# Synthesis report
# Sustainable fruit production to minimize residues

**Editor:** ZAVAGLI Franziska, Ctifl, zavagli@ctifl.fr, 00/33.5.53.58.13.10

**Editor partner affiliation:** Centre technique interprofessionnel des Fruits et Légumes (3, Ctifl)

22 rue Bergère, 75009 Paris, www.ctifl.fr, 00/33/1.47.70.16.93

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|---|---|
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**Document overview**

## IEG participants

| Name | Organization short name[1] | Address | Email | Phone | Type[2] | Scanning included? | No. reports / organization |
|---|---|---|---|---|---|---|---|
| Marianne BERTELSEN | AU | Kirstinebjergvej 10 5792 Aarslev (Denmark) | Marianne.Bertelsen@food.au.dk | 0045 8715 8328 | Research institute | Yes | 1 |
| Wendy VAN HEMELRIJCK | Pcfruit | Fruittuinweg 1 3800 Sint-Truiden (Belgium) | wendy.vanhemelrijck@pcfruit.be | 0032 11 69 71 20 | Research institute | Yes | 5 |
| Franziska ZAVAGLI | Ctifl | Centre de Lanxade, 28 route des Nébouts, 24130 Prigonrieux (France) | zavagli@ctifl.fr | 00/33/5.53.58.00.05 | Research institute | Yes | 3 |
| Hinrich HOLTHUSEN | OVA | Dep. Plant Protection and Diagnostics. Moorende 53 - 21635 Jork (Germany) | hinrich.holthusen@lwk-niedersachsen.de | +49 4162 6016-131 | Research institute | Yes | 1 |
| Marcel WENNEKER | StDLO | Lingewal 1, 6668 LA, Randwijk. (NL) | marcel.wenneker@wur.nl | 00/31/488473745 | Research institute | Yes | 1 |
| Peter Frans DE JONG | StDLO | Lingewal 1, 6668 LA, Randwijk. (NL) | peterfrans.dejong@wur.nl | 00/31/488473745 | Research institute | No | - |
| Mariano VILAJELIU | IRTA | IRTA-MAS BADIA. Canet de la Tallada. 17134 LA TALLADA D'EMPORDÀ (Spain) | mariano.vilajeliu@irta.cat | 00/34/972.78.02.75 | Research institute | Yes | 1 |
| Jordi CABREFIGA | IRTA | IRTA-MAS BADIA. Canet de la Tallada. 17134 LA TALLADA D'EMPORDÀ (Spain | jordi.cabrefiga@gmail.com | ???? | Research institute | No | - |

[1] If an EUFRUIT project partner, use EUFRUIT partner short name, if a contributing organization designate a partner short name
[2] Farm holder/grower, advisor/consultant, research institute/RSO, SME, NGO or other

| | | | | | | | |
|---|---|---|---|---|---|---|---|
| Andreas NAEF | Agroscope | Federal Department of Economic Affairs, Education and Research EAER – Agroscope. Schloss 1. 8820 Wädenswil (Switzerland) | andreas.naef@agroscope.admin.ch | +41 58 460 62 57 | Research institute | Yes | 1 |
| Markus KELDERER | Laimburg | VZ-Laimburg, Vadena, Laimburg 6 I- 39040 Ora (Italy) | Markus.Kelderer@provinz.bz.it | +39 0471 969662 | Research institute | Yes | 1 |
| Beatrice Michaela IACOMI | USAMV | 59 Mărăști bv.; 011464 Bucharest (Rumania) | b.iacomi@yahoo.fr | 0040/21/3182564 | Research institute | Yes | 1 |
| Ana Cornelia BUTCARU | USAMV | 59 Mărăști bv.; 011464 Bucharest (Rumania) | anabutcaru@gmail.com | 0040/21/3182564 | Research institute | No | - |
| Elena MARDARE | USAMV | 59 Mărăști bv.; 011464 Bucharest (Rumania) | elenamardare184@yahoo.com | ???? | Research institute | No | - |
| Alma VALIUSKAITE | LRCAF | Instituto al. 1; Akademija; LT-58344, Kedainiai distr. Lithuania | a.valiuskaite@lsdi.lt | +37037555217 | Research institute | Yes | 1 |
| Philippe BINARD | FRESHFEL | Rue de Trèves 49-51 1040 Brussels (Belgium) | philippe@freshfel.org | +32 2 777 15 80 | NGO or other | No | - |
| Helene DERUWE | FRESHFEL | Rue de Trèves 49-51 1040 Brussels (Belgium) | helene@freshfel.org | +32 2 777 15 80 | NGO or other | No | - |
| Daniel BRAY | UoG | Natural Resources Institute, UoG at Medway, Chatham Maritime, Kent ME4 4TB (UK) | D.Bray@greenwich.ac.uk | +44 1634 883729 | Research institute | Yes | 1 |

| | | | | | | | |
|---|---|---|---|---|---|---|---|
| Christina SCHEER | KOB | Schuhmacherhof 6, 88213 Ravensburg (Germany) | scheer@kob-bavendorf.de | 0049 751 7903 306 | Research institute | Yes | 1 |
| Francesco SPINELLI | UNIBO | DipSA – Dept. Ag. Sciences, V.le Fanin 44, 40127 Bologna. (Italy) | Francesco.spinelli3@unibo.it | +39 051 2088704 | Research institute | Yes | 3 |
| Christelle LACROIX | INRA | Unité de pathologie des plantes, INRA PACA, Domaine Saint Maurice, 67 allée des chênes CS 60094, 84143 Montfavet (France) | Christelle.lacroix@inra.fr | 0033-432722885 | Research institute | Yes | 1 |

## Synthesis findings

In the EUFRUIT project, WP3 is focusing on the reduction of pesticide residues on fruits and in the environment by using alternatives to chemical protection against pest sand diseases, developing strategies to limit the negative incidences of pesticides and adopting new spraying technologies. The following document is the third synthesis report of the IEG composed by members of the EUFRIN WG "Sustainable fruit production to minimize residues" and partners involved in the EUFRUIT project. The state of art has been done in eleven European countries (Belgium, Denmark, Germany, France, Italy, Lithuania, the Netherlands, Rumania, Spain, Switzerland, United Kingdom). The aim is to provide an overview on different alternatives techniques to pesticides which may already be used by the growers and others which are at an experimental stage. In 2018, eleven subjects were handled :

1) Biodiversity
2) Biological control (microorganisms, beneficial insects)
3) Cultural practices
4) Decision tools
5) Detection
6) Natural substances
7) Physical methods (mechanical, thermal, barriers, traps)
8) Plant resistance inducers
9) Semio-chemicals
10) Spray applications
11) System approach where different techniques to reduce the use of pesticides are combined

### I. Biodiversity

Orchards offer opportunities to foster ecosystem services, but input reduction is challenging. The principle is : apply a much as possible "soft protection practices" (i.e. prefer non-chemical solutions, use pesticides only as "last" resort, avoid non selective pesticides) and develop a supervised plant diversity management to enhance conservation biocontrol and limit pest outbreak. **INRA Gotheron** in a pear project between 1995 and 2005 (South-Eastern France) elaborated a design of a multi-species hedgerow to increase pear psyllid (*Cacopsylla pyri* L). Three main points came out :
1) ban plants hosting quarantine or key pests and diseases of the orchard and surrounding crops.
2) selection of plants hosting a rich and/or abundant natural enemy complex.
3) provide natural enemies with habitat and food resources (pollen, nectar, alternative prey) all year round.
Beside these criteria, tree species have of course to be adapted to soil and climate conditions.

