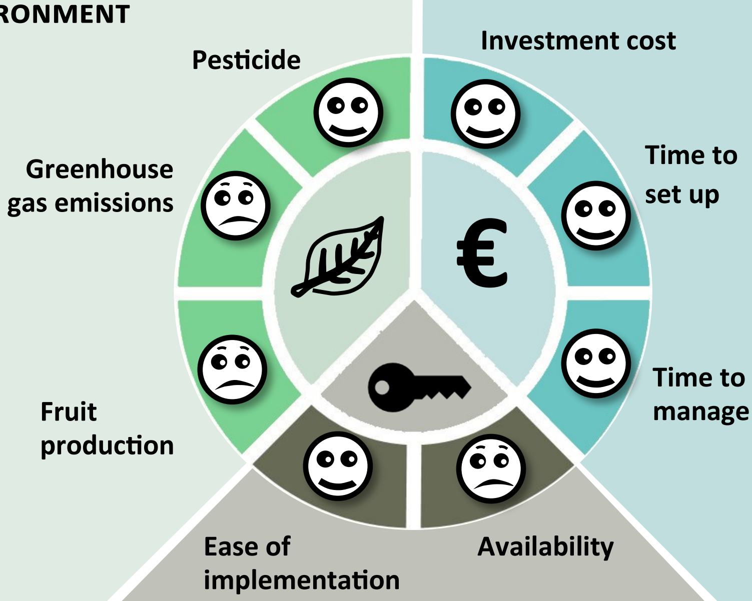
The practice's performance is expressed in comparison with conventional protection using synthetic fungicides.

AGRONOMY & ENVIRONMENT

Insufficient efficacy observed on primary scab.

May cause **an increase in emissions** due to an increase in the number of treatments.

Possible yield loss (scabbed fruit)



COSTS & BENEFITS

This is the substitution of an active ingredient, so no investment in specific equipment.

These regular treatments may entail additional treatments.

OPERATIONALITY

Technically easy but not approved.

Substance not approved on apple in November 2020

(approved for vines as a defence stimulator and compatible with organic production).

Positive effect | Neutral to positive effect | Room for improvement | Bottleneck

Credits. Authors C. Coureau, CTIFL A. Leblois, La Morinière; A. Alaphilippe, INRAE; Design & coordination: A. Alaphilippe, INRAE; Design & layout B. Rosies & B. Chieze. INRAE

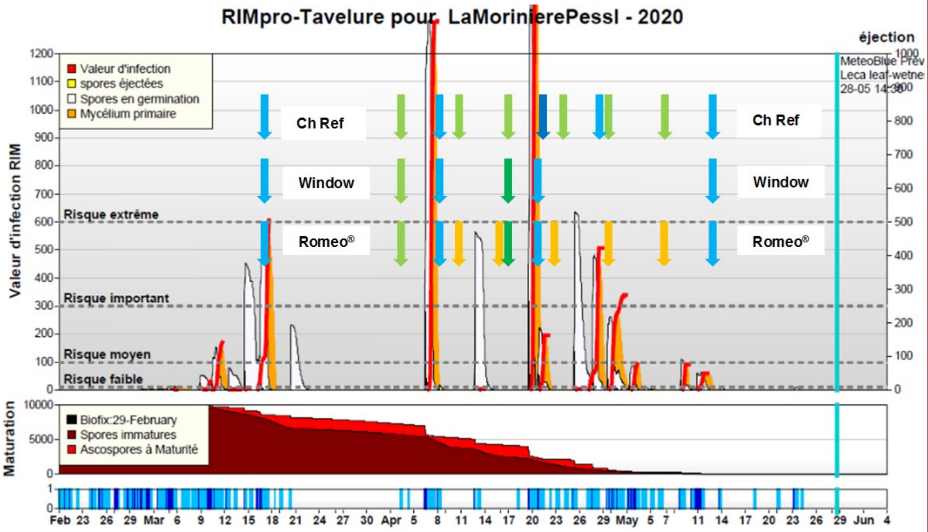
Detailed information on experimentation

Regular application of Romeo® for its plant defence stimulator effect. Treatment every week. However, 'low' risks of scab contamination are not treated (RIM <500, RIMpro modelling).

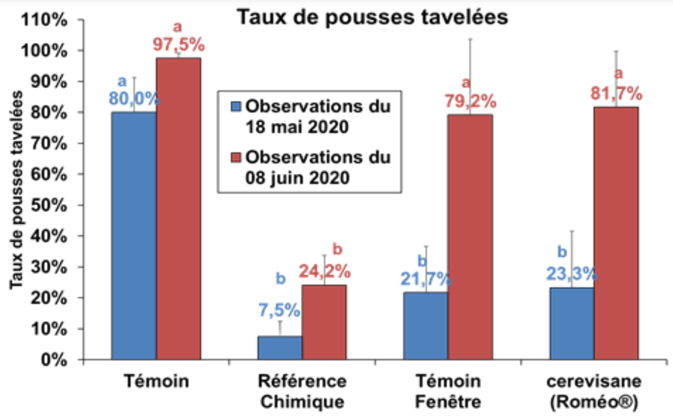
Cerivisane (Romeo®, 0.25 kg/ha) active ingredient obtained from the extract of the LAS117 strain of *Saccharomyces cerevisiae* yeast.

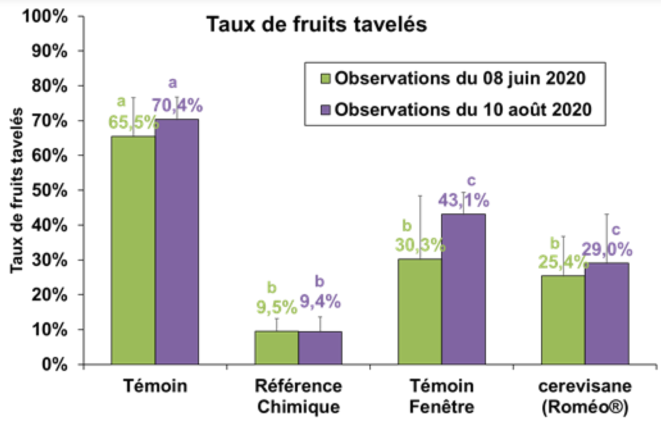
Principal action of the practice

The RIMPro model was used for scab risk assessment. No positioning of preventive treatment with a synthetic fungicide before a low risk of primary scab contamination. Positioning of Romeo®.



Results of the experiments





During the two years of studies, Romeo® applied at 0.25 kg/ha as a PDS before low risks (RIMpro modelling) did not demonstrate sufficient efficacy to control primary scab on leaves and fruit.

