Optimization of the mineral nutrition of strawberry crops: Monitoring using a theoretical fertilization schedule and soil bioavailability tests

François Lecompte (INRAE), Soukaina EL Mrini (INRA Maroc), Ahlam Hamim (INRA Maroc), Sophie Bomel (INRAE), Douaé Lamrahli (Messem), Hicham Essrifi (Messem), Ahmed Taleb (Danone), Aziz Didicheikh (GIZ)

01.01.2018 to 31.12.2020

Supported by:

Climate-KIC is supported by the EIT, a body of the European Union
History of experiments and selection of practice

• **Context**

To meet the environmental challenges caused by the leaching of fertilizers into the environment, fertilization management is the key tool for producers to reduce their consumption of inputs.

• **Method**

Monitoring of soil and plant status and adjustment of fertilizer inputs by moving from a static fertilization program to a program based on data on soil and plant status.

The experiment was conducted in 5 farm labs in the area of the Gharb-Loukkos in Morocco and lasted *for first 6 months of the growing season 2019-2020*
Practice description

**What?**
Monitor the fertilization of strawberry field crops based on a theoretical fertilization schedule, a P and K test at the beginning of the season and N tests during the cycle.

**Why?**
To preserve nutrient resources and limit losses to the environment and pollution by adapting inputs to the crop's needs while maintaining performance levels.

**Status?**
Ready to use
Main steps

1. Create a theoretical fertilization schedule (N, P, K) based on the expected biomass and nutrient levels.
2. Obtain a maximum quantity to be provided per element which is fractionated into theoretical doses according to the development kinetics of the culture.
3. These theoretical doses are adjusted according to an initial test for P and K, and during the cycle for nitrogen using a portable reflectometer (Nitrachek®).

<table>
<thead>
<tr>
<th>Nitrate concentration in soil solution (mg/l)</th>
<th>Multiplying coefficient</th>
</tr>
</thead>
<tbody>
<tr>
<td>&lt; 100</td>
<td>1,5</td>
</tr>
<tr>
<td>100-150</td>
<td>1</td>
</tr>
<tr>
<td>150-200</td>
<td>0.8</td>
</tr>
<tr>
<td>&gt; 200</td>
<td>0.5</td>
</tr>
</tbody>
</table>
Key results

Monitoring with the help of theoretical fertilization planning and bioavailability tests makes it possible to reduce fertilizer consumption, maintain yield and limit environmental pollution.

<table>
<thead>
<tr>
<th>Values over 6 months</th>
<th>Low inputs</th>
<th>Farmer</th>
</tr>
</thead>
<tbody>
<tr>
<td>Nitrogen (kg/ha)</td>
<td>54.2 ± 5.2</td>
<td>127.1 ± 8.1</td>
</tr>
<tr>
<td>Phosphorus (kg/ha)</td>
<td>5.7 ± 0.3</td>
<td>63.3 ± 14.8</td>
</tr>
<tr>
<td>Potassium (kg/ha)</td>
<td>108.4 ± 5.7</td>
<td>135.2 ± 8.3</td>
</tr>
<tr>
<td>Marketable yield (g/plant)</td>
<td>379 ± 63</td>
<td>392 ± 63</td>
</tr>
</tbody>
</table>

Average significant reduction of 88% for Phosphorus and 54% for Nitrogen over the first 6 months of the crop season.
Practice Performances

**Agronomy & Environment**
- Pesticide reduction has not been studied.
- Reduction in the use of N & P (less GHGs) and energy related to the pump injecting the fertilizers.
- No loss of yield but result to be consolidated.
- Reduction in the consumption of fertilizers, and potentially their loss in the environment.

**Costs & Benefits**
- Low investment cost and quickly amortized.
- Time required to set up the schedule is low.
- Time required for monitoring is low and distributed over the production period.
- Reduction of costs related to fertilizers.

**Operationality**
- Positive effect
- Neutral to positive effect
- Improvement areas
- Critical points

A well-known alternative practice that has already proven successful.