Biodiversity is also a central part of the plant health care strategies in organic farming. The EcoOrchard project contributes to the kowledge and experiences on Functional AgroBiodiversity (FAB) management both from practitioners and scientists. **Laimburg Research Centre** (Italy) is working on the performances of different seed mixtures and the impact a sowed flower strip in the middle of the tree rows can have on pests like rosy aphids and codling moths. Natural enemies were significantly more abundant on trees in the flower strip plots than in the control plots, but the reduction of damages in presence of beneficial insects remains low and the difference between the number of treatments in an orchard with flower strips and without is limited to one or two.

The gap to develop more biodiversity is about knowledge on the occurrence and biology of many natural predators. It is also necessary to adapt the practices to avoid negative incidences of the spray application on the beneficial insects. The AHDB project TF220 (UK) has explored the effects of pest control products on earwigs, who are generalist predators of pests in apples and pears. The conclusion is that it is unlikely that occasional spraying will have long term effects, but early summer applications have to be avoided.

## II. Biological control

**Microorganisms** :

On fruits, only a few products are registered in Europe. For example : ***Bacillus subtilis*, *Aureobasidium pullulans*** may be used for the control of some fungal pathogens like powdery mildew or postharvest diseases *(Botrytis cinerea*, *Monilinia fructigena*, …) or **granulovirus preparation** against codling moth or fruit tortrix. Further research is needed to identify new “alternative” solutions to chemical pesticides.

In Belgium (pcfruit, KU Leuven, ILVO) **entomopathogenic fungi products** (different *Beauveria bassiana* strains and *Metarhizium anisopliae*) were tested on thrips in strawberry. The best results were between 50 and 70 % efficacy, but others were less good. The inconvenient is that these products have to be sprayed multiple times in short interval.

To increase chances to apply biological control products at the right place for example against Fire blight on apple flowers, (bumble) bees may be of some help as **entomovector**. But the Belgian results showed that the visitation was limited because of the climate condition, and may be the low attractiveness of the species. A new approach will be to apply the biological control products with biological models and test *Osmia* sp. as a vector.

In packing houses, the idea is to apply biological control products **by nebulisation** to control storage diseases on apples. Pcfruit, KU Leuven, ILVO (Belgium) studied the distribution of the products in cold storage rooms and in paloxes. The application of biological control products by cold nebulisation is possible, but the tested products achieved max. 50-60 % efficacy against *Neofabraea* spp. An important point is, that fungicides sprayed in orchards may still have an impact on the biological control product applied on the fruits later.

As treatments close to harvest against storage diseases are a potential risk to have residues on apples, Agroscope (Switzerland) is working on **yeasts**, which have an antagonistic activity. The candidate *Metschnikowia pulcherrima* can be formulated and sprayed in field. The reduction of storage rot could be achieved with *M. pulcherima*, but in combination with fungicides applied 21 days before harvest.

Some **bacterial antagonists and lytic bacteriophages** against Fire blight, Xanthomonas, Pseudomonas, like *Bacillus spp*., are already available, other are identified and tested (Pseudomonas fluorescens, Pantoea agglomerans, Pantoea vagans). Lactic acid bacteria are very promising.
Further experiments are needed to optimize biological control products in practice (i.e. coformulats to enhance persistence, and environmental fitness, shelf-life…)

**Beneficial insects** :

At AU-BIOS (Denmark) a pilot study has been conducted to explore the potential of using **wood ants** to reduce pests in apple orchards against winter moths and other caterpillars. The success was limited due to increased aphid’s problems. Therefore, ants were offered a sugar solution to divert them from milking and protecting aphids. An interesting side effect was that ants may also use fungi (scab, *Monilia*) as a food source. This could be of potential interest.

Predator introduction, like ***Amblyseius andersoni***, against spider mites (*Tetranychus urticae*), on cherries “under cover”, at a rate of one sachet per 5 trees, give good results (UK project).

## III. Cultural practices

Apple scab usually survives over winter under the trees, in the dead, infected leaves from the previous season. The fungus continues to live within the leaves during winter, forming small, flask-shaped bodies, in which spores (ascospores) develop. These ascospores mature in spring and are forcibly ejected during spring rains. They are contaminating new shoots, leaves and further on small fruits. **Cultural practices consist in crushing “infected” leaves** fallen on the soil to reduce primary inoculum. At the Copenhagen University (Denmark), work has been conducted over 4 years on a strategic watering of the soil with covered with scabbed leaves to release ascospores in dry periods. 25 to 40 % ascospores could be released, but a lot of water is needed and in fact, no reduction of scab and number of fungicides could be achieved.

## IV. Decision tools

There are different type of tools :

- **Warning systems** for growers and advisory organisations based on observations, and models to predict infection risks of diseases and simulate pest development, but also their predators. The aim is to optimize treatments and apply them at the right moment.
- **Guidelines** to consider side-effects of plant protection products on beneficial insects.
- **Systems for treatment management**, like DOSA3D (Universitat de Lleida - Spain), a tool which calculates the dose taking into account the tree dimensions and the leaf density.

## V. Detection

A first step towards the **use of drones** equipped with spectral sensors for fire blight detection was achieved by identification and validation of suitable wavelengths (pcfruit – Belgium). However, the accuracy of 52-54% for correct identification of the tree status (healthy or infected) is not sufficient yet for practical implementation of the technique and warrants further improvement.

## VI. Natural substances

In France, there a **two types of alternative products to chemicals : the “biocontrol products” and the natural preparations “without danger”.** The biocontrol products are registered like pesticides and are divided in four groups. One of them contains products with natural substances coming from plants, animals, or minerals, like : pelargonic acid, eugenol, thymol, garlic extracts, clove oil, potassium bicarbonate, laminarin, potassium phosphonates, pyrethrins, sulphur. The natural preparations without danger are composed by base substances which are registered at European level, for example : *Equisetum arvense*, saccharose, *Salix cortex*, vinegar, …These preparations should be made by the growers themselves (fermented plant extract, herb infusion, decoction, maceration).