For more information

Contact: leblois.lamoriniere@orange.fr or claude.coureau@ctifl.fr

Trial characteristics

Scale **Validity**

Duration: 2019-2020

No. of repetitions: 4

Credits. Authors C. Coureau, CTIFL A. Leblois, La Morinière; A. Alaphilippe, INRAE; Design & coordination: A. Alaphilippe, INRAE; Design & layout B. Rosies & B. Chieze, INRAE

The project Friendly Fruit (2018-2020) was coordinated by INRAE with the financial support of the EIT KIC.

Climate-KIC is supported by the EIT, a body of the European Union

N°3

USE OF THE BIOCONTROL PRODUCT MYCO-SIN® TO CONTROL PRIMARY SCAB

Friendly Fruit

La Morinière – Station d'expérimentations

Status: Experimentation ongoing

What? Myco-Sin® is composed of 65% sulphur clay and 0.2% horsetail extract.

Why? Alternative product to be applied for the management of primary scab, preventive and fungicidal actions.

PRACTICE TESTED

Implementation (major steps):

Treatment to be applied as a preventive measure when rain is forecast for the management of primary scab, replacing synthetic or copper fungicides.

Conditions for implementation: No specific implementation conditions.

Interactions: No interaction observed with other phytosanitary products usually used on apple trees in the context of this trial.

PRACTICE PERFORMANCE

The performance of the practice is expressed in comparison with a biological control programme.

AGRONOMY & ENVIRONMENT

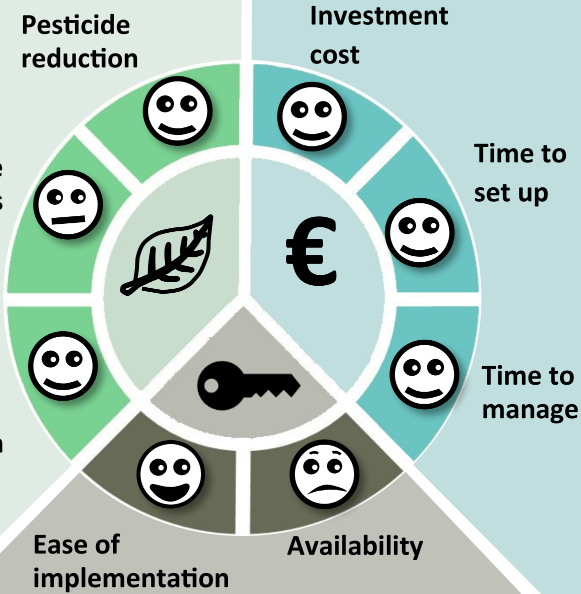
Replaces a fungicide. Efficacy comparable to a biological control product.

No increase in greenhouse gas emissions.

No loss in yields or quality.

COSTS & BENEFITS

This is the substitution of an active ingredient, so no investment in specific equipment or additional intervention is required.



Technique easy to implement but **substance not approved in France for anti-scab use. Authorised as a physical barrier (except organic production).**

OPERATIONALITY

Positive effect | Neutral to positive effect | Room for improvement | Bottleneck

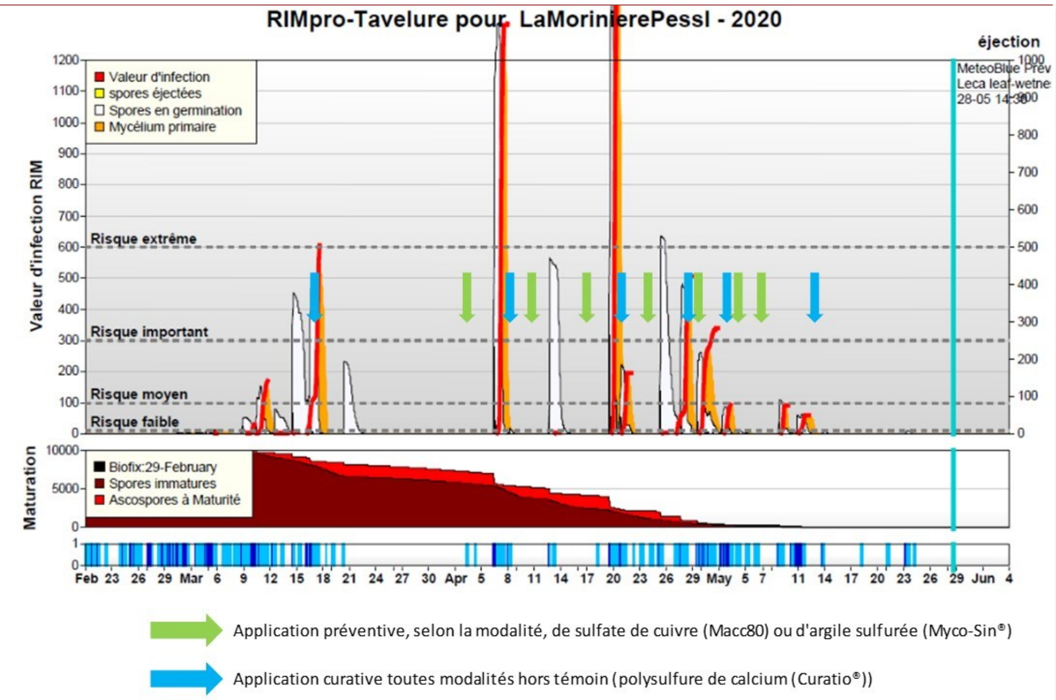
Credits. Authors C. Coureau, CTIFL A. Leblois, La Morinière; A. Alaphilippe, INRAE; Design & coordination: A. Alaphilippe, INRAE; Design & layout B. Rosies & B. Chieze. INRAE

Detailed information on experimentation

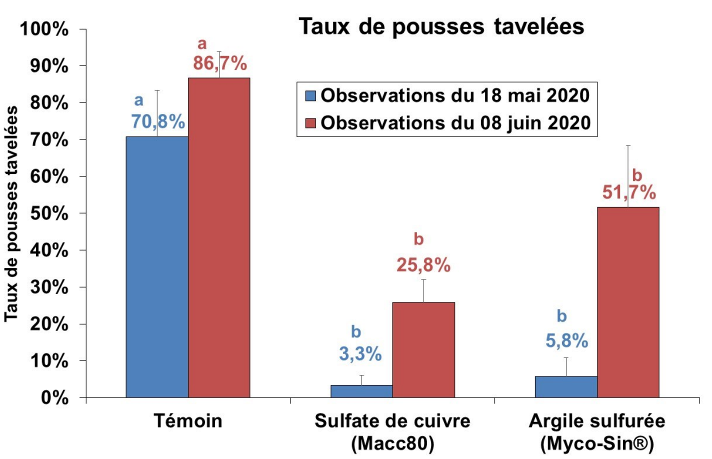
Application of Myco-sin (5 kg/ha) as a preventive measure before a forecast risk of primary scab contamination (RIMpro model). In this trial, Myco-sin replaced preventive copper treatments (150 g/ha).