Easy to set-up but requiring a short assistance for the tests' handling and interpretation.
Dissemination

The alternative practice is efficient and ready to implement

• **Leaflet** (overall method and results)

• **Short report** (detailed method and results) to be distributed to the 5 farmers

• **Short training session** for the technical consulting staff

• **Berry school event** (Morocco)
Mechanical weeding on young apple orchard

Anne Duval-Chaboussou, CTIFL
Antony Leblois, La Morinière
Claude Coureau, CTIFL

01.01.2018 to 31.12.2020

Supported by:

Climate-KIC is supported by the EIT, a body of the European Union
**What?** Foliar and residual weed chemical killer compare to mechanical weeding on young orchard


**Status?** Mechanical tools for weeding:
- A lot of different tools
- Expensive in invest (availability of tools)
- Expensive in operate (labour, gasoil, maintenance)
- Have a good worker
- Carbon footprint
History of experiments and selection of practice

Objective

Compare chemical weeding to mechanical weeding on young plantation, with or without over fertilization.

Material

Variety: Y101 (new variety) on Emla Plantation 2017
Density: 1 x 3.5 m
Training: axis
Irrigation: Drop 1 L/h

Methods

<table>
<thead>
<tr>
<th>Modality / Year</th>
<th>2018</th>
<th>2019</th>
<th>2020</th>
</tr>
</thead>
<tbody>
<tr>
<td>Chemical weeding – T0</td>
<td>X</td>
<td>X</td>
<td>X</td>
</tr>
<tr>
<td>Mecanical weeding – T1</td>
<td>X</td>
<td>X</td>
<td>X</td>
</tr>
<tr>
<td>Mecanical weeding + over fertilization – T2</td>
<td>X</td>
<td>X</td>
<td>X</td>
</tr>
</tbody>
</table>
Main steps to implement this practice

### Chemical weeding

<table>
<thead>
<tr>
<th>Date</th>
<th>Chemical</th>
<th>Dose (L/ha)</th>
</tr>
</thead>
<tbody>
<tr>
<td>20/04/2018</td>
<td>Glyphosate (300 g/L)</td>
<td>1.06</td>
</tr>
<tr>
<td>23/05/2018</td>
<td>Glyphosate (300 g/L)</td>
<td>1.06</td>
</tr>
<tr>
<td></td>
<td>2.4 D (600 g/L)</td>
<td>0.53</td>
</tr>
<tr>
<td>13/06/2018</td>
<td>Glufosinate (150 g/L)</td>
<td>1.66</td>
</tr>
<tr>
<td>13/07/2018</td>
<td>Glufosinate (150 g/L)</td>
<td>1.66</td>
</tr>
<tr>
<td>02/08/2018</td>
<td>Glufosinate (150 g/L)</td>
<td>1.66</td>
</tr>
<tr>
<td>25/03/2019</td>
<td>Glyphosate (486 g/L)</td>
<td>4</td>
</tr>
<tr>
<td></td>
<td>Isoxaben (107 g/L)</td>
<td>4.8</td>
</tr>
<tr>
<td></td>
<td>Napropamide (450 g/L)</td>
<td>5.2</td>
</tr>
<tr>
<td>20/05/2019</td>
<td>Glyphosate (486 g/L)</td>
<td>1.5</td>
</tr>
<tr>
<td>04/07/2019</td>
<td>Glyphosate (486 g/L)</td>
<td>1.5</td>
</tr>
</tbody>
</table>