More solutions are needed. They must be identified and tested in laboratory conditions and field. Furthermore, the registration of naturally occurring substances is difficult. Thus, the technical issues of the development of new substances are as important as the support for the registration of the substance.

To reduce the use of cupper against apple scab, potassium bicarbonate and sulphur or potassium bicarbonate and potassium silicate give good results (University of Bucarest – Romania). Obstbauzentrum Jork (Germany) tested a product, an ion salt form of pelargonic acid against apple sab, in greenhouse and open field. The results are similar or even better than the chemical or organic references. In Spain (IRTA), three basic substances (*Equisetum arvense* L, *Urtica* spp; and sodium hydrogen carbonate) and laminarin are under evauation in the control of apple scab.

The institute of Horticulture LRCAF (Lithuania) is working on plants, which are grown under the conditions of Lithuanian climate. *Thymus vulgaris* and *Coriandrum sativum* essential oils were extracted from local material. They inhibit *Alternaria* and *Fusarium gramineraum*. A student thesis is carried out on i) the selection of plant extracts and essential oils from different plants (*Asteraceae*, *Alliacea*e, … ; ii) the evaluation of their antifungal effect on strawberry diseases.

In the European project DROPSA, chitosan, laminarin, essential oils, *Bacillus subtilis* QST713 and benzothiadiazole were evaluated in the control of quarantine diseases caused by *Xanthomonas arboricola pv. pruni* (peach), *Pseudomonas syringae pv. actinidiae* (kiwi) and *X. fragariae* (strawberry).

## VII. Physical methods

**Mechanical techniques :**

Weed control in orchards becomes a major concern, because of the progressive exclusion of the glyphosate herbicide. **Mechanical weeding** is already practised in organic production, but new technologies are emerging. The important points are : to be able to work on the tree interspace, to have a good work speed, to be used on massive weed infestation and wet soil conditions. In future, new machines like the “GrassKiller” from Italy, working with high pressure (up to 1.250 bar) water and the “Electroherb” from Brasil, using high-frequency alternating current, may change weed management in orchards.

**Hot water treatment :**

There are **two types of applications**.

One is tested in orchards to **control weeds**. The temperature of the water goes up to 98°C, so the cost of the heating still hinders the general usage. KOB (Germany) showed in field trials several problems relayed to the high water quantity and the important time amount. Furthermore, economically this method was not satisfying. Another method with hot steam gave better results, but is still under investigation.

The second is already applied to **prevent apples form storage rots** (*Gloeosporium*). The treatment is applied quickly after harvest. The fruits are dipped in water by 48-50°C between 2 to 3 minutes and cold stored.

**Traps :**

Beside pheromones traps, other traps may **attract insects with their colour or with food attractant like sugar, vinegar**.

In case of apple sawfly, white seems to be the right colour. Wageningen (Netherland) is working on different type of traps, different type of “white” and different densities. The strategy is to prevent adults to come out of the soil, to catch away the adults and to prevent larvae to enter the soil.

**Barriers :**

- **Rain covers :**

Reduce the incidence of rain on the development of fungus and bacteria is the aim of a rain cover on the top of the trees. In practice, cherries are covered for a short time close to harvest to avoid fruit cracking. On apples and pears trials are going on at the University of Aarhus (Denmark), Ctifl (France), Laimburg (Italy), and with a new project, in Wageningen (Netherland). The main objective is to cover the whole season the orchard for apple scab protection, but also Gloeosporium. In Italy, but also in France, successful experiences have been achieved on kiwi against *Pseudomonas syringae pv. actinidae*.

After studying the technology on apples, the University of Aarhus (Denmark) had a three years trial on pears. Even if the light level is reduced by 30 %, no detrimental effects on yield, fruit size, colour and fruit quality was noticed. On the Conference variety the benefit is to have significantly greener fruit. The goal is to get organic production untreated. The main problem is the wind.

At Ctifl (France), there are two types of rain roofs : one is placed under the hail nets, the other is combined with the hail nets in order to form only one cover. The efficacy against apple scab depends on the type of rain cover, but the symptoms on shoots are reduced (between 2 for the combined solution and 20 % for the rain cover under the hailnets) and almost missing on fruits (less than 2 % in 2017). As a result of the “non treatments” under the rain covers, powdery mildew may develop. The strategy is to add a sulphur protection from March to the end of May. In 2017, Ctifl tested also the effect of two plant resistance inducers based on phosphonates, by spraying them one time a week in the same period as the sulphur. With these treatments, the apple scab on shoots was reduced to 3 %. But the rain covers seems to have a negative incidence on yield (quantity and colour). It was observed on an older orchard (Gala, 2004). After 4 years cover, the cumulated difference between the covered and uncovered parts of the orchards was 70 t/ha. On a younger orchard (Rosy Glow, 2014), the irrigation was adapted with two types of irrigation systems (drip irrigation and micro jet). Under rain cover, the micro jet gives less good results. Compared to micro jet in the not covered part, the differences are between 13 and 23 t/ha.

At Laimburg (Italy), the Keep in Touch® system provides a rainproof net on the upper part and an insect proof net on the lateral part. On Fuji, the maximum scab on shoots was around 8 % (in that case, the rain covers was opened at the beginning of April) and on fruits it was less than 1 % (end of the primary infection period and at harvest). On Cripps Pink, the rain covers seems to reduce *Alternaria* when opened in August, but against *Marsonin*a leaf blotch, no effect could be seen. To study the efficacy against *Gloeosporium*, the system was opened in July or August on Pinova and in August on Rosy Glow, the % of affected fruits were significantly reduced for Pinova when covered in July and for Rosy Glow. The thinning effect of the cover system was important on Fuji when opened before flowering and during flowering (up to 60-65 %).

Further research is needed to understand the mechanism of the protection under plastic tunnels against apple scab and *Gloeosporium* ; the effect of plastic on other pathogens ; the productivity and fruit quality under plastic ; the long term sustainability on soil. Other plastic tunnel types have to be investigated, as one of the major limitations for this technology are the costs.

The new project in Netherland will be on retractable roofs, with questions like : return of investment, fruit tree canker, image for agro tourism.

- **Exclusion netting**

**On apples**, nets may be used against codling moth, oriental moth and also Mediterranean fruit fly and Halyomorpha halys. At IRTA (Spain), the use of insecticides could significantly be reduced in a netted and closed orchard, but aphids (grey and woolly) have to be controlled. Work was done in two different ways : i) by releasing three types of *Coccinelidae,* but it was not sufficient ; ii) by having an autumn action by keeping the nets closed to avoid that grey aphids come back to the orchard combined with two kaolin spraying and introducing two parasitoids against woolly aphids. In the second case, a biological control of the aphids could be achieved in one trial. Furthermore, other common pests like San José scale and leafrollers may increase in exclusion netting orchards.