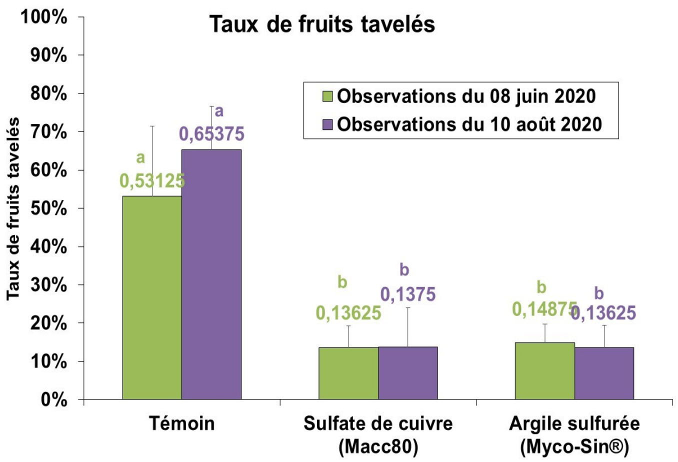
Principal action of the practice

The RIMpro model was used for scab risk assessment. Positioning of the treatment as a preventive before forecast risk.



Results of the experiments





In this trial, with a significant scab presence on the control plot, we observed the efficacy of Myco-sin® (5 kg/ha) applied as a preventive on contamination of primary scab, comparable to copper (150 g/ha).

Trial characteristics

Scale **Validity**

Duration: 2020

No. of repetitions: 4

For more information

Contact: leblois.lamoriniere@orange.fr or claude.coureau@ctifl.fr

The project Friendly Fruit (2018-2020) was coordinated by INRAE with the financial support of the EIT KIC.

Climate-KIC is supported by the EIT, a body of the European Union

Friendly Fruit

N°4

Use of organic manure as a form of carbon and nutrient fertilisation

IRTA

WAGENINGEN UNIVERSITY & RESEARCH

Experimentation ongoing

What? Organic fertilisation with compost of the solid fraction from pig slurry combined with mechanical weeding on apple tree rows.

Why ? Closing the nutrient cycle in a specific territory in the agri-food sector is key for the environment and also within the concept of the circular economy promoted by the EU. The practices developed will contribute globally to reduce greenhouse gas emissions, minimise dependence on the production of distant inputs and increase soil quality.

Practice tested

Compost of the solid fraction from pig slurry:

⇒ Applied at the end of winter with side delivery.

⇒ **Combined with** mechanical weeding on the tree row for better incorporation of organic manure.

Tree-row management:

With rolling cultivator + finger weeder periodically.

Interactions: Mechanical tree row management can include very interesting superficial working of the soil to incorporate organic matter. It depends on the machine used. Irrigation has to be considered.

Practice performance

In comparison to mineral fertilisation and chemical weed control.

Agronomy & environment

Herbicide suppression with **good weed regulation.**

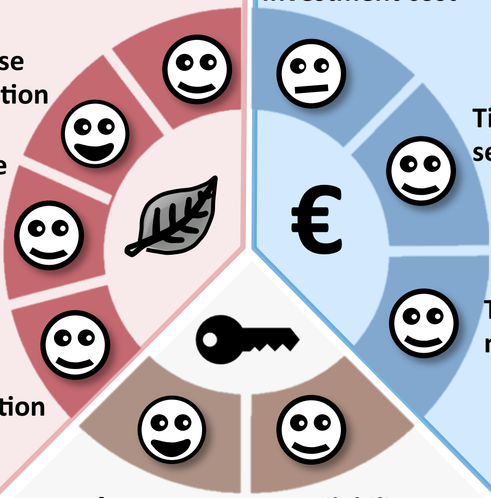
Reduction of about 58% of N applied.

No mineral fertiliser use.

Organic manures replaced mineral fertilisers **without effects** on fruit quality and yield.

Mechanical weeding shows greater fruit colour, but lower mean fruit weight (1st year only) compared to herbicide.

Increases soil biodiversity.



Costs & benefits

Specific investment in the machinery required for both mechanical weeding and fertilisation with side delivery.

Little time needed.

Similar time as classical fertilisation required. But more time needed for weed management.

Compatible with organic production.

It is a **ready-to-use** and **already disseminated** solution with no specific training required.

Promising alternative for grass and fertilisation row management. Lower input dependence and better nutrient management in high-density livestock areas.

Operationality

Positive effect — Neutral to positive effect — Room for improvement — Bottleneck

Credits. Authors: G. Avila, J. Bonany, IRTA; A. Alaphilippe, INRAE; Design & coordination: A. Alaphilippe, INRAE; Design & layout B. Rosies & B. Chieze, INRAE.

Detailed information on experimentation

Contextual elements: We have nearby sources of livestock manure that could be an alternative to the use of mineral fertilisers. Additionally, with the suppression of glyphosate use, experimentation on alternatives to herbicide use is required. The proposed combination could be a good alternative as long as it does not reduce fruit yields and quality.

Experimental design:

1 orchard (Annaglo variety, 5 years old), 3 fertilisation strategies x 2 tree-row weed management x 4 repetitions.

Plot size: 7 uniform trees (4 border trees and 3 central trees for evaluation).

Principal action of the practice

With societal pressure on agriculture to reduce water consumption, it is very important to reduce irrigation applications, of course without reducing fruit yield and quality.

How it works:

Compost of the solid fraction from pig slurry has been chosen for its potential for crop fertilisation and local availability.

Results of the experiments

In the first two years of the trial, no differences between mineral and organic fertilisation were found **regarding fruit yield and quality.** The foliar content of micro and macronutrients remained within standard values.

Mechanical weed control means herbicide use can be avoided while offering good weed control. It shows less mean fruit weight in only the first year of conversion and greater fruit colour compared to herbicide in the two years of trials. No data is yet available on soil biological quality and nitrification rates.