### Mecanical weeding

<table>
<thead>
<tr>
<th>Date</th>
<th>Tool</th>
<th>Brand</th>
<th>Speed (km/h)</th>
<th>Time h/ha</th>
</tr>
</thead>
<tbody>
<tr>
<td>20/04/2018</td>
<td>Hoeing</td>
<td>Solemat</td>
<td>2</td>
<td>2.5</td>
</tr>
<tr>
<td>26/04/2018</td>
<td>Disc harrow</td>
<td>Solemat</td>
<td>3</td>
<td>2.5</td>
</tr>
<tr>
<td>16/05/2018</td>
<td>Hoeing</td>
<td>Solemat</td>
<td>2</td>
<td>1.7</td>
</tr>
<tr>
<td>22/05/2018</td>
<td>Disc harrow</td>
<td>Solemat</td>
<td>3</td>
<td>2.5</td>
</tr>
<tr>
<td>20/06/2018</td>
<td>Brush</td>
<td>Solemat</td>
<td>2</td>
<td>2.5</td>
</tr>
<tr>
<td>21/06/2018</td>
<td>Disc harrow</td>
<td>Solemat</td>
<td>3</td>
<td>1.7</td>
</tr>
<tr>
<td>25/07/2018</td>
<td>Hoeing</td>
<td>Solemat</td>
<td>2</td>
<td>2.5</td>
</tr>
<tr>
<td>10/08/2018</td>
<td>Wires</td>
<td>Cucchi</td>
<td>1.5</td>
<td>1.7</td>
</tr>
<tr>
<td>12/10/2018</td>
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<td>Solemat</td>
<td>2</td>
<td>2.5</td>
</tr>
<tr>
<td>20/11/2018</td>
<td>Disc harrow</td>
<td>Solemat</td>
<td>3</td>
<td>2.5</td>
</tr>
<tr>
<td>18/04/2019</td>
<td>Disques émotteurs et finger Kress</td>
<td>ALM</td>
<td>4</td>
<td>0.9</td>
</tr>
<tr>
<td>14/05/2019</td>
<td>Wires</td>
<td>Cucchi</td>
<td>1.5</td>
<td>4.0</td>
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<td>16/05/2019</td>
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<td>Boisselet</td>
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<td>2.5</td>
</tr>
<tr>
<td>01/07/2019</td>
<td>Wires</td>
<td>Cucchi</td>
<td>1.5</td>
<td>4.0</td>
</tr>
<tr>
<td>02/07/2019</td>
<td>Hoeing</td>
<td>Clemens</td>
<td>2</td>
<td>2.5</td>
</tr>
<tr>
<td>23/10/2019</td>
<td>Wires</td>
<td>Herbanet</td>
<td>1.5</td>
<td>4</td>
</tr>
</tbody>
</table>

Over fertilization = manure or compost at fall
Synthesis of results

Labour time and number of passage between chemical and mechanical weeding

2018 / 2019 / 2020

- Chemical Weeding
  - 2020: 7
  - 2019: 3
  - 2018: 5

- Mechanical Weeding
  - 2020: 30
  - 2019: 17
  - 2018: 13

- Chemical Weeding
  - 2020: 5
  - 2019: 3
  - 2018: 5

- Mechanical Weeding
  - 2020: 6
  - 2019: 6
  - 2018: 10
Synthesis of results

Mechanical weeding: Less production, better with over fertilization in fall

Yield / weeding modality
- Add 2nd to 3rd leaf -

Size distribution (mm)
- Add 2nd to 3rd leaf -
Practice Performances
Roadmap for transfer – Next steps

Easy to transfer because already use in organic

- Expensive for growers / apples should be sold more expensive
- Buy expensive machine
- Find qualified labour
- Carbon impact?
Interrow management with a sawn grass legume mix

Aude, Annabelle, Lucas, Blandine, Hugo, Olivier, Laurent, Thierry

01.01.2018 to 31.12.2020

Supported by:
Summary of experiments

Objectives for the 3 years:
To optimize the cover management on the row/inrerrow in order to:
• avoid herbicide use
• increase soil carbon inputs
• optimize mechanization.

Tested solutions:
• Full grass cover
• Grass/legumine mix in the alley and mechanical weeding on the row
• Control with mown grass in the alley and mechanical weeding on the row
Description of the practice selected for the leaflet

What?
• A sawn grass/legumine mix on the alley, mown with a delivery on the tree row, combined with mechanical weeding on the tree row.
• In a mature orchard, spontaneous grass cover in the tree rows as in order to have a grass cover over the entire orchard, and to avoid herbicide use with mowing combined for row and interrow.

Why?
These practice combinations have been designed
• to suppress herbicide use,
• to optimise the work organisation, as well as
• to improve the soil health
thanks to the soil incorporation to the ground of the grass/legumine mix.
Main steps to implement this practice

Implementation grass/legumine mix

- Year 1: Seed bed preparation for seed sowing; Sawing and irrigation for 1st growth
- Year 1 & following: Mowing according to growth (3 to 4 times/season) with side delivery
- Earthing up on the tree row in order to incorporate the mulch (5cm depth) with discs.

Implementation fullgrass cover:

- Spontaneous growth on the tree row.
- Mowing with satellite according to growth

Interactions:
With fertilizer incorporation and irrigation.

Conditions of use: The composition of the grass/legumine mix has to be adapted to the pedo-climatic context.
2 orchards, one organic and one integrated fruit production, 15-years old; 0.3ha each (cv Ariane)

Control with mown gramineae in the alley and mechanical weeding on the row.
Key result of the experimentation: grass/legumine mix

Status:
Promising but needs to be confirmed

Message to take home:
The grass/legumine mix sawn in the alley and incorporated in the tree row represents a significant input in terms of biomass and C-content in particular. The N-input permit to spare the equivalent of up to 10 units N-fertilizer.
In comparison to an interrow sawn with long lasting sod and a classical mechanical weeding on the tree row.