At Laimburg (Italy), after 8 years trials combining hail nets, single row with downside open or closed, the percentage of affected fruits at harvest is significantly reduced compared to the untreated control, but different from one case to another, with good results (≤ 2 %) and bad results (around 15 % and even 36 %).

To help the pollinisation, bumble bees and wild bees are placed into the netted orchards.

**On cherries**, to protect against *Drosophila suzukii*, the combination of exclusion nets and spinosad treatments reaches a 100 % control (Agroscope – Switzerland).

## VIII. Plant resistance inducers

Extracts or chemical compounds inducing resistance are often referred to "plant activators", "inducers" or, if derived from micro-organisms, "elicitors". Classical inducers do not have a direct impact on pathogens, which clearly distinguishes them from fungicides. In France (INRA, Ctifl and other partners), a project called PEPS, was organised in three Work packages : 1) screening in lab by molecular analyses the plant resistance inducer potential of different compounds 2) evaluation of their performances in apple orchards when applied weekly on the scab primary contaminations or close to harvest against *Gloeosporium* 3 ) study in controlled condition the factors affecting their efficacy. Two compounds, a K-phoshonate and foliar fertilizers gave interesting results on apple scab, but not on storage diseases. The problem is the number of applications and the amount of phosphonate residues on fruits. The next step will be to use these types of products depending of the pathogen risks.

## IX. Semio-chemicals

To increase the efficacy of thrips chemical control, Pcfruit (Belgium) tested attractive additives. There are three types : 1) **gustatory stimulants** (stimulating feeding, making sprayed surface more preferred) ; 2) **attractant**s (volatile compounds making olfactory orientation possible) ; 3) repellents (volatile compounds to discourage insects to come on the plant). In laboratory condition and field, a gustatory stimulant, increased efficacy of the chemical insecticide by 20 to 30 %.

On *Drosophila suzukii*, insecticides were improved with a feeding enhancer. The best was composed of Baker"s yeast and brown sugar.

In the UK, large field trials are going on, testing the combination of semio-chemicals to attract hoverflies. The name of the commercial predator lure is "Magipal".

## X. Spray applications and environment protection

KOB (Germany) is partner of a BLE project, called Corona PRO. The aim of the project is to find a method to optimise the use of pesticides. Therefore orchards are scanned by **drones** to record gaps in the orchard and the surface structure of individual tees. These data generate individual applications maps. In combination with computer controlled sprayers, these new technology could reduce the output of pesticides.

Because of the high water density in the region "Altes Land", Jork (Germany) is testing different sprayers to reduce drift. In case of a **tunnel sprayer** compared to an axial fan sprayer, the reduction of pesticides is up to 20 % due to the recycling technique. Furthermore, the double-row sprayers increase the performance by 30 %. But there are some negative points : the maximum height and row spacing is 3.7 m ; it's not usable with hail nets or roofs ; the time to set-up and clean is longer and finally the handling is more difficult, because of the big seize. However, growers must be convinced of the biological efficacy and the investment.

Wageningen (Netherland) is studying several ways to improve the applications of pesticides while reducing the emission of crop protection products and achieving a uniform crop coverage. The methods are : i) regulate wind speed and spray direction ii) blow and spray trees from both sides at the same time iii) adjust spraying liquid by nozzle position iv) the nozzle choice v) adapt spraying to crop vi) reduce spray volume. Despite large variation, there are significant differences between techniques and adjustments, but the performances of the sprayers will come from the adaption of our orchards to the sprayers.

## XI. System approach where different techniques to reduce the use of pesticides are combined

**In France**, Ctifl coordinated a long term (6 years), multi-location and multi-factors apple orchards network. During the seasons, several techniques to reduce the use of pesticides were combined (ECOPHYTO modality) and compared to a reference system (called BASE). In terms of treatment frequency index reduction, to most important (> 75 % reduction) were obtained with resistant varieties combined with mating disruption or enclosure netting and the use of biological control insecticides and "alterntive" fungicides, or when treatment doses were adapted to the vegetation volume. On apple scab sensitive varieties, the most important reduction (> 50 %) was achieved with rain covers combined with mating disruption or Alt'Carpo nets. The adaption of treatment doses gave also good results. The "zero" residues were achieved with organic production systems (behalf cupper detection), scab resistance varieties with low codling moth pressure and no storage diseases treatments, rain cover on Gala and Alt'Carpo (with a low codling moth pressure), and also systems with doses adjustments but without storage diseases treatments.

In 2016, started an **Interreg Project** "Residue – poor fruit production – model orchards for improvement of integrated crop protection. Kob (Germany) is leading the project and Agroscope (Switzerland) is one of the partners. The goal is the construction of demonstration orchards in which combinations of promising measures are studied. The project is running up until 2019.

***List of action to reduce the use of pesticides and limit the risk to have residues on fruits and environment contaminations, presented in the scan reports (see Annex).***

| n° | EUFRUIT Partner | Fruit species | Pest & Diseases & other uses | Technology | Description | Short results |
|---|---|---|---|---|---|---|
| 9 | Laimburg | apples | pests | biodiversity | | Gap : little knowledge about occurrence and biology of many natural predators |
| 18 | UoG | pomefruits | general | biodiversity | effects of pest control products on earwigs | recommandation on insecticides which should be avoided |
| 21 | INRA | fruits | pests | biodiversity | multi-species hedgerows | Pear project (1995 - 2005) : three main principales. 1) ban plants hosting quarantine or key pests an diseases of the orchard and surrounding crops. 2) selection of plants hosting a rich and/or abundant natural enemy complex. 3) provide natural enemies with habitat and food ressources (pollen, nectar, alternative prey) all year round. |
| 1 | Aarhus University | apples | winter moths (Operophera brumata) & other caterpilllars | biological control | ants | despite feeding the ants with sugar, increased aphid damage was seen. |
| 2 | Pcfruit | strawberry | thrips | biological control | entomopathogenic fungi | less repercussions on beneficial arthropods and fruit residues |
| 2 | Pcfruit | apples & pears | Fire Blight | biological control | bumble bees to transfer the BCO (entomovectoring) | positive greenhouse results to establish BCO on flower stigma and flower bottom, but limited flower visitation in pears and apples. Attractant (mixture of terpenes) did not increase the visitation rates. Other idea : combine BCO spraying followed by BCO distribution with insects (bumble bees, honeybees, solitary bees) |
| 2 | Pcfruit | apples & pears | Fire Blight | biological control | apple & pear flower microbiomes | Aim : find candidate antagonists of Erwinia amylovora |
| 2 | Pcfruit | apples | storage diseases | biological control | by nebulisation at postharvest | computational fluid dynamics (CFD) model for the distribution of the biocontrol agent. Good results with this technique. |