Take home message: If results are confirmed, the substitution of mineral fertiliser with organic manure could contribute to reducing greenhouse gas emissions and at the same time solve the environmental challenge of surplus organic manure from pig farms.

For more information

Contact: joan.bonany@irta.cat or gloria.avila@irta.cat

Trial characteristics

Scale

Validity

Duration: 2019-2021

No. of repetitions: 4.

The project Friendly Fruit (2018-2020) was coordinated by INRAE with the financial support of the EIT KIC.

Climate-KIC is supported by the EIT, a body of the European Union

N°5

Optimised row-interrow management with grass cover over the entire orchard

Friendly Fruit — INRAE

✔ *Ready to use.*

What? In a mature orchard, grass cover over the entire orchard with spontaneous grass cover in tree rows in order to avoid herbicide use, combined mowing for row and interrow.

Why? To optimise the cover management on the tree row in order to suppress herbicide use, to increase carbon inputs into the soil, and optimise work organisation without increasing mechanisation.

Practice tested

Implementation (main steps):

1. Allow spontaneous 'grass' growth
2. Control for specific weeds, such as:
   - **Ragweed (*Ambrosia artemisiifolia*)**
   - ***Orobanche* (broomrape)** etc.
3. Mow according to growth

Conditions for use: Grass cover composition is linked to the pedo-climatic context and surrounding ground cover vegetation.

Interactions: High tree density makes it complicated. Tree row cover growth and composition may be altered by irrigation.

Practice performance

In comparison to an interrow sown with long-lasting sod and classical mechanical weeding on the tree row.

Agronomy & environment

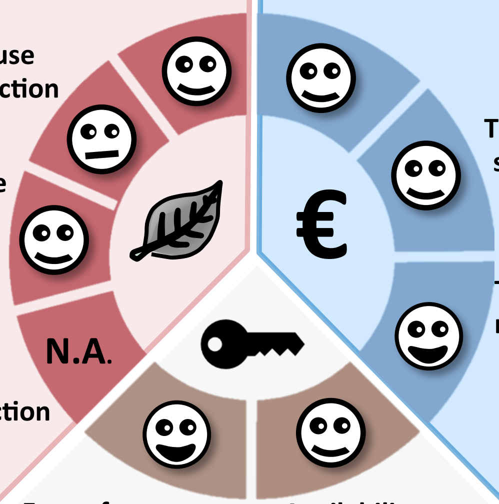
Suppression of herbicide applications by using ground cover.

Similar or lower mineral N supply.

Potential increase in soil organic matter (to be confirmed).

No effect compared to mechanical weeding (to be confirmed**)**.

Compatible with organic farming: it might **improve soil health.**



Costs & benefits

Specific investment for the satellite to mow.
Time to survey for undesirable weeds (such as *Ambrosia*).

No extra time for management and mechanical weeding suppressed.

Initial investment in a mowing machine might be required, no other investment needed.

Compatible with organic management.

Operationality

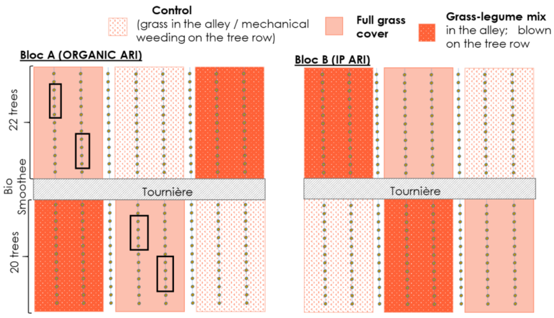
No specific skills or knowledge are required.

A **ready-to-use solution** and a promising alternative to chemical and mechanical weeding. However, impact on soil health and fruit production needs to be further investigated.

Positive effect — Neutral to positive effect — Room for improvement — Bottleneck

Credits. Authors: A. Alaphilippe , A. Richard. INRAE; Design & coordination: A. Alaphilippe, INRAE; Design & layout B. Rosies & B. Chieze. Photos: L. Tornatore. INRAE.

Detailed information on experimentation



With the removal of glyphosate, experimentation on alternatives to herbicide use is required, as well as to improve row/interrow management in terms of work organisation, mechanisation and its capacity to contribute to soil health. Here the combination tested made it possible to avoid mechanical weeding and so reduce machine and energy use.

Experimental design: 2 orchards, one organic and one integrated fruit production, 15 years old; 0.3ha each (Ariane variety) (8 rows of apple trees, 100 m long). **Control** with mown grass species in the alley and mechanical weeding on the row.

Principal action of the practice

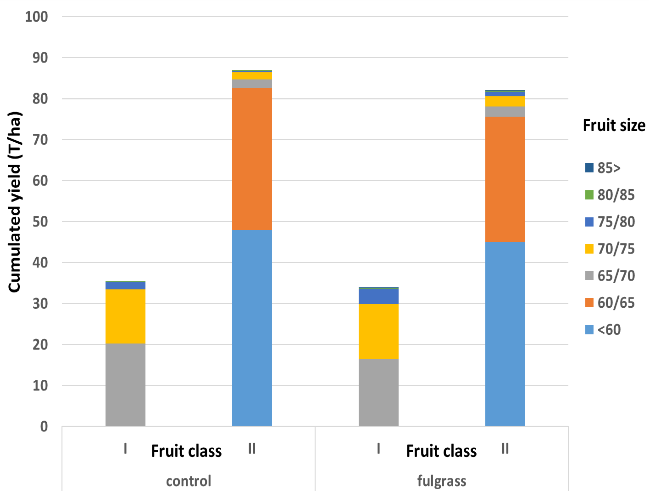
The grass mix sown in the alley at the time of orchard plantation makes 'spontaneous sowing' in the tree row possible.

This grass growth in the tree row offers soil cover sufficient to compete with other weeds. However, specific weeds such as Ragweed (*Ambrosia artemisiifolia)* and Orobanche (broomrape) have to be controlled, since they are invasive and hard to manage.

Experimental results

Although we observed a reduction in tree vigour (with no evolution of tree trunk diameters during the 2 seasons of experimentation), full grass cover did not affect (only one season) tree fruit production with similar quantity and quality (fruit size and class).

In our climatic conditions, the grass is mown in the alley and on the tree row around 3 times per year.



Take home message: This experimentation needs to be replicated and under other climatic conditions to confirmed these preliminary results.

For more information

Contact: aude.alaphilippe@inrae.fr

See leaflet no. 6.

Trial characteristics

Scale

Validity

Duration: 2018-2020

No. of repetitions: 8;
4 blocks in 2 orchards

Credits. Authors: A. Alaphilippe INRAE; Design & coordination: A. Alaphilippe, INRAE; Design & layout B. Rosies & B. Chieze. INRAE.