**Agronomy & Environment**

- Suppression of herbicide applications by using mechanical weeding.
- Similar or less mineral N supply by incorporation of legumine.
- Potential increase in soil organic matter (to be confirmed).
- Compare to mechanical weeding, no effect.
- It is compatible with organic farming; it might improve soil health.

**Costs & Benefits**

- **Specific investment** for the mowing machine with side depository.
- Extra time needed for seed bed preparation in already planted orchard.
- **No extra time** for management.
- **Initial investment** in the mowing machine might be requested, no other investment is requested. It is compatible with organic management.

**Operationality**

- It is a ready-to-use solution with available equipment. The seed mix has to be adapted to the farm context, but results need to be further confirmed.
- No specific skills or knowledge are requested.
Next steps:
- To integrate the soil C analysis and conclude the result synthesis.

These practices will be further experimented.

Scientific publication together with an update on LCA methodology concerning the modeling of C linked to climate change impact category.
Use of Organic manures as a form of carbon and nutrient fertilization

Glòria Avila (IRTA), Joan Bonany (IRTA)
Rachel Creamer (WUR), Henk Martens (WUR)

01.01.2018 to 31.12.2020

Supported by: Climate-KIC
Abundance of organic manure in certain European areas is both at the same time an environmental challenge and a opportunity for a circular bio-economy. The experiment consisted in comparing standard mineral fertilization with fertilization with organic manure from pig production. The organic manure was in form of composted solid fraction of pig slurry. Two different applications were tested. Either application on top of the soil combined with standard herbicide application strategy or application on top and the using mechanical weeding which helped to incorporate manure into the soil.

The practice was selected for the potential benefits for climate change. Mineral fertilization accounts for a high proportion of contribution to green house gases. Substitution of mineral fertilization by organic fertilization would potentially contribute to reduce green house gases, improve soil quality and at the same time reduce the environmental pressure of the surplus of pig slurry manure from pig farms in certain European regions. Combination with mechanical weeding would further add value in the sense of reduction of herbicides reducing the environmental impact and contribution to green house gases
Description of the practice selected for the leaflet

What?
Organic fertilization with compost of solid fraction of pig slurry combined with mechanical weeding on the tree row on apple trees

Why?
• Closing the cycle of nutrients in the agri-food sector in a specific territory
• Contribute globally to reduce greenhouse gas emissions, minimize dependence on the production of distant inputs, and increase soil quality.

Status? on-going experimentation
Main steps to implement this practice

The implementation of this practice by growers is very simple. Given the availability of organic manure, in this case, composted solid fraction of pig slurry, the grower should apply the organic manure at the end of winter or beginning of the vegetative season.

Appropriate organic manure spreader with side delivery is more convenient. Calculation of dosage is based on agronomical principles and estimates of nitrification rates combined with nutrient demand of plants.

If mechanical weeding is used as substitute of chemical herbicide to help in tilling the soil to better incorporate the organic manure into the soil, also appropriate machinery is necessary.
Main steps to implement this practice

Application of Compost of Pig slurry SF

Tree-row management with rolling cultivator + finger weeder (mechanical weed control and SF incorporation)
Expected Key result / Message to take home

- No differences between mineral and organic fertilization regarding fruit yield, fruit size or fruit color.
- Foliar content of micro and macronutrients within standard values
- Herbicide suppression with good weed control.
- Mechanical weed control show less mean fruit weight only the first year of conversion and greater fruit color compared to herbicide in the two years of trial.
- No data yet on soil biological quality and nitrification rates
- If results are confirmed, substitution of mineral fertilizer by organic manure could contribute to reduction of emission of greenhouses gases and at the same time solve the environmental challenge of surplus organic manure from pig farms
Results 2020 (2nd year)

Number of fruits per tree

- HERBICIDE
- TILLAGE

- MINERAL
- PIG SLURRY SF
- PIG SLURRY SF INCORPORATED
- MEAN
Results 2020 (2nd year)

Average fruit weight (g)