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| 2 | Pcfruit | strawberry | thrips | biological control | guidelines for the use of BCA on different climatic conditions | |
| 2 | Pcfruit | apple | aphids | biological control | banker plants & mass reared parasitoïds | inventory of orcahrds to get an overwiew on banker plants and the species that could be commercialised |
| 2 | Pcfruit | strawberry | thrips | biological control | predatory mites | preventive introduction to reduce the insecticide input |
| 2 | Pcfruit | pome & stone fruits | aphids | biological control | mass released parasitoids | successfull control of aphids, but depending on several factors (timing of starting the releases, aphid pressure, climate conditions). |
| 8 | Agroscope | pome fruits | scab, storage diseases | biological control | antagonistic yeast | screening in laboratory condition : strong anatgonstic. Formulated test product. Field testing : reduction of storage rot in combination with other fungicides. |
| 18 | UoG | cherries | spider mites | biological control | predatory mites | predator introduction at a rate of one sachet per 5 trees seems to be a potential tool for spider mite control. |
| 20 | UNIBO | fruits | pests | biological control | Bacillus thuringiensis ; Serratia ; Pseudomonas entomophila ; Burkholderia ; Chromobacterium , Xenorhabdus ; Photorhabdus luminiscens / nemtodes ; Metarhizium anisopliae | Photorhabdus luminiscens has been succesfully used to control Drosophila suzukii in cherry. |
| 20 | UNIBO | fruits | bacteria | biological control | cyclolipopeptides in Bacillus spp. ; phenolics in Pseudomonas fluorescens ; pseudopeptides in Pantoea agglomerans and vagans ; Trichoderma harzianum | bacterial antagonists and lytic bacteriophages against Fire blight, Xantomonas, Pseudomonas.<br>Lactic acid bacteria are very promising. |
| 8 | Agroscope | pome fruits | Fire Blight | biological control, natural substances | yeasts, acid clay (Mycosin), potassium aluminium sulphate (LMA) | 2018 : the weather during blom was highly favorable |

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| 4 | Jork | apples | weeds | chemical strategy | soil active herbicides in winter or in spring on the tree strip / repeated in summer and after post-harvest | Aim : reduce the use of glyphosate and other herbicides. Costs evaluation. |
| 1 | Aarhus University | apples | scab | cultural practices | prophylaxis : triggering ascospores release from overwintering leaves | up to 70 % of the spores were released during a dry period, but high water volumes were necessary. Different ways to apply the water (sprinkler, water wagon, …). Big droplets and 1,6 mm rain. 2-4 periods during spring. To small effect. 4 year study. |
| 20 | UNIBO | fruits | pests & diseases | cultural practices | irrigation, fertilization, use of bio-regulators, pruning, prophylaxis | Avoid all kind of excess.<br>Exemple : Drosophila suzukii. Clean harvest strategies, fruit removal, edge rows management, use of consociation with soya bean inside the orchards. |
| 2 | Pcfruit | fruits | | decision tools | warnings system for fruit growers and advisory organisations | infection risk of diseases like scab, powdery mildew or pests and phenological development |
| 2 | Pcfruit | apples & pears | wooly aphids & psylla | decision tools | earwig management tool & guidelines | Aim : to take into account the side-effects of pesticides on earwigs population. Results : a reduction of pear suker related residues on pears. |
| 2 | Pcfruit | cherries | Drosophila suzukii | decision tools | monitoring guidelines & phenology model | It reduces the amount of sprays when the pest is not yet present in the plot. |
| 2 | Pcfruit | pears | pear psylla | decision tools | phenology of the pest and beneficial arthropods | used for an improved warning system and advice in the extension service. Transfer to growers. |
| 2 | Pcfruit | apples | scab | decision tools | technique to determine the potential ascospore inoculum for an orchard at the beginning of the seazon | better organization of the treatments |
| 2 | Pcfruit | apples | scab | decision tools | technique to follow up the ascopore relaese in an orcahrd | this may be helpful to determine the star and the end of the ascospore season and can lead to reduce the treaments at the beginning and at the end of the scab ascopore season. |

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| 2 | Pcfruit | strawberry | Botrytis, Powdery mildew | decision tools | models | ongoing research |
| 2 | Pcfruit | strawberry | pests | decision tools | guidelines for monitoring | thresholds, identification help, methodology. Knowledge of the population size and phenology, leads to optimized treatments. |
| 2 | Pcfruit | strawberry | thrips | decision tools | guidelines for curative sprays | situation when the crop system is less favorable for predatory mite introductionor when the control by predatory mites is insufficient |
| 7 | IRTA | fruits | general | decision tools | DOSA3D | calculates the dose taking into account the tree dimensions and the leaf density. System for treatment management. |
| 8 | Agroscope | pome & stone fruits | general | decision tools | webpages with disease and pest modeling and monitoring information | for exemple : apple scab, pest monitroing data, crop stage data, insect pest forecasting, fireblight forecasting) |
| 2 | Pcfruit | pears | Fire Blight | detection | drones | only 52-54 % accurancy. |
| 8 | Agroscope | apples | ??? | genetics | varieties | trials done under a standard IP plant protection strategy and a low input strategy with reduced use of synthetic pesticides |
| 9 | Laimburg | apples | scab | genetics | varietes & rootstocks | challenges in research for Organic Farming (OF). Problem with resistant varieties : other diseases become prominent, resistance breakdown. |
| 4 | Jork | apples | scab | natural substances | ion salt form of pelargonic acid | greenhouse experiments and open field |

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| 9 | Laimburg | apples | apple sawfly | natural substances | Quassia amara extracts | |
| 9 | Laimburg | fruits | general | natural substances | natural and naturally derived substances | |
| 10 | Bucharest | apples | scab & powdery mildew | natural substances | potassium bicarbonate | Aim : reduce the use of copper, complete the sulphur treatments. Results of a 3 years trial (2014-2016) : potassium bicarbonate + sulphur = potassium bicarbonate + potassium silicate. No symptoms of phytotoxicity. |
| 12 | Lithuania | fruits | general | natural substances | plants | they are a valuable source of bioactive compounds : terpenes, phenolic compounds, essential oils, alkoloids. Obtained by extraction process. Results from a study in laboratory conditions : Thymus vulgaris, Coriandrum sativum essential oils / Alternaria ssp., F. graminearum. |
| 5 | Wageningen | apples | apple sawfly | physical method | plastic white traps | |
| 4 | Jork | apples | weeds | physical method | hot water treatment (98°C) | high costs |
| 9 | Laimburg | apples | storage diseases | physical method | hot water treatment | |
| 19 | KOB | fruits | weeds | physical method | hot water treatment (98°C) | technialy (water quantity and time) and economically not satisfaying. New topic : hot steam. |
| 4 | Jork | apples | weeds | physical method | mechanical weeding (roll hoe, Naturagriff, Krümler Ladurner Modell 7) | Important points : work on the tree interspace, speed, massive weed infestation, wet soil conditions |
| 7 | IRTA | fruits | weeds | physical method | mechanical weeding | alternative methods applicable in conventional and organic orchards |
| 8 | Agroscope | fruits | weeds | physical method | mechanical weeding | becoming more and more important in integrated production, due to political pressure on herbicides such as glyphosate |
| 8 | Agroscope | apples | thinning | physical method | mechanical thinning | used by organic farmers |
| 9 | Laimburg | apples | weeds | physical method | tilling & mulching | tillage in spring (nitrogen mobilization), a light cover of the tree row with the cut vegetation, new machinery that removes weeds by brushing |
| 9 | Laimburg | apples | thinning | physical method | mechanical thinning | |