Friendly Fruit The project Friendly Fruit (2018-2020) was coordinated by INRAE with the financial support of the EIT KIC.

Climate-KIC is supported by the EIT, a body of the European Union

Climate-KIC

INRAE

N°6

Optimised row-interrow management with a sown grass-legume mix in the interrow

Promising but needs to be confirmed

What ? A sown grass/legume mix on the alley, mown with delivery to the tree row, combined with mechanical weeding of the tree row.

Why ? This combination of practices has been designed to avoid herbicide use and optimise work organisation, as well as to improve soil health thanks to the incorporation of the grass/legume mix in the soil.

Practice tested

Implementation (main steps):

1. Seed bed preparation for sowing.
2. Sowing and irrigation for germination and 1st growth.
3. Mowing according to growth (3 to 4 times/season) with side delivery
4. Earthing up on tree row to incorporate the mulch (5cm depth) with discs.

Conditions for use: The composition of the grass legume mix must be adapted to the pedo-climatic context

Interactions: Could be combined with fertiliser incorporation and depends on irrigation.

Practice performance

In comparison to an interrow sown with long lasting sod and classical mechanical weeding on the tree row.

Agronomy & environment

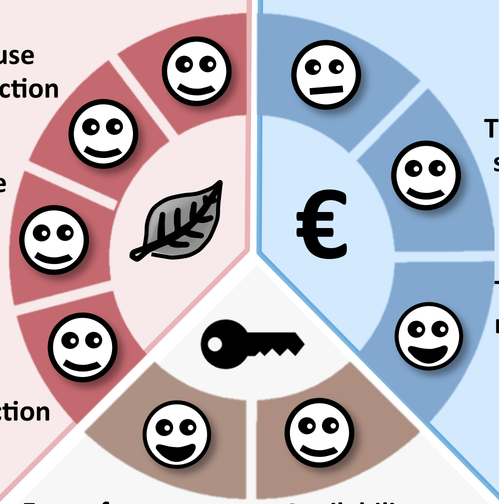
Suppression of herbicide applications by using mechanical weeding.

Similar or less mineral N supply by incorporating legumes.

Potential increase in soil organic matter (to be confirmed).

No effect compared to mechanical weeding**.**

Compatible with organic farming, might **improve soil health.**



Costs & benefits

Specific investment for the mowing machine with side discharge.

Extra time needed for seed bed preparation in already planted orchards.

No extra time for management.

Initial investment in the mowing machine might be required, no other investment is needed. It is **compatible with organic** management.

Operationality

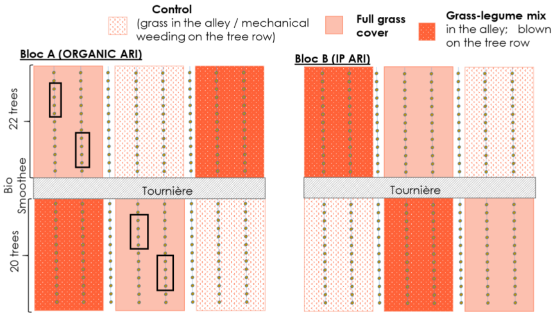
No specific skills or knowledge are required.

Ready-to-use if equipment available. Seed mix must be adapted to the farm context, but results need further confirmation.

Positive effect | Neutral to positive effect | Room for improvement | Bottleneck

Credits. Authors: A. Alaphilippe , A. Richard. INRAE; Design & coordination: A. Alaphilippe, INRAE; Design & layout B. Rosies & B. Chieze. Photos: L. Tornatore & A. Alaphilippe INRAE.

Detailed information on experimentation

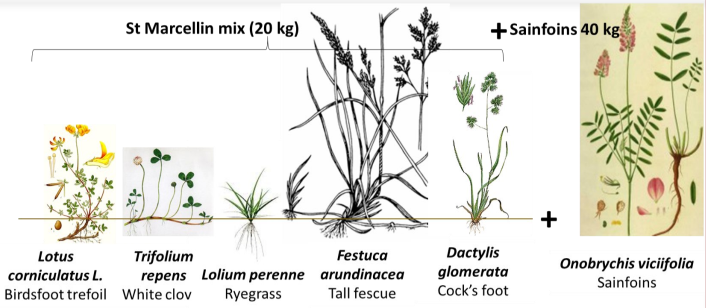


With the removal of glyphosate, experimentation on alternatives to herbicide use is required, as well as to improve row/interrow management in terms of work organisation, mechanisation and its capacity to contribute to soil health. Here the combination tested makes it possible improve the biomass production capacity of the interrow, while contributing to an increase in soil organic content.

Experimental design: 2 orchards, one organic and one integrated fruit production, 15 years old; 0.3ha each (Ariane variety) (8 rows of apple trees, 100 m long). **Control** with mown grass species in the alley and mechanical weeding on the row.

Principal action of the practice

The grass/legume mix sown in the alley has been chosen for its permanency, growth capacity, diversity in terms of root profile (deep and superficial), as well as for its capacity to provide nitrogen and floral resources for pollinators and other beneficials.

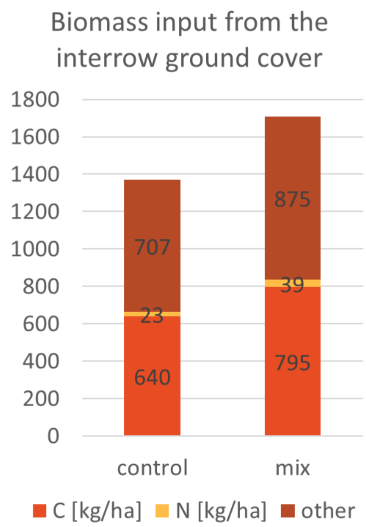


Results of the experiments

The grass/legume mix sown in the alley has been mown 3 times each year, the same as the control orchard with sod. In the 2020 season, it produced the equivalent of 1.71 tonne/ha biomass dry weight, compared to 1.39 for the control plot (an increase of 25%).

Both carbon and nitrogen inputs are boosted, by 24% and 71% respectively.

Take home message: The grass/legume mix sown in the alley and incorporated in the tree row represents a significant input in terms of biomass and C content in particular. This result has to be confirmed with the soil C content analysis. The N input makes it possible to spare the equivalent of up to 10 units of N fertiliser.



For more information

Contact: aude.alaphilippe@inrae.fr

See leaflets no. 5 and 7.