- MINERAL
- PIG SLURRY SF
- PIG SLURRY SF INCORPORATED
- MEAN

HERBICIDE
- a
- a
- a
- A

TILLAGE
- a
- a
- a
- A
Results 2020 (2nd year)

Fruit color Percentage >90% COLOR

- MINERAL
- PIG SLURRY SF
- PIG SLURRY SF INCORPORATED
- MEAN

<table>
<thead>
<tr>
<th></th>
<th>HERBICIDE</th>
<th>TILLAGE</th>
</tr>
</thead>
<tbody>
<tr>
<td>HERBICIDE</td>
<td>a</td>
<td>a</td>
</tr>
<tr>
<td>TILLAGE</td>
<td>a</td>
<td>a</td>
</tr>
</tbody>
</table>
Practice Performances

Most positive outcome
• No negative effects on production or quality

Most negative outcome
• Too early to say
• So far no negative outcomes
### Practice Performances

**Agronomy & Environment**

- Herbicide suppression with good weed regulation.
- Reduction of about 58% of the N applied.
- No mineral fertiliser use.
- Organic manures replaced mineral fertilizers *without effects* on fruit quality and yield.
- Mechanical weeding show greater fruit color, but less mean fruit weight (*1st* year only) compared to herbicide.
- It increases soil biodiversity.

**Costs & Benefits**

- Investment cost
- Time to set-up
- Time to manage

**Operationality**

- Positive outcome
- Neutral to positive outcome
- Areas of improvement
- Critical points

- Specific investment in the machineries for both mechanical weeding and fertilisation with lateral deposit.
- Little time needed

- Similar time requested: as classical fertilisation. More time for weed management.

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

- It is a promising alternative for grass and fertilization row management. It provides less dependence on inputs and improve nutrient management in high density livestock areas.

- It is *compatible with organic production*.
Roadmap for transfer– Next steps

Although practice would be readily transferable without any barrier other than availability of organic manure and machinery, the experiment is still ongoing and key data regarding medium term effects on production and quality as well as soil quality is still missing.
Modelling ecosystem services in apple orchards

G Vercambre, M Moradzadeh, P Valsesia, D Plénet, M Génard, J Borg, M Memah, F Lescourret – INRAE Avignon

01.01.2018 to 31.12.2020

Supported by:
Overview of the objectives

Ecosystem services

- Yield
- Size, quality (distribution)
- Prevention of N denitrification
- C sequestration
- Concentration of nitrates in horizon 0-30 cm
- Yearly variation of organic N
- Soil humidity (0 – 30 cm)
- Drainage
- Prevention of N leixiviatiion

Soil, climate

Cultural practices

Fruit production

Climate regulation

Nitrogen availability in soil

Regulation of water fluxes
Tree model

Focuses on growth and fruit quality controlled by environmental conditions and cultural practices.

**Climate**  **Irrigation**  **Pruning**  **Thinning**

The tree is composed of different **compartments**

The represented **processes/physiological states** are:

- **Carbon**
  - Light interception
  - Photosynthesis
  - Carbon storage and mobilisation
  - Exchanges
  - Respiration
  - Growth
  - Metabolic transformations (sugars)

- **Water**
  - Energy balance and water transfers
  - Leaf temperature and transpiration
  - Water potentials within the tree

- **Roots:**
  - old
  - new

- **Old wood**

- **Watersprouts**

- **Fruit bearing shoot (FBS)**

---

*Friendly Fruit Project – Annual and Final Project Meeting*  
*01-02 December 2020*
Tree model

Focuses on growth and fruit quality controlled by environmental conditions and cultural practices

Climate  Irrigation  Pruning  Thinning

The tree is composed of different compartments

The represented processes/physiological states are:

- **Carbon**
  - Light interception
  - Photosynthesis
  - Storage and mobilisation
  - Exchanges
  - Respiration
  - Growth
  - Metabolic transformations (sugars)

- **Nitrogen**
  - Absorption
  - Storage and mobilisation
  - Reduction of growth

- **Roots**: old
  - new
- **Old wood**
- **Watersprouts**
- **Fruit bearing shoot (FBS)**
Soil model

Soil of Stics, a widespread model of annual crops. Focuses on water, N and C processes controlled by environmental conditions and cultural practices.

**Soil+climate  Irrigation  Fertilisation**

The soil is cut into horizons, layers and sub-layers.