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| 1 | Aarhus University | pears | scab | physical method | rain roofs (1,6 m large) | reduced light levels (30 %), but no detrimental effects on yield, fruit size, color and fruit quality. 3 years study. |
| 2 | Pcfruit | small fruits & cherries + grapes | Drosophila suzukii | physical method | nets (whole plots or individual rows) | reduces the amount of sprays to nearly zero |
| 3 | Ctifl | apples | scab | physical method | rain roofs (Filpack and Voen) | efficacy against scab, but incidence on yield. Irrigation must be adopted. Devlopement of powdery mildew. |
| 5 | Wageningen | apples | scab | physical method | retractable rain roofs | new project in the Netherland. |
| 7 | IRTA | fruits | pests | physical method | exclusion nets | avoid damages of codling moth, leafrollers, Mediterranean fly. Promote biologicial control against aphids. Against also Halyomorpha halys. |
| 8 | Agroscope | cherries | Drosophila suzukii | physical method | exclusion nets | until 2015, rarely implemented because of jugh costs. Now used in combination with spinosad to reach 100 % control. |
| 8 | Agroscope | pome fruits | codling moth | physical method | exclusion nets | only used by pioneer farmers. Bumble bees and wild bees are placed to ensure pollination. |
| 9 | Laimburg | apples | scab | physical method | rain roofs | agronomic + carbon footprint |
| 9 | Laimburg | apples | codling moth | physical method | exclusion nets | agronomic + carbon footprint |
| 20 | UNIBO | fruits | pests & diseases | physical method | plastic tunnel & nets | Incidences on micro-climate inside orchards (t°, relative humidity, light quality and intensity, leaf wetness), but also on plant development, physiological response of the plant against pests and diseases, and on the pathogen virulence. Successful practical applications : pear / codling moth ; stone fruits / Drosophila ; apple, pears, stone fruits / Halyommorpha alays ; kiwifruit / Pseudomonas syringae pv. actinidae. |
| 3 | Ctifl | apples | scab, storage diseases | Plant resistance inducers | elicitors | large lab screening. 5 elicitors. Phosphonates gave the best results in orchards. High residues level. Interesting under rain roofs to reduce apple scab pressure. |
| 2 | Pcfruit | strawberry | thrips | Semio-chemicals | attractive additivies | higher spray efficacy and less applications |
| 2 | Pcfruit | cherries | Drosophila suzukii | Semio-chemicals | attractive additivies/baits | insecticide efficacy can be significantly increased by adding additives. |

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| 2 | Pcfruit | cherries | Drosophila suzukii | Semio-chemicals | attractive additivies/baits | Is it it possible to reduce the insecticide dosis ? |
| 2 | Pcfruit | cherries | Drosophila suzukii | Semio-chemicals | attractive additivies/baits | Is it possible to practice "Attract and kill" ? |
| 8 | Agroscope | pome fruits | codling moth | Semio-chemicals | mating disruption | 50 % of the apple growers of the Lake of Constance area. The combination of mating disruption and granulosis virus is used by 10 % of the organic producers. |
| 18 | UoG | pomefruits | general | Semio-chemicals | attractant for beneficial insects | a combination of semiochemicals to attract hoverflies. A commercial predator lure "Magipal". |
| 19 | KOB | apples | general | spray application | drone to pilote application | BLE-Project : Corona PRO. Model and demonstration orchards to reduce the application of pesticides. Orchards are scanned by drones. Gaps are recorded and serve to generate individual applications maps; Combination with computer controlled sprayers. |
| 2 | Pcfruit | fruits | general | spray application | movable wall to check the accuracy of the sprayer | in 2017, only 1 sprayer of 160 tested was correct. |
| 2 | Pcfruit | fruits | general | spray application | EVA app to plan the applications and set up the spraying schedule | 155 growers in 2017 ; 135 in 2018. Pcfruit = technical assistance |
| 4 | Jork | apples | general | spray application | tunnel technique | significant pesticide saving and drift reduction. More investigation is neede for the equipment. |
| 5 | Wageningen | fruits | general | spray application | performances | Aim : reduce the emission of crop protection products. Achieve a uniform crop coverage.<br>Method : crop dependent spraying based on crop volume or crop row volume dosage + adjusting spray parameters such as air speed and nozzle type |
| 2 | Pcfruit | cherries | Drosophila suzukii | system approach (combination of methods) | mass trapping ; repellents and deterrents ; Push and Pull | goal : no insecticides |
| 2 | Pcfruit | apples, pears, strawberry | general | system approach (combination of methods) | treatment schedule + different findings to achieve the "zero residues" level | treatment schedule are based on larger preharvest interval to avoid residues. |

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| 3 | Ctifl | apples | general | system approach (combination of methods) | scab management, models, prophylaxis, biocontrol products, exlusing nets, biodiversity | 6 years national project. |
| 4 | Jork | apples | root sucker | system approach (combination of methods) | pelargonic acid (8 %) in summer combined to post-harvest glyphosate application or mechanical weed management | Aim : alternatives to glufosinate |
| 8 | Agroscope | apples | general | system approach (combination of methods) | residue-poor fruit production (apples, cherries, pears) | Agroscope long-terme trial : adapt fungal diseases strategies, insect exclusion netting, mating disruption, mulching leaves to reduce scab inoculum, modern storage techniques.<br>The low-residue strategy is not profitable without a price premium compared to integrated production. |
| 8 | Agroscope | cherries | Pseudomonas | system approach (combination of methods) | acid clay, white stem painting and summer pruning | New trial. |
| 9 | Laimburg | apples | codling moth | system approach (combination of methods) | mating disruption ; granolosis virus ; entomophagous nematodes | |
| 9 | Laimburg | apples | scab | system approach (combination of methods) | less susceptible varieties, reduction of ascospore concentraton, organic farming products | copper, sulphur, lime sulphur, carbonates & forecasting models. But copper accumulates in the soils. |
| 18 | UoG | cherries | Drosophila suzukii | system approach (combination of methods) | dry bait ; entompathogenic fungi : repellents and oviposition deterrents ; push pull | |
| 19 | KOB | | general | system approach (combination of methods) | nets, roofs | Project (december 2015 to december 2019) : 2 ha model orchard |

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| 19 | KOB | cherries | Drosophila suzukii | system approach (combination of methods) | alternative methods to insecticides | A three component strategy seems to be the best : insects nets, hygiene and insecticides. |

## Summary for EIP dissemination

**Project title:** **EUFRUIT: European Fruit Network**

**Keywords:** fruits, pesticide residues, alternative products and techniques, environmental friendly crop protection

**Summary:**

The synthesis report 2018 of WP3 provides information from 14 European institutes, partner of the EUFRUIT project and members of the EUFRIN WG "Sustainable fruit production to minimize residues", on on-going research and practices to reduce the use of pesticides and limit the risk to have residues on fruits and in the environment.