Experiment conditions

Scale

Validity

Duration: 2018-2020

No. of repetitions: 8; 4 blocks in 2 orchards

The project Friendly Fruit (2018-2020) was coordinated by INRAE with the financial support of the EIT KIC.

Climate-KIC is supported by the EIT, a body of the European Union

Credits. Authors: A. Alaphilippe , A. Richard. INRAE; Design & coordination: A. Alaphilippe, INRAE; Design & layout B. Rosies & B. Chieze. Photos: L. Tornatore & A. Alaphilippe INRAE.

Friendly Fruit

N°9

An Internet of Things (IoT) solution for improved irrigation scheduling

ALMA MATER STUDIORUM UNIVERSITÀ DI BOLOGNA

IRTA

Promising but needs to be confirmed

What? An irrigation scheduling system combining on-site sensors with now-casting meteorological conditions to better fit irrigation water use to actual crop needs.

Why? Under climate change, water availability can be a limiting factor for agricultural productivity. Better irrigation management through the use of soil sensors and weather data can lead to significant water savings without compromising production or quality

Practice tested

In orchards, the following should be installed:

- Capacitance soil water content sensors at 20, 40 and 60 cm depths.
- A water meter in the irrigation line.
- Use a cloud platform to capture probe data and combine it with forecast weather data to calculate an irrigation schedule based on the water budget method corrected by soil probes.
- Use the irrigation schedule to change periodically (weekly basis) the irrigation controller.
- Or link the web platform with the irrigation controller to change the schedule on a daily basis.

Interactions: The practice can be efficiently combined with fertigation.

Practice performance

In comparison with less sophisticated (e.g. not considering future weather or IoT configurations) scheduling services.

Agronomy & environment

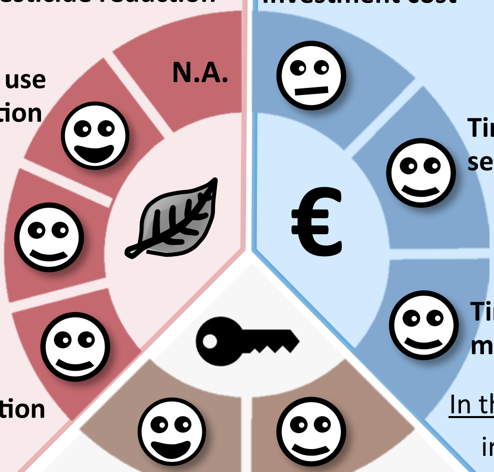
Not yet known.

Reduction of about 25% of the water volumes applied. Could be further improved.

As water is reduced, energy for pumping is proportionally reduced.

Substantially reduces water used **without negative effects** on quality and yield.

Monitoring of soil water content at different depths allows for potential reduction of lixiviation of nutrients.



Costs & benefits

Specific investment for the scheduling system needed. Costs should consider water savings.

Little time needed to install the scheduling system or to manage (could be operated without direct control of the irrigation station).

In the non-IoT configuration: an existing irrigation system can be used **plus** the cost of the service.

It may be necessary to replace the irrigation controller at the pumping station.

Operationality

Training course is needed. It is a **ready-to-use** and **already disseminated** system that provides water savings in either configuration.

In addition to important water savings, the IoT version saves the irrigation manager a tremendous amount of time for programming.

Positive effect — Neutral to positive effect — Room for improvement — Bottleneck

Credits. Authors: J. Bonany, IRTA; L. Corelli Grappadelli, UNIBO; A. Alaphilippe, INRAE; Design & coordination: A. Alaphilippe, INRAE; Design & layout B. Rosies & B. Chieze, INRAE.

Detailed information on experimentation

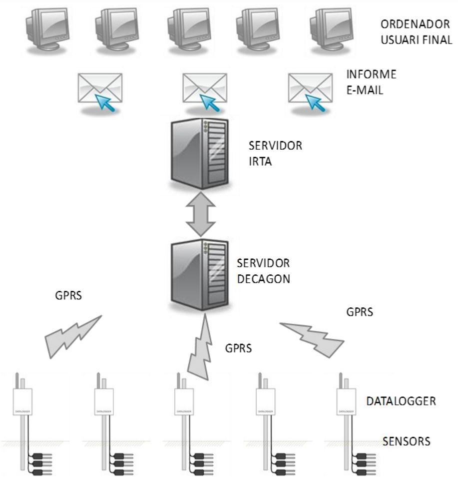
Set-up: A web-based Decision Support System (DSS) that makes use of soil water content sensors wirelessly connected (IoT) to forecast of evapotranspiration to schedule irrigation on commercial apple orchards in France (Golden variety), Italy (Fuji variety) and Spain (Cripps Pink variety).

Control: Traditional scheduling method.

The orchards were equipped with sensors and loggers (soil water content and flow meters).

• Fruit size monitoring to check the performance of the system.

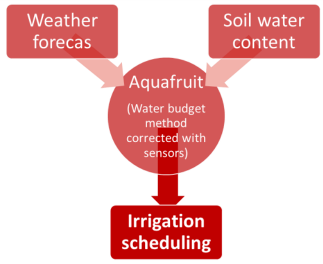
• DSS running with irrigation schedules delivered to growers participating in the project.



Principal action of the practice

Irrigation scheduling must take into account:

- The crop, type of soil, orchard design and meteorological conditions.
- This solution also includes the weather forecast for the site, in order to reduce the amount of water used when rain is forecast.
- This scheduling system uses specific information from individual orchards on water availability in the soil and is coupled with now-casting solutions to provide orchard-specific evapotranspiration estimates.



Results of the experiments

Solutions such as the one tested here, in both configurations, make it possible to achieve around 20 -30% reductions in irrigation volumes. The simpler solution is readily adoptable for any existing irrigation system. The IoT version requires economic investment in cases where the existing irrigation controller is not IoT compatible. Further water savings are possible when a layer of automation is added to the system by which the irrigation schedule is automatically delivered to the irrigation controller on a daily basis. There is no indication of production or quality losses.

Furthermore, this solution should save energy in cases where water is pumped and should reduce nutrient losses through lixiviation from the root zone.

For more information

Contacts: joan.bonany@irta.cat or luca.corelli@unibo.it

Experiment conditions

Scale **Validity**

Duration: 2018-2020

3 sites: France, Italy and Spain

Credits. Authors: J. Bonany, IRTA; L. Corelli Grappadelli, UNIBO; A. Alaphilippe, INRAE; Design & coordination: A. Alaphilippe, INRAE; Design & layout B. Rosies & B. Chieze. INRAE.