The represented processes/states are:

- Water
  - Supply and infiltration
  - Soil evaporation
  - Water transfers between layers
  - Water potential/layer (water content)
  - Collar water potential (**link with the tree model**)**
  - Distribution of water absorption by roots
  - Water balance/layer

![Diagram of soil layers and tree](image)
Soil model

Soil of Stics, a widespread model of annual crops. Focuses on water, N and C processes controlled by environmental conditions and cultural practices

Soil+climate  Irrigation  Fertilisation

The soil is cut into horizons, layers and sub-layers

The represented processes/states are:

- Nitrogen
  - Initialisation
  - Supply
  - Transformation
    - Immobilisation
    - Mineralisation
    - Nitrification
    - Denitrification
  - Leaching

Tree

Soil model
Soil model

Soil of Stics, a widespread model of annual crops. Focuses on water, N and C processes controlled by environmental conditions and cultural practices

**Soil+climate  Irrigation  Fertilisation**

The soil is **cut into horizons, layers and sub-layers**

The represented **processes/states** are:

- **Carbon**
  - Initialisation
  - Supply (organic, residues)
  - Transformation
    - ✓ Immobilisation
    - ✓ Mineralisation

![Soil model diagram](image)
Illustration of intermediate variables
Ecosystem services

Yield (tons of fresh mass/ha)

Distribution of fruit sizes at harvest

Distribution of fruit quality (gSS/gFM) at harvest

![Graphs showing yield and distribution of fruit sizes and quality]
Ecosystem services

- Drain water (mm)
- Nitrogen leaching (kg N-NO₃/ha)
- N₂O emission (kg N-N₂O/ha)
- Carbon sequestration (tons C/ha)
- NO₃ concentration down to 30 cm (g N-NO₃/kg soil)
Interactions with stakeholders
(Ctifl, advisory service, experimental station)

Ecosystem services

- Fruit production
- Climate regulation
- Nitrogen availability in soil
- Regulation of water fluxes

Relevance of indicators?
Which priority?

Interannual variability
- Yield
- Size, quality (distribution)
- Prevention of N denitrification
- C sequestration
- Concentration of nitrates in horizon 0-30 cm
- Yearly variation of organic N
- Soil humidity (0 – 30 cm)
- Drainage
- Prevention of N leaching

Other services/outputs?
Biodiversity

Soil, CC

Cultural practices

Soil management (covers, machinery)
N fertilization (forms, timing...)

Which scenarios?

Respective contributions to output variation

Friendly Fruit Project – Annual and Final Project Meeting 01-02 December 2020
Take home messages – Next steps

• The first fruit crop model that represents a bundle of ES
• A tool to interact with stakeholders for the multi-functionality and sustainability of fruit growing
• The stakeholders are interested in the whole range of ES studied and suggested interesting scenarios

• To go further
  ✓ Estimation and tests of the model by confrontation to experimental data have still to be done
  ✓ Urgent need for modelling ground management (covers, …)
  ✓ Workshops with stakeholders

Relationships between cropping systems and ES bundles (Demestihias et al 2019)
Non chemical soil fumigation in strawberry: the Biofumigation and the ASD techniques

Daniela Giovannini & Gianluca Baruzzi-CREA
History of experiments and selection of practice

✓ 2 years trials
  ✓ 2018/2019 and 2019/2020;
  ✓ Commercial farm, growing strawberry protected under tunnel
  ✓ Replanting soil/ chemical fumigation
✓ Cultivar: Sabrosa*
  ✓ Plant material: bare-root plants
  ✓ harvest period: January-May

TREATMENTS:
1. STANDARD – Chemical fumigation (chloropicrin + 1,3-D mixture)
2. BIOFUM - Biofumigation with biocide plants
3. ASD - Anaerobic soil disinfestation
4. UNTREATED - Non-fumigated soil
5. ASD Variant (simplified application)

BIOFUMIGATION AND ASD:
✓ Easy to apply;
✓ applied already in several countries proved promising in containing soilborne pests and diseases;
✓ involve incorporation of remarkable amounts organic matter, hence play also a role as soil amendments;
✓ commercial products are available=simplified application and more consistent results

Typical multi-span tunnel used in Southern Italy for strawberry
Description of the practice selected for the leaflet

What?

Soil incorporation pre-planting of:

**BIOFUMIGATION**: defatted seed meals of Brassicaceae plants
(commercial product: 'BioFence' pellets, Nutrien Italia S.p.A);

**ASD**: organic matter material of vegetable origin
(commercial product: 'Soil Resetting', granular, Thatchtec, NL).

Why?