The choice has been made to illustrate the state of the art by examples on several topics like :

- Biodiversity – how to preserve beneficial insects and how to provide natural enemies with habitat and food
- Biological control like entomopathogenic fungi, predatory mites, antagonistic yeasts, microorganisms, peptides
- Chemical strategies to reduce the use of pesticides
- Cultural practices
- Decision tools
- Genetics
- Natural substances
- Physical methods to control weeds, but also to protect against fungi and insects with hot water, rain covers and nets, or to regulate yield by mechanical thinning
- Plant resistance inducers (PRI)
- Semio-chemicals
- innovative spray applications to protect environment
- a system approach where different techniques are combined to reduce pesticides,

The first part of the report is a selection of presentation discussed during the IEG meeting. The annex provides all the scan documents written by the project partners, where more details on a specific technique or strategy can be find.

The goal is to share knowledge coming from research and to analyse what is already used in practice by the growers and technicians, what are the hurdles to develop it on a larger scale, what can be communicate to the whole food chain, what is acceptable by the growers and the society. Furthermore the synthesis reports aims to point out where gaps exist and where more research is needed.

**Contact information**

EIG editor: ZAVAGLI Franziska, Ctifl, Centre de Lanxade, 28 route des Nébouts, 24130 Prigonrieux, zavagli@ctifl.fr, 00/33.5.53.58.13.10

Project coordinator: Michelle H. Williams; Aarhus University, Department of Food Science, Kirstinebjergvej 10, 5792 Aarslev, Denmark; mw@food.au.dk; +45 25170049

Contributing project partners: AU, Pcfruit, Ctifl, OVA, StDLO, IRTA, Agroscope, Laimburg, USAMV, LRCAF, FRESHFEL, UoG, UNIBO, INRA

| Name | Contact person | Address | Email | Phone | Type |
|---|---|---|---|---|---|
| AU | Marianne BERTELSEN | Kirstinebjergvej 10 5792 Aarslev (Denmark) | Marianne.Bertelsen@food.au.dk | 0045 8715 8328 | Research institute |
| Pcfruit | Wendy VAN HEMELRIJCK | Fruittuinweg 1<br>3800 Sint-Truiden (Belgium) | wendy.vanhemelrijck@pcfruit.be | 0032 11 69 71 20 | Research institute |
| Ctifl | Franziska ZAVAGLI | Centre de Lanxade, 28 route des Nébouts, 24130 Prigonrieux (France) | zavagli@ctifl.fr | 00/33/5.53.58.00.05 | Research institute |
| OVA | Hinrich HOLTHUSEN | Dep. Plant Protection and Diagnostics. Moorende 53 - 21635 Jork (Germany) | hinrich.holthusen@lwk-niedersachsen.de | +49 4162 6016-131 | Research institute |
| StDLO | Marcel WENNEKER | Lingewal 1, 6668 LA, Randwijk. (NL) | marcel.wenneker@wur.nl | 00/31/488473745 | Research institute |
| StDLO | Peter Frans DE JONG | Lingewal 1, 6668 LA, Randwijk. (NL) | peterfrans.dejong@wur.nl | 00/31/488473745 | Research institute |
| IRTA | Mariano VILAJELIU | IRTA-MAS BADIA. Canet de la Tallada. 17134 LA TALLADA D'EMPORDÀ (Spain) | mariano.vilajeliu@irta.cat | 00/34/972.78.02.75 | Research institute |
| IRTA | Jordi CABREFIGA | IRTA-MAS BADIA. Canet de la Tallada. 17134 LA TALLADA D'EMPORDÀ (Spain | jordi.cabrefiga@gmail.com | ???? | Research institute |
| Agroscope | Andreas NAEF | Federal Department of Economic Affairs, Education and Research EAER – Agroscope. Schloss 1. 8820 Wädenswil (Switzerland) | andreas.naef@agroscope.admin.ch | +41 58 460 62 57 | Research institute |
| Laimburg | Markus Kelderer | VZ-Laimburg, Vadena, Laimburg 6<br>I- 39040 Ora (Italy) | Markus.Kelderer@provinz.bz.it | +39 0471 969662 | Research institute |
| USAMV | Beatrice Michaela IACOMI | 59 Mărăşti bv.; 011464 Bucharest (Rumania) | b.iacomi@yahoo.fr | 0040/21/3182564 | Research institute |

| | | | | | |
|---|---|---|---|---|---|
| USAMV | Ana Cornelia BUTCARU | 59 Mărăști bv.; 011464 Bucharest (Rumania) | anabutcaru@gmail.com | 0040/21/3182564 | Research institute |
| USAMV | Elena MARDARE | 59 Mărăști bv.; 011464 Bucharest (Rumania) | elenamardare184@yahoo.com | ???? | Research institute |
| LRCAF | Alma VALIUSKAITE | Instituto al. 1; Akademija; LT-58344, Kedainiai distr. Lithuania | a.valiuskaite@lsdi.lt | +37037555217 | Research institute |
| FRESHFEL | Philippe BINARD | Rue de Trèves 49-51 1040 Brussels (Belgium) | philippe@freshfel.org | +32 2 777 15 80 | NGO or other |
| FRESHFEL | Helene DERUWE | Rue de Trèves 49-51 1040 Brussels (Belgium) | helene@freshfel.org | +32 2 777 15 80 | NGO or other |
| UoG | | Natural Resources Institute, UoG at Medway, Chatham Maritime, Kent ME4 4TB (UK) | | 00/44/1645 883304 | Research institute |
| UNIBO | Francesco SPINELLI | DipSA – Dept. Ag. Sciences, V.le Fanin 44, 40127 Bologna. (Italy) | Francesco.spinelli3@unibo.it | +39 051 2088704 | Research institute |
| INRA | | Unité Ecodéveloppement – INRA PACA. Domaine Saint Paul, Site Agroparc. CS 40 509 – 84914 Avignon Cedex 9 (France) | | 0033-432722574 | Research institute |

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| Project period: | 2016 - 2019 |
| Project status: | Ongoing |
| Funded by: | Horizon 2020 |
| Total budget: | €1.8m |