The project Friendly Fruit (2018-2020) was coordinated by INRAE with the financial support of the EIT KIC.

Climate-KIC is supported by the EIT, a body of the European Union

Friendly Fruit

N°8

Drone and Artificial Intelligence to help save water and produce high quality apples

Promising but needs to be confirmed

INRAE — Montpellier SupAgro

What? Using drones for image acquisition (thermal IR) and automated data processing by artificial intelligence (user-friendly application) saves irrigation water in orchards by identifying leaks and possible clogging.

Why? With parsimonious watering systems such as drip irrigation, malfunctions are difficult to identify, but are a real problem in terms of fruit quality, tree survival and infrastructure longevity.

Practice tested

Data acquisition by either the farmer or a service provider following **these implementation steps:**

1. Install the application on a laptop (internet required).
2. On a cloudless day, fly the drone (equipped with multispectral + thermal camera) to collect images (≈ 18'/ha).
3. Copy the images on the laptop and run the application.
4. Once the map and file are edited, send someone to the site to check and solve problems.
5. Regularly check the availability of updates.

Step 2

Steps 1 & 3

Steps 4

Period: During fruit growth, when irrigating.

Interactions: Not yet operational with nets.

Practice performance

In comparison with an irrigated orchard, monitored with soil moisture sensors (capacitive).

Agronomy & environment

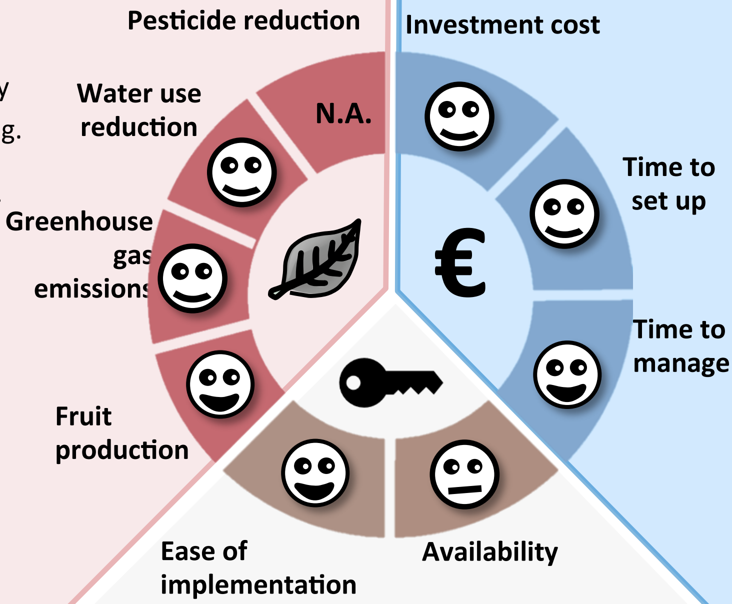
Not studied.

Reduction of water use by avoiding leaks and clogging.

Reduced energy for water pumping and lower fuel consumption for malfunction detection.

Reduces the amount of water waste and avoids irregularity in watering, **improving** fruit quality.

Provides regular water supply, with more fruit for fresh market and limits quality loss.



Costs & benefits

Specific investment to buy the drone. Benefits due to the water and time saved.

Little time needed to fly the drone (≈ 18min/ha).

Saves time for monitoring leaks and clogging.

Needs a little **investment** in the drone (or provider), **counterbalanced** with the monitoring time and water saved and may extend the irrigation system lifetime.

Operationality

Tools and software do not require specific skills or knowledge. **Validated on-station. Coupling** drones and AI is promising: more Apps using drones for monitoring and management are available.

Positive effect — Neutral to positive effect — Room for improvement — Bottleneck

Credits. Authors: M. Delalande, A. Alaphilippe INRAE; JL Regnard, SupAgro; Photo :M. Delalande, INRAE; Design & coordination: A. Alaphilippe, INRAE; Design & layout B. Rosies & B. Chieze. INRAE.

Detailed information on experimentation

Objective of the experimentation: Mimic leaks and clogging in a commercial orchard and take images by drone when orchard is experiencing water deficit, during normal watering (irrigation managed by capacitive probes) and over-watering. These images were used to train a neural network (an Artificial Intelligence technique) to recognise the different water statuses experienced by apple trees.

Experimental orchards:

⇒ INRAe Diascope, Montpellier, on a collection of 242 apple varieties, planted in an experimental orchard in 2014.

⇒ Near Girona, Catalonia, on a 2001-planted Gala-Brookfield orchard without hail-nets.

⇒ In a Gala-Venus orchard, planted in 2014, covered by grey hail-nets. The identification of a tree's water status is more difficult in these conditions and needs further development.

Principal action of the practice

How it works:

Orchard images are entered into the algorithm and an Artificial Intelligence procedure cuts the images into small parts and analyses each piece created. From these small pieces, a prediction is produced in the form of a map: blue spots have a high probability of revealing a leak and red spots have a high probability of revealing clogging. Together with the map, a file is generated with GPS coordinates of each location with a potential malfunction.

Images must be collected on a cloudless day, with little wind. With an acquisition time of ≈ 18mn/ha, this technique can be deployed almost everywhere.

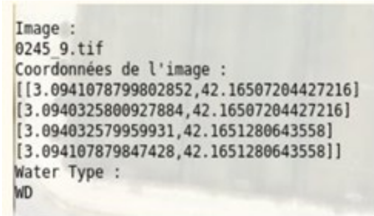
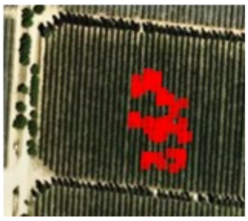


Image :
0245_9.tif
Coordonnées de l'image :
[[3.0941078799802852,42.16507204427216]
[3.0940325800927884,42.16507204427216]
[3.094032579959931,42.1651280643558]
[3.094107879847428,42.1651280643558]]
Water Type :
WD



Results of the experiments

Take home message: The AI application for identifying misfunctioning in drip irrigation systems is close to ready-to-use status, but its robustness needs to be improved before releasing the AI-based application.

The next steps before release concern improvements to the algorithm:

- By training in different orchards (environmental conditions x agricultural practices).
- By using other cameras (most commonly used cameras).

Experiment conditions

Scale **Validity**

Duration: 2018-2020

No. of repetitions: 3 orchards

For more information

Contacts: magalie.delalande@inrae.fr or jean-luc.regnard@supagro.fr

Credits. Authors: M. Delalande, A. Alaphilippe INRAE; JL Regnard, SupAgro; Photo :M. Delalande, INRAE; Design & coordination: A. Alaphilippe, INRAE; Design & layout B. Rosies & B. Chieze, INRAE.