To contain soilborne pests and pathogens of previous strawberry planting and minimize replanting syndrome (impacting plant growth, yield quantity and quality) with no use of chemical fumigants.

Status?

BIOFUMIGATION: promising but results need to be confirmed
ASD: almost ready-to-use.
Main steps to implement **Biofumigation** practice

In the interval time between previous strawberry planting removal and new planting:

1. Soil tillage;
2. Incorporation of 'BioFence' pellets (2.5-3.0 t/ha) at a 0-30 cm soil depth;
3. Irrigation to activate hydrolysis of glucosinolates;
4. Preparation of raised beds including the treated soil only; mulching;
5. Planting
Main steps to implement the **ASD** practice

In the interval time between previous crop removal and new strawberry planting:

1. Soil tillage;
2. Incorporation of 'Soil Resetting' (8 t/ha) to a 0-30 cm soil depth;
3. Irrigation to initiate product decomposition;
4. Sealing the treated soil with totally impermeable (TIF) film;
5. TIF removal after not less than 3 weeks;
6. Preparation of raised beds including the treated soil only, mulching;
7. Planting

**ALTERNATIVE TESTED IN YEAR 2**
Biofumigation with defatted seed meals of Brassicaceae (commercial product: Biofence®, Nutrien Italia S.p.A) shows potential as an eco-friendly alternative to soil chemical fumigation on strawberry; additional experimentation is needed to optimize conditions and increase efficacy.
Expected Key result / Message to take home

**ASD**

**Yield per plant**

<table>
<thead>
<tr>
<th>Year</th>
<th>Treatment</th>
<th>2019</th>
<th>2020</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Chemical Fumigation</td>
<td>A</td>
<td>A</td>
</tr>
<tr>
<td></td>
<td>ASD (SoilResetting)</td>
<td>b</td>
<td>B</td>
</tr>
<tr>
<td></td>
<td>Untreated</td>
<td>c</td>
<td></td>
</tr>
</tbody>
</table>

**Fruit weight**

<table>
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<th>Year</th>
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</tbody>
</table>

Anaerobic soil disinfestation (commercial product: Soil Resetting®, Thatchtec, NL) added pre-planting is a promising eco-friendly alternative to conventional soil chemical fumigation on strawberry.
Practice Performances: BIOFUMIGATION

In comparison with chemical fumigation:

**AGRonomy & Environment**
- Pesticides reduction by substituting chemical fumigation
- Decrease in machinery use due no chemical fumigation application.
- Compared to chemical fumigation, it might moderately decrease yield and fruit weight.

**Operationality**
- Positive outcome
- Neutral to positive outcome
- Areas of improvement
- Critical points

**Costs & Benefits**
- No extra investment in comparison to chemical fumigation.
- Little time to set-up
- Little time to manage.
- Cheaper practice than chemical fumigation.
- Compatible with organic farming.
- Can add commercial value to the crop yield.

**Pesticides reduction**
- Global warming potential
- Investment cost
- Time to set-up
- Time to manage
- Ease to implement
- Ready to use

**Fruit production**

It is a promising alternative to chemical soil fumigation, with no harm to operators and environment.
Practice Performances: ASD

In comparison with chemical fumigation:

**Agronomy & Environment**
- **Pesticides reduction** by substituting chemical fumigation.
- Decrease in machinery use due to no chemical fumigation applications.
- Compared to chemical fumigation, it might slightly decrease fruit production.
- Alternative to chemical fumigation to contain pests and pathogens harmful to the crop.

**Operationality**
- Ready-to-use alternative to chemical soil fumigation, with no harm to operators and environment.
- Positive outcome.

**Costs & Benefits**
- No extra investment in comparison to chemical fumigation.
- Little time to set-up.
- Little time to manage.
- Same costs or slightly higher than chemical fumigation.

Compatibility with organic farming.
Can add commercial value to the crop yield.
Roadmap for transfer– Next steps

- Spread the results through technical & dissemination articles (including the Leaflets) or on portals specialized in informing the horticulture/fruit sector; organize seminars/promote events (i.e. open days) dedicated to stakeholders

- Large scale testing/demonstration involving growers associations, including the organic sector, still necessary to move from an experimental phase (although carried out in a commercial farm) to an applicative phase