Geographical regions:

| Country | Regions (NUTS 3 REGIONS) |
|---|---|
| Denmark | DK011 (Copenhagen), DK012 (Copenhagen and its environs), DK013 (North Zealand), DK014 (Bornholm), DK021 (East Zealand), DK022 (West- and South Zealand), DK031 (Funen), DK032 (South Jutland), DK041 (West Jutland), DK042 (East Jutland), DK050 (North Jutland). |
| Belgium | BE211 Arr. Antwerpen - BE212 Arr. Mechelen - BE213 Arr. Turnhout- BE221 Arr. Hasselt - BE222 Arr. Maaseik - BE223 Arr. Tongeren - BE231 Arr. Aalst - BE232 Arr. Dendermonde - BE233 Arr. Eeklo - BE234 Arr. Gent - BE235 Arr. Oudenaarde - BE236 Arr. Sint-Niklaas - BE241 Arr. Halle-Vilvoorde - BE242 Arr. Leuven - BE251 Arr. Brugge - BE252 Arr. Diksmuide - BE253 Arr. Ieper - BE254 Arr. Kortrijk - BE255 Arr. Oostende - BE256 Arr. Roeselare - BE257 Arr. Tielt - BE258 Arr. Veurne - BE310 Arr. Nivelles - BE331 Arr. Huy - BE332 Arr. Liège - BE334 Arr. Waremme - BE335 Verviers |
| France | FR211 Ardennes, FR241 Cher, FR244 Indre-et-Loire, FR246 Loiret, FR301 Nord, FR302 Pas-de-Calais, FR411 Meurthe-et-Moselle, FR412 Meuse, FR413 Moselle, FR414 Vosges, FR421 Bas-Rhin, FR422 Haut-Rhin, FR432 Jura, FR433 Haute-Saône, FR511 Loire-Atlantique, FR512 Maine-et-Loire, FR514 Sarthe, FR515 Vendée, FR532 Charente-Maritime, FR533 Deux-Sèvres, FR534 Vienne, FR611 Dordogne, FR614 Lot-et-Garonne, FR615 Pyrénées-Atlantiques, FR623 Haute-Garonne, FR628 Tarn-et-Garonne, FR631 Corrèze, FR632 Creuse, FR633 Haute-Vienne, FR712 Ardèche, FR713 Drôme, FR714 Isère, FR716 Rhône, FR717 Savoie, FR718 Haute-Savoie, FR721 Allier, FR722 Cantal, FR723 Haute-Loire, FR811 Aude, FR812 Gard, FR813 Hérault, FR815 Pyrénées-Orientales, FR821 Alpes-de-Haute-Provence, FR822 Hautes-Alpes, FR823 Alpes-Maritimes, FR824 Bouches-du-Rhône, FR825 Var, FR826 Vaucluse, FR831 Corse-du-Sud, FR832 Haute-Corse |
| Germany | DE600 Hamburg; DE932 Cuxhaven; DE933 Harburg; DE939 Stade; DEF09 Pinneberg, DE9 (Niedersachsen); DE8 (Mecklenburg-Vorpommern); DEF0 (Schleswig-Holstein); DEE0 (Sachsen-Anhalt); DEA (Nordrhein-Westfalen) |
| Netherlands | NL230 Flevoland; NL310 Utrecht; NL321 Kop van Noord-Holland; NL338 Oost-Zuid-Holland; NL341 Zeeuwsch-Vlaanderen; NL342 Overig Zeeland; NL411 West-Noord-Brabant; NL412 Midden-Noord-Brabant; NL422 Midden-Limburg; NL423 Zuid-Limburg. |
| Spain | ES 512 Girona, ES513 Lleida |
| Switzerland | CH011 Vaud, CH012 Valais, CH021 Bern, CH022 Fribourg, CH023 Solothurn, CH024 Neuchâtel, CH025 Jura, CH032 Basel-Landschaft, CH033 Aargau, CH040 Zürich, CH052 Schaffhausen, CH055 St. Gallen, CH056 Graubünden, CH057 Thurgau, CH061 Luzern, CH063 Schwyz, CH066 Zug, CH070 Ticino |
| Italy | ITH10 Bozen-Bolzano, ITH54 Modena, ITH55 Ferrara, ITH57 Ravenna, ITH58 Forlì-Cesena, ITH59 Rimini, ITD20 Trentino-Alto Adige |
| Romania | RO111 Bihor, RO112 Bistrița-Năsăud, RO113 Cluj, RO114 Maramureș, RO115 Satu Mare, RO116 Sălaj, RO121 Alba, RO122 Brașov, RO123 Covasna, RO124 Harghita, RO125 Mureș, RO126 Sibiu, RO211 Bacău, RO212 Botoșani, RO213 Iași, RO214 Neamț, RO215 Suceava, RO216 Vaslui, RO221 Brăila, |

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| | RO222 Buzău, RO223 Constanța, RO224 Galați, RO225 Tulcea, RO226 Vrancea, RO311 Argeș, RO312 Călărași, RO313 Dâmbovița, RO314 Giurgiu, RO315 Ialomița, RO316 Prahova, RO317 Telorman, RO321 București, RO322 Ilfov, RO411 Dolj, RO412 Gorj, RO413 Mehedinți, RO414 Olt, RO415 Vâlcea, RO421 Arad, RO422 Caraș-Severin, RO423 Hunedoara, RO424 Timiș |
| Lithuania | LT001 Alytaus apskritis, LT002 Kauno apskritis, LT003 Klaipėdos apskritis, LT004 Marijampolės apskritis, LT005 Panevėžio apskritis, LT006 Šiaulių apskritis, LT007 Tauragės apskritis, LT008 Telšių apskritis, LT009 Utenos apskritis, LT00A Vilniaus apskritis |
| UK | UKG11 Herefordshire, UKG12, Worcestershire, UKH12 Cambridgeshire, UKH16 North and West Norfolk, UKH17 Breckland and South Norfolk, UKJ22 East Sussex, UKJ35 South Hampshire, UKJ36 Central Hampshire, UKJ37 North Hamphshire, UKJ41 Medway, UKJ43 Kent Thames Gateway, UKJ44 East Kent, UKJ45 Mid Kent, UKJ46 West Kent |
| Sweden | SE224 Skåne län, SE123 Östergötlands län, SE221 Blekinge län, SE213 Kalmar, SE231 Halland, SE232 Västra Götaland |

Project web page: www.eufrin.org

## Annex: Scanning reports

**List of the scanning reports : 20 documents (**PDF file joint)

- Aarhus University (DK)
- Pcfruit (BE)
- Ctifl (F)
- OVA Jork (DE)
- St DLO Wageningen (NL)
- IRTA (ES)
- Agroscope (CH))
- Laimburg (IT)
- USAMV (RO)
- LRCAF (LT)
- UoG (UK)
- KOB
- UNIBO (IT)
- INRA (F)