Friendly Fruit The project Friendly Fruit (2018-2020) was coordinated by INRAE with the financial support of the EIT KIC.

Climate-KIC is supported by the EIT, a body of the European Union

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N°9

EVAPORATIVE COOLING FOR HEATWAVE MANAGEMENT

Friendly Fruit

National Research Council of Italy
Institute of BioEconomy
Department of Biology, Agriculture and Food Science

Promising but needs to be confirmed

What? Effective recommendations for introducing and operating evaporative cooling through over-canopy irrigation in apple orchards.

Why? Thanks to a targeted analysis of increasing heatwave hazards in Europe, the practice has been designed to support the mitigation of potential damage in apple production.

PRACTICE TESTED

Implementation (main steps):

1. Set up dripline irrigation: 2,900 m/ha with 28 drippers/ha positioned at 40 cm; flow: 1.6 mm/h.
2. Set up over-canopy irrigation: 800 m of PE, in 6 lines, with 34 sprinklers/ha; flow: 4.5 mm/h; density 16.8 m x 17.5 m.
3. Installation of air temperature sensors

Interactions: The practice can be efficiently combined with shading nets. No negative interactions.

Climatic zone: Mediterranean and Central Europe

PRACTICE PERFORMANCE

In comparison with a classical orchard with no heatwave management and dripline irrigation.

AGRONOMY & ENVIRONMENT

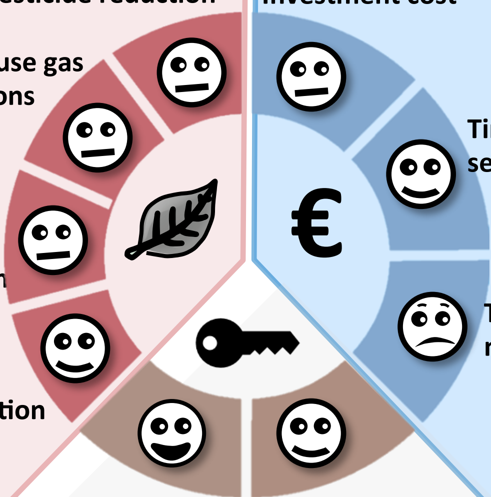
No risk in terms of pests and diseases.

Does not induce extra energy use or greenhouse gas emissions.

No increase in water use, but optimisation.

Favours skin pigmentation due to increase in anthocyanin.

Boosts daily photosynthesis and **maintains stable production** under extreme summer temperature conditions.



COSTS & BENEFITS

Initial investment for the irrigation system: doubling irrigation lines and including over-canopy sprinklers.

Dedicated time needed to install the irrigation. Dedicated time to monitor temperature. It will be automated.

Provides decrease of 2-4°C in canopy temperature during extreme heat.

OPERATIONALITY

No specific skills or knowledge are required.

Ready-to-use and promising alternative to counter the effects of heatwaves and maintain production and income.

Positive effect | Neutral to positive effect | Room for improvement | Bottleneck

Credits. Authors: F. Rossi, S. Tadic, C. Chieco CNR-IBE. A. Alaphilippe, INRAE; Design & coordination: A. Alaphilippe, INRAE; Design & layout B. Rosies & B. Chieze. INRAE.

Detailed information on experimentation

Cooling irrigation set-up: Combination of the dripline with an over-canopy irrigation system (800 m of PE, in 6 lines, with 34 sprinklers per hectare operating at a flow capacity of 4.5 mm/h). System density 16.8 m x 17.5 m.

Control system: Dripline length 2,900 m/ha with 28 drippers/ha positioned at 40 cm spacing on the row at a flow of 1.6 mm/h.
For water volume equivalency, a second line of drippers was added.

The orchard was equipped with a black anti-hail-net (20% shading coefficient). The cooling system was activated from 12am until 3pm when the temperature reached the 30°C threshold. Leaf, fruit and air temperature sensors were installed in experimental orchards.

Principal action of the practice

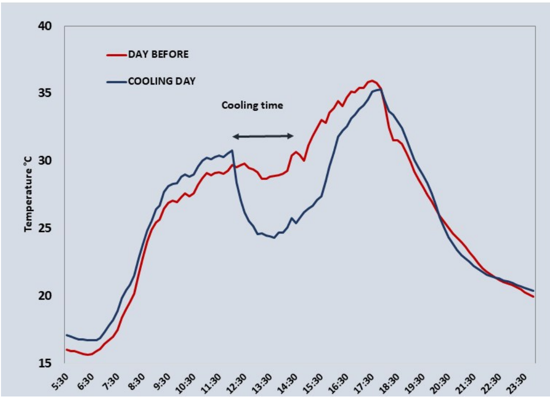
Modification of the irrigation plan. Activation of the evaporative cooling irrigation is triggered by the farmer (automatically or manually) at a fixed threshold, with a minimum duration of 2 hours.

How it works: It affects the microclimate. Indeed, evaporative cooling has demonstrated its capacity to help reduce temperatures during extreme heatwave events. It is a tool in a farmer's arsenal for tackling climate change and its impacts on tree performance and productivity.

Results of the experiments

Evaporative cooling reduces fruit surface temperature by 4°C (see figure right).

Take home message: Evaporative cooling has demonstrated its capacity to help reduce temperatures during extreme heatwave events. It is a tool in a farmer's arsenal for tackling climate change and its impacts on tree performance and productivity.



For more information

Contact: federica.rossi@ibe.cnr.it

Microclimatic physiological and productive effect of the overcanopy irrigation in an apple orchard. L. Manfrini, G. Gatti, B. Morandi, L. Corelli Grappadelli, G. Bortolotti, F. Rossi, O. Facini, C. Chieco, M. Gerin, D. Solimando, T. Letterio and S. Anconelli . Acta Hortic. 1281. ISHS 2020. DOI 10.17660/ActaHortic.2020.1281.50 XXX IHC – Proc. Int. Symp. on Evaluation of Cultivars, Rootstocks and Management Systems for Sustainable Production of Deciduous Fruit Crops.

Experiment conditions

Scale

Validity

Duration: 2018-2020

No. of repetitions: 2

Credits. Authors: F. Rossi, S. Tadic, C. Chieco CNR-IBE. A. Alaphilippe, INRAE; Design & coordination: A. Alaphilippe, INRAE; Design & layout B. Rosies & B. Chieze. INRAE.

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